NIST NCSTAR 2

Draft Report of the Technical Investigation of The Station Nightclub Fire

William L. Grosshandler
Nelson Bryner
Daniel Madrzykowski
Fire Research Division
Building and Fire Research Laboratory
National Institute of Standards and Technology

Kenneth Kuntz
Federal Emergency Management Agency
U.S. Department of Homeland Security

March 2005

U.S. Department of Commerce
Carlos M. Gutierrez, Secretary

Technology Administration
Phillip J. Bond, Under Secretary for Technology

National Institute of Standards and Technology
Hratch Semerjian, Acting Director

NIST NCSTAR 2

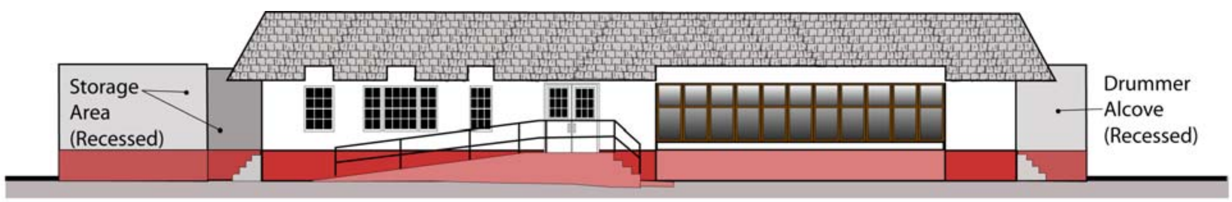
Draft Report of the Technical Investigation of The Station Nightclub Fire

William L. Grosshandler

Nelson Bryner

Daniel Madrzykowski

Kenneth Kuntz



National Institute of Standards and Technology • Technology Administration • U.S. Department of Commerce

NIST NCSTAR 2

Draft Report of the Technical Investigation of The Station Nightclub Fire

William L. Grosshandler
Nelson Bryner
Daniel Madrzykowski
Fire Research Division
Building and Fire Research Laboratory
National Institute of Standards and Technology

Kenneth Kuntz
Federal Emergency Management Agency
U.S. Department of Homeland Security

March 2005

U.S. Department of Commerce
Carlos M. Gutierrez, Secretary

Technology Administration
Phillip J. Bond, Under Secretary for Technology

National Institute of Standards and Technology
Hratch Semerjian, Acting Director

Disclaimer

Certain commercial entities, equipment, products, or materials are identified in this document in order to describe a procedure or concept adequately or to trace the history of the procedures and practices used. Such identification is not intended to imply recommendation, endorsement, or implication that the entities, products, materials, or equipment are necessarily the best available for the purpose.

Disclaimer

The policy of NIST is to use the International System of Units (metric units) in all publications. In this document, however, units are presented in metric units or the inch-pound system, whichever is prevalent to the discipline. Conversion tables are provided in an appendix to this report.

Disclaimer

The NIST-led investigation of The Station Nightclub fire was conducted during the same time period as civil and criminal legal actions involving the same incident, which limited the Team's access to physical evidence and the ability to interview many witnesses.

Use in Legal Proceedings

No part of any report resulting from a NIST investigation can be used in any suit or action for damages arising out of any matter mentioned in such report (15 USC 281a; as amended by P.L. 107-231).

National Institute of Standards and Technology NCST Act Report (NCSTAR) 2
Natl. Inst. of Std. NCST Act Rept. 2, XXX pages (March 2005)
CODEN: NSPUE2

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON: 2005

For sale by the Superintendent of Documents, U.S. Government Printing Office
Internet: bookstore.gpo.gov — Phone: (202) 512-1800 — Fax: (202) 512-2250
Mail: Stop SSOP, Washington, DC 20402-0001

ABSTRACT

A fire occurred on the night of Feb. 20, 2003, in The Station nightclub at 211 Cowesett Avenue, West Warwick, Rhode Island. A band that was on the platform that night, during its performance, used pyrotechnics that ignited polyurethane foam insulation lining the walls and ceiling of the platform. The fire spread quickly along the ceiling area over the dance floor. Smoke was visible in the exit doorways in a little more than one minute, and flames were observed breaking through a portion of the roof in less than five minutes. Egress from the nightclub, which was not equipped with sprinklers, was hampered by crowding at the main entrance to the building. One hundred people lost their lives in the fire. On Feb. 27, 2003, under the authority of the National Construction Safety Team (NCST) Act, the National Institute of Standards and Technology (NIST) established a National Construction Safety Team to determine the likely technical cause or causes of the building failure that led to the high number of casualties in that fire. This report documents the procedures, findings, and issues raised by the investigation. Twelve recommendations to improve model building and fire codes, standards and practices (as they existed in February 2003) resulted from the investigation, including (a) strengthening the requirements for the installation of automatic fire sprinklers, (b) increasing the factor of safety on the time for occupants to egress, (c) tightening the restriction on the application of flexible polyurethane foam as a finish product, (d) further limiting the use of pyrotechnics, (e) eliminating the practice of grandfathering buildings from complying with new life safety requirements, (f) requiring redundancy in the passive and active fire protection system, and (g) conducting research in specific areas to underpin the recommended changes.

Note: This version of the report is a draft for public comment.

Keywords: fire investigation, NCST, nightclub fire, sprinklers, egress, fire spread, polyurethane foam, fire modeling

TABLE OF CONTENTS

LIST OF ACRONYMS, ABBREVIATIONS AND UNITS

AHJ	Authority Having Jurisdiction
AIA	American Insurance Association
ALS	Advanced Life Safety
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATF	Bureau of Alcohol, Tobacco and Firearms
BBC	Basic Building Code
BCMC	Board for the Coordination of Model Codes
BFPC	Basic Fire Prevention Code
BLS	Basic Life Safety
BOCA	Building Officials and Code Administrators (previously Building Officials Conference of America)
CFD	computational fluid dynamics
DHS	Department of Homeland Security
FDS	Fire Dynamics Simulator
FEMA	Federal Emergency Management Agency
FPC	Fire Prevention Code
FR	fire retarded
HRR	heat release rate
IBC	International Building Code
ICC	International Code Council
IEBC	International Existing Building Code
IFC	International Fire Code
IR	infrared
ISO	International Organization for Standardization
LCL_0	lethal concentration, low
LSF	life safety feature

NCST	National Construction Safety Team
NBC	National Building Code
NFC	National Fire Code
NFPA	National Fire Protection Association
NFR	non-flame retarded
NIOSH	National Institute of Occupational Safety and Health
NIST	National Institute of Standards and Technology
ODP	Office of Domestic Preparedness
OSHA	U.S. Occupational Safety and Health Administration
PUF	polyurethane foam
RI	Rhode Island
SBC	Standard Building Code
SNEFEAP	Southern New England Fire Emergency Assistance Plan
TC	thermocouple
TIA	Technical Interim Amendment
UFC	Uniform Fire Code
USC	United States Code
USFA	United States Fire Administration
WFD	Warwick Fire Department
WWFD	West Warwick Fire Department

Units

°C	degrees Celsius
°F	degrees Fahrenheit
ft	feet
gpm	gallons/minute
in	inch
kg	kilogram
kW	kilowatt
L	liter
m	meter
mm	millimeter

min	minute
MW	megawatt
psi	pounds/in^2
s	second
W	Watt
μm	micrometer

PREFACE

On Feb. 27, 2003, under the authority of the National Construction Safety Team (NCST) Act, the National Institute of Standards and Technology (NIST) established a Team to determine the likely technical cause or causes of the building failure that led to a high number of casualties in The Station nightclub fire in West Warwick, Rhode Island on the night of Feb. 20, 2003. The investigation consisted of the following tasks:

- identification of technical issues and hypotheses requiring investigation through consultations with experts in fire protection engineering, and emergency evacuation, and members of other teams investigating The Station fire;
- data collection from local authorities, contractors and suppliers, building and fire protection design documents, records, plans, and specifications, video and photographic data, telephone and radio transmissions, field data, a limited number of interviews and other oral and written accounts from building occupants and emergency responders, and other witnesses as reported by the news media;
- analysis and comparison of model building and fire codes and practices, as well as review and analysis of practices used in operation of the building;
- simulation and analysis of phenomena (with associated uncertainties), including fire spread, smoke movement, tenability, occupant behavior and response, evacuation issues, and operation of active and passive fire protection systems;
- testing to provide additional data and support computer predictions; and
- preparation of the final report, following established NIST Editorial Review Board procedures, augmented by the NCST Advisory Committee.

As required by the NCST Act and its implementing regulations, priority in the investigation was ceded to the local criminal investigation. No physical evidence was obtained from the scene and access to witnesses and local authorities was limited due to the criminal investigations and civil litigation.

It should be noted that state and local building regulations -- rather than model codes -- govern building design, construction and operation. Comparisons of a building design and operation to provisions within model codes as part of the technical failure investigation by NIST have been done to enable an assessment of possible improvements in public safety through revision of model codes, standards and practices. The recommendations are directed toward the current national model codes maintained by the National Fire Protection Association (NFPA) and the International Code Council (ICC), the standards within those codes and elsewhere (e.g., ASTM International, and Underwriters Laboratories (UL)), and the practices associated with their adoption and implementation.

The NCST Act requires that at least one member of the Team be an employee of NIST, and that experts who are not employees of NIST shall also be appointed to the Team by the NIST Director. The members of the Team included the following:

- William Grosshandler (Lead Investigator), NIST Building and Fire Research Laboratory
- Nelson Bryner, NIST Building and Fire Research Laboratory

- Daniel Madrzykowski, NIST Building and Fire Research Laboratory
- Kenneth Kuntz, DHS/FEMA, US Fire Administration

Koffel Associates, Inc., provided a review of model building and fire codes; Ove Arup & Partners Massachusetts, Inc., assisted with the analysis of the evacuation process. Portions of both contractor reports have been integrated into this final report.

ACKNOWLEDGMENT

The number of people from NIST assisting the investigation extended beyond the official team members. Of particular note is Stephen Kerber, who devoted a tremendous amount of time and energy to running the fire simulations. The assistance provided by William Walton and Kevin McGrattan in this effort is also acknowledged. Erica Kuligowski was responsible for the egress simulations and was consulted regarding the behavior of humans in fire. The foam panel and full-scale mock-up experiments were ably supported by David Stroup, Laurean DeLauter, and Roy McLane.

Outside of NIST, the cooperation of the Bureau of Alcohol, Tobacco, and Firearms (Christopher Porreca in particular), and the assistance of the Army Research Laboratory (Steven Hoke) are acknowledged. Within the Department of Homeland Security, the Office of Domestic Preparedness coordinated their own investigation with NIST's work. The cooperation of the State of Rhode Island is acknowledged, in particular the Office of the State Fire Marshal and the Warwick field office of the Attorney General. WPRI-TV supplied the Team with the complete video taken on the night of the fire, and the *Providence Journal* provided NIST with information from their interviews with survivors of the incident.

EXECUTIVE SUMMARY

Note: This version of the report is a draft for public comment. NIST welcomes, in particular, any corrections of information in this draft, or any additional information that will improve the final report. NIST will consider all comments received by April 4, 2005, and will respond as it deems appropriate.

Comments can be sent via surface mail, facsimile, or e-mail as indicated below:

The Station Investigation
National Institute of Standards and Technology
100 Bureau Drive, Stop 8660
Gaithersburg, MD 20899-8660

Facsimile: (301) 975-4052
E-mail: NCST@nist.gov

An electronic version of the report and copies of the NIST videos are located on the NIST Web site:
http://www.nist.gov/ncst

Under the authority of the National Construction Safety Team Act, an investigation team was deployed by the NIST Director on Feb. 27, 2003 to investigate the failure seven days earlier of The Station nightclub in West Warwick, Rhode Island. The objectives of the investigation were the following:

- to establish the likely technical cause or causes of the building failure;
- to evaluate the technical aspects of evacuation and emergency response procedures;
- to recommend, as necessary, specific improvements to building standards, codes, and practices based on the findings made pursuant to the duties listed above; and
- to recommend any research and other appropriate actions needed to improve the structural safety of buildings, and improve evacuation and emergency response procedures, based upon the findings of the investigation.

The NIST team met these objectives primarily by reviewing and analyzing model building and fire codes, public documents, photographic and video data, telephone and radio transmissions, published accounts, and discussions with local authorities and several witnesses, by simulating and analyzing the fire spread, smoke movement, tenability, occupant behavior and response, and the impact of fire sprinklers, and by testing representative materials (not obtained from the site) to provide additional data and support the simulation predictions. The simulations and supporting fire tests were particularly important given that NIST was not able to obtain any physical evidence from the incident scene due to the ongoing criminal investigation and civil litigation. While the access to physical materials was denied to NIST, the Institute's investigators were provided extensive video tape footage taken before, during, and after the fire.

This report describes the methodology used to conduct the investigation, details what occurred on the night of Feb. 20, 2003, reviews the history of the building and the model codes and standards that would have applied to a building of this type, presents the results of testing and simulations, and includes recommendations to improve building safety, evacuation and emergency response procedures. It is important to note that state and local building regulations -- rather than model codes -- governed The

Station. NIST's comparison of the nightclub with model codes has been done strictly to enable an assessment of possible improvements in public safety through revision of codes, standards and practices. The recommendations are directed toward the current model codes maintained by the National Fire Protection Association (NFPA) and the International Code Council (ICC), the standards within those codes and elsewhere (e.g., ASTM International, and Underwriters Laboratories (UL)), and the practices associated with their adoption and implementation.

FINDINGS

The Station nightclub was a single-story wood frame building with a footprint of about 412 m^2 (4484 ft^2). The main entrance on the north side, with double doors, led to a short hallway with a single interior door. In addition to the main entrance, there were doors leading directly to the outside adjacent to the platform (commonly, but less precisely, referred to as the stage) on the west end of the building, and at the side of the main bar at the east end of the building. The kitchen also had an exit door. There were windows along the north side of the building on both sides of the main entrance.

The fire began when pyrotechnics used during the performance of a band ignited polyurethane foam lining portions of the walls and ceiling of the platform, and spread quickly along the ceiling area over the dance floor. Smoke was visible in the exit doorways in a little more than one minute and flames were observed breaking through a portion of the roof in less than five minutes. Egress from the nightclub was hampered by the crowding at the main entrance to the building. One hundred people lost their lives in the fire.

The most far-reaching findings from the investigation that had a direct bearing on the outcome of the incident are summarized here, grouped according to the materials and behavior of the fire, the building fire protection systems, the evacuation process, and the emergency response. Additional technical findings are presented in Chapter 8 of the report.

Materials

- A non-fire retarded foam sample purchased by NIST ignited within 10 seconds when exposed to a pyrotechnic device (15x15 gerb) in an arrangement similar to the set up on the platform of the nightclub. When a plywood panel with fire retarded polyurethane foam was exposed in a similar manner to a 15 x 15 gerb, no ignition of the panel occurred, nor did the plywood ignite with no foam present.
- As could be seen in the WPRI video, flames spread rapidly over the foam in the nightclub, generating smoke and enough heat (calculated to be almost 60 MW at its peak) to ignite the wood paneling underneath and adjacent to the foam. The wood paneling in the nightclub was estimated to contain over 95 percent of the fuel load, so that once most of the foam was consumed (estimated to be around two minutes after ignition of the foam), the fire transitioned to a wood frame building fire, with a steady heat release rate calculated to be around 45 MW.
- There was no fire resistant barrier between the interior of the nightclub and foam thermal insulation which had been installed in the stud space on the interior side of external walls of the drummer's alcove.

- In the reconstruction of the *platform area fire* conducted at NIST, within 90 seconds after ignition of the non-fire retarded polyurethane foam conditions near the middle of the dance floor at head height (1.5 m, or 5 ft, above the floor) were lethal.
- NIST could not obtain samples of the foam that actually had been applied to the nightclub walls to conduct a chemical analysis to determine if the polyurethane material contained fire retardants; however, the ignition behavior of the foam exhibited on the WPRI video was consistent with the behavior observed in the NIST testing with a non-fire retardant foam.

Fire Protection Systems

- Experiments conducted at NIST in a reconstruction of *the platform area* fire demonstrated that a water sprinkler system installed in the test room in accordance with NFPA 13 was able to control the fire initiated in non-fire retarded polyurethane foam panels and maintain tenable (survivable) conditions at head height in the test room for the duration (over five minutes) of the experiment. A computer simulation of the full nightclub with and without sprinklers led to a similar positive result for the sprinklered scenario.
- Automatic fire sprinklers were not installed in The Station nightclub, nor would they have been required for such existing structures under the 2003 editions of the model codes.
- A heat detection/fire alarm system was installed in The Station nightclub, which activated (sound and light strobe) 41 seconds after ignition of the polyurethane foam, by which time the crowd had already begun to move toward the exits.

Occupant Load and Egress

- The first patrons recognized the fire danger about 24 seconds after ignition of the foam; the bulk of the crowd began to evacuate shortly after that, around the time the band stopped playing (30 seconds).
- The rate of egress from the main entrance at the front of the building was limited by the single doorway inside the vestibule, not the double doors visible from the outside.
- About 2/3 of the occupants appear to have attempted to leave through the single main entrance in the front of the building; many were unsuccessful.
- Prior to 1-1/2 minutes into the fire, a crowd-crush occurred in the front vestibule which almost entirely disrupted the flow through the main exit. The precise event which led to the crowd-crush likely was related to the arrangement of the single interior door with merging streams of traffic and the pressure to escape the rapidly deteriorating conditions in the main area of the nightclub.
- Measurements of temperature, heat flux and gas species in a reconstruction of the platform area fire at NIST and computer models of the NIST experiment and the full nightclub suggest that the conditions around the platform, dance floor, sunroom, and dart room would have led to severe incapacitation or death within about 1-1/2 minutes after ignition of the foam for anyone remaining standing, and for not much longer even close to the floor.
- The number of building occupants at the time of the fire was reported by the Providence Journal to be 440; the occupant limit for a building similar to The Station nightclub would be 420 persons according to current model codes.

Emergency Response

- The first 911 call reporting a fire was before 11:09 p.m., less than 40 seconds after ignition of the foam; West Warwick police officers on the scene reported the fire about one minute after ignition of the foam, leading to the dispatch of four engine companies, a tower-ladder truck, a rescue unit, and a battalion chief .
- The first fire engine, staffed with one firefighter and a fire officer, was confirmed on-scene less than five minutes after the first 911 call was received, well within the limit of the NFPA standard for fire department response; however, NFPA standards recommend a minimum staffing level of four firefighters on both engine and truck companies, which was not achieved.
- A mass casualty plan was implemented capably within about 10 minutes of arrival of the first engine on the scene, such that within two hours of the start of the fire, all occupants needing medical attention had been evacuated from the scene and transported to medical facilities.

RECOMMENDATIONS

The findings presented above, and others that are documented in this report, raised a number of issues concerning model building codes and standards, and the practices surrounding their adoption, application, and enforcement. The specific sections of the current NFPA and ICC model codes that relate to these issues are identified in the report. The following twelve recommendations are made to improve model codes and standards, enhance fire safety and emergency response practices, and support research necessary to accomplish the improvements. Some significant actions already have been taken by the state of Rhode Island and the NFPA that incorporate aspects of the recommendations of this report, and these actions are described in the full report.

The first four recommendations should be applied in the model codes to all new and existing nightclubs regardless of size. The application to all existing nightclubs is a recognition that (i) the environment within The Station became lethal considerably sooner than 1-1/2 minutes, and (ii) the control of building contents, finish materials, and occupancy limits has been demonstrated to be considerably less rigorous in nightclubs (see Appendix C for multiple examples) than in most other places of assembly.

Recommendation 1

*NIST recommends that model codes require sprinkler systems for **all** new and existing nightclubs regardless of size, and that state and local authorities adopt this provision.*

Recommendation 2

In relation to the fire performance of finish materials and building contents, NIST recommends that model codes require, and that state and local authorities adopt the following provisions:

a) *certain classes of materials (including non-fire retarded flexible polyurethane foam) that are known to easily ignite and rapidly propagate flames (i.e., they have an ignition temperature below some minimum, or a flame spread index and heat release rate greater than some maximum values) be clearly and specifically forbidden, with no exceptions, as finish materials from all new and existing nightclubs;*

b) *greater guidance be provided for when large-scale tests are required to demonstrate that materials do not pose an undue hazard for the use intended;*

c) *the pass/fail criteria for flame spread tests and large-scale tests (including ASTM E-84, NFPA 255, and NFPA 286) be established using best measurement and prediction practices; and*

d) *strengthen provisions in NFPA 1126 (Use of Pyrotechnics before a Proximate Audience) which apply to all new and existing nightclubs and from other places of assembly through the following actions: banning the use of pyrotechnic devices from buildings less than 10,000 ft^2; requiring that all materials (including structural, finish, and contents) in structures that pyrotechnic devices are to be permitted meet low flame spread and heat release rate criteria , and require a minimum clearance greater than twice the designed projection of the device from the nearest fixed surface or moveable contents.*

Recommendation 3

NIST recommends that the factor of safety on the time for occupants to egress from ***all*** *new and existing nightclubs be increased in the model codes in the following manner, and that state and local authorities adopt these provisions:*

a) *Compute the number of required exits and the permitted occupant loads assuming at least one exit (other than the main entrance) will be inaccessible in an emergency evacuation.*

b) *Increase the capacity of the main entrance to accommodate, at a minimum, 2/3 of the maximum permitted occupant level during an emergency.*

c) *Eliminate trade-offs between sprinkler installation and factors that impact the time to evacuate buildings.*

d) *Require staff training and evacuation plans for buildings that cannot be evacuated in less than 1-1/2 minutes.*

e) *Provide improved means for occupants to locate emergency routes -- such as exit signs near the floor and floor lighting -- once standard exit signs become obscured by smoke.*

f) *Establish the threshold building area and occupant limits for egress provisions using best practices for estimating tenability and evacuation time.*

g) *Require explicit evacuation directions be provided to occupants prior to the start of any public event inside a structure used for public assembly.*

Recommendation 4

NIST recommends that model building and fire codes require, and that state and local authorities adopt, the application of new life-safety provisions to existing as well as new nightclubs, and that the practice of grandfathering older structures be eliminated. Exemptions from the new provisions should be on a case-by-case basis and justified by a comprehensive fire safety analysis using best practices.

Recommendation 5

NIST recommends that model codes and standards require redundancy in the passive and active fire protection systems to ensure adequate performance of the structure when one or more of the protective systems is compromised by uncertain behaviors of the building owner or occupants such as the following:

a) *installing building decorations or temporary features that greatly exceed flame spread or fire load provisions;*

b) *exposing the building to strong ignition sources;*

c) *exceeding the posted occupancy limits;*

d) *temporarily blocking an exit; and*

e) *disabling sprinklers or other life safety systems for maintenance.*

Recommendation 6

NIST recommends that when performing an analysis of proposed changes to model building and fire codes, proper account should be taken of the soundness of and safety factor provided by the existing provisions in light of the history of similar building failures.

Recommendation 7

NIST recommends that the model codes increase the number of portable fire extinguishers required, with their number and placement based upon a minimum time for access and application in a fully occupied building, and that staff be properly trained in their use.

Even though the first fire engine arrived expeditiously, the speed at which the fire engulfed The Station rendered it impossible for the fire department to save the structure or the lives of many victims. However, the importance of the role of fire prevention activities in avoiding a future tragedy was highlighted by this incident. As in all mass causality events, especially those where the window of opportunity for rescue is extremely limited, effective and efficient communications within and among the various responding agencies is imperative. Developing effective interoperable communications requires addressing numerous critical success factors, including frequent use of interoperable communications equipment and procedures, formal governance and collaboration, formal standard operating procedures, appropriate technology, and multiagency training and exercises. Tools and best practice models addressing many of these success factors, including a statewide communications interoperability planning methodology are available though the Department of Homeland Security's SAFECOM Program.

Recommendation 8

NIST recommends that the model codes provide specific guidance on how to implement an effective fire inspection program, including the training necessary to implement it, and that state and local authorities adopt such guidance in practice. Items to consider include the following:

a) *documentation of building permits and alterations;*

b) *means of egress inspection and record-keeping;*

c) *frequency and rigor of fire inspections, including follow-up and auditing procedures;*

d) *education and training of inspectors and owner; and*

e) *guidelines on recourse available to the inspector for identified deviations from code provisions .*

Recommendation 9

NIST recommends that

a) *career and volunteer fire departments comply with the minimum apparatus staffing such as those suggested in NFPA Standards 1710 and 1720, respectively, and NFPA 1500 as appropriate;*

b) *public safety agencies at all levels give greater attention to the difficulty of communications systems interoperability, and that fire service and emergency medical services organizations make every effort to assure they develop and maintain sufficiently robust, interoperable communications capabilities to support major incident operations, including those requiring substantial mutual aid augmentations, such as those suggested in NFPA Standard 1221; and*

c) *major incident/mass casualty operations be conducted utilizing appropriate Incident Command/Unified Command structures, policies and practices such as those suggested in NFPA Standard 1561.*

NIST is required, under the NCST Act, to identify areas of research needed to support improvements to model building codes, standards and practices. Based upon the findings of this investigation and the resultant recommendations presented above, additional research is recommended in three general areas: human behavior and people movement, material behavior and fire spread, and decision aids.

Recommendation 10

NIST recommends that research be conducted to better understand human behavior in emergency situations, and to predict the impact of building design on safe egress in fires and other emergencies (real or perceived), including the following:

a) *the impact of fire products (gases, heat, and obscuration) on occupant decisions and egress speeds;*

b) *exit number, placement, size and signage;*

c) *conditions leading to and mitigating crowd crush;*

d) *the role of crowd managers and group interactions;*

e) *theoretical models of group behavior in emergency situations suitable for coupling to fire and smoke movement simulations; and*

f) *the level of safety that model codes afford occupants of buildings.*

Recommendation 11

NIST recommends that research be conducted to understand fire spread and suppression better in order to provide the tools needed by the design profession to address recommendations 1 through 10 above. The following specific capabilities require research:

a) *prediction of flame spread over <u>actual</u> wall, ceiling and floor lining materials, and room furnishings;*

b) *<u>quantification</u> of smoke and toxic gas production in realistic room fires; and*

c) *development of generalized models for fire suppression with fixed sprinklers and for firefighter hose streams.*

Recommendation 12

NIST recommends that research be conducted to:

a) *refine computer-aided decision tools for determining the costs and benefits of alternative code changes and fire safety technologies, and*

b) *develop computer models to assist communities in allocating resources (money and staff) to ensure that their response to an emergency with a large number of casualties is effective.*

Chapter 1 BACKGROUND

1.1 INTRODUCTION

A fire occurred on the night of Feb. 20, 2003, in The Station nightclub at 211 Cowesett Avenue, West Warwick, Rhode Island. A band that was performing that night, during its performance, used pyrotechnics that ignited foam insulation lining the walls and ceiling of the platform being used as a stage. The fire spread quickly along the ceiling area over the dance floor. Smoke was visible in the exit doorways in a little more than one minute, and flames were observed breaking through a portion of the roof in less than five minutes. Egress from the nightclub was hampered by crowding at the main entrance to the building. One hundred people lost their lives in the fire.

The National Institute of Standards and Technology (NIST), under the authority of the National Construction Safety Team (NCST) Act [1], established a National Construction Safety Team (Team) on Feb. 27, 2003, to determine the likely technical causes of the building failure that led to the high number of casualties in that fire. The investigation included the following tasks:

- identification of technical issues and major hypotheses requiring investigation through consultations with experts in fire protection engineering, and emergency evacuation, and members of other teams investigating The Station fire;
- data collection from local authorities, contractors and suppliers, building and fire protection design documents, records, plans, specifications, video and photographic data, telephone and radio transmissions, field data, and a limited number of interviews and other oral and written accounts from building occupants and emergency responders, and other witnesses as reported by the news media;
- analysis and comparison of building and fire codes and practices, and review and analysis of practices used in operation of the building;
- simulation and analysis of phenomena (with associated uncertainties), including fire spread, smoke movement, tenability, occupant behavior and response, evacuation issues, and operation of active and passive fire protection systems; and
- testing to provide additional data and support simulation predictions.

This document constitutes the draft report of the NIST investigation into The Station fire. The building and surroundings as they were prior to the fire are described in the following section of this chapter. The general history of the building is reviewed here as well. Chapter 2 provides a timeline of the incident, including the ignition and spread of the fire, the evacuation process, and firefighting activities. The fire and emergency response and procedures are detailed in Chapter 3. Chapter 4 describes the testing and supporting experiments, and Chapter 5 provides background and results of the computer simulation of the fire and smoke movement. An analysis of the evacuation process is provided in Chapter 6. Chapter 7 reviews the model building and fire codes that are relevant to a structure like The Station. The report concludes with a summary of findings and recommendations in Chapter 8. There are a number of appendices that provide more detail, or information that is peripheral to the main objectives. NIST video recordings and animations are included in the CD that accompanies this report.

1.2 DESCRIPTION OF THE BUILDING AND SITE

The Station nightclub was located at 211 Cowesett Avenue, West Warwick, Rhode Island. It was a single-story wood frame building with a footprint of about 412 m^2 (4484 ft^2) and a small basement under the main bar room. Figure 1-1 is a photograph of the building on its lot. The north-facing front door of the nightclub was set back about 42 m (140 ft) from Cowesett Avenue, a three-lane, two way street that runs east-to-west. Kulas Road is two lanes wide and runs along the east side of the building, about 10 m (33 ft) east of the side bar exit. There was no direct street access to the building from either the west or south sides. Parking for over 100 cars was provided in the front and to the west side of the building.

A distant aerial view of the area, Figure 1-2, shows the nightclub in relation to the community. Note the location of Fire Station #4 across Cowesett Avenue about 500 m (1650 ft) to the west of The Station.

Figure 1-3 is a sketch showing the north side of the building approximately as it looked on February 20, 2003. Note the windows on the left which are in the main bar area, the windows on the right in the sunroom/poolroom, the ramp and stairs leading from the main entrance in front, and the stairways leading from side exits on the west and east of the building. Inside the double doors of the main entrance is a vestibule with a single doorway. Figures 1-4a and 1-4b are photographs of the north side and north west corner of the building as they looked within a year or two of the February 20, 2003 fire. The external walls were primarily covered with painted wood shingles or panels above a concrete foundation. The roof was flat with a wood shingle façade along the front and sides, as seen in the photographs.

Figure 1-5 shows a plan view of the nightclub floor, a composite from multiple sources of information obtained during the investigation. Entering from the front through the double doors would have brought one into a short entrance hall with a single door at the far end that led to the ticket-taker area. To the right of the ticket taker was an assembly area containing the dance floor, sunroom (or poolroom), elevated dining area, and a platform (imprecisely referred to as a stage) with the drummer's alcove. A dressing room was situated in the northwest corner and an exit to the outside was located between the platform and dressing room. Except for the front of the sunroom, which was composed of darkened glass windows, there were no other windows in the right half of the nightclub.

Turning left at the ticket-taker area would have brought one into the main (or horseshoe) bar room. An exit to the outside was located on the far left wall. There were no windows on that wall but windows lined most of the front of the main bar room.

The kitchen separated the main bar room from a smaller assembly area (or dart room) and back bar. There was one door to the outside from within the kitchen. A storage area, office, and restrooms were located in the back of the nightclub. There were no additional exits leading directly to the outside from these rooms; any windows or exits that had been installed were covered with bars or paneling.

Figures 1-6a and 1-6b show different views inside the nightclub, highlighting the exit doors next to the platform and the exit from the main bar area.

1.3 HISTORY OF THE BUILDING[1]

The Station nightclub was a single-story wood frame building, with a small basement. Over the years the building was sold multiple times and changed function, as shown in Table 1-1.

[1] This section is taken from the contract report prepared by Koffel Associates, Inc. [11]

Figure 1-1. General orientation of building and site [2]

Figure 1-2. Aerial photograph of the community around The Station nightclub [2]

]

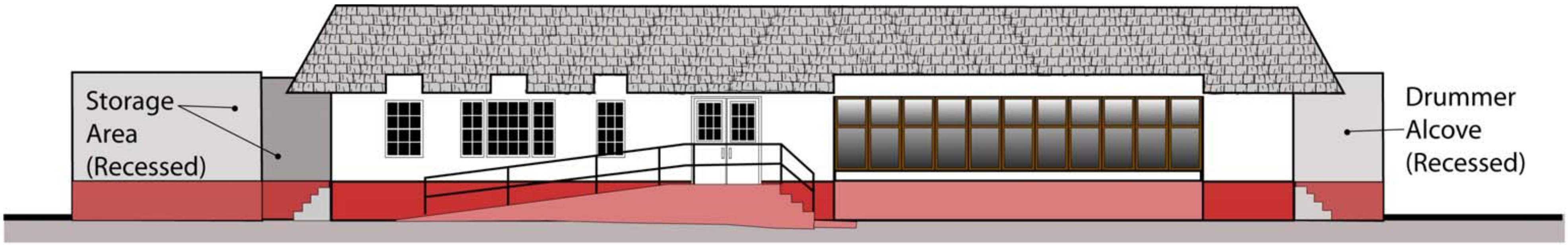


Figure 1-3. Sketch of the north side of The Station nightclub locating the main entrance, front stairway/ramp, windows in the main bar area (left), sunroom/pool room (right), and exit stairs from the east and west sides

Figure 1-4a. Front view of The Station nightclub showing the main entrance [3]

Figure 1-4b. View of the northwest corner showing the sunroom windows [3

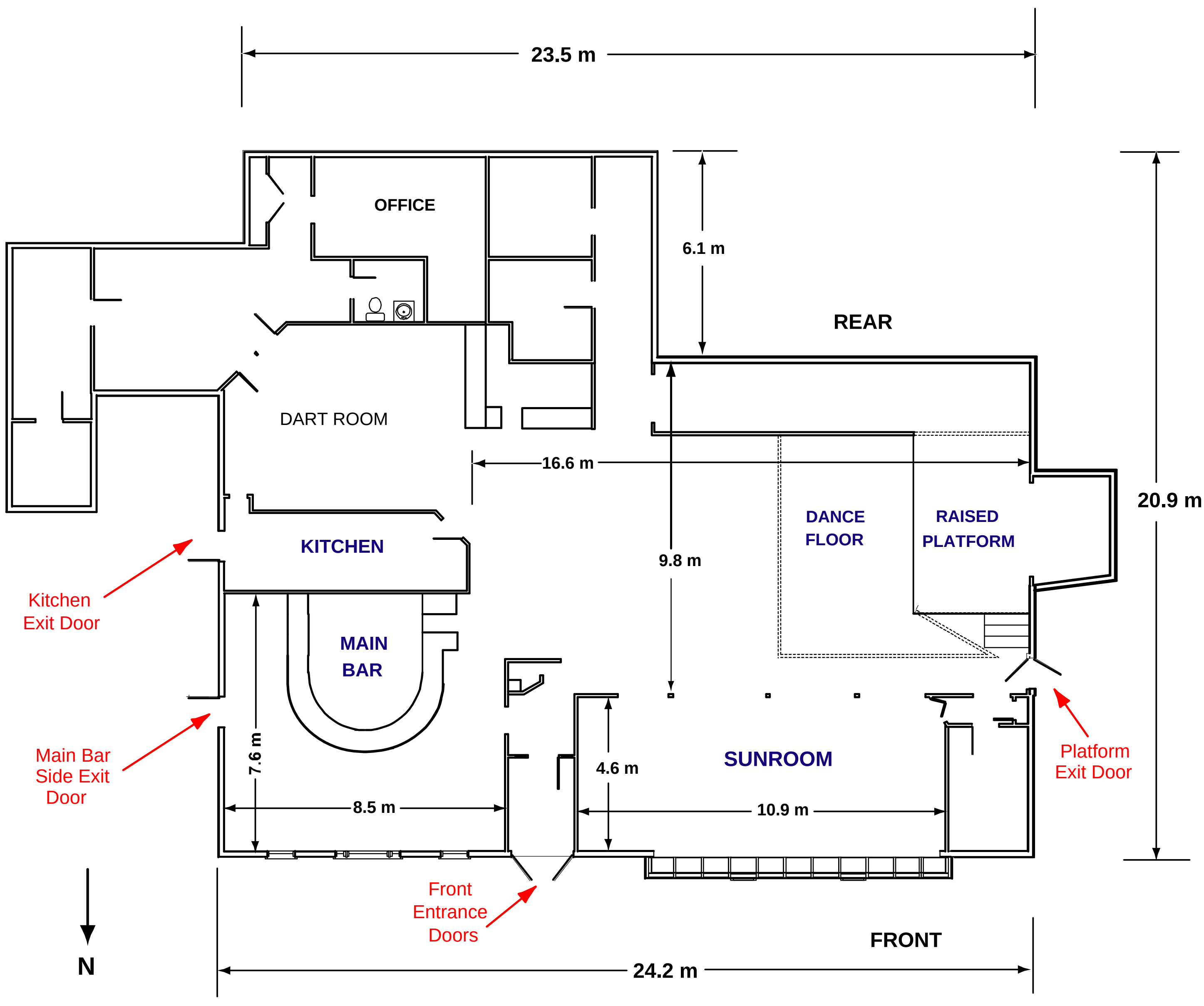


Figure 1-5. Plan view of The Station showing different rooms and exits.

Figure 1-6a. View of inside of nightclub showing exit sign above door near platform [4]

Figure 1-6b. View of inside of nightclub showing exit sign above door in main bar area [4]

On the night of the fire, The Station nightclub looked different from when it was built in 1946 [5]. While the club was still a single-story wood building with a small basement, it was modified numerous times over its 57 years [6, 7]. Although the original plans of the building were not located, several sources reported that the building was modified over the years. The modifications included small additions, multiple reconfigurations of the interior, rebuilding after a fire, and rebuilding after a car rammed the front of the building [5].

The original date of construction has been variously reported to be 1946 or 1950. The 1946 date is based on a *Providence Journal* article dated July 13, 2003 [5]. The article reports the land was purchased in 1945; the nightclub (originally named Casey's Inn) was constructed in 1946 and changed hands in 1947. The Town of West Warwick tax records, dated May 30, 2001, indicate that the building was constructed in 1950 [8]. West Warwick land records indicate the property changed hands in November 1945 and 1947, suggesting the construction took place in 1946 as reported by the *Providence Journal* (W. Warwick Land Use Record undated, [5,9]). For the purposes of this report, the date of construction will be 1946.

In an effort to document the original building construction date, construction permits were reviewed at the Town of West Warwick for 211 Cowesett Avenue. The permits document dates of construction and provide brief narratives of work to be completed. However, the details of the construction are not included in the permits. It is not possible to determine from the permits the extent of work completed, or if the work was completed in compliance with model codes of the time.

The building was damaged by fire in March 1972. The July 2003 *Providence Journal* article reported the firefighters cut holes in the roof [5]. The contents of the building sustained fire and smoke damage, but the building structure remained. The first building permit issued after the fire was in November 1974. The permit makes no mention of roof fire damage repair. It simply states that the work included interior paneling and partitions. Workmen reported that smoke-stained and charred structural framing remained in the building continuously up until the February 2003 fire.

In June 2001, a car ran through the front of the building. A building permit was issued on June 19, 2001 to repair the damage [10]. The extent of the damage is not detailed; however, the permit indicates that a window and a portion of the exterior wall adjacent to the window were replaced.

The Town of West Warwick tax records indicate the building consisted of a small basement, 165 m^2 (1794 ft^2) in area, and a main level of 412 m^2 (4484 ft^2) [5]. The tax record depicts the general outline of the building with dimensions, not including windows or doors.

1.4 PREVIOUS INCIDENTS AT THE STATION[2]

At the time of the 1972 fire mentioned above, the building housed a nightclub named Julio's [5]. The ensuing fire alarm alerted responders; firefighters arrived to find the building engulfed in flames. They contained the fire, but much of the interior of the club had been significantly damaged. Investigators determined that the fire started in the rear center of the building and worked up through the ceiling and into the attic. No occupants were in the club at the time of the fire.

No other significant fire incidents or egress difficulties were reported to have occurred in this building prior to February 20, 2003.

[2] This section taken from the contract report prepared by Ove Arup & Partners Massachusetts [12].

Table 1-1. Time Line of Construction and Changes of Use		
Date	**Modification**	**Extent of Construction**
Spring 1946	Original construction as a night club	New construction
June 1964	Change of ownership Converted to meeting house (same Use Group as restaurant)	Unknown if any
May 1967	Change of ownership and name Converted to night club	See permit July 27, 1967
July 27, 1967 (building permit 6748)		Commercial alterations Paneling inside Rebuild two porches in front New sign outside
1968	Name change	Unknown
June 1969	Nightclub closed	
April 1970	Change of ownership and name	See permit May 18, 1970 Converted to restaurant and removed the bar
May 18, 1970 (building permit 8018)		Alterations to Business Roofing, paneling etc.
Fall 1970	Renamed	Unspecified remodeling
June 1971	Bank forecloses Reopens as night club	
October 18, 1971	Alterations and remodeling	
March 1972	Fire Club may have remained closed until 1974	
June 1974	Change of ownership	
November 15, 1974	Convert to restaurant	Commercial alterations Interior paneling and partitions
April 29, 1975 (building permit 10558)	Commercial exterior alterations and renovations	
July 1, 1975 (building permit 10641)	Addition	Addition 30.6 m^2 (330 ft^2)
February 1985	Change of ownership Change of name Converted to “pub”	
February 20, 1985 (building permit 14930)		Remodeling and renovations to existing restaurant
Late 1980’s	Pub closed	
1991	Reopened as nightclub	
January 1993	Change of ownership renamed	
January 1995	Change of ownership	
December 1999	Non-permitted work	
March 2000	Change of ownership renamed	
June 19, 2001 (building permit B01-1098)	Repair damage from car ramming building	Remove damaged window and replace size for size, replace damaged sill plate and reframe damaged exterior wall and interior wall and exterior siding

1.5 JURISPRUDENCE

Subsequent to the events of February 20, 2003, a large number of public and private legal actions have begun. While they are outside the scope of this investigation, NIST notes that a Grand Jury has returned indictments and a trial is pending; private suits have been filed seeking damages; disputes have arisen involving Workers Compensation; and OSHA has issued a citation which is presently being contested. NIST expresses no views on the merits of any of these proceedings.

In addition, these ongoing legal actions limited NIST's access to some physical evidence and the ability to interview some witnesses.

1.6 REFERENCES FOR CHAPTER 1

[1] National Construction Safety Team Act, Public Law 107-231 -- Oct. 1, 2002, Congress of the United States of America.

[2] purchased from GlobeXplorer 2004

[3] photograph by Anthony Baldino III (undated)

[4] Butler, Brian, Video by WPRI, Channel 12, February 20, 2003.

[5] *Providence Journal*, Zachary R. Mider July 13, 2003.

[6] West Warwick Application for Building Permit Number 6748. July 27, 1967.

[7] West Warwick Application for Building Permit Number 8018. May 18, 1970.

[8] West Warwick, Rhode Island Commercial /Industrial Property Record Card May 30, 2001

[9] West Warwick, Rhode Island Land Use Record. Undated.

[10] W. Warwick Application for Building Permit Number B01-1098, June 19, 2001.

[11] "Code Analysis of the Station Nightclub Warwick Rhode Island," Koffel Associates, Inc., Ellicott City, MD, NIST contract report # KA 03732-004, June 23, 2004.

[12] "Evaluation of Limitations to Egress through Doorways in Emergency Situations," Ove Arup & Partners Massachusetts Inc., NIST contract report #32979, February 18, 2004.

Chapter 2 DESCRIPTION AND TIMELINE OF THE INCIDENT

2.1 INTRODUCTION

A basic element of any fire investigation is the development of the timeline of events. Most of the deaths in The Station fire occurred during the evacuation process; hence, a focus of the NIST investigation was on documenting the egress event. Overlaying the progress of the fire, the movement of occupants, and the collapse of the building was the response to the emergency by the fire and police departments and EMS teams in West Warwick and surrounding regions. The intent of this review is to help understand the incident so that the details and occurrences that resulted in the large loss of life can be identified.

The timelines generated in this chapter integrate information from a range of sources to identify the specific events that occurred starting just after 11:07 pm, Eastern Standard Time (EST), Feb. 20, 2003 as well as the order in which they transpired. The timeline is presented as a collection of overviews and snapshots. Overviews describe a series of significant events that occur on the time scale of hours, and serve to place the events in a broader framework. Snapshots focus on a shorter time period, and provide details resolved down to a few seconds.

2.2 OVERVIEW NARRATIVE

About 11:07 pm, the lights were dimmed just prior to the band stepping onto the performance platform. Once the band was on the platform, a set of multi-colored lights were activated and four pyrotechnic devices (gerbs) were ignited to begin the show. The hot particulates which were part of the stream of white sparklers discharged by the gerbs struck both sides and the top of the opening to the alcove where the band's drummer was situated. In a matter of seconds the hot particulates ignited the polyurethane foam on both sides of the platform.

Eleven seconds after ignition, the band noticed the flames and the crowd soon began to realize that the fire was not an intentional part of the show. Within 25 seconds, the flames reached the ceiling on both sides of the platform and spread very quickly across the polyurethane foam. The band stopped playing 30 seconds after the fire had started, and the bulk of the crowd began to evacuate. At approximately 41 seconds, the fire alarm sounded and the emergency strobe lights began to flash.

In less than 60 seconds, the Rhode Island Emergency 911 Center began receiving calls from cell phones reporting a fire, and at about the same time, a West Warwick Police officer who was at the nightclub reported to the police dispatcher that there was a fire inside The Station on Cowesett Avenue. This information was immediately relayed to the West Warwick Fire Department (WWFD). The fire department assigned and dispatched Engine 4, Engine 1, Engine 2, Engine 3, Ladder 1, and Battalion Chief 1 to the fire scene.

Inside the nightclub, the fire continued to develop and in about 90 seconds, the thick black smoke layer appeared to have dropped to within 0.3 m (1 ft) of the main floor of the nightclub. Less than 100 seconds after ignition, the main front doorway became clogged with occupants trying to exit the main floor. Club patrons and staff were breaking windows on the front of the nightclub from the area of the main bar and exiting through the windows. Patrons who had escaped were attempting to extricate people who had been wedged in the front doorway. Shortly after 11:13 pm (5 minutes after ignition), flames were observed extending out of the windows and front doorway.

A few seconds later, Engine 4 arrived at the nightclub and began to pull a hose line to near the front door. Water from the booster tank on Engine 4 was initiated at approximately 11:14 pm (about 6 min into the fire). Additional fire fighters arrived on Ladder 1, Engine 2 and Engine 3. Battalion 1 activated the Warwick Task Force which invoked a mutual aid agreement and dispatched seven additional engine/ladder companies from surrounding communities. Battalion 1 also requested 12 rescues (ambulance units). At approximately 11:22 pm, the West Warwick Fire Chief indicated that he was responding to the fire scene. As the chief was responding, he asked the fire dispatcher to contact Metro Fire Control and implement the Mass Casualty Plan. The Engine 3 officer had set up a triage area in the parking lot of and inside the Cowesett Inn. Engine 4 was applying water on the fire by about 11:24 pm, and at least three hose lines were being used to apply water to the area around the front door by 11:28 pm.

Shortly after 11:32 pm, the fire chief asked the fire dispatcher to contact the State Fire Marshal's Office and request a state fire marshal be sent to the scene. The fire dispatcher advised Triage that Kent County Hospital was overwhelmed with injured victims and that additional victims should be directed to Rhode Island Trauma Center, and Triage responded that the rescue units were using their own discretion as to which hospital the victims were being transported.

At about 11:57 pm , a portion of the nightclub roof appeared to collapse. The fire chief ordered a roll call to account for all fire fighters on the fire ground. Around midnight the Warwick ladder unit raised its ladder, and began applying a master stream to the fire. Approximately ten minutes after the collapse of the main roof section, a portion of the roof around the sunroom collapsed. Sometime between 12:15 am and 1:00 am, February 21,the State Fire Marshal arrived on the fire scene, the incident commander asked the fire dispatcher to cancel additional rescue units, and Triage reported that all patients had been transported.

An overview timeline is shown in Figures 2-1a and 2-1b. Detailed events are summarized in Table 2-1.

2.3 OVERALL INCIDENT TIMELINE

The overall incident timeline was assembled from the video footage inside and outside The Station filmed by WPRI-TV [1], published interviews with occupants by the *Providence Journal,* a video taken by an amateur using a handheld camcorder [2], audio tapes, and fire department records. A high-quality digital version of the TV video was provided to NIST by WPRI. The amateur video [2] was retained as evidence by the Office of the Attorney General for Rhode Island. The Attorney General's staff permitted the NIST investigators to review the tape in the Warwick fire investigation field office. Audio tapes from two sources were also retained by the Attorney General. The first audio set contained digital recordings of cellular phone calls to the Rhode Island Emergency (911) Center. The second audio set included cassette tapes of radio communications from the WWFD. The Attorney General's staff allowed investigation team members to listen to both the 911 and fire department recordings at the field office.

In order to integrate the events on the two videos with the audio recordings, it was necessary to establish a common time reference. Each of the two videos was time-stamped by the camera/camcorder, but the two clocks were not synchronized. The 911 audio recordings were time-stamped, but it appeared that the 911 clock did not match either of the two video clocks. The fire department radio transmissions were not continuously time-stamped, but the central dispatch (fire alarm) periodically inserted a clock time either before or after a transmission. The fire department communication system did not record continuously, but instead recorded only when a radio transmission occurred. The result is that the dispatcher may have inserted a clock time twice in 5 minutes, but then not provided another clock time for 30 minutes.

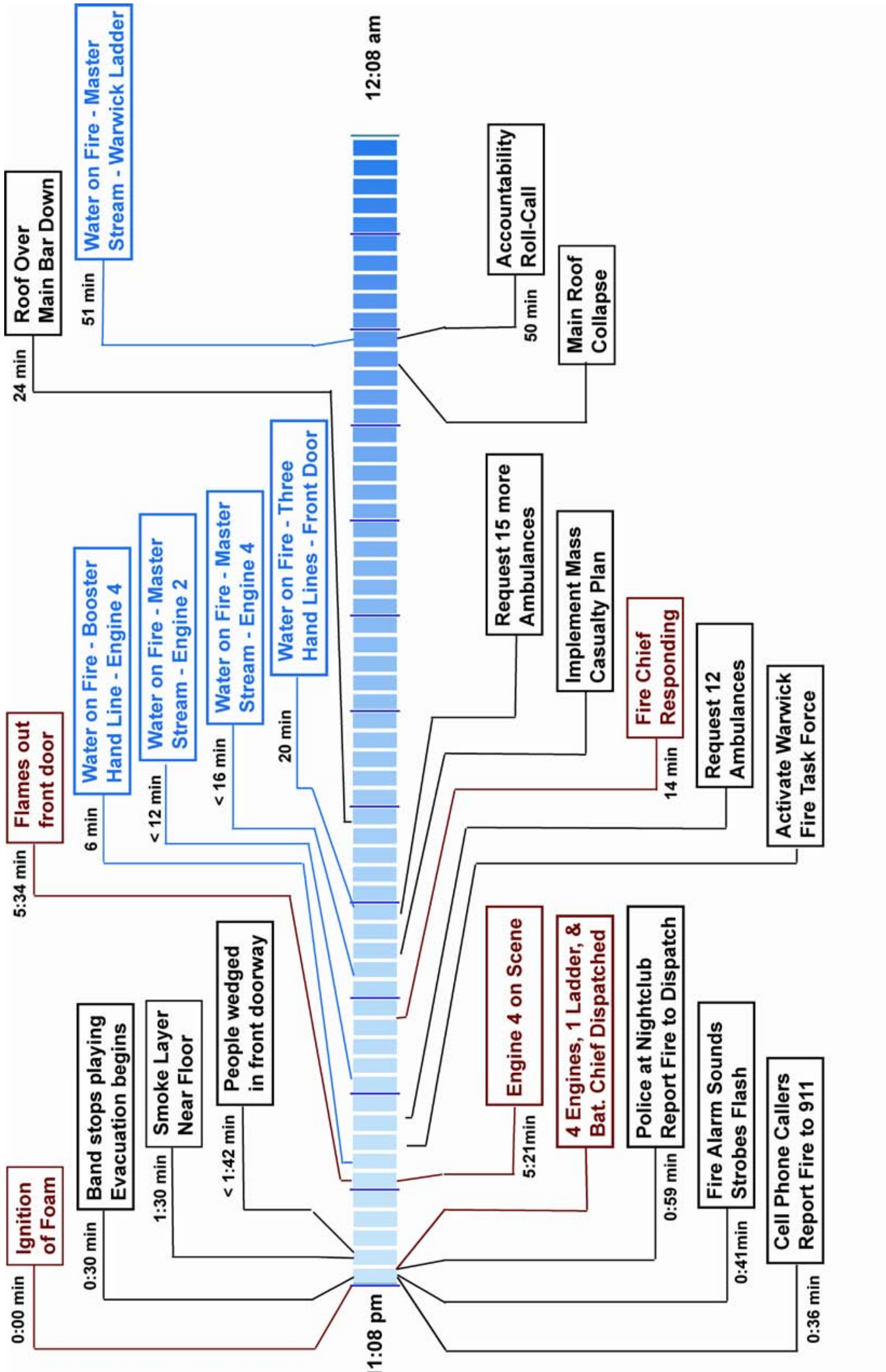


Figure 2-1a. Overview Timeline of The Station Nightclub Fire

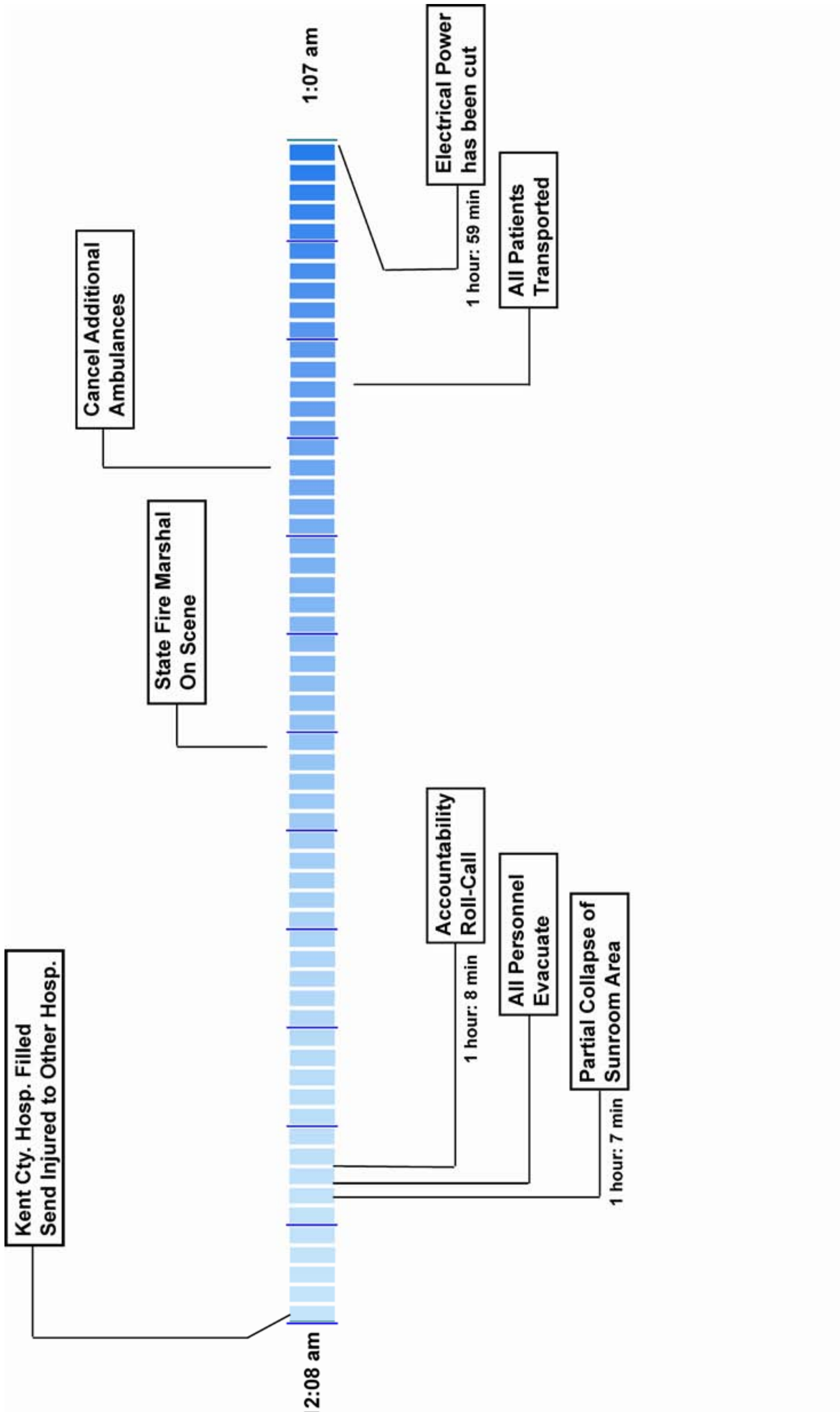


Figure 2-1b. Overview Timeline of The Station Nightclub Fire (cont.)

Table 2-1. Summary of Incident Timeline. (Uncertainty in time is less than +/- 5 s for times showing seconds, and +/- 30 s for times without seconds.)

EST	Fire Time	Description
11:08 pm	0:00:00	First flames on upper wall, left of platform
	0:00:25	Flames touching ceiling on both sides of platform
	0:00:30	Band stops playing, crowd begins to evacuate
11:09	0:00:36	Three Cell phone caller reports fire to 911
	0:00:41	Fire alarm sounds and strobes begin to flash
11:09	0:00:59	Report received of fire at Station Nightclub- Police on Scene,
11:09	0:01:13	Fire alarm recorded at WWFD
	0:01:30	Thick black smoke from pool room windows. Smoke appears to be at floor level inside.
	0:01:42	People piled up in doorway. Smoke pouring out above people.
11:10	0:02:00	E-4, E-1, E-2, E-3, L-1, B-1 assigned/dispatched
	0:04:38	Smoke approximately 0.3 m above floor inside. Flames near door
	0:05:12	First observation of flames out front of building
11:13	0:05:21	Engine 4 on scene. Fire department confirmed on scene, front of building
	0:05:34	Fire Department commences running first hose line (1 ¾”). Flames (2.5 m to 3 m) extending from front exit
	0:05:43	Flames extend from front windows
11:14	0:06	Engine 4 on scene reporting heavy fire
		Water from 1 ¾” hose line directed to the main entrance
		Battalion 1 – activate Warwick Task Force (seven additional engines/ladders) Mutual Aid
		Battalion 1 to Fire Alarm – request 12 rescue units
	0:11	Engine 2 – monitor; knock it down, Master Stream from E-2 on fire at club entrance
11:22	0:14	Fire Chief responding
		Fire Chief 1 to Fire Alarm- Metro Fire Control; Implement Mass Casualty Plan
11:24	0:16	Master Stream off Engine 4 operational – water on center of fire
		any available rescue units, request 15 more

EST	Fire Time	Description
11:28	0:20	Three hose streams, three hand lines streaming on front door area
11:32	0:24	Area/Roof over Main Bar appears down
11:33	0:25	Master Stream off Engine 4 still operating
		Fire Chief 1 to Fire Alarm – need State Fire Marshal asap
11:40		Rescue 2 at Kent County Hospital
		Command to Triage-Triage –need 10-24 stretchers
		Fire Alarm to Triage – Kent County overwhelmed; send to RI Trauma
		Engine 3 to Fire Alarm – repeat; rescues using own discretion; Engine 3 triaging out of here
		Battalion 1- accountability Roll Call – roof down?
11:57	0:49	Middle of Accountability Check- Accountability –Fire Alarm to E-1,E-2,E-3,E-4, Rescue 1, FC, SH
11:58	0:50	Warwick Ladder platform water operating
		Fire Alarm to Command – Kent filled to max; Rescue 1 – approaching scene with doctor from Kent Cty
12:09 am	1:01	Master stream off ladder platform still operating
12:15	1:07	Partial collapse of pool room area begins
12:16	1:08	Warble tone ----- partial collapse; all personnel out
		Accountability Check – E-1, E-2, E-3, E-4, L-1, R-1, E-5, E-7, R-3
12:22	1:14	Master stream from ladder platform still operating
12:23	1:15	Streets appear clear and casualties gone
12:37	1:29	Naragansett Electric Power Truck visible on Cowesett
		State Fire Marshal on scene; Narragansett responding
		Command to Fire Alarm – notify chaplain; cancel additional rescues; cancel LifeFlight helicopter
		Command to Fire Alarm – Chief Rock (Fire Chief 2) and State Fire Marshal meet in front of building
		Safety – cancelled all Rescue, Triage to Fire Alarm – all patients transported
1:06		Rescue 1 clear
1:07		Fire Alarm – Power has been cut

After careful review of the video and audio recordings, links were discovered which allowed all the recordings to be tied to a common clock. West Warwick Fire Department records indicated that the first unit, Engine 4, arrived on the scene at 23:13:22. Engine 4 also notified the WWFD dispatcher over the radio that they were on scene and the dispatcher inserted a clock time of 23:14. While it was not clear that the same clock was used to record the arrival and the dispatcher's time stamp of the radio transmission, the two clock times suggested that both clock times were relatively consistent. It was also possible that the same clock was used for both times and there was a short delay after Engine 4 arrived and their report of being on scene. For development of this timeline, it was assumed that the earlier time, 23:13:22, was the time of arrival of Engine 4.

The arrival time of Engine 4 provided a link to the WPRI video because Engine 4 was visible in the video. A siren could be heard in the background of the WPRI video and seconds later, Engine 4 appeared on the video. The video did not actually show Engine 4 pulling into the parking lot of the nightclub. But 5 minutes 21 seconds after ignition, Engine 4 was shown to be in the parking lot of the nightclub. It was possible that Engine 4 arrived slightly earlier, but was simply not visible in the field of view of the WPRI camera. The arrival time from the fire department records, 23:13:22, was paired to the appearance of Engine 4 in the WPRI video at 5:21 after ignition. This link allowed the fire department records, fire department radio tapes, and the WPRI video to be tied to a common clock.

The fire department radio tapes could be linked to the 911 audio tapes because one of the cell phone callers was relayed from the 911 center to the WWFD. Part of the communication between the cell caller and the WWFD could be overheard on the fire department radio transmissions. Unfortunately, the dispatcher did not insert a clock time on that specific radio transmission, but had inserted a clock time with a preceding transmission. Again, since the radio transmissions were only recorded during actual transmissions, it was not possible to ascertain how much time had passed between the previous clock time insertion and the cell call being transferred to the WWFD. Since each cell call to the 911 center was time stamped automatically, it was possible to link the fire department radio transmissions to the 911 calls.

While the WPRI video captured the first 6 minutes of the fire, the amateur video tape was longer and recorded later in the evolution of the incident. A link between the two video times was found through common events captured on the amateur tape and fire department transmission records. During the fire department response and suppression operations, the WWFD conducted two roll calls of personnel on the fire ground. The first roll call appeared to be associated with the collapse of a significant portion of the nightclub roof. The second roll call was requested when part of the sunroom collapsed. The warble tones used by the fire department to signal a roll call could be heard on both the amateur video tape and the fire department radio transmissions. The fire dispatcher did insert a clock time on the radio transmission announcing the second roll-call. Comparing the time stamp on the amateur video with the fire department radio transmissions identified the amateur video clock to be 3:32 min behind the fire department clock. The amateur video times were adjusted by adding 3:32 min to each time mark.

By linking the fire department radio transmissions to the WPRI video, the 911 cell calls, and the amateur video, all the events were placed on a common timeline. Combining this with the fire department incident record allowed the timeline to reference a single clock time. However, since most of the fire department radio transmissions did not have an inserted clock-time, the timeline shown in Figure 2-1 provides the order in which all of the events occurred, but not necessarily the specific times at which they occurred.

2.4 EVACUATION TIMELINE[1]

Three types of data were used to develop a reasonable and verified description of the evacuation: video footage, photographs and eyewitness statements from the *Providence Journal*. While many newspaper articles reported various details of the incident, the building, and the evacuation, no conclusions were drawn from such sources unless they could be independently verified through review of photographs, video footage, or eyewitness statements.

Short of personal observation, visual evidence can provide investigators with the most reliable depiction of the events of an incident such as this. By considering visual evidence, the investigator does not rely upon the interpretations or views of other observers. Due to inherent inaccuracies involved with eyewitness accounts, visual evidence was given priority in developing the timeline.

The evacuation timeline presented here was assembled with the assistance of Ove Arup & Partners Massachusetts, Inc. Their final report to NIST [3] is quoted freely in this chapter without further reference; however, any conclusions and findings that are presented are solely those of NIST. The timeline includes events specific to the evacuation of the building, as well as those specific to the development of the fire. Various sources were contacted as part of this effort. However, because litigation activities were underway, some potential sources were unable to provide us their information.

The video footage recorded inside and outside of the club before and during the fire by WPRI-TV camera operator [1] was of great benefit to this task. This video showed various activities prior to the incident, as well as the initiation of the fire and portions of the ensuing evacuation. The television news crew's video was used as the primary source of data for this task. Available photographs were used to confirm various details observed in the video, as well as to gain observations of different parts of the club, both before and during the fire.

While eyewitness statements have some drawbacks, they can provide valuable insight, especially since video footage and photographs were not available for all aspects of this incident, or of areas and features of The Station nightclub. In this review, eyewitness statements, primarily as reported by the *Providence Journal* and the *Boston Globe*, were used to draw conclusions regarding occurrences outside of the view of the available visual evidence sources. Unless they could be disproved, eyewitness statements were assumed accurate based on the experience of the eyewitness; conclusions drawn from these were independently verified, where possible. NIST also provided an anonymous toll free hotline and an email address for voluntary input from the general public to generate additional communications, none of which contradicted the published accounts.

Photographs used in this analysis were in digital form, and thus no software was necessary in their processing. The WPRI video was provided to NIST in digital form as well. In order to obtain still images from this video, the media editing software Pinnacle Studio SE, Version 7.15.1, was employed. This software allowed specific individual video frames to be extracted from the video while maintaining image quality.

The timeline that resulted from this analysis, with reference to the still frames from which events were identified (refer to Appendix A for images), is provided in Figures 2-2a through 2-2d . The timeline indicates times in relation to the initiation of fire on the platform, estimated to occur at 11:08:01 pm EST (06:22 video time).

[1] This section taken from the contract report prepared by Ove Arup & Partners Massachusetts [3].

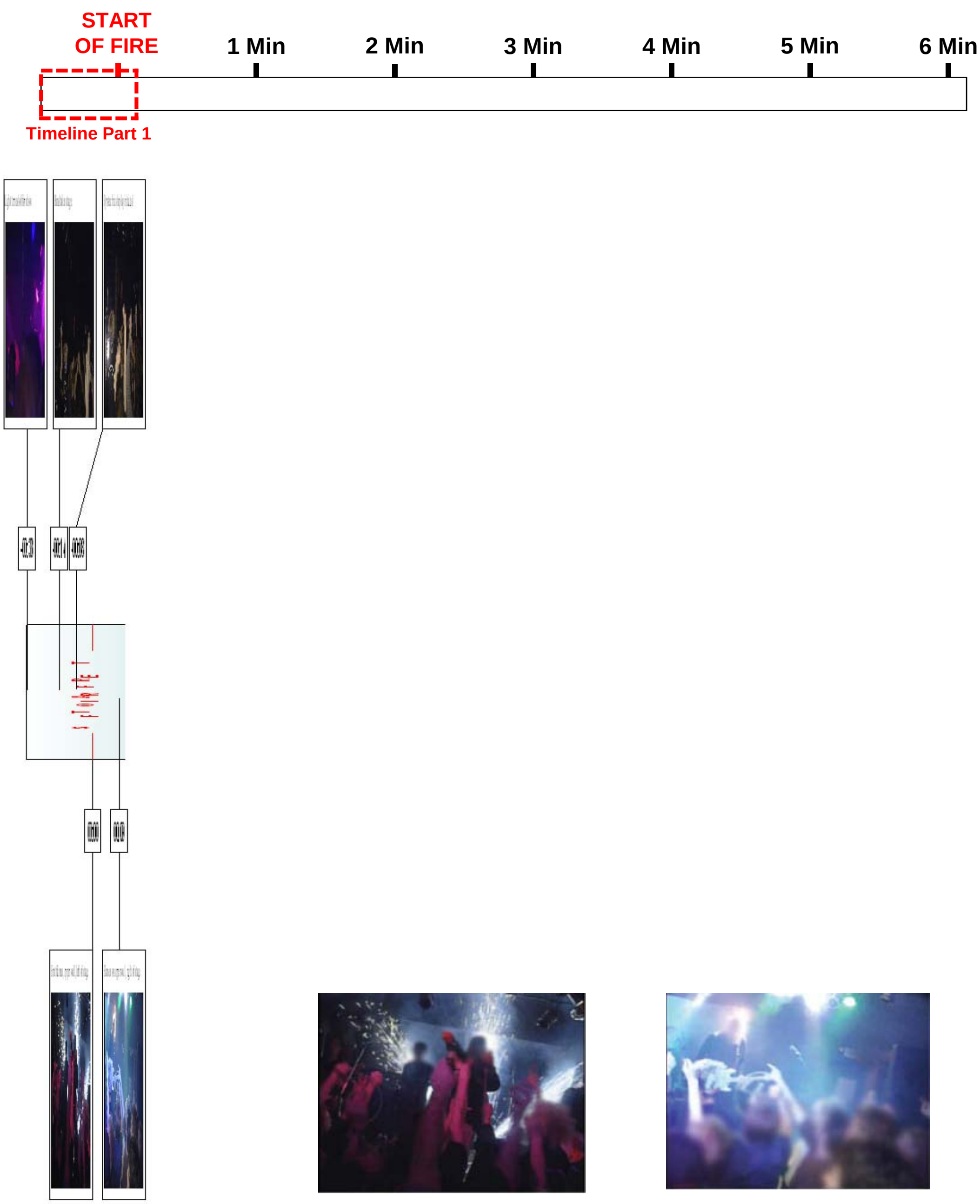


Figure 2-2a. Evacuation Timeline (33 seconds before to 10 seconds after ignition). Video stills copyright © 2003 TVL Broadcasting, Inc. All rights reserved.

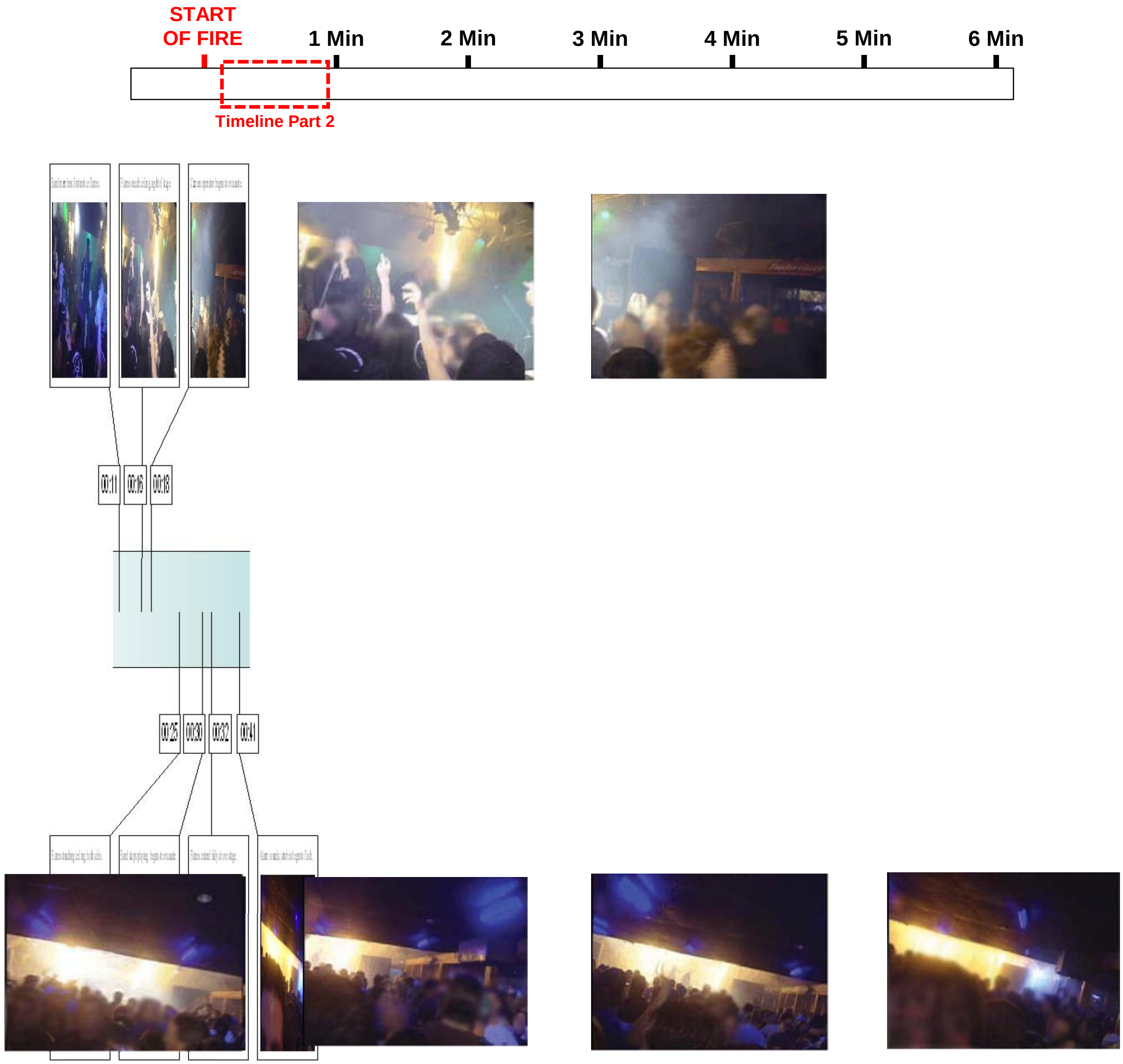


Figure 2-2b. Evacuation Timeline (10 seconds to 50 seconds after ignition). Video stills copyright © 2003 TVL Broadcasting, Inc. All rights reserved.

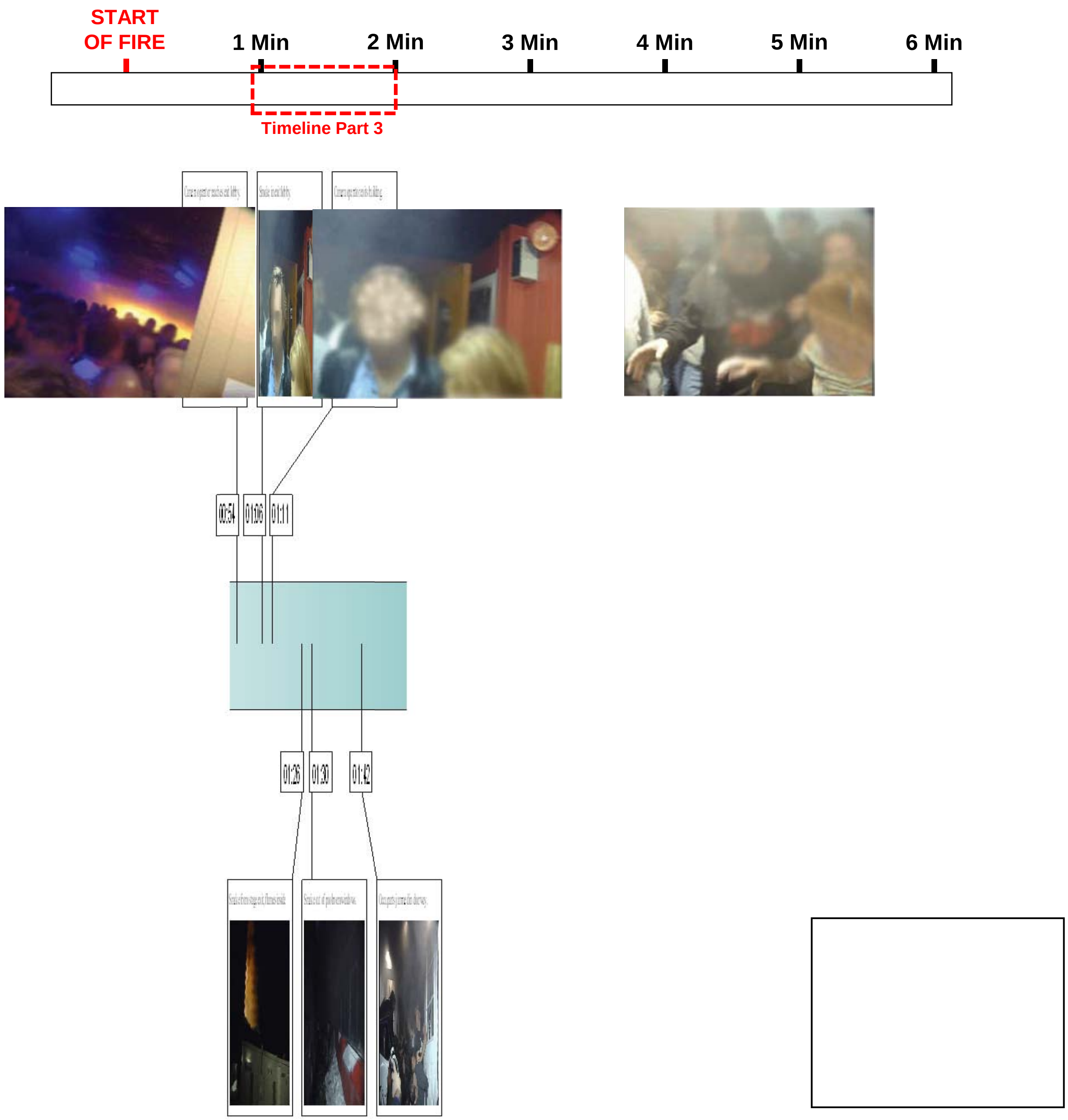


Figure 2-2c. Incident Timeline (50 seconds to 2 minutes after ignition). Video stills copyright © 2003 TVL Broadcasting, Inc. All rights reserved.

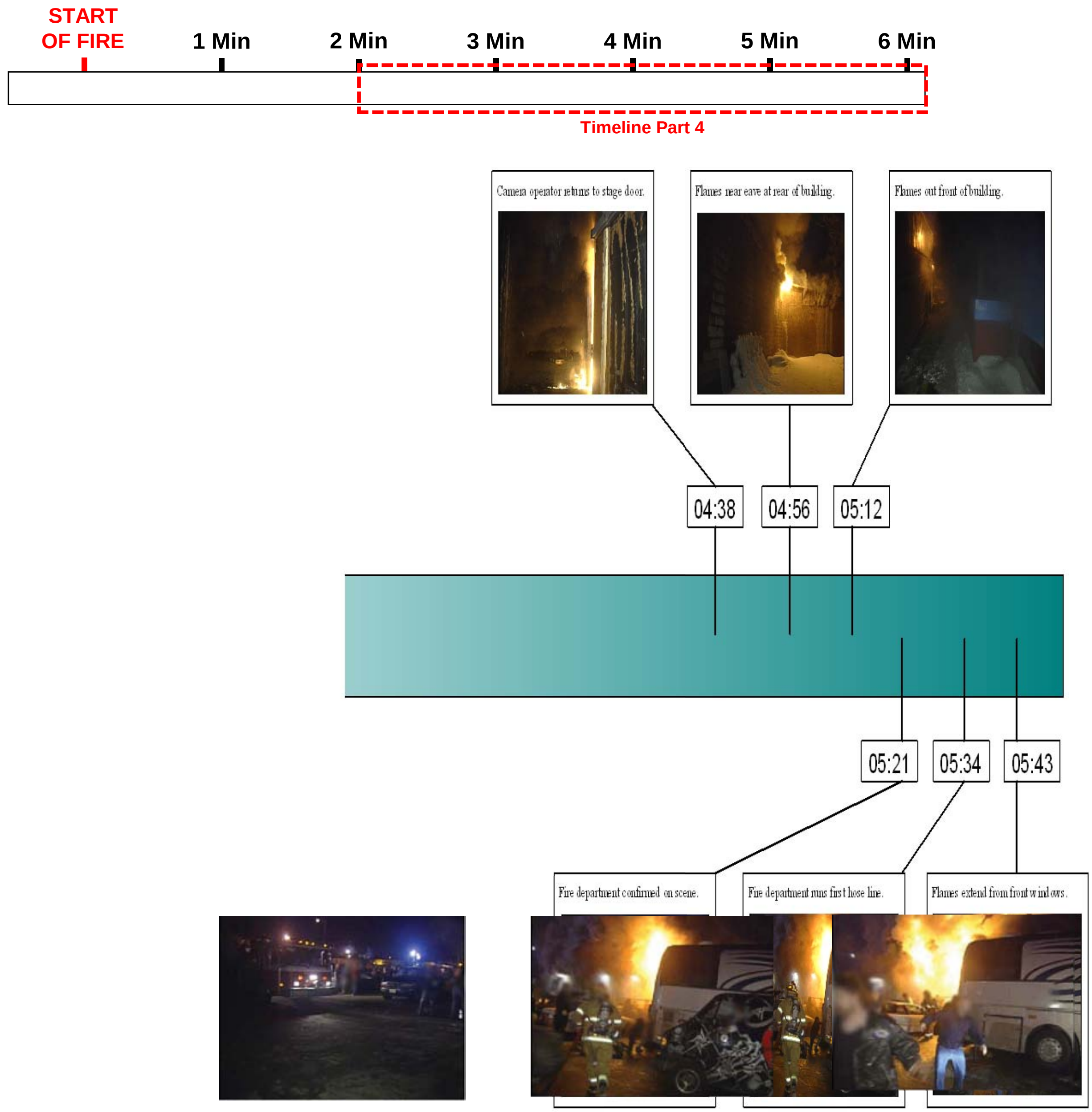


Figure 2-2d. Incident Timeline, Part 4 (2 minutes after ignition to 5:43). Video stills copyright © 2003 TVL Broadcasting, Inc. All rights reserved.

The focus was the time period beginning when portions of the club lights were shut down in preparation for the show, until the videographer placed the camera on the ground in the parking lot and significant flames were seen at the front of the building. The polyurethane foam along the vertical corners of the walls forming the drummers alcove ignited 8 seconds after the pyrotechnic display was initiated, as seen in Fig. 2-2a.. The videographer moved his camera aside 7 seconds later to view the growing fire along the wall better; the band members near the back of the platform noticed the flames 4 seconds later. (Refer to Fig. 2-2b.) The videographer swung his camera around and headed for the exit at the front of the building 18 seconds after ignition of the foam; the first patrons could be seen on the videotape to recognize the fire danger at 24 seconds. Around the time the band stopped playing (30 seconds fire time), the bulk of the crowd had begun the evacuation process. At 41 seconds the fire alarm could be heard and the strobe seen on the video. (See Fig. 2-2b.)

The videographer made his way to the exit lobby while continuing to capture the movement of the crowd leaving the area around the dance floor. As seen in Fig. 2-2c, he exited the building at 1 minute 11 seconds (fire time) along with a steady stream of occupants. Sometime estimated to be around 1 minute 30 seconds after ignition of the foam, the front exit became blocked with people, and occupants could be seen breaking windows and escaping from the poolroom/sunroom. The result of the crowd crush at the front exit was captured on the video at 1 minute 42 seconds (Fig. 2-2c). The latest time recorded for an occupant escaping from inside the main bar (through a window) was at 4 minutes 8 seconds; however, people stuck in the front entrance are seen in the video to have escaped as late as 5-1/2 minutes into the fire, just before the fire department ran its first hose line (Fig. 2-2d). (One patron claimed to have been pulled from the bottom of the pile by a firefighter considerably later, but this has not been confirmed by the NIST investigation.)

Table 2-2 provides a summary of the events making up the evacuation timeline. "Video Time" refers to the absolute counter time associated with the events as captured on the television crew video, while "Fire Time" refers to the time of events relative to the start of the fire.

2.5 REFERENCES FOR CHAPTER 2

[1] Butler, Brian, Video by WPRI, Channel 12, Feb. 20, 2003.

[2] Personal communication between N. Bryner and M. Stone, Rhode Island Attorney General's office, West Warwick, June 2, 2004.

[3] "Evaluation of Limitations to Egress through Doorways in Emergency Situations," Ove Arup & Partners Massachusetts Inc., NIST contract report #32979, Feb. 18, 2004.

Table 2-2. Summary of Evacuation Timeline Developed from Video Analysis [1, 3] (Uncertainty in time is less than +/- 2 seconds)

Video Time	Fire Time	Description
0:05:49	- 0:00:33	Platform lights turned off for beginning of show.
0:06:08	- 0:00:14	Band first shown on platform.
0:06:14	- 0:00:08	Pyrotechnic display initiated.
0:06:22	0:00:00	First flames on upper wall, left of platform.
0:06:31	0:00:09	Flames on upper wall, right of platform. Pyrotechnic display ends.
0:06:33	0:00:11	Band members first notice flames.
0:06:38	0:00:16	Flames reach ceiling to right of platform.
0:06:40	0:00:18	Camera operator begins to evacuate.
0:06:47	0:00:25	Flames touching ceiling on both sides of platform.
0:06:52	0:00:30	Band stops playing, begins to evacuate.
0:06:54	0:00:32	Flames extend fully across ceiling above platform.
0:07:03	0:00:41	Fire alarm sounds and strobes begin to flash.
0:07:16	0:00:54	Camera operator reaches exit lobby.
0:07:28	0:01:06	Smoke in outer exit lobby.
0:07:33	0:01:11	Camera operator exits building.
0:07:48	0:01:26	Smoke coming out of platform exit. Flames visible inside at this location.
0:07:52	0:01:30	Thick black smoke from pool room windows. Smoke appears to be at floor level inside. Occupants egressing through windows.
0:08:04	0:01:42	Camera operator returns to main exit. People piled up in doorway. Smoke pouring out above people.
0:10:30	0:04:08	Occupants still being assisted through main bar windows
0:11:00	0:04:38	Camera operator returns to platform exit. Smoke ~1 ft above floor inside. Flames near door.
0:11:18	0:04:56	Flames outside building at roof level in rear.
0:11:34	0:05:12	Flames first recorded out front of building.
0:11:43	0:05:21	Fire department confirmed on scene.
0:11:56	0:05:34	Fire department commences running first hose line. Flames extending from main exit ~2.5 to 3 m.
0:12:05	0:05:43	Flames extend from front windows.

Chapter 3
THE EMERGENCY INCIDENT RESPONSE

3.1 INTRODUCTION

Beginning late Thursday evening, Feb. 20, 2003, Rhode Island's fire/rescue, emergency medical services and law enforcement agencies were challenged by the largest life loss fire incident in the state's history. In a matter of minutes The Station nightclub became engulfed in flames, producing both a major mass fatality and mass casualty incident that drew upon the resources of virtually every fire and emergency medical services (EMS) provider in the State, a variety of law enforcement agencies and others.

The fire and resulting structure loss was principally limited to the single story, wood framed, unsprinklered, public occupancy, commercial building of relatively modest size [approximately 412 m^2 (4484 ft^2)]. Several vehicles in the vicinity of the building were also lost or damaged by the fire. As described in Chapter 1, the structure stood facing north, at the left rear of a roughly rectangular corner lot at the southwest intersection of Cowesett Avenue and Kulas Road. The corner lot had been carved from a steeply graded hillside and then leveled and re-graded to provide relatively level access along the length of the Cowesett Avenue frontage, while on the Kulas Road (east) side, the grade rose away to the rear and southeast corner of the lot from Cowesett Avenue at a significant incline. The south or back line and the west side property line were covered by relatively heavy brush comprised of various small trees, bushes and ground cover and accumulated snow pack. The length of the rear property line was also contained and obstructed by a privacy style fence.

The site's contours maximized the Cowesett Avenue access and parking (north half of the lot) and placed the structure lower than adjacent perimeter grades at the rear on the east and south (back) sides. The structure's proximity to the berm-like elevated boundary on the east and along the south/back side property line limited tactical operations at the rear and southeast corner of the building. This area also provided no personnel access/egress points to the structure on either side. The building's placement on the lot and its irregular configuration, the higher graded perimeters, and the narrow distance between firefighters and the southeast side and south facing rear walls of the structure presented a risk to fire ground operations due to the rapidly deteriorating conditions, including the possibility the building would collapse. The east side of the lot along Kulas Road also presented an electrocution hazard risk to fire ground operations due to overhead electrical lines and a pole-mounted transformer at the service drop to the structure.

The northeast front facing side, the full front (north facing) and west side of the structure each contained slightly elevated entrance ways into the building and were accessible from the relatively level parking areas extending from the building to the north and west.

In other respects, the structure presented no obvious hazards beyond those normally associated with comparable occupancies nor were there any other nearby at-risk structural exposures. However, vehicle fire exposure risks filled the parking area, in the front of and extending from the structure to the west. This area contained numerous vehicles of various types including a tour bus, media van, cars and trucks, as well as residual snow banks/piles from previous plowing. Although the tour bus was removed during the early minutes of the fire, other vehicles parked near the northeast side (adjacent to the single door bar area exit) in the immediate proximity of the building were exposed to sufficient radiant heat to produce secondary ignitions, requiring extinguishment and producing additional vehicle fire losses from the incident.

The human toll from the fire was far more devastating. Within only minutes of the pyrotechnic display ignitions, 96 people perished, unable to egress safely ahead of the intense and fast moving fire. Most of the fatalities occurred in the moments prior to the arrival of the first emergency services units. Four more died within days, subsequent to hospitalization, raising the final fatality count to 100.

More than 200 other victims, many seriously hurt from burns, respiratory insult and physical trauma, were provided emergency care and triaged at the scene, then transported to hospitals across the State. This major mass casualty incident (MCI) effectively concluded its emergency on-scene and pre-hospital care operation (casualty collection, triage and transport) phase in less than two hours from the fire's onset. The operation was accomplished expeditiously through the combined efforts of dozens of agencies (some 60 EMS units and untold number of individual care providers), notwithstanding the communications interoperability challenges experienced by many of the responding units.

Subsequent to the fire's suppression and once the scene was cleared of casualties, the next major phase began -- the recovery and identification of the fatality remains. These activities opened the opportunity for police, fire investigators and others to access the primary loss area to collect and document information in support of their investigations.

The State Fire Marshal and Medical Examiner's personnel coordinated the recovery of the dead. Fire Department personnel were utilized to collect individuals' remains and to move them to a holding area at the northwest corner of the lot while awaiting transport. The respective investigative teams documented the fire scene and the body recoveries, attempting to identify the deceased as early on in the process as possible. This phase of the operation continued until the recovery and removal of the last victims by late afternoon, on Friday, Feb. 21. The scene had been secured with temporary fencing and site control transferred to the law enforcement authorities conducting the follow on investigations.

Fire department on-scene operations concluded with the last 'stand-by' engine company returning to quarters some 24 hours after the ignition of the pyrotechnics that came to produce the fourth deadliest public assembly fire loss in the Nation's history.

3.2 THE WEST WARWICK FIRE DEPARTMENT

The description of the West Warwick Fire Department (WWFD) provided in the DHS/ODP After-action Report (Annex A, p. A-1) [1] forms the basis of the information summarized here. The WWFD provided both emergency medical and fire suppression services to a community of approximately 30,000. West Warwick is situated geographically at about the center of the state, and comprises a primary response area of just under eight square miles. The Department operated from four stations with a combined response capability of four engine companies, one tower/ladder company, two rescue-ambulances and one special hazards unit or squad-type apparatus with a light tower.

The Department's 66 uniformed personnel were divided into four rotating platoons typically comprised of not less than one battalion chief and 12 other officers and firefighters per shift. An officer and firefighter each staffed Engines 1, 3 and 4. An officer and firefighter cross-staffed Ladder 1 and the special hazards unit and two firefighter/EMT-C's cross-staffed Engine 2 and Rescue (ambulance) 2, while two firefighter/EMT-C's staffed Rescue (ambulance) 1. (Note: cross staffing indicates the personnel responded on either of the indicated apparatus depending on the nature of the assignment.)

At the time of the fire, the WWFD's unit staffing (as noted above) was about half the minimum complement of engine and truck company personnel suggested in the applicable National Fire Protection Association (NFPA) Standards (1500 [4] and 1710 [5] respectively). The Standards advocate a minimum crew of four members operating from each type of apparatus. Unit staffing levels directly affect the firefighting crew's tactical performance capabilities, the speed at and duration of which they can be relied upon to accomplish various tasks, such as establishing water supply, advancing hand lines, or effecting rescues, as well as the overall scope and effectiveness of the tactical intervention strategy being applied in a given situation.

The WWFD routinely relied upon substantial mutual-aid augmentation [principally from the Warwick Fire Department (WFD) and the Coventry Fire Department (CFD)] to respond to its working structure fires due in large part to its below standard staffing levels. In general, the additional response times of mutual aid assets can delay the effective implementation of the Incident Command (IC) based strategies and tactics necessary to successfully mitigate significant incidents. In this case, however, the large loss of life was not connected to any delay in establishing the Incident Command.

3.3 THE FIRE AND EMERGENCY MEDICAL SERVICES RESPONSE

A "structure fire with person(s) trapped" type incident by its nature produces a situation where occupant rescue and fire suppression activities are competing for immediate priority attention. The response to this incident involved major concurrent tactical challenges (the fire suppression, the mass casualty management, scene control and traffic management and the subsequent victim identification, community support, and incident investigation) requiring concurrent intervention activities by fire suppression, EMS, law enforcement personnel and others from a plethora of agencies.

The following overview is intended to provide a general description of the incident's progression noting key tactical challenges and how they were addressed. The overview timeline (Fig. 2-1a and 2-1b, and Table 2-1) summarize the sequence of events that are described in more detail in this chapter. Invaluable contributions were made by literally hundreds of service providers from a host of agencies working in common cause, even though there were problems in the response.

3.3.1 The Initial Alarm

On Feb. 20, 2003 at approximately 11:09 p.m., the West Warwick Police Department dispatcher received a radio call from an off duty officer at the scene stating there was a fire at The Station nightclub located at 211 Cowesett Avenue. Within seconds the State's 911 call center also began receiving calls for help and relayed the alarm to West Warwick's fire dispatcher who initiated a standard structure fire response at approximately 11:10 p.m.

The duty chief, four engine companies, the tower/ladder company and a rescue-ambulance responded to the initial alarm. Calls continued to come in, indicating the extraordinary severity of the fire and that numerous people were trapped and injured, which prompted the assignment of additional rescue-ambulances and other assets from both the adjoining jurisdictions and across the state.

At approximately six minutes into the fire, and within moments of his arrival, the WWFD's on-duty chief (acting Battalion 1) requested the activation of a task force from the nearby Warwick Fire Department for mutual aid. Warwick Fire Department units monitoring the alarm traffic and anticipating the assignment went "in-route" when dispatched at approximately 11:14 p.m. The WFD response was comprised of an augmented task force including a chief officer, 3 engines, 1 truck and 2 rescue-ambulances. The WWFD on-duty chief then requested 12 rescue-ambulances to be dispatched in addition to those already responding. The dispatchers received multiple alarm/mutual aid requests as the incident progressed.

3.3.2 The Incident Command

The initial Incident Command (IC) was established with the arrival of the WWFD on-duty Chief (acting Battalion 1) who positioned his command vehicle at the west end of the alarm assignment structure on Cowesett Avenue.

From this location the IC had a fair view of the front of the burning structure, the large number of casualties disbursed among the crowds of other people in the parking area in front of The Station and along both sides of the roadway to the east, the Kulas Road intersection with Cowesett Avenue, and some of the area on the street in front of the Cowesett Inn. As one scanned from a southerly direction to the east the following could be seen:

- directly south -
    - the immediate parking area in front of the building with numerous at-risk vehicle exposures, the at-risk structure with heavy fire showing, and the steep grade incline and wooded area to the rear of the lot
- to the southeast –
    - at a distance, the rise of Kulas Road up-grade away from Cowesett Avenue with adjacent utility poles and overhead wires with a transformer
    - in the near ground, the approximate length and width of the parking area and vehicle loading
- looking east -
    - on the right of Cowesett Avenue, the length of the street section in front of The Station
    - on the left, the area in front of and to the west side parking areas of the Cowesett Inn

The fire ground scene was chaotic. The fire was rapidly enveloping the structure with a large collection of victims trapped at the main entrance and an unknown number still likely to be in the building. Dozens of victims with obvious injuries were scattered across the operational area, including the parking lot and along the street looking east toward the Inn.

The concurrent and emerging operational objectives of rescuing victims, providing mass casualty care/transport and mounting an attack to extinguish the fire were apparent to the IC who immediately requested additional assistance.

The IC directed WWFD's Engine 2 to lay-in supply lines from the hydrant in front of the Cowesett Inn and to support the first due unit's (Engine 4) suppression operations. During these initial activities, the primary command focus was to establish a water supply and accomplish as many victim rescues as possible given the rapidly deteriorating fire conditions.

At 11:22 p.m., less than 14 minutes into the fire, WWFD's Chief of the Department notified dispatch that he was responding. Moments later while in route, he ordered the formal activation of the Mass Casualty Incident (MCI) component of the mutual aid plan.

Upon his arrival, approximately six minutes later, he conducted a brief assessment of the unfolding operations and moved the position of the IC forward of the original command location, in the parking lot at the front of the building. Also recognizing the magnitude of the incident's casualties, the Chief immediately requested any available rescue-ambulance to respond. He specifically requested 15 additional units beyond those units previously deployed and those currently responding to the initial IC's request for "any available unit." Although the Chief did not formally announce his assumption of command or the new IC location his presence became obvious to the dispatchers and the personnel already engaged in rescue and suppression operations at the scene.

The IC (WWFD Chief) was joined in short order by the department chiefs from the Warwick FD and the Cranston FD at the newly positioned IC area at the front of the building. From this vantage point the command group could better observe and direct the rescue efforts at the entranceway and the fire attack. The chiefs from the mutual aid departments functioned as a command group to support the IC and to direct the assignment of their respective department assets.

Upon the arrival of the Chief from the Coventry FD the IC requested that he assess and report on the unfolding EMS activities at and near the Cowesett Inn. In this role the Coventry Chief became the EMS liaison to the IC for the remainder of those operations.

Although the IC group did not adopt a traditional IC structure or paradigm, it functioned in a fashion that was, in effect, driven by the unprecedented magnitude of the mutual aid response and the huge coordination challenge presented by the high volume of communications necessary for the multiple responding units. As discussed in the DHS/ODP After-action Report (Annex A, p. A-21) [1], the respective chiefs relayed commands to their dispatchers and arriving units on their respective radio channels, as no common channel was available to effectively handle the volume of radio traffic emanating from the scene.

The resulting fragmentation of vital communications posed substantial challenges to area dispatchers who were trying to satisfy the numerous "any available unit" requests from their respective assets already at the scene. The generalized requests for "any available units" initiated to various dispatch centers by the mutual aid companies produced confusion regarding which units had already responded and which were still available. Since units were being self-deployed, dispatchers had to poll departments to see if they could respond rather than relying on the call-ups driven by the mutual aid system's resource cascade. The communications difficulties also led to Basic Life Safety (BLS) patients being transported by Advanced Life Safety (ALS) units on a first-come-first-served basis, which is a less effective use of resources. From a command/operations perspective the incident could have been better managed. In spite of this situation, all the critical requirements were achieved with the fire being extinguished in little over an hour and the evacuation of the last casualty in less than two hours from the initiation of the incident.

At approximately 4 am the Command group met at the Cowesett Inn to plan the demobilization of the incident. This effort prioritized the actions necessary to close out the on-scene operations, identified the additional equipment and various staff resources needed to accomplish a wide range of related tasks both at the scene and elsewhere, and insured the necessary notification and coordination with other participating agency personnel. Principal among these activities was the effort to structure the process and staff the victim recovery activities that would conclude the fire ground operations.

The absence of a centralized communications capability and record of the IC operations during this incident precludes a meaningful objective review of those activities. However, the assets needed, both personnel and apparatus, did materialize in a timely fashion. Given the time needed to collect, triage and care for the casualties, these services were capably provided by the initial mutual aid responders.

3.3.3 Fire Attack

The first fire apparatus, WWFD Engine 4 and Tower/ladder 1, were located less than 800 m (half a mile) west of the nightclub on Cowesett Avenue and arrived on scene within three minutes of dispatch and approximately 5 ½ minutes into the fire. On arrival Engine 4 reported "heavy fire" conditions at the scene, as flames were visible at multiple locations and heavy volumes of thick black smoke were emanating from various points of the structure. Engine 4 was able to pull into the parking lot and positioned almost directly in front (the north side) of the building, a few meters west of the main entrance, while Tower/ladder 1 passed the parking lot and turned south on Kulas Road to position on the upgrade, east side of the structure. The location of WWFD Tower/ladder 1 was tactically compromised by pole mounted power lines extending parallel along Kulas Road between the blazing structure and the apparatus.

Within moments of their arrival, Engine 4's crew with assistance of Tower/ladder 1's personnel and bystanders, had extended a 1 ¾" hand line from the unit and advanced to the main entrance of the club. The fire conditions were deteriorating rapidly. Significant volumes of fire were enveloping the building and heavy smoke was billowing from the main entrance, secondary exits, and knocked out windows in the sunroom and main bar area on either side of the main entrance. At the same time, occupants were trying to escape through that main entrance, with tiers of entrapped victims stacked on top of one another in the doorway. As the crew approached, they utilized a 1 ¾" hand line, served by the unit's on board water supply, to retard the fire at this principal egress point. This was to provide the entrapped victims a protective water curtain while units assisted individuals. (It has not been determined how many people may have been rescued during this phase, nor when they may have been removed from the front doorway; however, it was reported [2], without confirmation from the fire department, that one person was pulled from near the bottom of the pile as much as an hour after the fire department arrived on the scene.)

Upon its arrival WWFD Engine 2 laid-in, providing two 3" water supply lines from the hydrant across the street at the corner of Cowesett Avenue and Coit Avenue adjacent to the southeast corner of the Cowesett Inn, to support Engine 4's operations, which had exhausted its on board water supply. Engine 2 was able to enter the parking lot positioning a short distance behind Engine 4. The crew established a supply line to the first arriving unit (WWFD Engine 4) enabling that unit to recharge its previously deployed hand lines once the two supply lines from the hydrant were charged. WWFD personnel were also able to advance additional hand lines and initiate a master stream operation at the front of the structure utilizing Engine 4's deck gun.

When the WWFD Special Hazards unit arrived it was positioned at the northeast corner of the property facing south on Kulas Road directly behind WWFD Tower/ladder 1 and raised the unit's light mast to illuminate the scene. WWFD Engines 3 and 1 were not employed in the suppression operations but were positioned nearby on Cowesett Avenue across the street from the Inn.

WFD Engine 1 laid-in, providing approximately 90 m (300 ft) of 4" supply line from a hydrant on the east side of Kulas Road above the fire ground. They positioned the apparatus facing down-grade (north) in the south bound lane of Kulas Road just above WWFD Tower/ladder 1 and Special Hazards unit at the east side of the lot. The crew initiated a master stream operation with their deck gun from that position to attack the fire to the interior of the building near the main entrance area.

WFD Ladder 1 was the last apparatus to be engaged in the suppression effort. It backed into the parking lot in front of the structure just to the west of the WWFD initial assignments (Engines 4 and 2). Although equipped with a 4" supply line, Ladder 1 did not have an on board pump capability and attempts to begin master stream operations were initially ineffective due to low water pressure. This operational challenge was overcome by re-routing the supply line to one of the WWFD's engines which then provided the necessary water pressure to establish and maintain an effective master stream

Figure 3-1 shows the layout of the fire ground during the fire attack and suppression activities. The initial attack was mounted by WWFD's first unit, Engine 4, approximately 6 ½ minutes into the fire with the advance of a 1 ¾" line to the main entrance of the structure and the primary victim cache, and continued until the unit's on board water supply was exhausted. While the two, 3" supply lines to the front of the structure were being laid and charged, rescue efforts continued along the building's north face, through both the broken windows and exits. However, these efforts were pursued without the benefit of protective hose lines and were substantially hampered by the rapid fire propagation, radiant heat and heavy volumes of smoke discharge from the structure.

Once the two 3" supply lines to Engine 4 were established approximately 10 minutes after their arrival, an apparatus mounted deck gun/master stream operation was initiated from WWFD's Engine 2 and additional hand lines deployed at the front and to the west side of the structure.

The frontal attack was almost immediately augmented with the arrival of WFD's Engine 1, which had laid its own supply line. Once positioned, Engine 1 began a master stream operation from its deck gun on the east side of the structure and then extended hand lines down the grade to the east side front of the building. These attack lines were most effectively applied to suppress the multiple vehicle fires adjacent to the northeast corner of the structure.

Less than 25 minutes into the incident, the structure was showing fire through the roof in the area of the main bar, which appeared to have substantially self-ventilated or partially collapsed. Shortly thereafter WFD's Ladder 1 was backed into the west side of the parking lot. The unit was provided a 4" supply line from a hydrant located at 198 Narragansett Avenue by Cranston FD's Engine 4. However, due to the extended length of the supply line and the hydrant pressure, this source was not sufficient to produce an effective flow. These efforts were suspended and the supply line was then repositioned to allow WWFD's Engine 4 to initiate pumping operations in support of WFD Ladder 1's elevated master stream operations.

The major section of the main roof collapsed a little more than 45 minutes in to the fire, prompting the IC to initiate an accountability check of the suppression crews. The roll call produced no indication of missing personnel and suppression operations continued.

The sunroom area at the front of the club included a window-wall approximately 9 m (29 ft) long just to the west of the main entrance facing the parking lot. The roofing and structural support for this element of the building's façade collapsed a little more than an hour into the fire, which prompted the IC to initiate another personnel accountability check.

After this second major element of the structure failed, little remained of the building except sections of the exterior walls at the front (primarily in the area of the main entrance which had been the focus of substantial suppression effort). The west and rear walls were heavily damaged, and elements of the nightclub's storage area, food preparation and office areas to the southeast corner of the structure were effectively destroyed although some components of interior compartment separations still remained standing at that end of the structure.

The fire attack continued with the master stream operations knocking down the residual pockets of major fire in the remaining structure while hand lines were used to address areas that were difficult for the

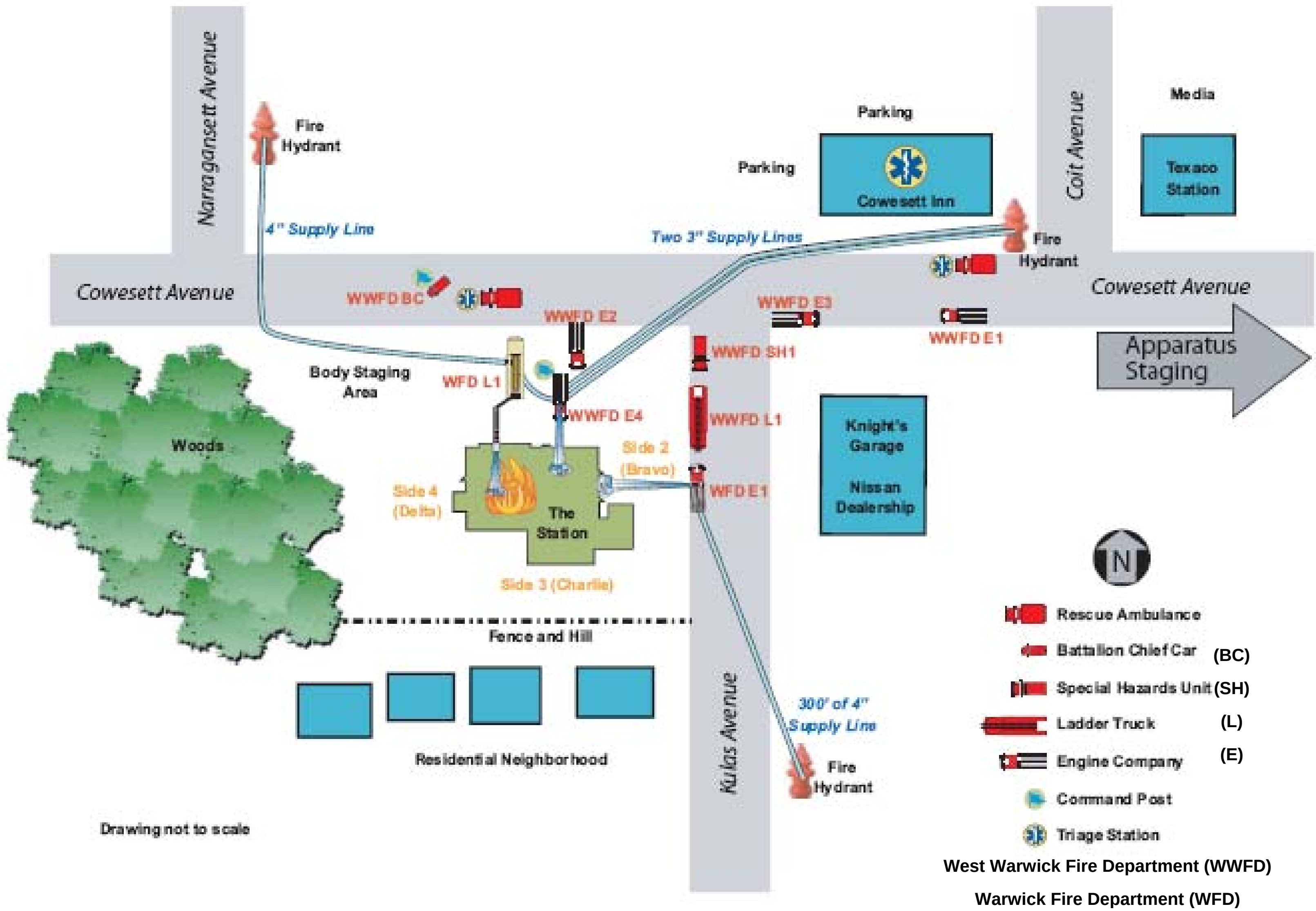


Figure 3-1. Schematic of primary apparatus deployment

master streams to reach. With the structure now heavily damaged (essentially a total loss) and the fire effectively suppressed, the interior of the structure became accessible for the first time in the operation.

No interior fire suppression attack had been possible at the outset of operations due to the untenable conditions and none was initiated until this final stage of the incident. Once able to get inside, suppression personnel checked the area for possible survivors, extinguished the last of the residual fires and wet down hot spots.

At this point the fire suppression and rescue efforts were essentially terminated and operations at the building transitioned into a victim recovery and identification phase that continued until the last of the 96 fatality remains were removed from the structure and transported to the State Medical Examiner's facilities. The final body recovery efforts were completed by late afternoon on Friday, Feb. 21.

No firefighter fatalities occurred during the extinguishment of this fire. Five firefighters were injured: one with a fractured ankle, and four with smoke inhalation, cuts and bruises.

3.3.4 The Water Supply

The incident area had immediate access to a municipal hydrant system to support fire ground operations. Although positioned short distances away (see Figure 3-1), the incident site had expedient access to three hydrants, all of which were utilized.

The first hydrant was located a few dozen meters northeast of the incident site on Cowesett Avenue near the corner of Coit Avenue and in front of the east side of the Cowesett Inn. That hydrant supported two, 3" supply lines to WWFD's Engine 4 while that team attacked the fire from the front of the building in the parking lot a few meters west of the structure's main entrance.

The two other hydrants both provided 4" supply lines to the units they supported respectively. One, at the southeast corner of the site on the opposite side of the Kulas Road incline at about the crest of the grade, provided WFD Engine 1 supply for its master stream and hand line operations. The other was on the east side of Narragansett Avenue to the north and upgrade of the intersection with Cowesett Avenue some distance from the northwest corner of the site. That hydrant supported the master stream operations of WFD Ladder 1 positioned to the west of the two WWFD engines in the parking lot.

The hydrants' proximity to the incident site's northwest, northeast and southeast corners allowed apparatus to lay-in to the fire ground from all three directions. When supported by the pumping operations of the various engine assignments, the water system's pressure and flow was sufficient to sustain the multiple master streams and the numerous hand lines utilized to extinguish the structure and the various vehicle fires.

3.4 MUTUAL AID

Most emergency services providers, and fire departments in particular, develop and operate with the assistance of mutual aid compacts or agreements with neighboring departments to augment their capability to respond to incidents when their assets are committed or otherwise unable to satisfy the community's emergency response requirements. Such compacts are typically designed to rapidly augment the department's staffing or equipment during an emergency when needs exceed their capabilities.

Mutual aid agreements vary widely in scope and content. Some agreements are designed to provide assets as specifically requested while others provide for the routine deployment of another department's specialized assets such as hazardous materials units, advanced life support (ALS), bomb disposal units, water supply, aerial apparatus or other specialty units when an alarm is initially transmitted. In the latter situation, the mutual aid assets are in effect shared by signatories to the agreements, and are utilized independent of actual jurisdictional or organizational ownership. All agreements benefit the member agencies by providing emergency surge capabilities (staffing, equipment, etc.) from other agencies that would be prohibitively expensive to operate and maintain in each jurisdiction.

While mutual aid arrangements have an obvious practical value, they also have limiting characteristics. Assets which are infrequently used by a department requesting the mutual aid from another may be in use by the department possessing the asset on a regular basis, and therefore unavailable when needed by others. In a wide scope event, there may be more departments in need of specific assets than are available within the member compact. Jurisdictional differences in equipment, tactics and communications systems may also present interoperability challenges to the effective use of mutual aid assets, as was the situation at this incident. Some agreements are relatively small in scope, limited for example, to nearby departments. Others may apply to all the departments in a county -- or as in the case with Rhode Island, cover a multi-state region.

Most agreements center on strategic principles that assure that the specific mutual aid requested will normally come from the nearest jurisdiction with the assets available. Depending on the amount of aid needed (the number, magnitude and/or the diversity of the assets required) the aid is typically moved toward the incident in a fashion that first thins the assets of the area departments nearest the incident and then progressively back-fills or covers those departments providing the initial aid with units from departments further away, providing for successive concentric waves of resource augmentation.

Mutual aid was provided to the West Warwick F.D. and the other fire departments throughout the state in conjunction with the Southern New England Fire Emergency Assistance Plan (SNEFEAP). The plan was designed to augment each department’s staffing and equipment capabilities through an anticipated incident severity progression of up to seven alarms beyond the initial assignments. This is designed to be achieved by providing both assets to the scene and back-fill /coverage for the departments providing emergency fire-EMS assistance to others.

The mutual aid support provided to the respective major operational activities at The Station nightclub fire is summarized briefly in the following sections. These sections provide a general overview of the incident’s magnitude and complexity and are not intended to identify or chronicle all of the individual contributions that were made.

3.4.1 The Fire Suppression Operations

The Station nightclub fire required only a relatively modest augmentation of the West Warwick Fire Department’s available suppression equipment resources to contain and extinguish. Beyond the WWFD’s response, this fire required only two additional apparatus from the Warwick Fire Department to augment the direct fire suppression operations at the scene (WFD Engine 1 and Ladder truck 1). The additional units from WFD that were utilized (one engine and one ladder truck) did not exceed WWFD’s equipment complement capabilities; WWFD’s own similar assets were deployed to the scene but were not utilized in the suppression effort.

The initial WFD task force group dispatched had been supplemented with an additional engine company, rescue-ambulance and special hazards unit at the election of the responding department. Beyond WFD’s substantial response of equipment and personnel, Cranston FD and Coventry FD also provided numerous units and substantial staffing (including approximately 100 firefighters and command officers) to support on-scene operations and to cover WWFD's stations and service area during the incident.

During this stage of operations significant numbers of the officers and staff on the mutual aid units were also deployed to the scene but not involved in direct suppression support. These personnel were primarily employed to provide the critical on-site cadre necessary to effectively initiate and maintain the coordinated casualty collection, triage, pre-hospital victim care and survivor support operations.

3.4.2 The Mass Casualty Incident Operations

In stark contrast to the suppression operation's minimal equipment resource demand on the mutual aid system, the magnitude of the resulting EMS-fire casualty management operation drew upon substantial personnel and equipment resources from throughout in the state. The incident management also benefited from the mutual aid plan's everyday use of fill-in/coverage assignments and direct incident support by and for the EMS units of various departments. This is done in essentially the same fashion as the deployment of the suppression units and other specialized assets.

Initially, the incident site was strewn with numerous victims: many with obvious injuries were sitting on and in the surrounding cars, and some were on guard rails and snow banks, while others stood and milled about or lay on the ground. The immediate availability of shelter from the winter cold was afforded by the proximity of the Cowesett Inn just a few dozen meters across and down the street. Many of the uninjured survivors and walking-wounded migrated there spontaneously to flee the scene and seek/secure assistance. Given its on duty support staff, size, diverse facilities, configuration and cross-street location, the Inn readily became the primary triage and survivor assistance center at the scene.

As this incident's high casualty count became increasingly apparent, the mass casualty incident (MCI) operation began to unfold with dispatchers receiving multiple requests from the scene for "any available rescue" to respond. The casualty collection and care began with the first arriving rescue- ambulance units being besieged by those in need of care or requesting medical assistance for others. A number of these first-in units initially effectively served as field triage and care stations, transferring casualties to other units in and beyond the immediate fire ground congestion on Cowesett Avenue between The Station and the Cowesett Inn.

Initial command of the EMS operations evolved quickly as personnel and equipment became available. As EMS units and company officers arrived they began organizing the chaotic scene. The triage and care efforts that were initially attended by the first arriving EMS providers wherever the units were positioned on-scene began to center on the Inn and its immediate area. For much of the incident's duration, at least three distinct triage areas were operating simultaneously: one near The Station on Cowesett initiated by an officer and crew from Hopkins Hill FD from Coventry, one on the outside of the Inn at the front door established by a Cranston FD officer and crew, and another inside the Inn under the direction of a WFD officer.

As additional chief officers and crews from Warwick, Cranston and Coventry fire departments began to arrive, the management of the EMS operations evolved significantly. The needs and activities of the respective triage sections were afforded greater command cognizance through the use of an EMS liaison to the IC, a role filled by the Coventry FD Chief.

A Cranston FD deputy chief assumed the role of transportation coordinator and began staging units away from the immediate area of the Inn at a parking lot of a nearby restaurant. This action was initiated to reduce the congestion at the site and to better coordinate the loading and transfer of victims to regional hospitals. The effective coordination of both incoming unit staging and on-scene activities was significantly compromised due to non-interoperable radio equipment between command elements and responding units, as mentioned earlier [1]. The communications challenges also materially hampered direct coordination with regional hospitals. As a result, the transportation officer was, more often than not, unable to communicate directly with the hospitals to ascertain their status and capabilities -- and therefore unable to direct units to the most appropriate medical facilities.

Less than two hours after the initial alarm, the MCI management effort had effectively organized multiple field triage and care locations as well as the in-door operations at the Cowesett Inn and the last of the casualties were transported. The wide scale ground transportation EMS evacuation of 186 casualties had been accomplished using nearly 40 fire department-based emergency medical services units, 20 private sector ambulances from a variety of commercial providers, and buses used to shelter and transport those with only minor injuries. More than 200 people may have been injured in the incident, most of whom were transported to medical facilities throughout the state by EMS providers and private vehicles.

3.4.3 The Law Enforcement Scene Security & Traffic Management Operations

Beyond their immediate response and assistance at the scene, the West Warwick Police Department (WWPD), the Warwick Police Department, the Coventry Police Department and other local agencies including the Rhode Island State Police personnel played key roles in managing and supporting the incident security, access and traffic management efforts necessary to effectively access, stage, deploy and permit egress by the significant numbers of rescue/ambulances (about 60 units) and all the other fire apparatus and emergency services units that responded. Their collective efforts assured the volume of EMS units had effective access to the scene and its adjacent staging areas. They also assured that the traffic management effort provided for the safe exit of emergency vehicles once they were loaded with victims and in route to area hospitals.

3.4.4 The Mass Fatality Recovery and Victim Identification Operations

The impact and consequence of such a significant number of fire casualties (both injured and killed) extended beyond the fire service organizations involved to also challenge the area’s local law enforcement agencies, the State Police, the State Fire Marshal’s Office, the State Medical Examiner’s Office and other regulatory authorities. There were extraordinary informational, tactical and technical challenges requiring the coordination and contribution of virtually every agency involved. These included identifying uninjured survivors, those who had been EMS triaged and transported and to where, those who might still be missing, and those who were among the dead

These operations generally required two concurrent efforts; one to physically recover and identify the remains on site, and the other -- accomplished off-site at facilities conducive to conducting confidential interviews -- was to collect victim identification profiles from friends and relatives of those still unaccounted for.

The victim profiles included physical descriptions of the person such as sex, height, weight, hair and eye color etc., and any available information about what they had been wearing when last seen (such as clothing items and jewelry). This information was used to assist with subsequent identification efforts, including forensic examinations by the State Medical Examiner.

Both of these activities were accomplished with a regard for the privacy and dignity of the victims and their survivors. During the recovery of the physical remains, efforts were made to avoid additional trauma to the deceased and to collect personal effects that might aid in the victim’s identification. These actions were accomplished while shielding the area from the view of bystanders. The collection of victim identification profiles was also handled discreetly, to the extent possible given the circumstances. Interviews were conducted in private and the information collected was treated as confidential.

The victim identification processes, both investigatory and forensic, continued through the weekend and until the last fatality was positively identified on Tuesday evening, Feb. 25. Completion of the victim recovery and identification operation effectively brought a close to the response efforts, with the exception of the on-going fire investigation.

3.4.5 Post-fire Investigation Operations

Major fires, especially those producing a significant number of injuries and/or fatalities, often involve concurrent investigations by various local and state law enforcement agencies and other regulatory authorities, as occurred in this case. By law, in most jurisdictions, fire losses in general -- and particularly those resulting in serious injuries and/or deaths -- are investigated to determine at the very least, the location of the origin of each fire and its cause (natural, accidental, criminal, etc.). Depending on a variety of other factors, they also may be the subject of other inquiries, reviews, or hearings by a range of regulatory/technical authorities. The sooner that relevant information regarding witnesses/persons involved and specific facts can be collected, the more effective the initial incident information management effort and subsequent investigations are likely to be. Law enforcement agencies typically play the key role in this aspect of overall incident management security and in supporting the public’s information needs.

The RI State Fire Marshal was on the scene of this multiple fatality fire within an hour of the IC’s request for his assistance. Even though the origin and cause of this fire was known (actually captured on video-tape) the State Fire Marshal’s Office conducted an investigation to document the loss, and to determine the parties responsible for the catastrophic loss of life and injury. These efforts were conducted in conjunction with local authorities, primarily WWPD and WPD although other authorities (including the RI State Police) participated substantially.

Owing to the magnitude of the incident, the State Attorney General’s Office oversaw and directed various aspects of the inquiry. The Warwick PD also played a key role by establishing and staffing an office dedicated to assembling investigative reports and related information.

Post-incident investigation is part of the emergency response function. The subsequent investigative efforts are normally necessary to determine the origin and cause of the fire and to ascertain if the circumstances of the incident warrant the filing of criminal charges, the issuance of notice of regulatory violations, and legal actions (such as condemnation orders) to protect the public safety and to enforce laws and regulations. This typically involves local and state agencies working in collaboration with each other, as was the case in the investigation of The Station nightclub fire.

A number of Federal agencies responded after the fact to The Station nightclub fire. At the request of the State's Attorney General, the Bureau of Alcohol, Tobacco, and Firearms (ATF) provided direct technical assistance to the AG's investigation. The U.S. Occupational Safety and Health Administration conducted its own investigation due to its jurisdiction over worker safety and health [3]. The Office of Domestic Preparedness in the Department of Homeland Security was interested in how the community responded to this mass casualty event [1]. The National Institute of Occupational Safety and Health was not involved because there were no firefighter deaths.

3.5 OBSERVATIONS

The use of standard Incident Command structures and practices facilitated the concurrent fire suppression and mass casualty incident management operations. The early involvement of the EMS teams within the overall IC effort allowed the chief officers directing the EMS operation to focus on their casualty care and management challenges and to enable the fire suppression command forces to direct victim rescue and extinguishment efforts.

As is common in wide-area mutual aid responses, various responding agencies/units were unable to establish or maintain effective voice communications with IC. The Incident Commander's ability to effectively apply the available resources is critically dependent upon wireless voice communications with the responding units. The need for effective communication systems and equipment (e.g., interoperable with multiple common channels and the ability to handle a large amount of traffic) at large-scale events cannot be overstated.

The arrival time of WWFD's first due units (Engine 4 & Ladder 1) of the initial response assignment was within the four minute objective specified in NFPA Standard 1710 [5]. The model standard further suggests that the remainder of the first full alarm assignment should arrive within eight minutes. The achievement of the latter objective could not be confirmed from the information available to this investigation.

WWFD's fire apparatus staffing of the first full alarm assignment was half of the firefighter staffing recommended by NFPA Standard 1710, which suggests a minimum of four personnel on both engine and truck companies. Had WWFD apparatus staffing been consistent with the model standard at least ten additional firefighters would have been available to more expeditiously establish water supply to the suppression units, establish master stream operations from the first arriving ladder/truck company, and support victim rescue and casualty care operations.

3.6 REFERENCES FOR CHAPTER 3

[1] "Rhode Island -- The Station Club Fire After-Action Report," Office of Domestic Preparedness, Department of Homeland Security, October 2004.

[2] Crowley, C.F., The Station Nightclub Disaster - A survivor's story: Saved by a pileup; *Providence Journal*. Providence, R.I.: Mar 10, 2003. pg. A.01

[3] Occupational Safety and Health Administration Citation and Notification of Penalty, dated August 19, 2003 based on inspection # 304991086.

[4] *NFPA 1500, Standard on Fire Department Occupational Safety and Health Program*, National Fire Protection Association, Quincy, MA, 2002.

[5] *NFPA 1710, Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*, National Fire Protection Association, Quincy, MA, 2001.

Chapter 4 MATERIALS TESTING AND SUPPORTING EXPERIMENTS

4.1 INTRODUCTION

Combustible interior finishes, scenery, or decorations have played an unfortunate but significant role in fires that have occurred in places of assembly over the last 100 years. Often resulting in hundreds of fatalities, examples of these fires include the Iroquois Theatre (602 died, Chicago, IL, 1903), the Rhythm Club (207 fatalities, Natchez MS, 1940), and the Cocoanut Grove (492 died, Boston, MA, 1942) [1]. In each of these incidents, fire-related material properties, including ignitability, heat release rate, and rapid flame spread contributed significantly to fire growth that resulted in a tragic loss of life. In an effort to minimize the repetition of this type of fire, standard test methods for assessing the rate of flame spread, heat release rate, and ignitibility have been developed.

Standard tests can generate critical fire-related material property data that can be a valuable resource for fire protection engineers, code officials, and code enforcement personnel. In the U.S., flammability and fire spread properties of materials are often evaluated using UL 94 –*Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances* [2] and ASTM E-84 – *Standard Test Method for Surface Burning Characteristics of Building Materials* [3]. The heat release rate properties of materials can be assessed using ASTM E-1354 – *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter* [4]. Both the spontaneous ignition temperature (SIT) and flash ignition temperature (FIT) for plastics can be determined using ASTM D 1929 - *Standard Test Method for Determining Ignition Temperatures of Plastics* [5].

Standard tests have a limited ability to predict performance in real fire scenarios and no single standard tests should be used as the sole criterion to assess the total fire hazard. Under carefully controlled laboratory conditions, standard tests do allow comparisons such as, Will material "A" ignite more quickly than material "B"? or, Will material "A" contribute to more rapid flame spread than material "B"? Standard tests do allow the performance of different materials to be rated or compared, but the relationship between standard test performance and actual fire performance can be much more complicated. For example, while a standard test may provide a comparative measure of flame spread, it is difficult for the same standard test to predict the overall fire hazard because the standard test does not incorporate or measure important fire behavior properties including melting, ease of ignition, heat release rate, and products of combustion. Additional properties need to be included for a complete fire-hazard or fire-risk assessment of the materials or assemblies under fire actual conditions.

4.1.1 Standard Tests for Flammability and Fire Spread – UL 94 and E-84

UL 94 includes six different tests to compare the relative burning characteristics of different materials, or assessing any change in the burning characteristics prior to, or during, use. These tests include (1) Horizontal Burning Test –HB, (2) 20 mm Vertical Burning Test – V-0, V-1, or V-2, (3) 125 mm Vertical Burning Test – 5VA or 5VB, (4) Radiant Panel Flames Spread Test, (5) Thin Material Vertical Burning Test – VTM-0, VTM-1, or VTM-2, and (6) Horizontal Burning Foamed Material Test – HBF, HF-1, or HF-2. These test methods typically involve exposing small samples (less than 500 mm x 150 mm) to a flame or radiant panel for a specified period of time, then removing the heat source, and observing whether the sample continues to flame or glow. A burning rate with units of mm/min can be calculated from the time required by the flame to burn a specific distance. Each test method includes criteria for classifying or rating the performance of each material.

For example, an HF-1 rating could be achieved by a 150 mm x 40 mm sample of polyurethane foam if after exposure to a small flame source for 60 s (a) no more than four of five samples continued to flame for more than 2 s after the flame was removed and no more than one sample continued to flame for more than 10 s, (b) the foam did not continue to glow for more than 30 s after the flame was removed, and (c) the cotton indicator that was positioned below the test sample was not ignited by flaming particles or drops.

While UL 94 does utilize both horizontal and vertical sample orientations, the impact of corner geometry, ventilation effects, and prolonged exposure to high thermal flux are not included in the test conditions. Ignition temperature, mass loss rate, and heat release rate data are also not recorded.

The E-84 test method was developed with the anticipation that a large test would provide a more realistic environment for surface burning behavior of building materials. E-84 involves a much larger test specimen than UL 94, up to 0.610 m x 7.3 m, which is mounted on the ceiling of a 0.45 m wide x 0.32 m high x 7.6 m long “tunnel” apparatus. A natural gas fired burner, 88 kW, is positioned at one end of the test sample and the flames from the burner impinge on an approximately 3.25 m^2 area of the sample. The specimen is exposed to the flames and hot gases of the burner for a 10 minute test period. The hot gases and combustion products flow along the unburned portion of the sample and are exhausted at the other end of the apparatus. The extension of the visible flames is recorded as a function of time and is used to determine a flame spread index, which is based upon the extent of burning that occurs with a red oak plank. Red oak is assigned a value of 100, and the flame spread index of other materials are normalized accordingly. For example, Douglas fir plywood, fire retardant treated Douglas fire plywood, type X gypsum board, and rigid polyurethane foam are 91, 17, 9, and 24, respectively.

Loose-fill insulation, plastics, and wall coverings can be tested by using different sample mountings and support screens. The large specimen does allow for the development of physical and structural failure modes, such as cracking and buckling, which may not occur on smaller specimens. The openness of the tunnel design does allow for testing of composite assemblies, panels, and boards. Although plastics can be tested in the apparatus, thermoplastic materials can drip or fall to the floor of the apparatus and result in low values for flame spread index that do not relate to their true fire hazard potential. The test configuration is limited to a horizontal ceiling orientation. Vertical or corner configurations, different flame exposure periods, and different heat fluxes are not included in the test method.

4.1.2 Standard Tests for Heat Release Rate Properties of Materials – E-1354

The E-1354 test method utilizes a cone calorimeter to collect data on heat release rate, mass loss rate, optical density of smoke, and gas concentrations in combustion products. The cone calorimeter exposes relatively small samples (10 cm x 10 cm) to a uniform thermal flux. The thermal flux can be varied from 5 kW/m^2 to 100 kW/m^2 in either a horizontal or vertical sample orientation. An electric spark is used to ignite the combustible gases near the surface of the sample. The sample is positioned on a load cell to track mass loss rate throughout the burn. Additional instruments allow the optical density of the smoke and gas concentrations to be monitored continuously. While the cone calorimeter can provide heat release rate as a function of thermal flux, the impact of ventilation, corner geometries, and composite assemblies are difficult to characterize.

4.1.3 Standard Test for Determining Ignition Temperature of Plastics – D 1929

The D-1929 test method utilizes a hot air furnace to determine the ignition temperatures for small samples of plastic materials. A specimen of a material, in pellet, powder, sheet, or foam form, and up to 3 g in mass or 20 mm x 20 mm x 50 mm in size is inserted into a pre-heated tube furnace. Air flows from the bottom up and out through the top of the vertically oriented tube at a velocity of 25 mm/s. After insertion, the sample remains inside the furnace for up to 10 minutes. At the end of 10 minutes, depending on whether ignition has or has not occurred, the temperature of the furnace is lowered or raised and repeated at the new temperature with a new specimen. The lowest air temperature at which ignition occurred is recorded as the ignition temperature. The Flash Ignition Temperature determination uses a pilot flame at the top of the furnace while the Spontaneous Ignition Temperature determination does not utilize a pilot flame. This test method is limited to a temperature of 400 ^{o}C, which is much lower than typical gas temperatures in the upper layer of a room fire (600 ^{o}C). The exposure time is limited to 10 minutes and the air flow is limited to a single velocity.

4.2 MATERIAL PROPERTIES FOR FIRE MODELS

Computational fire models incorporate specific material properties in order to calculate fire development and growth for a given fire incident. These material properties, such as thermal conductivity, heat capacity, density, and heat of combustion are utilized by the model to predict if and when a component will ignite and how much energy or heat will be released as the component burns. The ignition and subsequent release of energy causes the fire to grow and spread throughout a structure.

For common building materials including gypsum or pine paneling, these materials can be found in various handbooks [6,7,8] or in the combustion/fire literature [9,10,11] (Table 4-1). For less common building materials, such as flexible polyurethane foam, one can estimate a set of thermal properties from similar materials or one can characterize the properties by conducting tests on representative samples of the material. Since the quality of the model predictions is directly related to how accurately the material properties have been characterized, testing representative material samples provides more accurate properties. The properties in Table 4-1 were either measured in this investigation or taken from the literature.

The type and composition of the materials that were identified as being present inside the nightclub were characterized generically as flexible polyurethane foam, ceiling tiles, wood paneling, carpet, and an industrial pyrotechnic device. This materials testing conducted by NIST and described in this chapter did not include any materials actually recovered from the nightclub. NIST was not able to determine whether the foam in the nightclub was (a) fire retardant, (b) non-fire retardant, or (c) a combination of fire retardant and non-fire retardant foams.

Four test series were conducted and are described in this chapter or the appendices:

1) properties of polyurethane foam;

2) cone calorimeter heat release measurements of several polyurethane foams, plywood, carpet, and ceiling tile;

3) heat flux and temperature measurements of pyrotechnic devices impinging on surfaces; and

4) fire growth measurements in real-scale mockups of the platform, main floor, and alcove.

Data from each of these test series provided insight into the material properties, fire spread, heat flux, and fire growth of the different materials. The properties of the polyurethane foam that were measured included the density, ignition temperature, and heat of vaporization, all of which are required to accurately simulate fire spread. The cone calorimeter measurements established an appropriate range of heat release rates for those materials tested. (Note that both fire retardant and non-fire retardant foams ignited and burned when exposed to an external thermal flux in the cone calorimeter.) The experiments that involved discharging pyrotechnic devices against a foam-covered wall verified that non-fire retarded polyurethane foam could be ignited by a shower of sparklers. (The fire retardant foam did not ignite in a similar test.) The real-scale mockups of the platform, main floor, and alcove provided data to evaluate the performance of the computer fire model. The information from all four test series led to an improved set of input data for the combustion model used in predicting the behavior of the fire (presented in Chapter 5), and allowed a better understanding of the parameters that affected the performance of the computer simulation of the entire nightclub.

Table 4.1 Material Properties of Common Building Materials and Selected Plastics [4,5,6]

Material	Thermal conductivity W/m-°C	Density kg/m^3	Heat capacity kJ/kg-°C	Heat of combustion MJ/kg	Piloted ignition heat flux limit, kW/m^2	Ignition temperature °C	Heat of vapor-ization kJ/kg	Flame spread index[a]
Douglas Fir	0.11	420	2.72					70-100
Fiber Insulating Board	0.048	240						
Fiber Board Medium Density		749		7 - 12 12 - 13		167		
Gypsum	0.48	1440	0.84	3				10-15
Hardboard					27			< 200
Pine white yellow	 0.112 0.147	 430 640	 2.8					 72-215 130-195
Plywood Panelling					29			< 200
Polystyrene Foam		32.9		17 - 21 36 - 41				
Polyurethane Foam[b]	0.034	22[b]	1.4	21 - 28[b]		370[b]	1000 - 1600[b]	

[a] based upon ASTM E84 [3]

[b] data from NIST investigation

4.3 POLYURETHANE FOAM

4.3.1 Background

Polyurethane refers to a large category of materials including surface coatings, elastomers, and foams, rigid or flexible, and thermoplastic or thermosetting [12,13]. While large quantities of polyurethanes are used to manufacture adhesives and protective coatings, the foam type of polyurethane is widely used in the production of upholstered furniture, bedding, sponges, toys, wearing apparel, and medical dressings. Rigid urethane foams are used for insulation in building constructions. Flexible polyurethane foams are used in packaging materials and acoustical insulation panels.

The urethane linkage, which all polyurethanes have in common, involves the reaction of an isocyanate group with a hydroxyl-containing group. Common hydroxyl-bearing groups include polyether alcohols, polyester alcohols, carboxylic acids, and amines. If the hydroxyl-bearing group incorporates multiple ether groups, then the resulting polyurethane will have a number of ether linkages and is typically referred to as a polyether polyurethane. If the hydroxyl-bearing group incorporates multiple ester groups, then the resulting polyurethane will have a number of ester linkages and is termed as a polyester polyurethane foam. A more detailed description of urethane formation chemistry is in Appendix H.

Both polyether and polyester formulations of polyurethane can be used as packaging materials. The polyurethane foam which is offered for packaging typically does not include any fire retardant additives or incorporate any fire retardant compounds into the urethane structure. As a packaging material, the polyurethane foam (ether and ester) is commercially available in a range of sizes including 1.22 m (4 ft) x 2.44 m (8 ft) sheets. The gray colored foam can be obtained in several geometries including solid blocks, uniform thickness sheets, and convoluted or “egg-crate” sheets.

4.3.2 Locations in Nightclub

In The Station nightclub, polyurethane foam had been installed on the rear wall, platform wall, and in the alcove as a sound attenuation material (Figure 4.1). A roll of gray convoluted foam was recovered by other investigators from the basement of the burned out nightclub one day after the fire and turned over to the West Warwick Police Department as evidence. That foam did not appear to have been painted or to have been mounted on any surface. Samples from this recovered foam were tested, upon the request of the state of Rhode Island, by the Bureau of Alcohol, Tobacco, and Firearms (ATF) in a cone calorimeter at the ATF Fire Laboratory in Maryland [23]. NIST had no access to the material examined by the ATF Fire Laboratory, and was not able to conduct a chemical analysis to determine if the foam contained fire retardants. (Note: The ignition behavior of the NIST non-fire retardant foam, described in Section 4.5.2, was consistent with the behavior exhibited by the foam on the walls of the nightclub as documented by the WPRI-TV video.)

Photographs of the nightclub interior do not clearly demonstrate whether staples, nails, organic adhesive, or some combination of all three were used to mount the foam on the wall. The foam appeared to have been mounted over the top of the previous wall material, which, depending on the location was either wood paneling or gypsum board. In some areas, portions of the alcove in particular, the foam was installed over rigid polystyrene foam thermal insulation laid between the wood studs. The foam was installed in either full 1.22 m x 2.44 m sheets or was trimmed to fit the geometry.

The photographs of the nightclub interior do clearly show gaps where two sheets of foam meet. Gaps between the foam and the wall can also be observed at various locations, typically at external corners of the alcove. While the gray color of the foam can be observed in some photos of various bands that had performed at The Station, later photos show a darker color, indicating that the foam may have been sprayed with a black paint. The surface of the foam also had a glittery appearance that may have been a result of the wet paint being dusted with glitter or sparkle dust. Some of the glitter would have become partially embedded in the wet paint and would have provided the more sparkling appearance that was observed in some of the video of the nightclub interior.

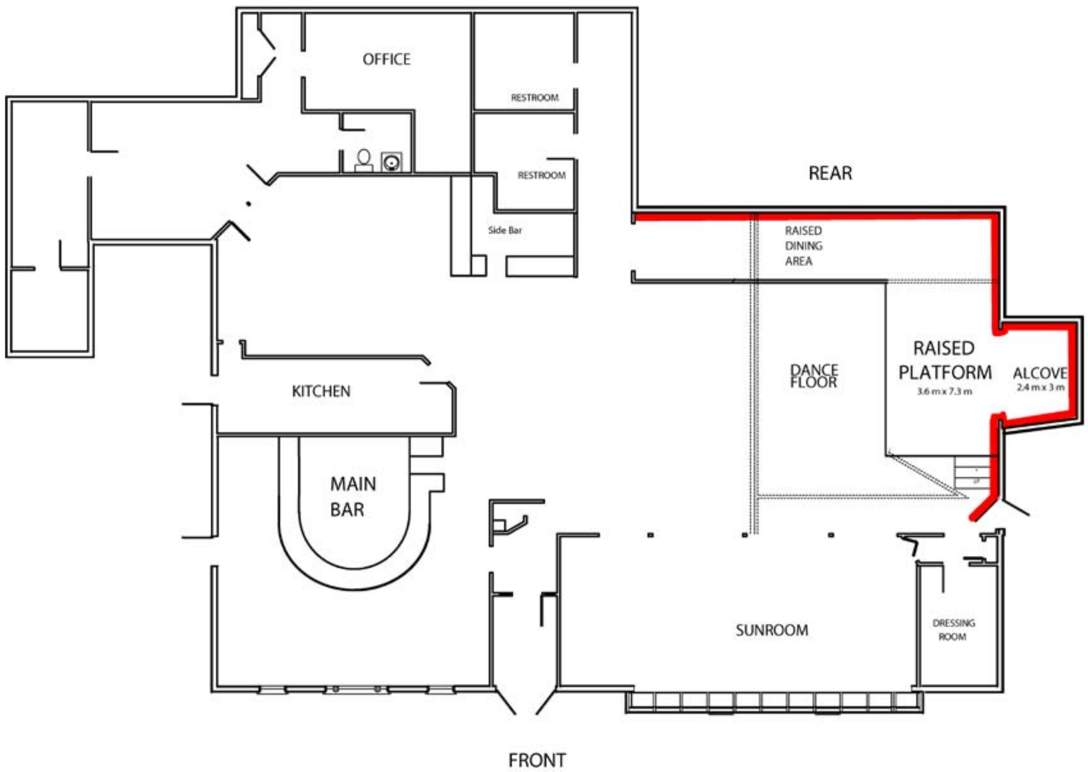


Figure 4-1. Portion of Nightclub with Polyurethane Foam Mounted on Wall (shaded red section).

4.3.3 NIST Foam Samples

After experiencing some difficulty, NIST was able to locate a source of non-fire retardant polyether polyurethane foam. Recent consolidations within the polyurethane foam manufacturing industry appear to have reduced the range of polyurethane foam products available to the public. The non-fire retardant polyurethane foam (ether) was purchased in two lots from a single distributor. Unfortunately, the distributor was not able to identify the manufacturer of the foam. Foam distributors typically purchase foam from a number of different sources based on price and availability. Foam arrives at distributor's warehouse in tractor-trailer sized lots. While bulk shipment may contain source information, stock is broken down into smaller units and source information is typically not maintained on each individual piece of foam. When foam arrives at a warehouse, new stock is intermingled with old stock.

The foam was purchased in two lots as 1.22 m x 2.44 m sheets (flat or in rolls). The rear surface of each sheet was flat. The front side was convoluted, with a series of peaks and depressions that resembled the surface of a continuous egg crate. Lot A was nominally 40 mm thick measured from the back to the peak; lot B was nominally 30 mm thick. Peak-to-peak spacing, and valley to sheet back dimensions are described in Appendix D.

NIST also purchased a number of 1.22 m (4 ft) x 2.44 m (8 ft) sheets of fire retardant polyester polyurethane foam from a commercial supplier in single lot. It is possible that the distributor had intermingled foam from different sources within a single purchase. Unfortunately, as with the purchase of the non-retardant polyether foam, the distributor was not able to identify the manufacturer of the foam for the same reasons. The fire retardant foam was measured at 0.03 m (1.5 in) and 0.010 m (0.4 in) at its thickest and thinnest dimensions, respectively (See Appendix D).

4.3.4 Heat of Vaporization and Ignition Temperature of Non-flame retarded Polyurethane Foam

Polyurethane foams can be produced in numerous ways with different properties, and because the behavior of the polyurethane foam in the fire was critical to the incident, measurements were made on the NIST-purchased materials to confirm literature values, fill gaps in the data, or narrow uncertainties.

The heat of vaporization is a measure of the amount of energy that is necessary to convert a material from a condensed to a vapor phase. Differential scanning calorimeter(DSC) and thermal gravimetric analysis (TGA) techniques were used by NIST to calculate the heat of vaporization for samples of non-fire retarded, flexible polyether polyurethane foam (lot B). These instruments yielded a range of heats of vaporization between 1000 and 1600 kJ/kg.

The ignition temperature was determined by Southwest Research Institute using ASTM D 1929. As described in Appendix D, the piloted ignition temperature of non-fire retarded flexible polyurethane foam (lot B) was found to be 370 ^{o}C +/- 5 ^{o}C.

4.3.5 Heat Release Rate of Polyurethane Foams

The cone calorimeter was used to determine the heat release rate of the NIST-purchased polyurethane foams. The test protocol detailed in ASTM E 1354 [14] was used for these experiments. Samples which measured 0.1 m x 0.1 m were cut from the larger sheets. These samples were then stored in a controlled humidity (50 % relative humidity) and temperature (23 ^{o}C) room for at least two weeks. Then each sample was wrapped in an aluminum foil, except for the exposed side, and positioned in the cone calorimeter. A test plus two replicates of each sample (total of three tests) were conducted with an external heat flux from 20 kW/m^2 to 70 kW/m^2. In all tests, the convoluted side was exposed to the thermal flux.

Data from these tests (23 in all) are tabulated in Table 4-2. (Additional data and plots of the heat release rate for each sample versus time are in Appendix D.) Focusing on the last column of the table, one can see that the non-flame retarded NIST samples have a peak heat release rate of around 600 kW/m^2 when exposed to an incident radiant flux of 35 kW/m^2. This compares to a peak heat release rate of 453 kW/m^2 for the flame retarded NIST sample at the same external flux, and less than 300 kW/m^2 for the sample tested by ATF. A plot of the peak heat release rate as a function of incident radiation is shown in Fig. 4-2a, comparing the NIST results to the ATF measurements. As expected, the peak heat release rate increases about linearly with imposed heat flux.

The time to sustained ignition is another measure of the fire hazard posed by a material. The times to ignition are shown in the third column in Table 4.2. Both lots A and B of the NIST non-fire retarded polyurethane foam needed 6 to 7 seconds for sustained ignition when exposed to 35 kW/m^2 of radiant heat. The fire retarded NIST sample resisted ignition for 13 seconds, and the ATF sample ignited in 3 seconds at a slightly higher irradiance level (40 kW/m^2). Figure 4-2b is a plot of the time to ignition (expressed as $1/t^{1/2}$) as a function of incident flux, comparing the NIST non-fire retarded polyurethane (lot B) to the cone calorimeter measurements made by ATF on their foam [23].

Table 4.2 Peak HRR, time to sustained Ignition, and time to Peak HRR

polyurethane foam sample ID	External Radiant Flux, kW/m^2	Time to Sustained Ignition, Average,* seconds	Time to Peak Heat Release, Average,* seconds	Peak Heat Release Rate, Average,* kW/m^2
NIST				
PUF-FR	35	13	36	453
PUF-NFR-A	35	7	30	605
PUF-NFR-B	20	14	45	450
	35	6	30	586
	40	4	29	820
	60	3	24	1154
	70	3	21	970
ATF [23]				
Polyether PUF	20	9	37	260
Polyether PUF	40	3	31	297
Polyether PUF	60	1	26	415

* Average values include all individual test runs at each specific external thermal flux. Data from individual test runs are provided in Appendix A.

The time to ignition in the cone calorimeter is governed by the ignition temperature, the imposed radiant flux, and the effective thermal inertia, kρc, of the material, where k is the thermal conductivity, ρ is the density, and c is the specific heat averaged over the heating period. As explained in Appendix E, the time to ignition is inversely related to the square of the imposed radiant flux and directly related to the effective thermal inertia. From the measured ignition temperature[#] and ignition delay at 35 kW/m^2, kρc is estimated to be about 0.075 (kW/m^2-^{o}C)^2-s for the NIST (lot B) non-fire retarded polyurethane foam.

The precise reasons why the polyether foam tested by ATF differed from the behavior of the foams tested by NIST are not clear. (NIST did not have access to the foam from the fire scene tested by ATF.) However, the shorter time necessary for ignition of the ATF foam suggests that the effective value of kρc was less. It is possible that the behaviors were influenced by the different molecular structure, additives, or manufacturing processes. It is also not clear under what conditions the foam had been stored in the basement of the nightclub or whether it had always been stored in the basement, nor what impact aging or water from fire fighting operations may have had on the foam. Using the properties of either foam, the fire is predicted to spread rapidly, with the foam acting as an ignition source for the wood layer underneath. The contribution from the foam to the total heat release in the fire was much less than from the wood, once the wood was ignited by the burning foam.

[#] Measured here using ASTM D 1929. The ignition temperature can also be inferred from the limiting heat flux necessary for piloted ignition in the cone calorimeter.

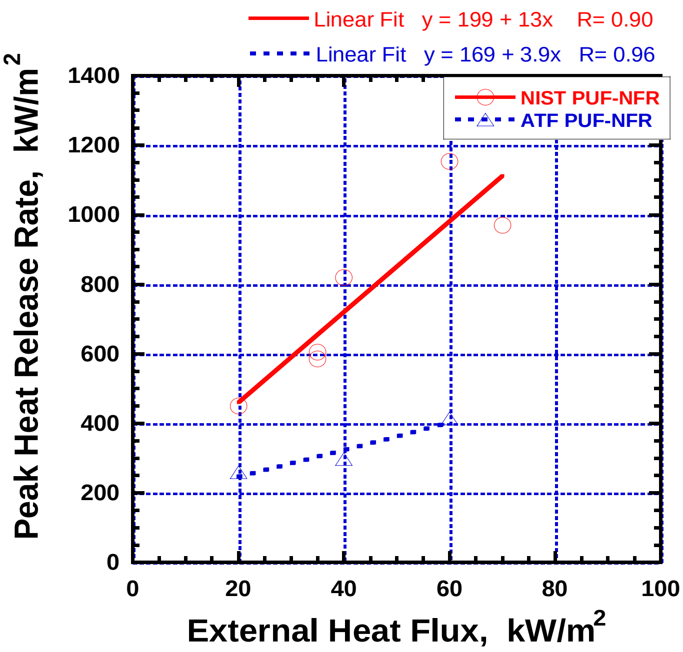


Figure 4-2a. Peak heat release rate versus external heat flux for different polyurethane foams tested at NIST and ATF.

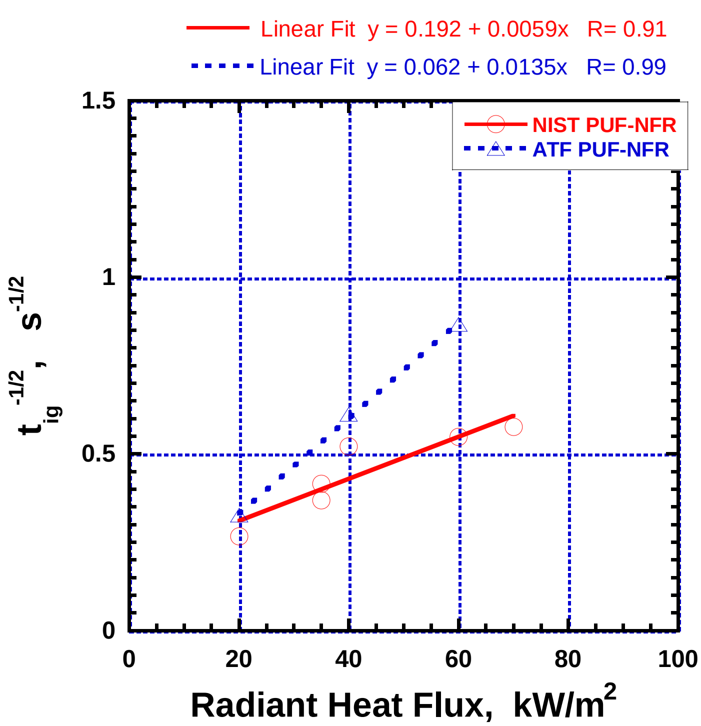


Figure 4-2b. Time to sustained ignition versus external heat flux for different polyurethane foams tested at NIST and ATF.

Table 4.3 Cone Calorimeter Tests				
Material	External Flux kW/m^2	Number of Samples	Test ID	Manufacturer
Poly(ether) Polyurethane Foam convoluted/egg crate non-fire retardant - gray	35	3	PUF-NFR-A	A
Poly(ether) Polyurethane Foam convoluted/egg crate non-fire retardant - gray	20, 35, 40, 60, and 70	20	PUF-NFR-B	B
Poly(ester) Polyurethane Foam convoluted/egg crate fire retardant - gray color	35	3	PUF-FR	C
Wood Paneling plywood substrate, birch finish 5 mm thick	35 and 70	6	WP	D
Carpet Flooring polyester short nap, 6.2 mm thick 100% filament olefin ave. tufted face wt 39 oz twist tough bind 14.00, beige color	35 and 70	6	CF	E
Ceiling Tile type 942B 610 mm x 1219 mm x 16 mm (24 in x 48 in x 0.62 in)	35 and 70	6	CT	F

4.4 CONE CALORIMETER MEASUREMENTS OF FINISH MATERIALS

Cone calorimeter experiments were conducted on four other common finish materials similar to those in the nightclub. Two external heat fluxes were examined to account for the changing conditions experienced by the materials in the actual fire. All of the cone calorimeter tests conducted on the materials representative of those in the nightclub (polyurethane foams, wood paneling, carpet flooring, and ceiling tiles) and the external fluxes that were imposed on the samples are summarized in Table 4.3. The complete data set (time to ignition, peak heat release rate, time to peak heat release rate, total heat release rate, specimen total mass loss, average mass loss rate, average effective heat of combustion, average smoke extinction area, average carbon dioxide yield, and average carbon monoxide yield) can be found in Appendix D for each of the 38 tests.

4.4.1 Acoustical Ceiling Tiles

A suspended or dropped ceiling had been installed in the nightclub except for in the sunroom, the platform area, and the dance floor areas (Figure 4-3). Each 0.61 m (2 ft) x 1.22 m (4 ft) x .016 m (0.625 in) panel had been installed or dropped into a metal grid support system. Photographs of the nightclub interior clearly demonstrate that the ceiling tiles had been painted black. It was not clear from the photographs whether the paint had been applied by brush, roller, or spray can. The surface of the tiles also had a glittery appearance that may have been a result of the wet paint being dusted with glitter.

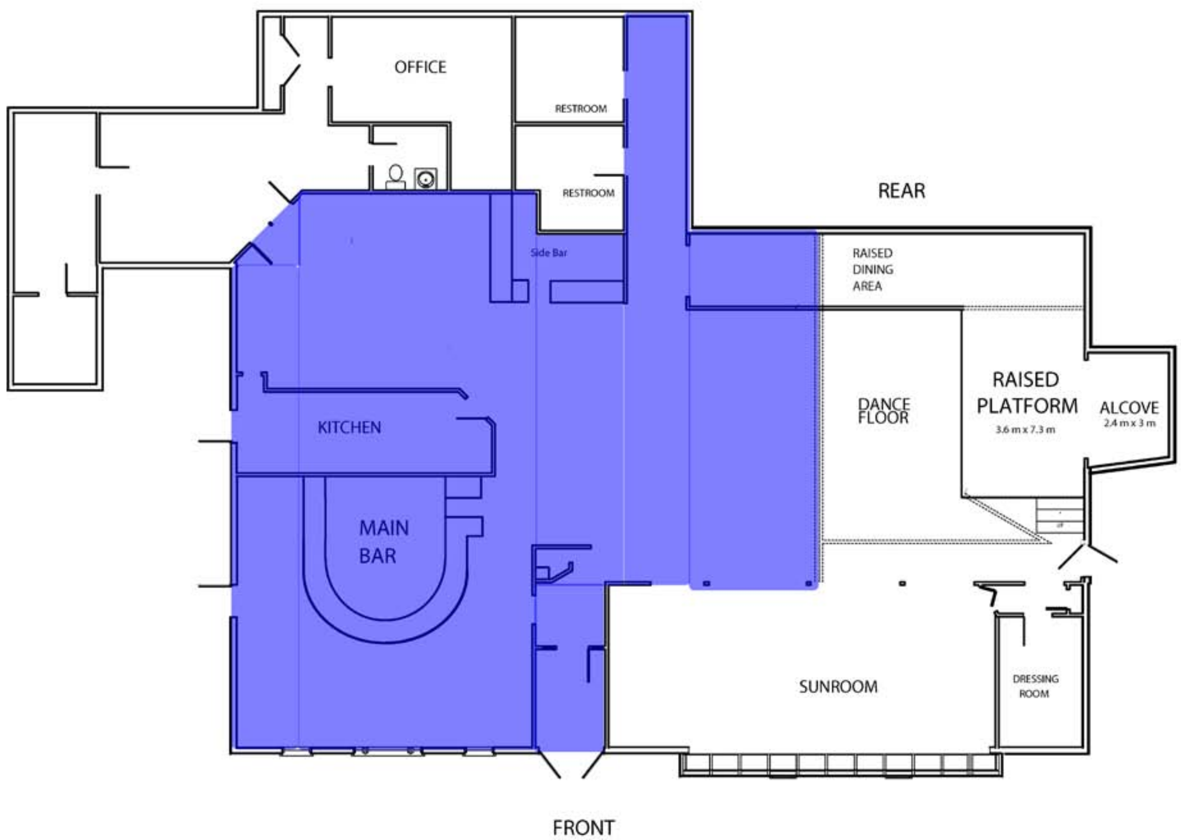


Figure 4-3. Portion of Nightclub with Acoustical Tile Ceiling (shaded blue section).

Labeling found on a surviving acoustical tile indicated that that the tile was a mineral fiber type of material, a 942 (residential coding) or 755 (commercial coding). Samples of 942B acoustical tiles were purchased from a local supplier for these cone calorimeter tests. The front side of each panel (see Appendix D) exhibited a factory-applied coat of white vinyl-latex paint while the rear side of each panel was unpainted. Samples that measured 0.1 m x 0.1 m were cut from the larger panels. These samples were then stored in a controlled humidity (50 % relative humidity) and temperature (23 °C) room for at least two weeks. Then each sample was wrapped in an aluminum foil, except for the exposed side, and positioned in the cone calorimeter. In all tests, the painted side was exposed to the thermal flux.

When exposed to 35 kW/m^2 of external heat flux, the ceiling tiles did not ignite. Ignition and peak heat release rate values (average) are tabulated in Table 4.4. Each test was terminated after 3 minutes of exposure when none of the three samples ignited. As the thermal flux was increased to 70 kW/m^2, ignition did occur and the samples reached their peak heat release rate in approximately 20 seconds. The ceiling tiles demonstrated an average peak heat release rate of 57 kW/m^2. Individual test data and plots of the heat release rate for each sample versus time are in Appendix D.

Table 4.4 Cone Calorimeter Results for Ceiling Tile, Wood Panels, & Carpet

Sample ID	External Thermal Flux, kW/m^2	Time to Sustained Ignition, seconds	Time to Peak Heat Release Rate, seconds	Peak Heat Release Rate kW/m^2
Ceiling Tile (CT)	35	Did not ignite		
	70	8	20	57
Wood Paneling (WP)	35	41	129	437
	70	15	85	526
Carpet Flooring (CF)	35	54	192	627
	70	20	78	1371

4.4.2 Wood Paneling

Wood paneling had been installed in the nightclub around the platform area, around the sunroom, back bar area, and entry way (Figure 4-4). Interior photographs of the nightclub did not provide sufficient information to identify the specific brand or type of paneling.

A veneer type paneling which utilizes a plywood substrate was selected as being representative of the fuel load contributed by the paneling. The wood paneling was purchased from a local retailer in 1.22 m (4 ft) x 2.44 m (8 ft) sheets. The 0.0003 m (0.0125 in) birch veneer was laminated to a 0.006 m (0.25 in) thick three-ply Luan mahogany backer layer. The front side of each panel (Appendix D) had a glossy coat of finish while the rear side of each panel was unfinished plywood. Samples that measured 0.1 m x 0.1 m were cut from the larger panels. These samples were then stored in a controlled humidity (50 % relative humidity) and temperature (23 ^{o}C) room for at least two weeks. Then, each sample was wrapped in an aluminum foil, except for the exposed side, and positioned in the cone calorimeter. In all tests, the veneer side was exposed to the thermal flux.

When irradiated with 35 kW/m^2 of external heat, the wood paneling reached its average peak heat release rate, 440 kW/m^2 , in approximately 130 seconds. At the lower thermal flux, each sample required about 40 seconds to achieve sustained ignition. At the higher flux, 70 kW/m^2, the wood panel samples required much less time to sustain ignition, resulted in a higher average peak heat release rate of 530 kW/m^2, and required substantially less time, 85 seconds, to achieve the peak value. Individual test data and plots of the heat release rate for each sample versus time are in Appendix D.

The heat release curves exhibited a two peak shape, with the second peak much greater than the first peak. Each wood panel sample charred significantly as it burned, and the char represented a greater fraction of the total available fuel than that which was burned early in the test. In the higher thermal flux exposure, the additional flux caused more of the fuel to be burned early in the test, so the two peaks were closer in value.

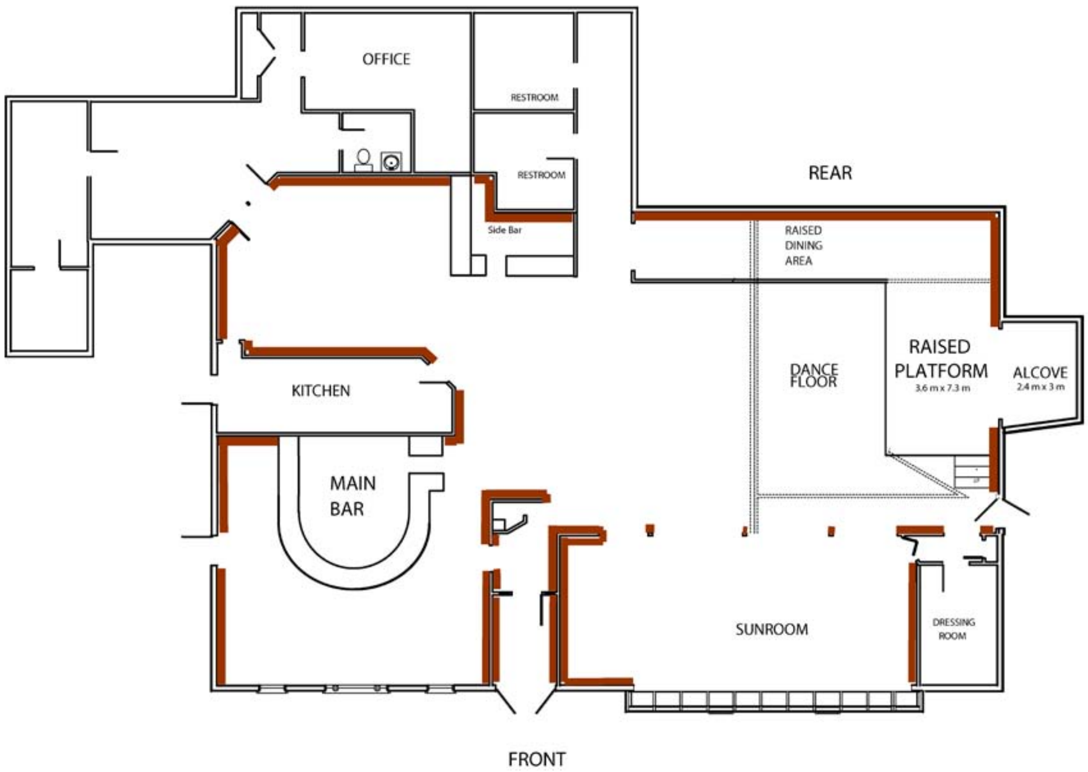


Figure 4- 4. Portion of Nightclub with Wood Paneling (brown shaded sections).

4.4.3 Carpet Flooring

Carpet flooring had been installed in the nightclub on the elevated section along the rear wall and around the platform area. (Figure 4-5). Interior photographs of the nightclub did not provide sufficient information to identify the specific brand or type of carpeting.

A closed-loop olefin carpet with a binding layer was selected as representing the fuel load contributed by the carpeting. The carpet was purchased from a local supplier in a 3.2 m (12 ft) wide x 15.7 m (50 ft) long continuous roll. The 0.006 m (0.25 in) nylon pile was embedded in a 0.002 m (0.1 in) thick binding layer. Samples that measured 0.1 m x 0.1 m were cut from the roll. These samples were then stored in a controlled humidity (50 % relative humidity) and temperature (23 ^{o}C) room for at least two weeks. Then each sample was wrapped in an aluminum foil, except for the exposed side, and positioned in the cone calorimeter. In all tests, the olefin pile side was exposed to the thermal flux.

When exposed to 35 kW/m^2 of external heat flux, the average peak heat release rate for the three carpet samples was 627 kW/m^2. The carpet required about 54 seconds, on average, to achieve sustained ignition, and approximately 190 seconds to reach its peak heat release rate (Table 4.4). When exposed to the higher external heat flux of 70 kW/m^2, the carpeting reached its peak heat release rate in about half the time. Peak heat release rates for all three carpet samples averaged 1370 kW/m^2. Individual test data and plots of the heat release rate for each sample versus time are in Appendix D.

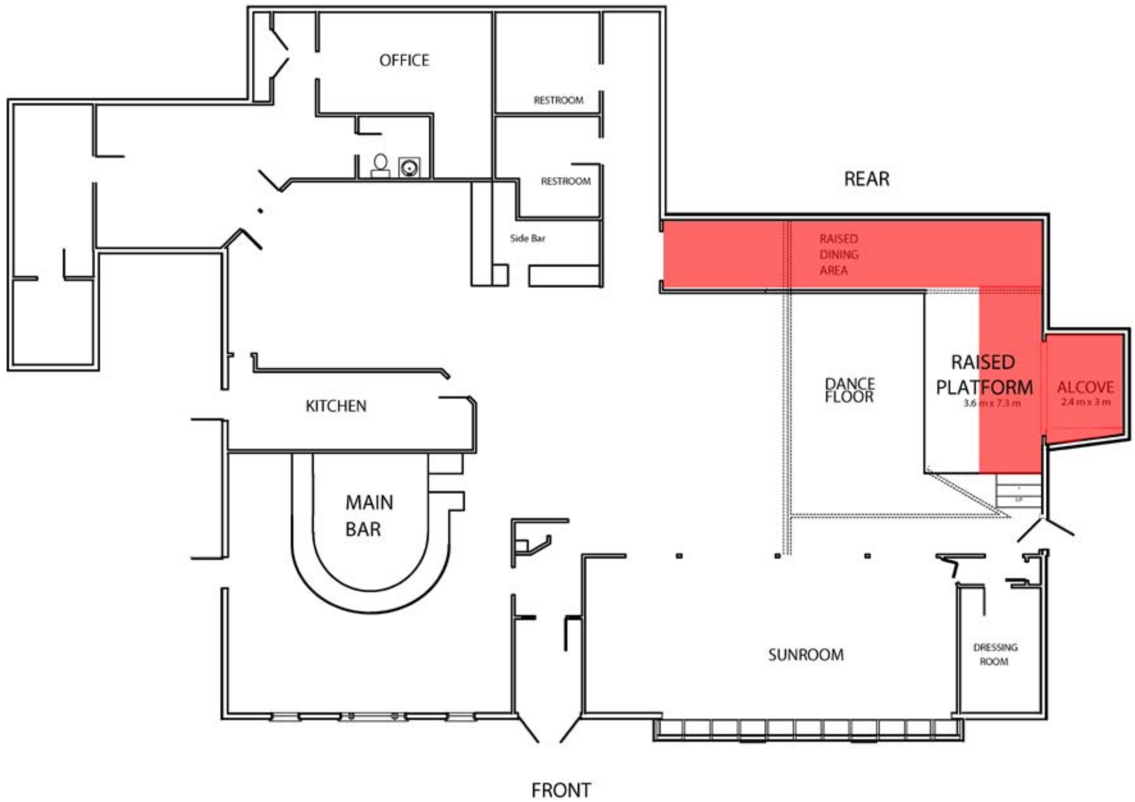


Figure 4-5. Portion of Nightclub with Carpeting.

For the lower flux exposure, the heat release curve exhibited a relatively brief step at around 200 kW/m^2 and then increased gradually to a single broad peak. As the carpet initially began to burn, some of the energy released was conducted into the olefin pile, but instead of producing a char, the polymer melted and formed a more uniform density fuel. As the burning continued, it increased at a relatively steady rate, reached its peak and decreased at a more rapid rate. At the higher flux exposure, the additional energy from the internal heating caused the melting to occur more rapidly, so the initial step seen at the lower flux was not observed.

4.4.4 Fuel Load Properties – Ignitability, Mass, and Location

The contribution of assorted fuels to fire spread and total heat release rate can be very different. The cone calorimeter test data demonstrated that the polyurethane foam, both the fire retardant and non-fire retardant formulations, could ignite in less than 15 seconds of exposure to 20 kW/m^2 of external heat flux. Once ignited, the polyurethane foam reached peak heat release rates ranging from 450 kW/m^2 to1150 kW/m^2 in less than 60 seconds. Both the wood paneling and carpet flooring required from 80 seconds to 200 seconds to reach peak heat release values which ranged from 440 kW/m^2 to 1370 kW/m^2.

The polyurethane foam was a low density material and was quick to ignite, but the mass of the foam was consumed in a relatively short period of time. The foam would have contributed to a quick initial fire growth, but typically would not have had sufficient mass to carry the fire past the initial stages. Wood and the carpet flooring had greater mass and were a larger source of energy than the foam, although the wood and carpet required a longer times to ignite. Once ignited, both the wood and carpet would provide a substantial amount of the energy released during a fire. The ceiling tiles would have released relatively little energy compared to the other fuel components.

The contribution of a specific fuel is dependent on the relative amounts of the fuel and how quickly the fuel becomes involved in the fire. Wood is often found in flooring, wall paneling, and structural members such as studs, joists and rafters. Carpeting is typically used only as a floor covering. In a wood frame structure, the wood component of the fuel load may provide the bulk of the energy released. The location of the fuel can also impact when and how rapidly a specific fuel becomes a contributor to the heat release rate. For instance, wood paneling near the ceiling ordinarily would become involved more quickly than wood flooring.

4.5 PYROTECHNIC DEVICE TEST SERIES

A series of full scale experiments was conducted to document the thermal characteristics of a discharging pyrotechnic device like those that were ignited in the nightclub on Feb. 20, 2003. At the beginning of the show, four separate pyrotechnic devices, or gerbs, were discharged on the platform in front of the alcove. Two gerbs, which had been positioned on the floor of the platform, discharged vertically along the centerline of the alcove opening (Figure 4-10). Two additional pyrotechnic gerbs, which were located near the other two gerbs on the platform floor, sprayed white "sparklers" at a 45 degree angle to both the left and right sides of the alcove. The WPRI-TV video of the nightclub interior showed that glowing particles or “sparklers” ignited the foam on both sides of the alcove in approximately 10 seconds.

The throw, or distance the hot particles traveled, the period of "sparkler" discharge, and the white appearance of hot particles, were consistent with a pyrotechnic device called a Silver 15 x 15 Stage Gerb. Forty silver 15 x 15 gerbs were purchased from a commercial manufacturer of stage pyrotechnics. Appendix F provides a detailed description of the gerbs.

For the NIST tests, each gerb or pair of gerbs was discharged either along or against a gypsum board wall or a foam covered gypsum board wall. The wall was painted black to enhance the contrast with the white sparklers, and a grid of 0.3 m (1 ft) squares was painted on it. Gerbs were also discharged against the wall in a plane perpendicular to the wall (Figure 4-11). Heat flux gauges and thermocouples were embedded in the gypsum wall. The instrumentation was positioned so that the sparkler discharge was centered over the flux gauges and thermocouples. Examples of typical data, heat flux and gas temperature, are plotted versus time in Appendix F, and each discharge was video taped using a standard mini-DV digital video camera and an infrared camera.

4.5.1 Gypsum Wall Board

The gerbs were ignited electrically. Each discharge was recorded using a standard video camera and an infrared camera. The infrared camera utilized a barium-strontium-titanate solid state detector with a spectral response of 8 µm to 14 µm. The IR camera was included in these experiments to provide a qualitative image of the hot gas plume as well as the spray of the white sparklers.

The visible images show that each gerb discharged a spray of white sparklers for at least 14.5 seconds, but no more than 16 seconds. While most of the sparklers were thrown less than 2.74 m (9 ft), a limited number of sparklers traveled in excess of 4.6 m (15 ft) from the tip of the gerb. For the gerbs that were positioned at 45^{o}, the infrared images show a central core of hot gases, a plume of warm gases that does not travel as far as the hot metallic particles. The buoyant hot gases developed a vertical trajectory within 1.2 m (4 ft) of the gerb tip. For the gerbs that were positioned vertically, the infrared images again

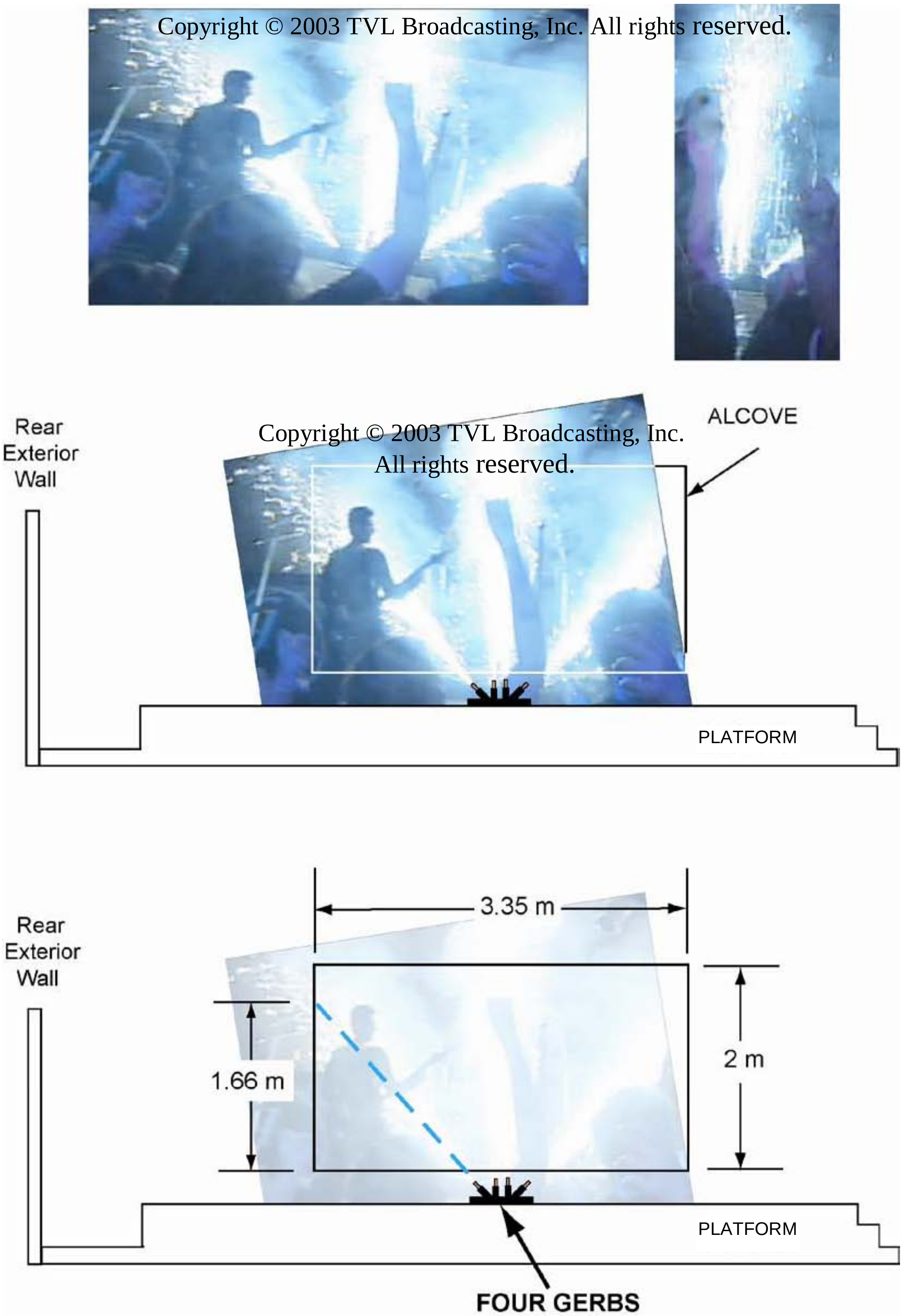


Figure 4-10. Pyrotechnics (15 x 15 gerbs) positioned on nightclub platform. Video image copyright © 2003 TVL Broadcasting, Inc. All rights reserved.

Figure 4-11. Single Gerb at 45 degrees and in a Plane Perpendicular to Wall.

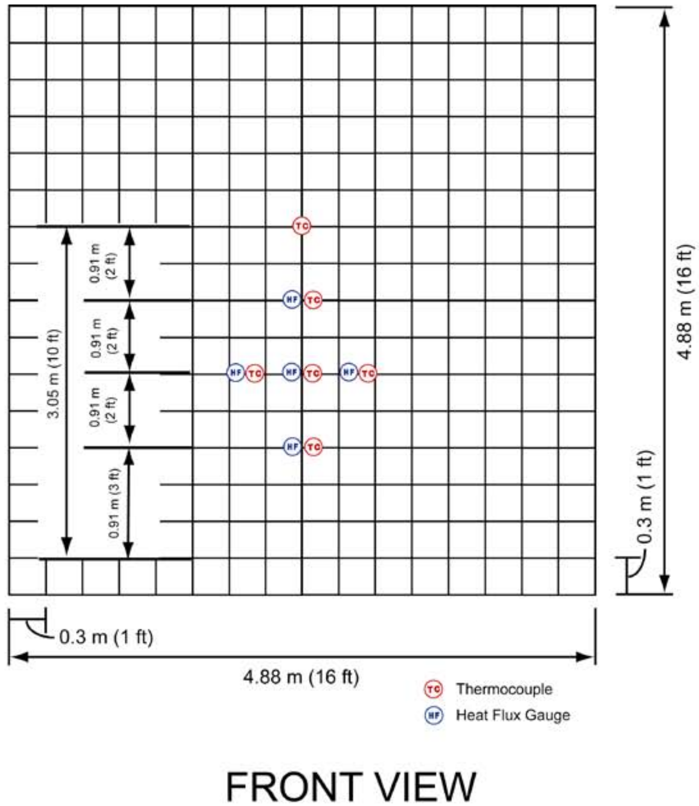
demonstrate a central core of hot gases; in this vertical configuration, the plume of combustion gases is aligned with the trajectory of the hot sparklers. The measured heat fluxes from the gerbs impinging on the wall were less than 2.5 W/m^2.

4.5.2 Foam Covered Wall

The video recorded in the nightclub demonstrates that there were four gerbs positioned in front of the alcove. The two vertical gerbs were spaced about 0.1 m (4 in) apart and the two 45 degree gerbs were each positioned about 0.25 m (10 in) outside the vertical gerbs. This arrangement placed the tip of the 45 degree gerbs approximately 1.21 m (4 ft) from each of the side walls of the alcove. The spray of hot sparklers would have impinged on a foam covered wall from about that distance.

In order to simulate this arrangement, a single gerb which was angled at 45 degrees was discharged against (and in a plane perpendicular to) the wall from a distance of 1.22 m (4 ft). A single 1.22 m (4 ft) by 2.44 m (8 ft) sheet of non-fire retardant polyurethane foam (PUF-NFR-B) was stapled to the gypsum board wall. A single gerb was positioned at a 45 degree angle so that the tip of the gerb was 1.22 m (4 ft) from the wall surface. The tip of the gerb was located 0.3 m (1ft) above the floor. While temperature data were collected during the gerb discharge, the heat flux gauges were removed to prevent damage from dripping and burning plastic.

Still images were captured from the video recorded by the standard video and IR camera. For gerbs that were positioned at 45 degrees in a plane parallel to the wall, pairs of visible and infrared images are shown for times from 0 seconds to 30 seconds in Figure 4-13a through 4-13h.



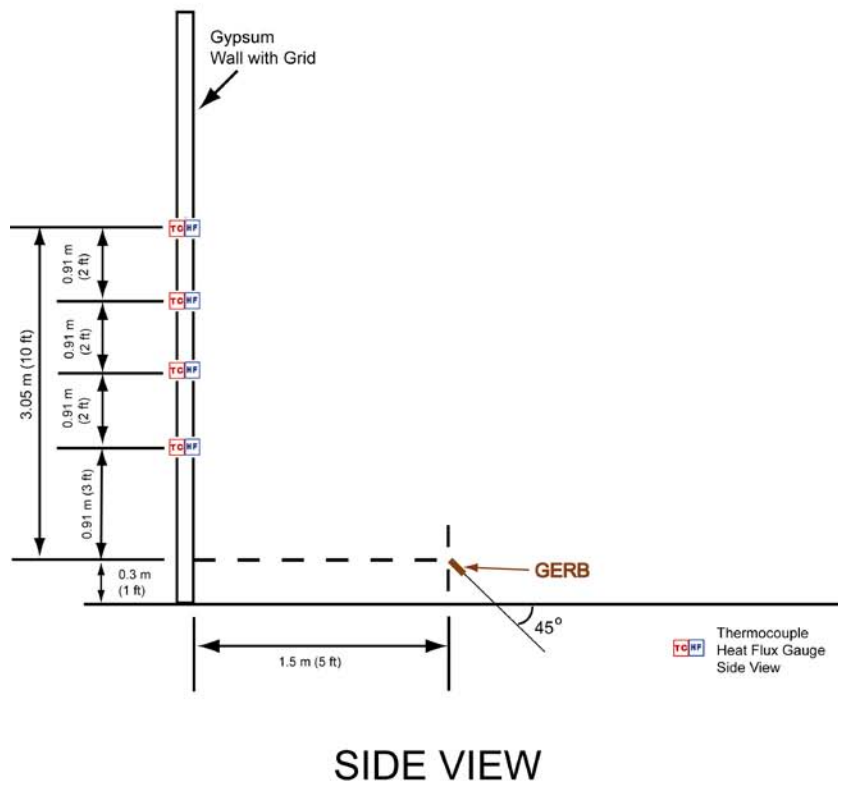


Figure 4-12. Instrumentation Diagram for a Single Gerb at 45 degrees and in a Plane Perpendicular to Wall.

The visible images demonstrate that the gerb discharged a spray of white sparklers for 15 seconds. The spray of hot sparklers impacted the wall between 0.91 m (3 ft) and 1.5 m (5 ft) above the floor. Within 2 seconds after ignition, a thermal pattern (white area in IR image) developed on the wall. This area of increased temperature was oval in shape with a horizontal width of 0.3 m (1 ft) and a vertical dimension of 0.61 m (2ft). A similarly sized and positioned thermal pattern was also seen at 5 seconds into the discharge. The edges of the thermal pattern appeared fuzzy or diffuse. At 10 seconds after ignition, this thermal pattern had sharper edges and a black “haloing” appeared around the pattern. This haloing or shadowing has been observed under laboratory conditions in the presence of a significant thermal gradient. BST detectors measure relative levels of infrared radiation and are AC-coupled. The AC-coupling can cause a "black halo" or shadowing effect that increases as the relative radiation difference between an object and its surroundings increases unless a DC restoration process is included in the signal output circuitry. This would be consistent with the foam burning before t = 10 seconds. Although not clearly seen in the standard video camera, flames were observed on the right hand side of the hot sparkler pattern at 9 seconds. By 15 seconds a well defined and hot thermal plume was observed in the IR image. Gas temperatures are plotted versus time in Appendix F, Figs. F-16a and F-16b.

The alcove in the nightclub was 2.0 m (6.5 ft) tall and the gerbs were positioned vertically at the center of the alcove opening. In the NIST tests, similar gerbs easily reached that height, as did the plume of hot gases. It can be seen from the WPRI video, however, that the pair of vertically-directed gerbs on the platform of the nightclub did not ignite the foam at the top of the alcove.

The width of the alcove in the nightclub was 3.0 m (10 ft) and the end of each gerbs was offset from the center of the opening by about one foot. The NIST tests demonstrated that a 15 x 15 gerb which was angled at 45 degrees and discharged against (and in a plane perpendicular to) a wall from a distance of 1.22 m (4 ft) could ignite a sheet of polyurethane foam in approximately 10 seconds. This is similar to the ignition sequence observed in the WPRI video.

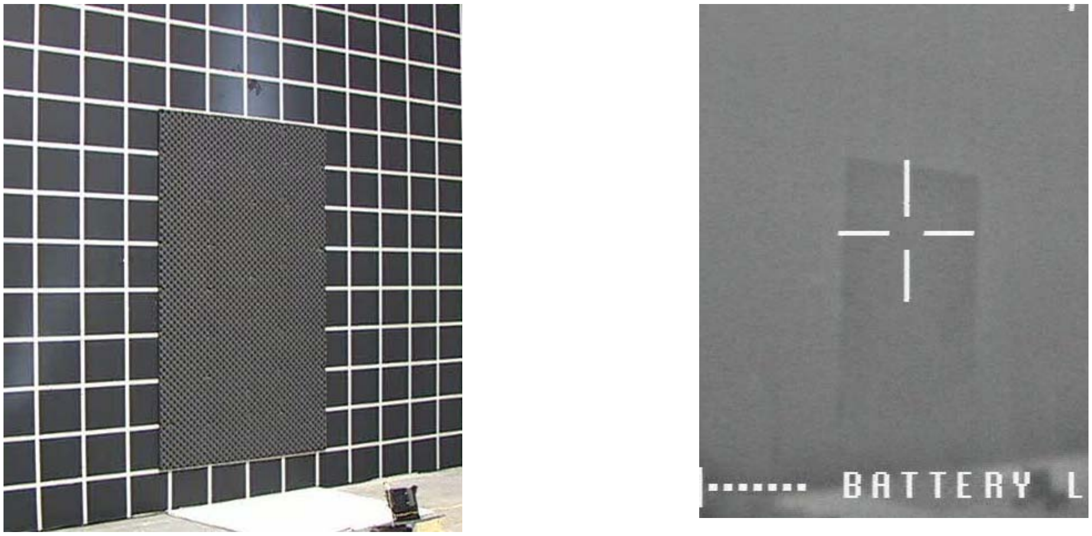


Figure 4-13a. Standard and Infrared Video Images of Non-fire Retarded Polyurethane Foam on Gypsum Board Wall just before ignition at t = 0 seconds.

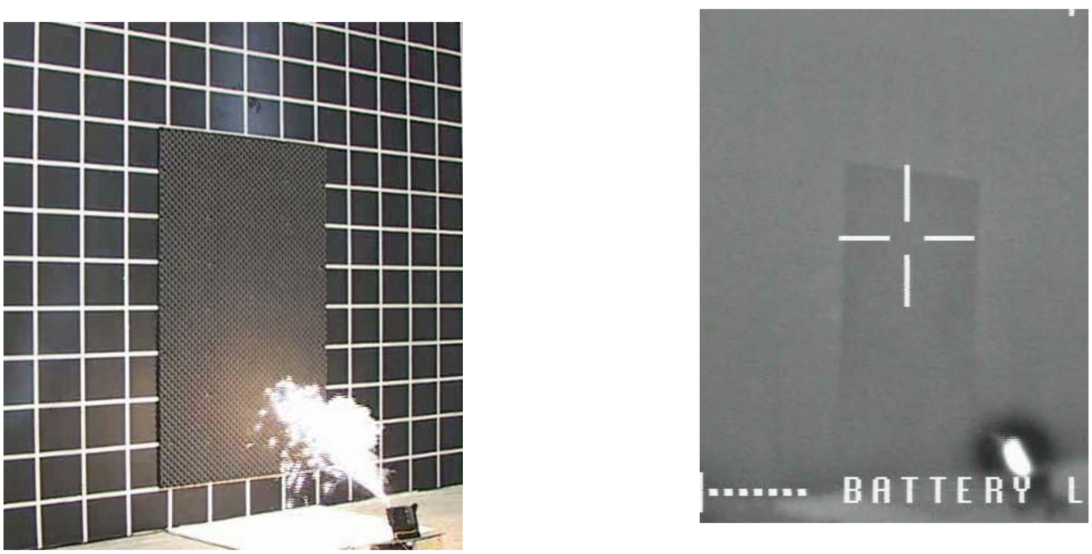


Figure 4-13b. Standard and Infrared Video Images of Gerb Discharge onto a Non-fire Retarded Polyurethane Foam Sheet on Gypsum Board Wall at t = 0.5 seconds.

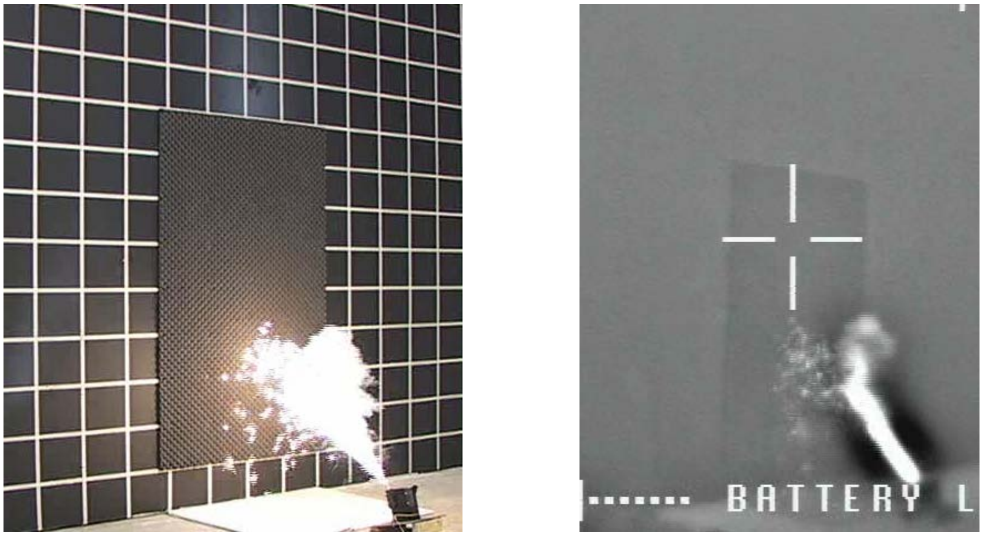


Figure 4-13c. Standard and Infrared Video Images of Gerb Discharge onto a Non-fire Retarded Polyurethane Foam Sheet on Gypsum Board Wall at t = 1 second.

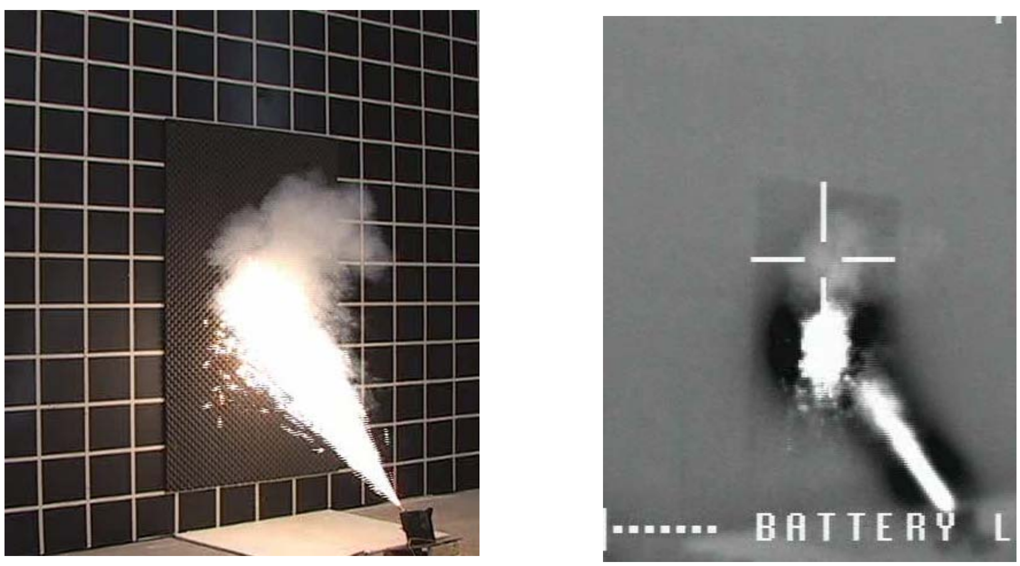


Figure4-13d. Standard and Infrared Video Images of Gerb Discharge onto a Non-fire Retarded Polyurethane Foam Sheet on Gypsum Board Wall at t = 2 seconds.

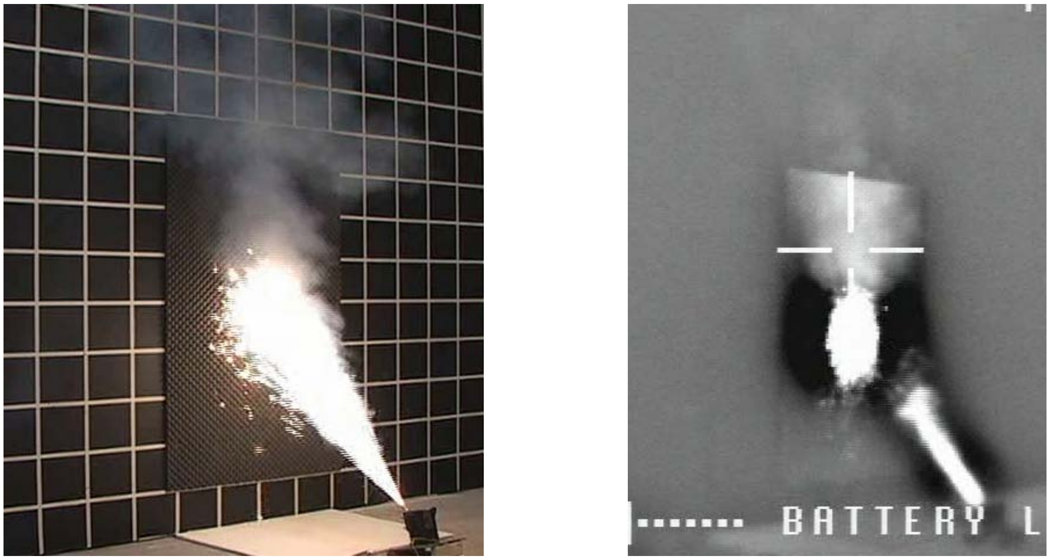


Figure 4-13e. Standard and Infrared Video Images of Gerb Discharge onto a Non-fire Retarded Polyurethane Foam Sheet on Gypsum Board Wall at t = 5 seconds.

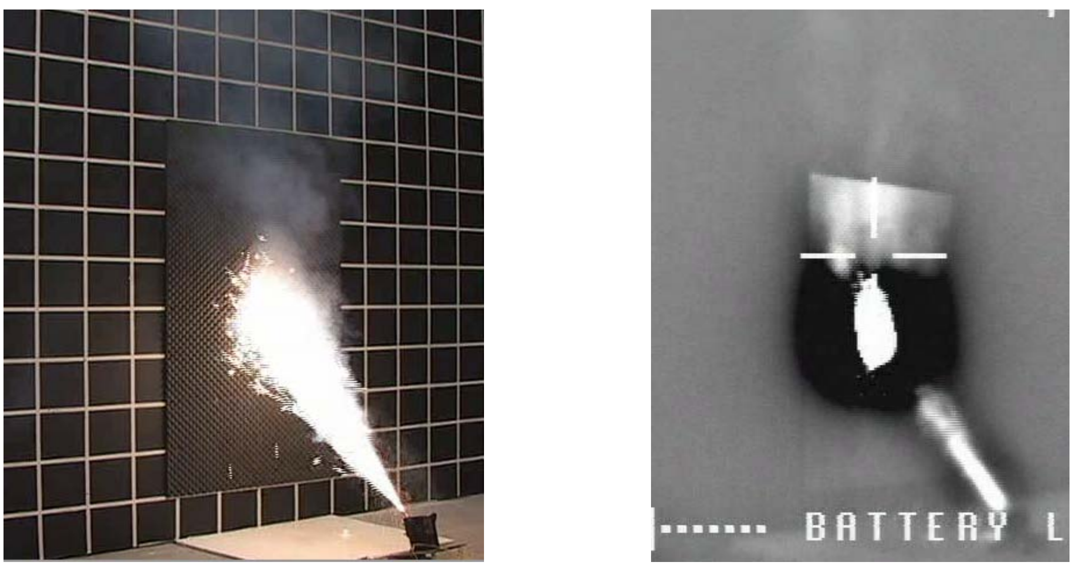


Figure 4-13f. Standard and Infrared Video Images of Gerb Discharge onto a Non-fire Retarded Polyurethane Foam Sheet on Gypsum Board Wall at t = 10seconds.

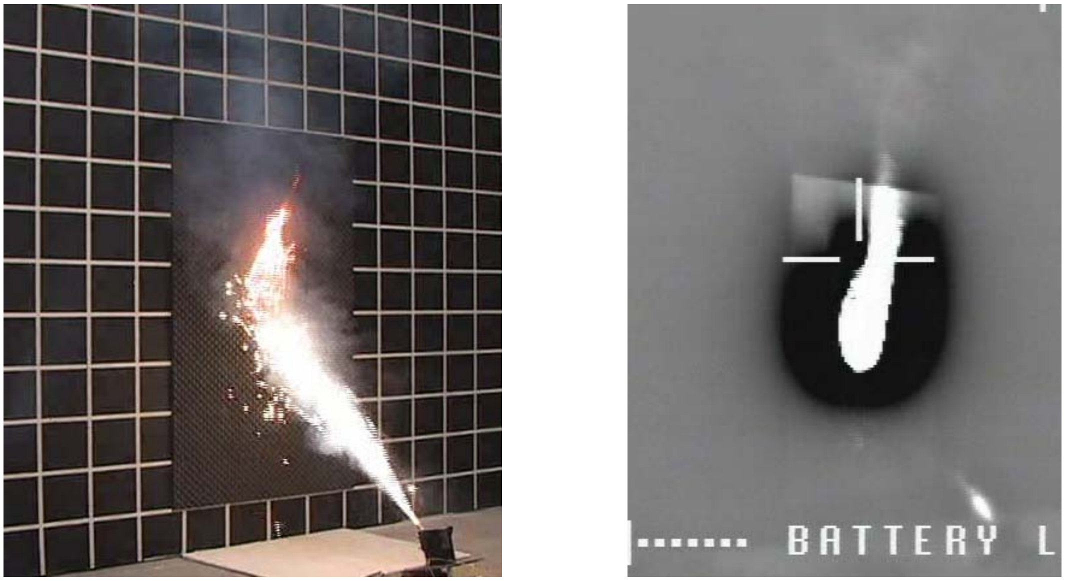


Figure 4-13g. Standard and Infrared Video Images of Gerb Discharge onto a Non-fire Retarded Polyurethane Foam Sheet on Gypsum Board Wall at t = 15 seconds.

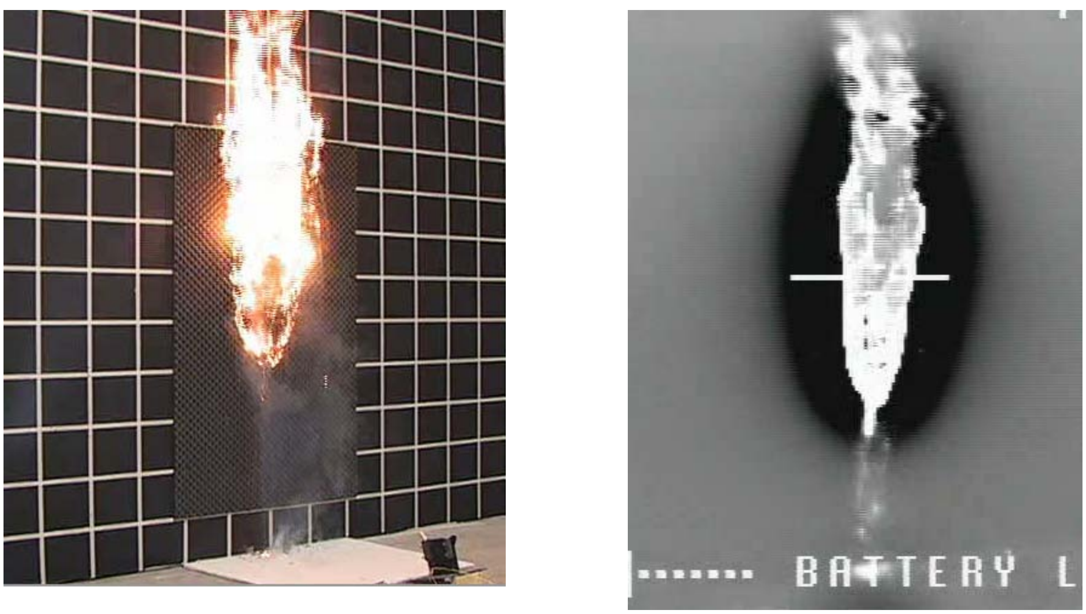


Figure 4-13h. Standard and Infrared Video Images of Gerb Discharge onto a Non-fire Retarded Polyurethane Foam Sheet on Gypsum Board Wall at 30 seconds.

4.5.3 Impingement of Gerbs on Wood Paneling

A test using an arrangement similar to the one above was conducted using a bare wood panel to determine if the wood could be ignited by a 15 x 15 gerb. A 1.22 m (4 ft) x 2.44 m (8 ft) panel of 6.4 mm (1/4 in) plywood with a birch veneer was mounted vertically 1.22 m (4 ft) from a gerb angled at 45 degrees from the floor. The plywood panel had been cut in two with the exposed surface of the upper portion offset about 1 - 2 mm back from the front surface of the lower portion, forming a small lip 1.22 m from the floor. The purpose of the lip was to capture hot sparklers in an attempt to increase the likelihood that the gerb could cause ignition of the wood.

Figure 4-14a shows the sparklers from the gerb impinging on the wood panel about half way through the test. No ignition was observed. The hot sparklers did create small black marks and craters in the finish of the panel, as can be seen in Figure 4-14b.

Figure 4-14a. Gerb impinging on wood panel

Figure 4-14b. Damage to wood panel following impingement by sparklers from gerb. Lip on panel surface can be seen as line below mounting screws.

4.5.4 Impingement of Gerbs on Fire Retarded Polyurethane Foam

A test using the arrangement similar to the one above was conducted with a piece of the fire retardant polyurethane (PUF-FR) attached to the wood panel to determine if the foam could be ignited by a 15 x 15 gerb. A 1.22 m (4 ft) x 2.44 m (8 ft) panel of 4.6 mm (0.18 in) thick plywood with a birch veneer was mounted vertically with a 0.71 m (28 in) high x 0.97 m (38 in) wide piece of foam centered on the panel as shown in Figure 4-15a. The foam was positioned 1.22 m (4 ft) from the gerb discharge tip. The gerb was angled 45 degrees above horizontal as in the previous experiments. The foam had been cut in two with the exposed surface of the upper portion offset from the front surface of the lower portion, forming a small gap and lip along the horizontal centerline of the foam. The purpose of the gap was to capture hot sparks in an attempt to increase the likelihood that the gerb could cause ignition of the foam.

Figure 4-15a shows the sparks from the gerb impinging on the foam. No ignition was observed. The hot sparks did cause “pitting” in the foam. The pits are area where the sparks melted or burned away small amounts of foam, but the process did not propagate. Examples of the pitting can be seen in Figure 4-15b.

The experiment was repeated with a new piece of foam. The lower piece of foam overlapped the upper piece of foam, creating a small ledge as shown in Figure 4-15c. The positioning of the gerb was the same. The results were similar to the previous experiment; i.e., no ignition, just minor scorching and small holes in the foam from some of the sparks (see Figures 4-15c and 4-15d). The temperatures in the plume as a function of time are plotted in Appendix F, Figs. F-24 and F-25.

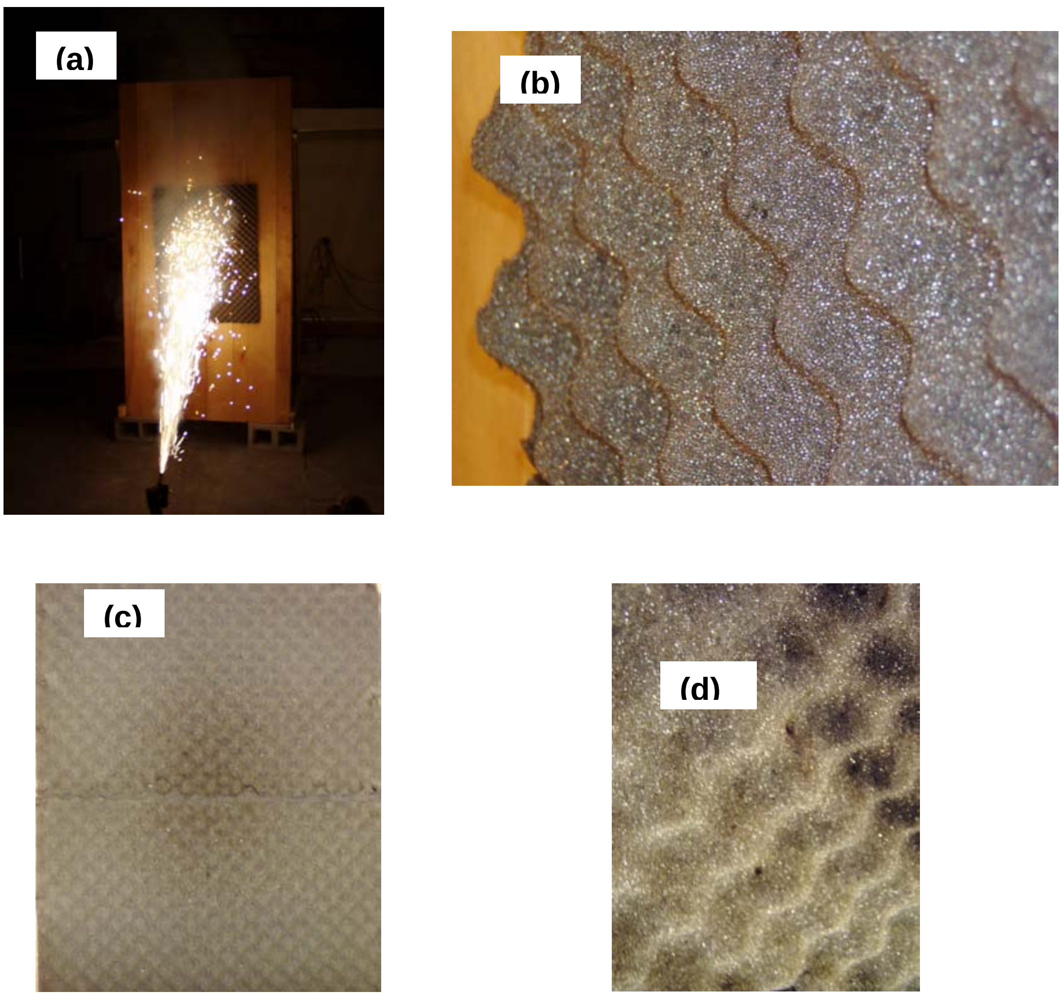


Figure 4-15. Gerb impinging fire retardant polyurethane foam (a); evidence of pitting (b); horizontal ledge at mid-plane to catch sparks, and evidence of scorching in second sample (c); and close-up of scorched area (d).

4.6 FIRE GROWTH MEASUREMENTS IN REAL-SCALE PLATFORM AREA MOCKUP

Real-scale platform area mockup experiments were conducted to characterize the fire growth and spread in the early stage of the fire. Approximately 20 % of the nightclub was reconstructed in real scale with polyurethane foam covered walls, a drummer's alcove, a raised platform, carpeting, and wood paneling. Figure 4-16 shows the dimensions of the mock-up floor plan and compares the test compartment to a floor plan of the nightclub. Data collected on fire spread (gas temperatures, heat fluxes, and gas concentrations) allow the performance of the computer fire model to be assessed. The degree to which the computer fire model is able to mimic the fire growth for this real-scale mockup is indicative of the quality of the simulation of the fire in The Station presented in Chapter 5, within the limitations of uncertain materials and imprecise dimensions for the actual nightclub.

Two real-scale tests were conducted: one without automatic sprinklers, and one with automatic sprinklers. By designing the real-scale mockup experiments carefully, in terms of controlling factors such as fuel and ventilation, the mockup tests provided a means to determine the benefit of automatic sprinklers in a fire similar to what occurred in The Station, and to gain insight as to conditions in the nightclub during the early fire growth and spread, in particular the levels of CO and HCN since these cannot be predicted by the computer fire model.

4.6.1 Test Configuration

The physical mock-up was recreated in the NIST large fire laboratory. The overall floor dimensions of the test room were 10.8 m by 7.0 m, and the ceiling height was 3.8 m. A single opening, 0.91 m wide and 2.0 m high was located in the wall opposite the alcove. An isometric view of the test compartment is shown in Figure 4-17.

The test area was constructed with a structural steel frame, lined with two layers of 12 mm thick calcium silicate board, and covered with 12 mm thick gypsum board. The walls of the alcove and the raised floor area had 5.2 mm thick plywood paneling installed over the gypsum board. The paneling had a flame spread index of 200 or less per ASTM E-84 [15], according to the manufacturer. The plywood paneling extended 3.6 m from the raised floor along the rear wall of the test area.. The rear wall was adjacent to the platform on the right as one stands on the platform facing the audience (stage-right). A non-fire retarded, ester-based, polyurethane foam (PUF-NFR-B) was glued over the paneling in the alcove and along the walls on both sides of the alcove opening and to the rear wall, as shown in Figure 4-18. The polyester polyurethane foam was from the second lot of PUF-NFR-B foam tested and described earlier in this chapter. The flat side of the foam was mounted next to the plywood and the convoluted side was left exposed. The foam was installed from the top of the wall down to 1.35 m above the floor. It was also applied to the ceiling of the alcove and extended for 2.4 m from the raised floor along the rear wall.

4.6.2 Instrumentation

The test room was equipped with thermocouples, video cameras, heat flux gauges, bi-directional probes, and gas extraction probes to measure carbon monoxide (CO), carbon dioxide (CO_2), oxygen (O_2), and hydrogen cyanide (HCN). In addition, fixed temperature and rate-of-rise heat detectors were installed, as were sprinklers. In one test, the sprinklers were not supplied with water but were monitored for time to activation. Figure 4-19 is a schematic floor plan of the instrumentation positions.

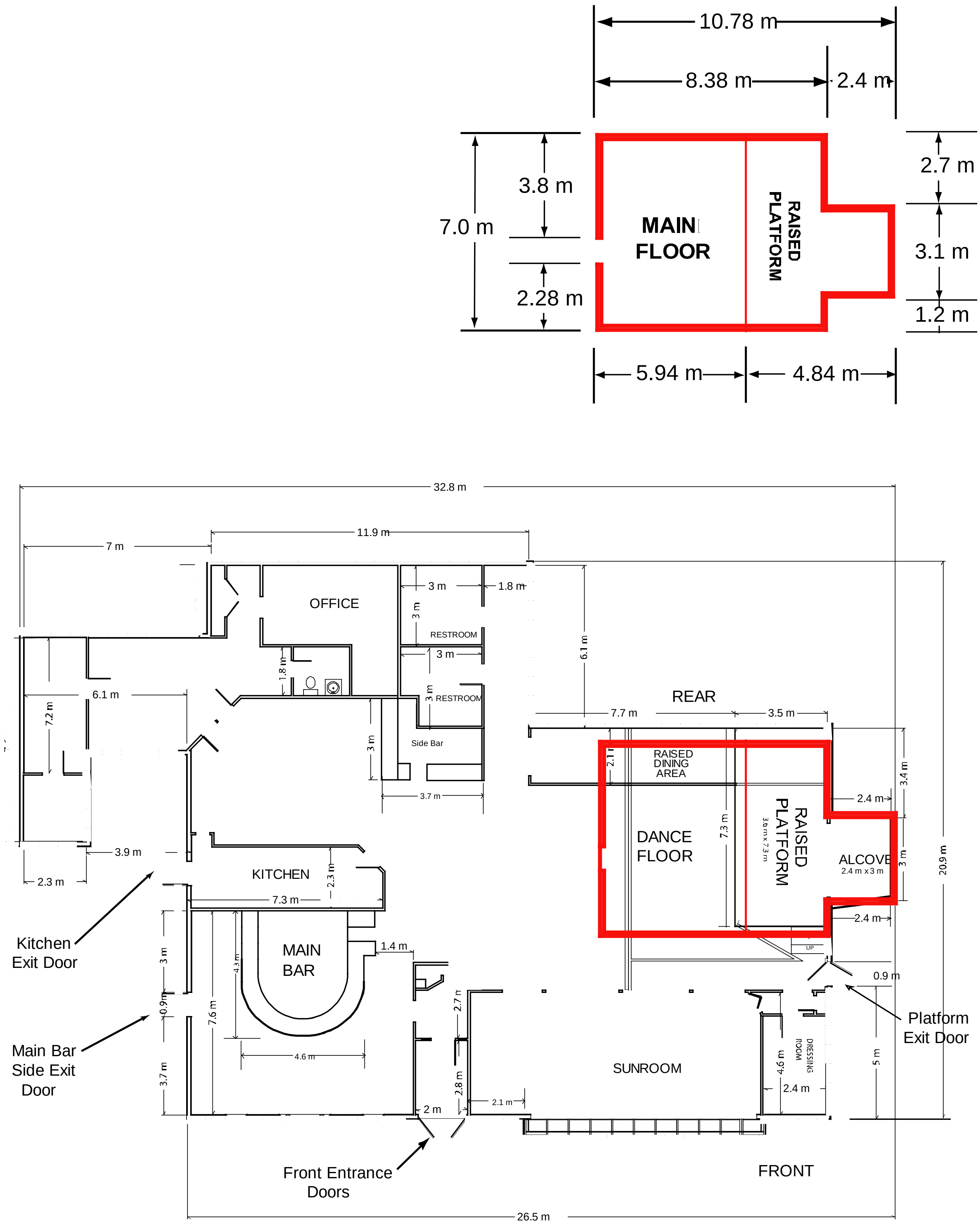


Figure 4-16. Real-Scale Mockup Floor Plan versus Station Nightclub Floor Plan.

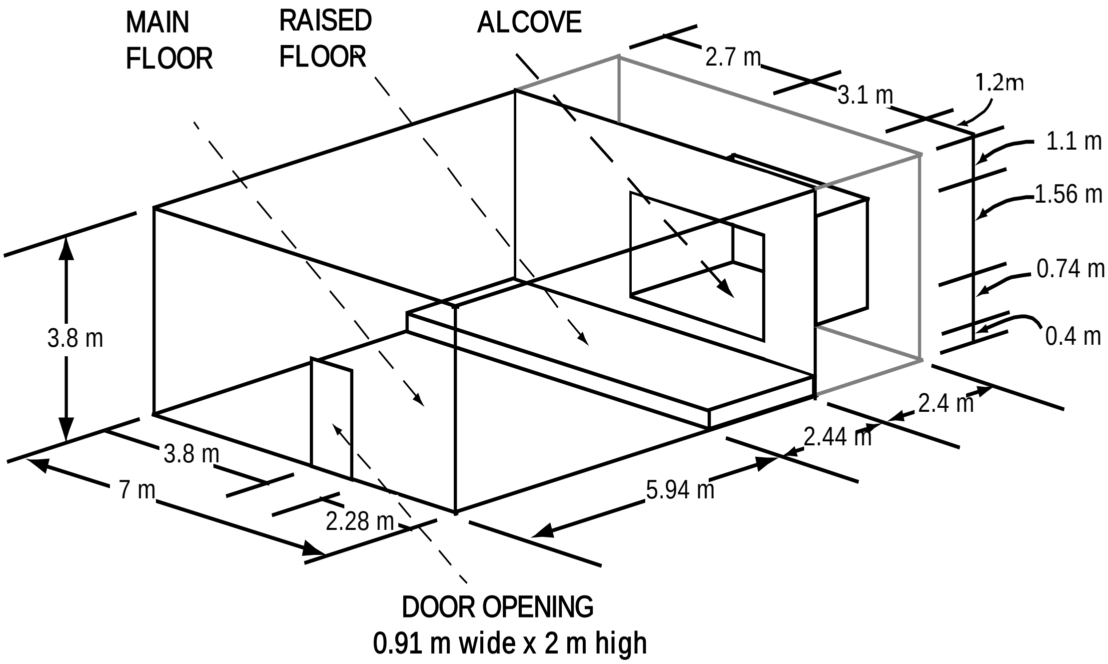


Figure 4-17. Isometric view of the test compartment.

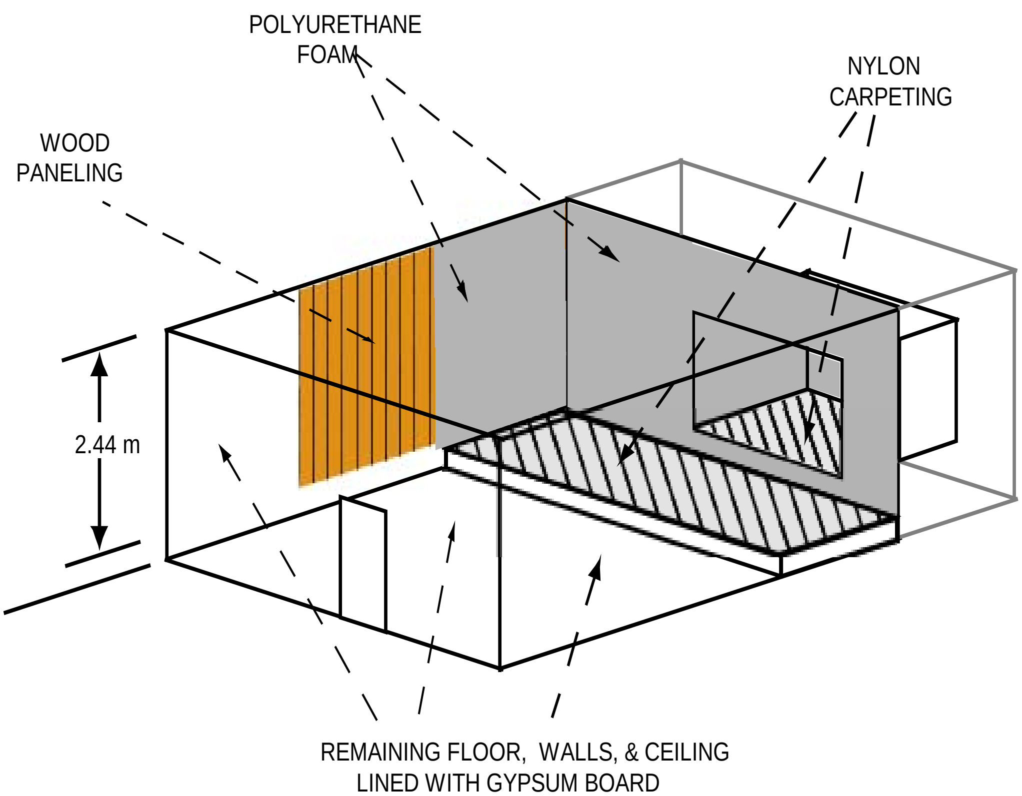


Figure 4-18. Floor plan showing the test area and the fuel locations.

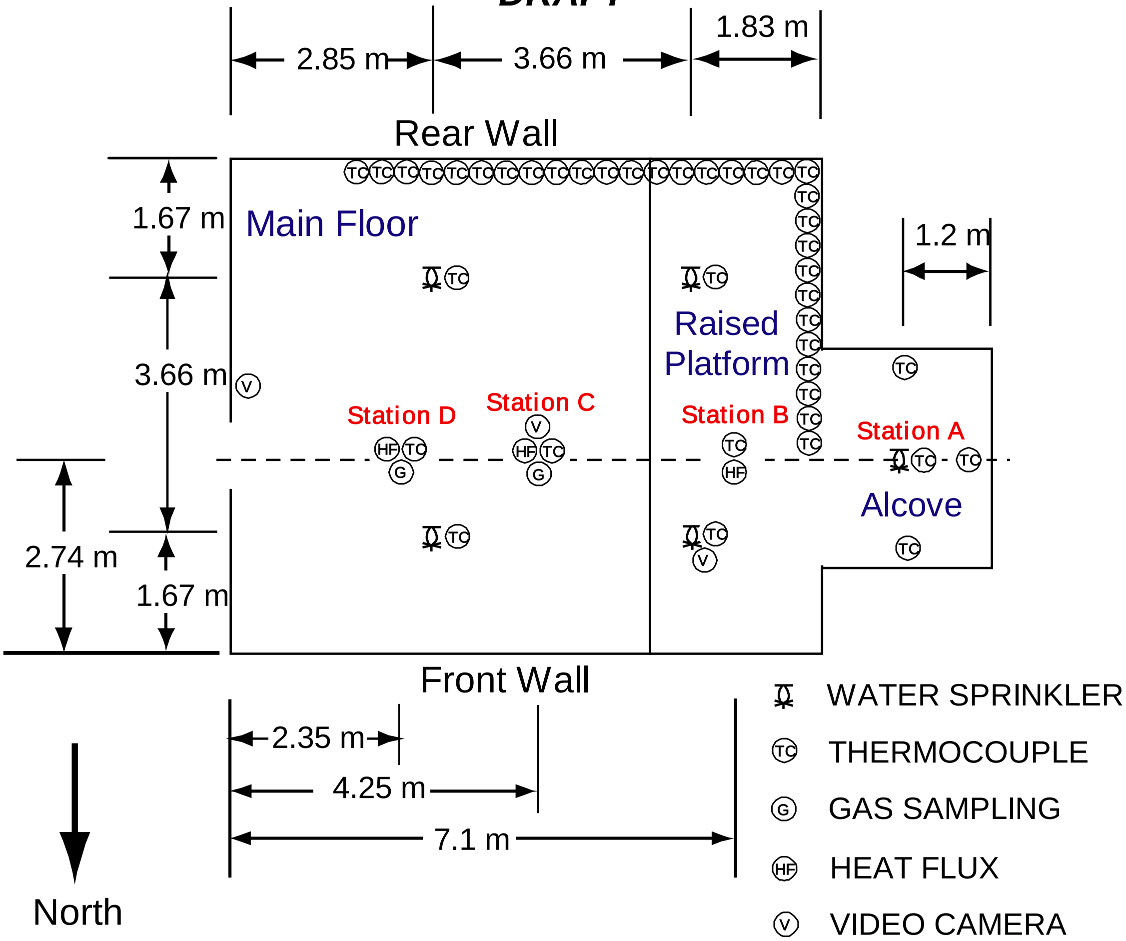


Figure 4-19. Schematic floor plan with instrumentation positions.

4.6.3 Experimental Procedure

Prior to ignition, each of the analyzers was zeroed and calibrated and the data acquisition system and videos were started to collect background data. Data for 194 channels were recorded at 1 second intervals. Ignition of the foam was initiated simultaneously with electric matches at two locations on the outer corners of the alcove, 1.66 m above the raised floor area. The fire gases that emerged from the open door on the south end of the test room were captured in the hood of the oxygen depletion calorimeter. The data were reduced and plotted versus time for each of the channels.

The succession of video frames on the left of Fig. 4-20 show how rapidly the fire spreads during the first 50 seconds, compared to how quickly the fire is controlled with sprinklers in the frames along the right. The first sprinkler activates on the right of the platform 24 seconds after ignition. By 30 seconds the sprinkler above the platform on the left and the sprinkler in the alcove have activated.

4.6.4 Temperature

The temperatures were measured with 0.51 mm nominal diameter bare bead, type K thermocouples, distributed as shown in Fig. 4-21. The standard uncertainty in temperature of the wire itself is ± 2.2 °C at 277 °C and increases to ± 9.5 °C at 871 °C as determined by the wire manufacturer [16]. The uncertainty of the temperature in the environment surrounding the thermocouple is known to be much greater than

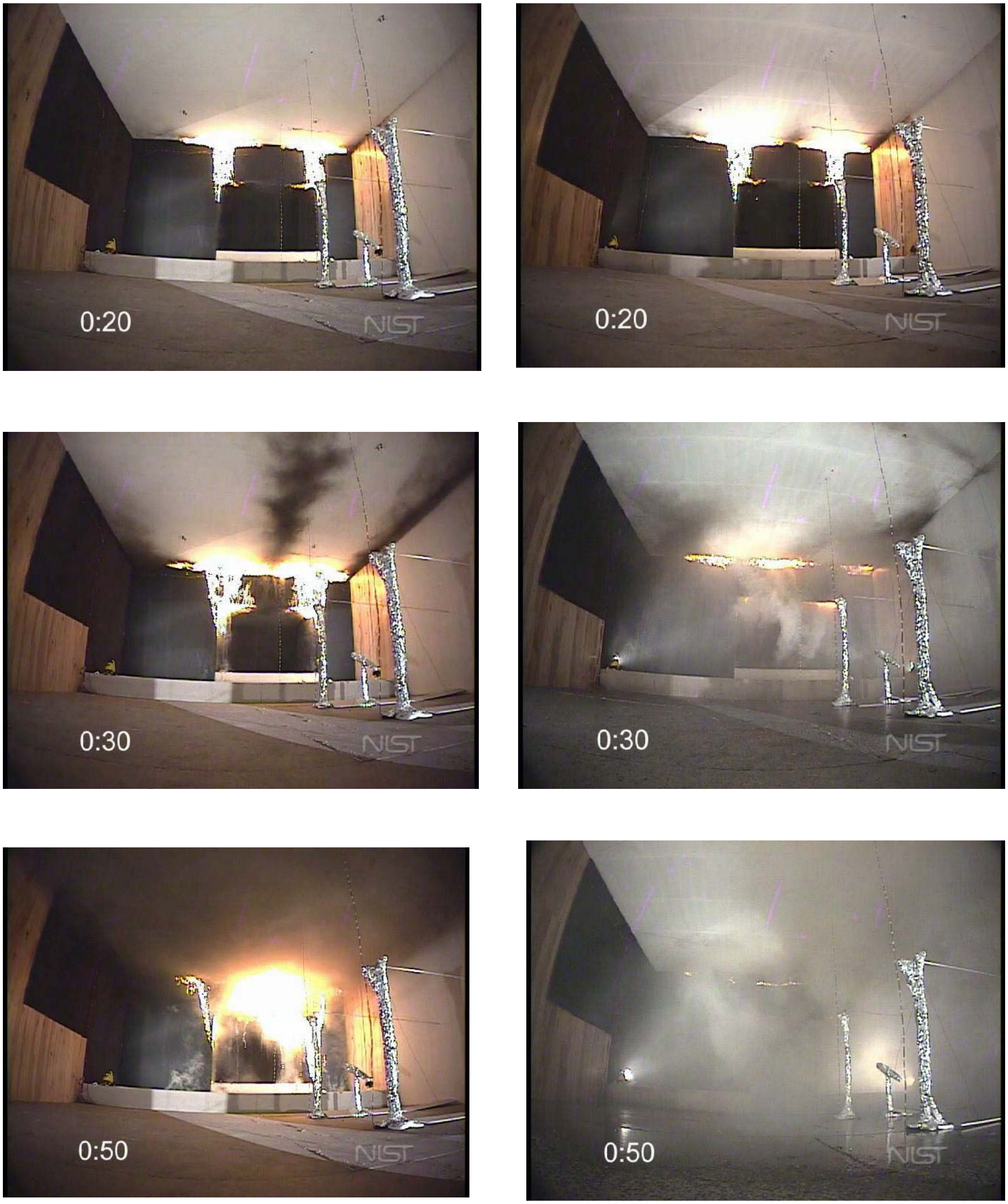


Figure 4-20. Still frames taken from video of full-scale mock-up experiments. Time after ignition is indicated in lower left of each frame. Left column: unsprinklered; right column: sprinklered (first head activates at 24 seconds)

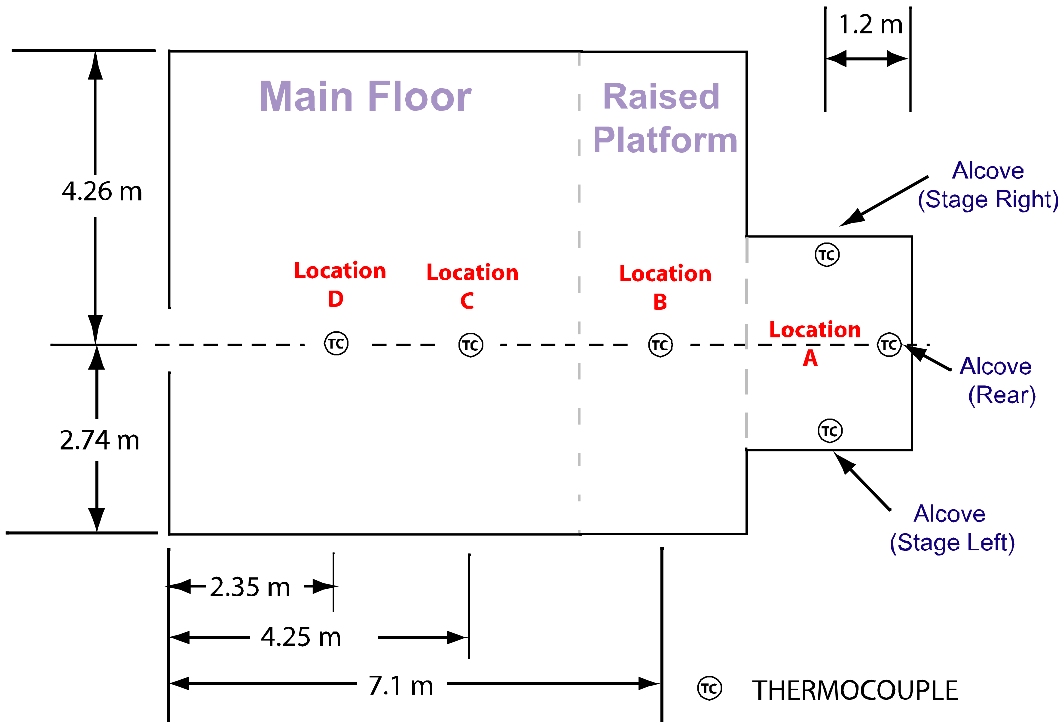


Figure 4-21. Schematic floor plan with thermocouple positions.

that of the wire[17][18]. Temperatures were not corrected for radiation since the radiant environment was dynamic and the local velocity needed for such a correction was not measured. Radiation tends to increase thermocouple temperatures in cooler regions of the fire room and to decrease thermocouple temperatures in hotter regions.

The thermocouple array over the platform floor area had a thermocouple located at 0.025 m, 0.30 m, 0.61 m, 0.91 m, 1.22 m, 1.52 m, 1.83 m, 2.13 m, 2.44 m, 2.74 m, 3.05 m, 3.35 m, 3.66 m below the ceiling. For the platform floor thermocouple array, the thermocouple that was located 3.66 m below the ceiling, was positioned on the platform floor. The two thermocouple arrays on the main floor also had a thermocouple located at 3.66 m below the ceiling, but in each case, the thermocouple was positioned 0.15 m above the main floor. Vertical thermocouple arrays were installed in the center of each wall of the alcove. Each array had a thermocouple located at 0.30 m, 0.61 m, 0.91 m, 1.22 m, 1.52 m, and 1.83 m below the ceiling of the alcove. A horizontal thermocouple array was installed 0.30 m below the ceiling. The array began at the centerline of the alcove opening and continued north along the rear wall, and then followed the platform wall west for 6.1 m. The thermocouples were spaced approximately 0.30 m apart. In addition, thermocouples were located adjacent to the sprinklers.

Selected temperatures versus time are plotted in Fig. 4-22 through Fig. 4-24 for the unsprinklered experiment. Results for the sprinklered experiment, at the same locations in the test room, are provided in Fig. 4-25 through Fig. 4-27. Additional temperature plots are presented in Appendix G.

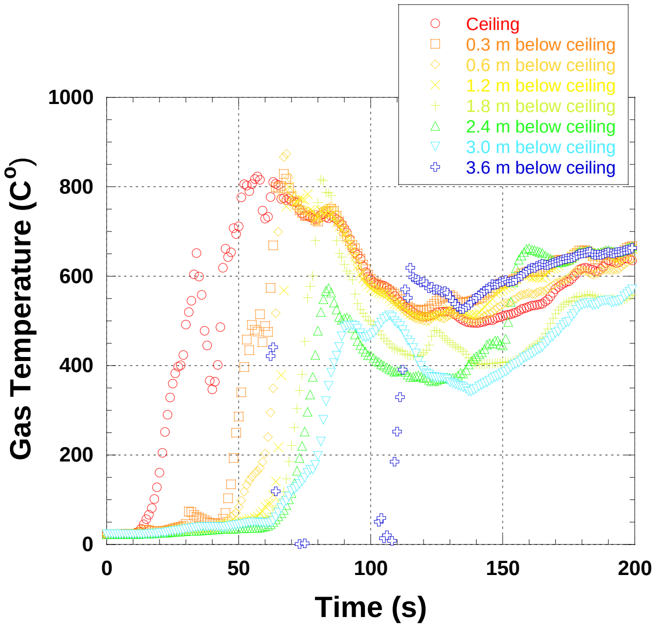


Figure 4-22. Temperatures versus Time for Unsprinklered Mockup Test. Thermocouples positioned on Platform (Location B) from ceiling to platform floor.

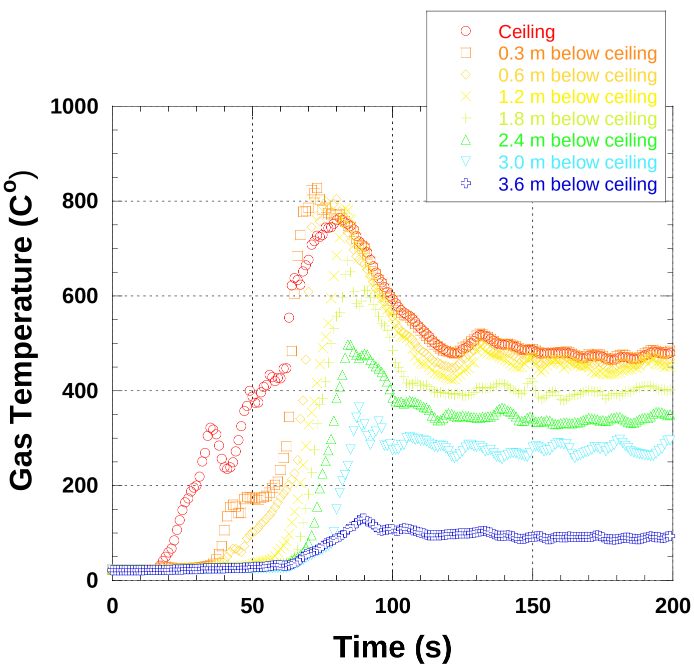


Figure 4-23. Temperatures versus Time for Unsprinklered Mockup Test. Thermocouples positioned on Main Floor (Location C) from ceiling to floor.

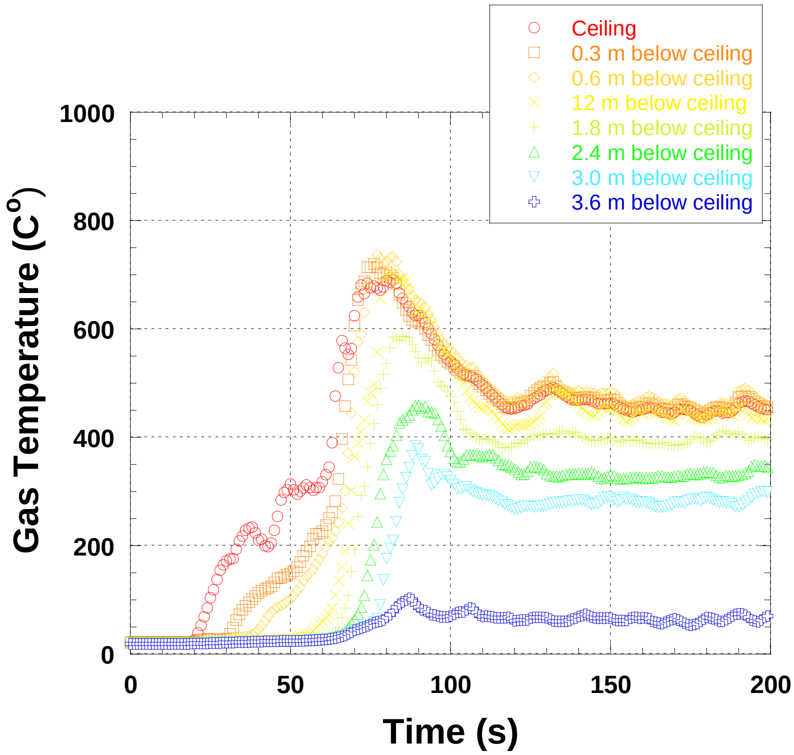


Figure 4-24. Temperatures versus Time for Unsprinklered Mockup Test. Thermocouples positioned on Main Floor (Location D) from ceiling to floor.

For the unsprinklered case, the temperature at the ceiling measured at location B (Fig. 4-22) began to increase within 10 seconds of ignition and continued to increase to over 800 °C in approximately 50 seconds. In less than 60 seconds, the temperature exceeded 50 °C 1.4 m (4.5 ft) above the floor (2.4 m below the ceiling). The hot gases began to form an upper layer and the layer began to descend; in just over 110 seconds, the temperature at the floor of the platform had increased to over 600 °C.

The thermocouple array at location C was installed 6.7 m from the foam covered platform wall, 3 m further away from the platform wall than the thermocouples at location B. The temperatures required about 15 seconds longer to begin increasing than those measured at location B, and required approximately 70 seconds to reach peak temperatures of 800 °C. From Fig, 4-23 one can see that the temperatures at 3.6 m below the ceiling did not begin to increase until 60 seconds after ignition and then the temperatures reached peak values of approximately 100 °C in 90 s. The temperatures at location C exceeded 50 °C at the 1.4 m (4.5 ft) above the floor (2.4 m below the ceiling) elevation in less than 70 seconds.

The thermocouple array at location D was installed 8.5 m from the foam covered platform wall, an additional 1.8 m further away from the platform wall than the thermocouples at location C. The temperatures began to rise in about 20 seconds (see Fig. 4-24), and required approximately 80 seconds to reach peak temperatures of 700 °C. The temperatures at 3.6 m below the ceiling did not begin to increase until 70 seconds after ignition and reached peak values of approximately 100 °C in 90 s. The temperatures near the floor at location D were about the same as the values recorded at the floor on the platform, Location C.

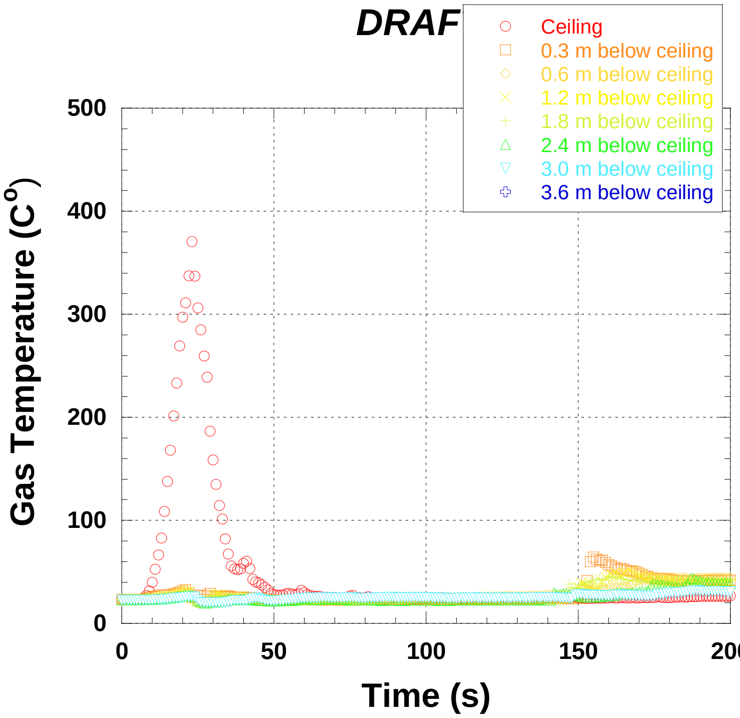


Figure 4-25. Temperatures versus Time for Sprinklered Mockup Test. Thermocouples positioned on Platform (Location B) from ceiling to platform floor.

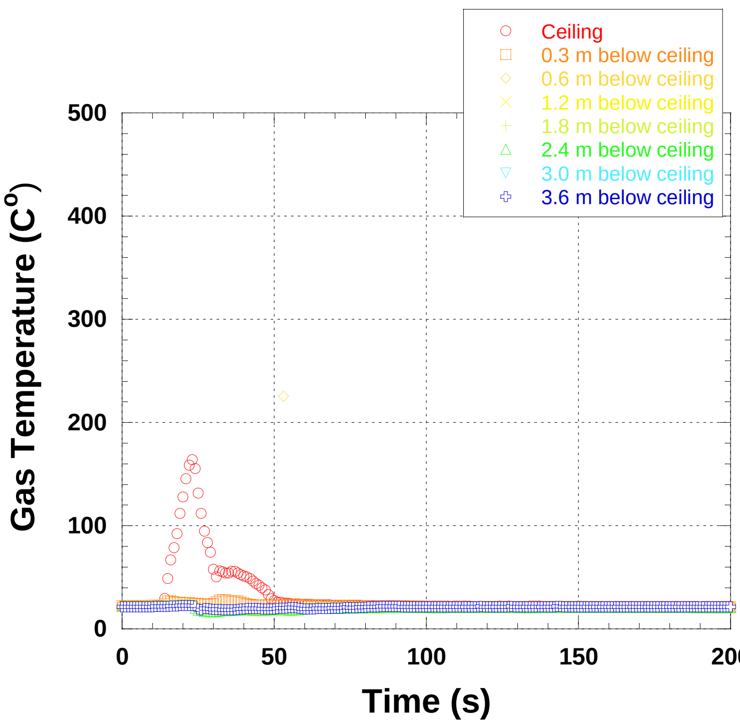


Figure 4- 26. Temperatures versus Time for Sprinklered Mockup Test. Thermocouples positioned on Main Floor (Location C) from ceiling to floor.

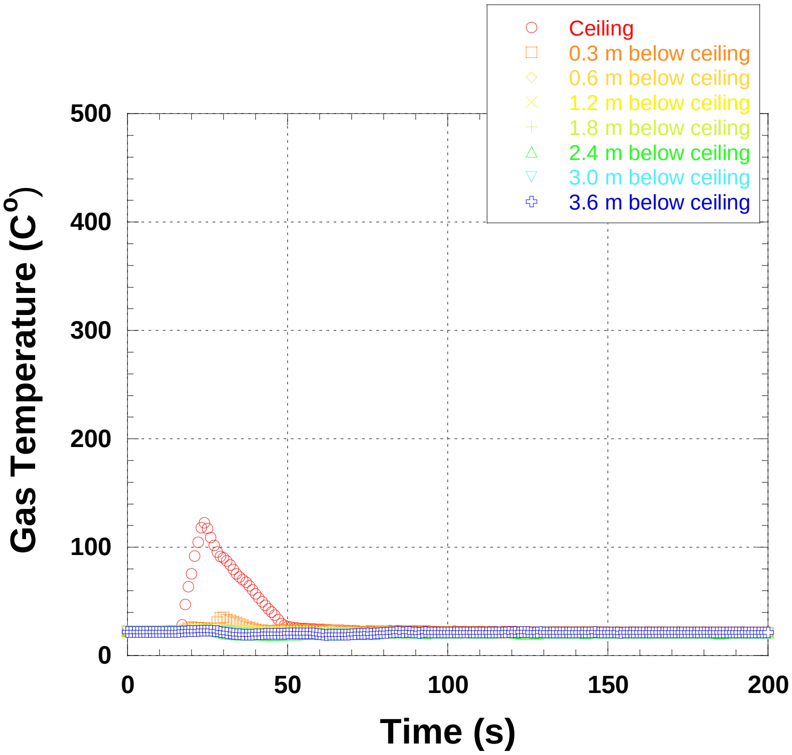


Figure 4-27. Temperatures versus Time for Sprinklered Mockup Test. Thermocouples positioned on Main Floor (Location D) from ceiling to floor.

For the sprinklered test burn, the ceiling thermocouple at location B (on the platform) recorded a peak temperature of 380 °C about 20 seconds after ignition, as can be seen in Fig. 4-25. When the sprinkler activated, the ceiling temperature quickly decreased, dropping to about 20 °C within 40 the next seconds of ignition. The activation of the sprinklers caused the other thermocouples at lower elevations to record near ambient temperatures throughout the test burn.

At location C (Fig. 4-26), the ceiling temperatures reached a peak temperature of 170 °C in about 20 seconds and declined to near ambient temperatures within 60 seconds. For location D (Fig. 4-27), the ceiling temperatures reached a peak temperature of 130 °C in about 20 seconds and declined to near ambient temperatures within 60 seconds. Thermocouples at lower elevations for both locations appeared to remain at near ambient temperatures throughout the test .

The comparison between the temperatures at the ceiling and 1.4 m above the floor for the sprinklered and unsprinklered experimental data is striking, as demonstrated in Fig. 4-28a for location C and Fig. 4-28b for location D. At 25 seconds, the temperatures at the ceiling were about 175 ºC at location C and 125 ºC at location D for both experiments, indicative of the fire being properly replicated up to the point when the sprinkler activated. During the next 25 seconds the temperatures throughout the compartment returned to close to ambient conditions in the sprinklered compartment. This compared to a continuing rapid rise in temperatures for the unsprinklered compartment, which reached ceiling temperatures in excess of 300 ºC at 50 seconds, and peaks of 700 ºC plus in the following 25 seconds. Peak temperatures of 400 ºC to 500 ºC were reached 1.4 m above the floor for the unsprinklered test; temperatures did not rise at all for the sprinklered compartment at this location.

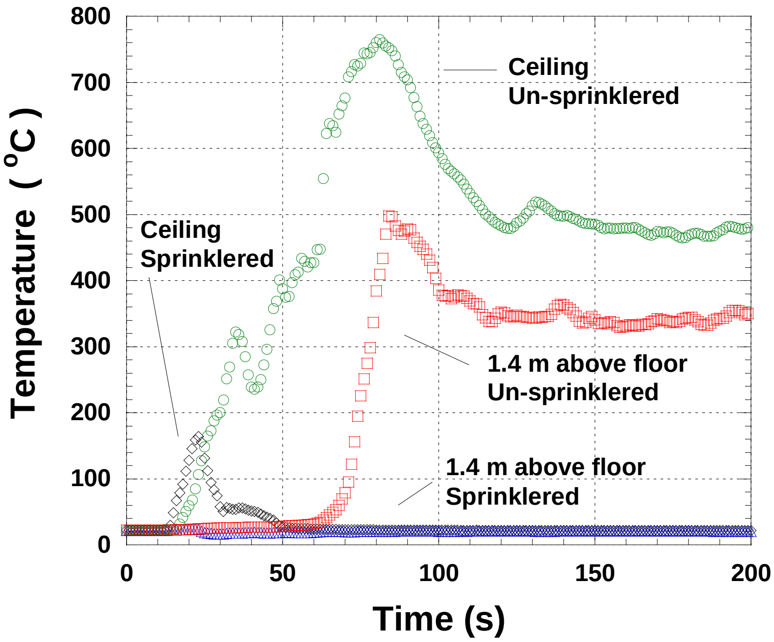


Figure 4-28a. Temperatures versus Time for Unsprinklered and Sprinklered Mockup Test. Thermocouples positioned on Main Floor (Location C) at ceiling and 1.4 m (4.5 ft) above floor.

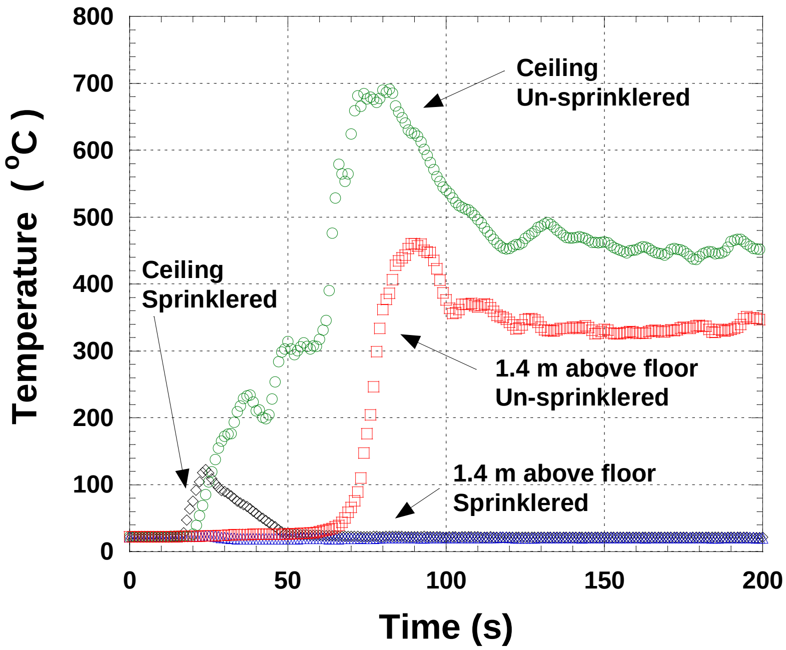


Figure 4-28b. Temperatures versus Time for Unsprinklered and Sprinklered Mockup Test. Thermocouples positioned on Main Floor (Location D) at ceiling and 1.4 m (4.5 ft) above floor.

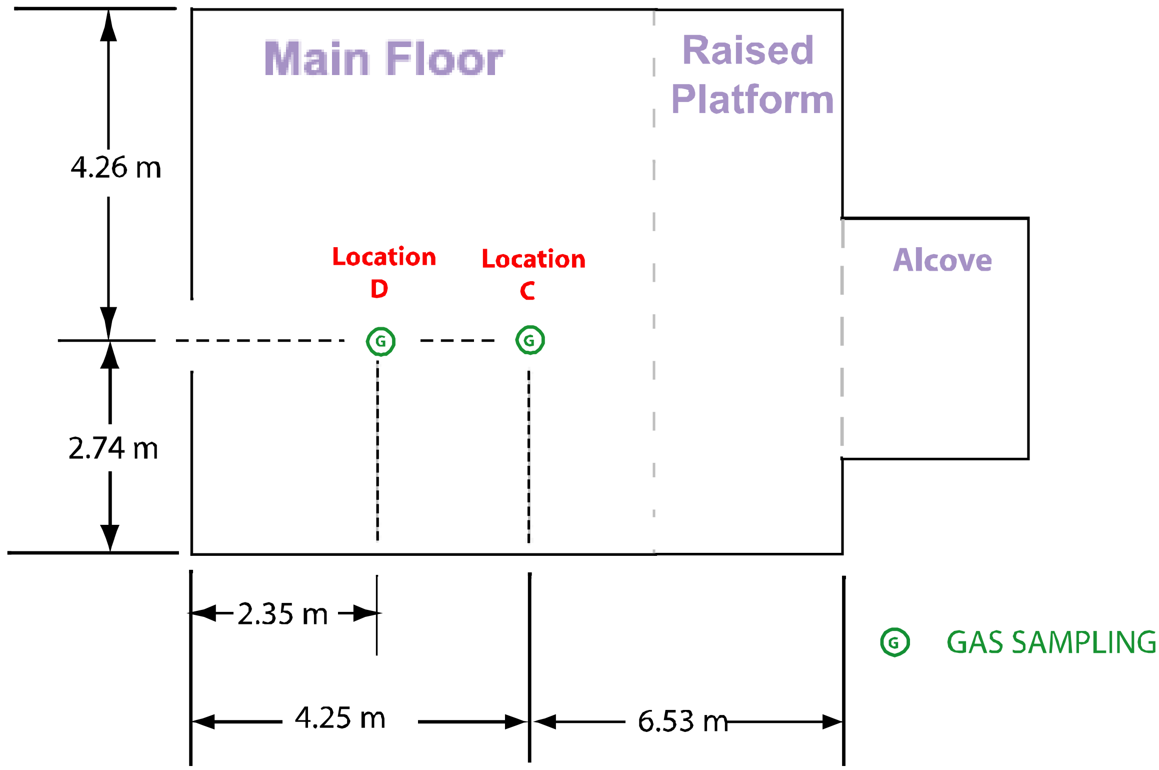


Figure 4-29. Schematic floor plan with gas sampling locations.

4.6.5 Oxygen Depletion and Gas Volume Fractions

For fires burning in the open under the laboratory hood, the chemical power measured by the oxygen depletion calorimeter is equal to the heat release rate from the fire as a function of time. However, for a fire within a room, the effluent from the enclosure is a mixed average of the upper layer gases, and does not represent the instantaneous heat release rate of the fire. With this limitation in mind, oxygen depletion rate was measured using the NIST 10 MW hood. The measurement system was calibrated with a gas burner placed directly under the hood (not in the enclosure) with heat release rates as high as 5 MW and an expanded uncertainty (95 % confidence level) of 11 % for fires larger than 400 kW. Bryant et al. [19] provide details on the operation and uncertainty in measurements associated with the oxygen depletion calorimeter.

There was a significant time delay between ignition of the foam in the full-scale mock-up and the first indication in the oxygen depletion calorimeter that heat was being released by the fire. The fire gases generated inside the test room did not exit the door way and enter the calorimeter until about 70 seconds later, and by the time they were detected, the combustion products had mixed with fresh air in the room. The result was that the measured heat release represented an average over time. The measured peak for the unsprinklered test was 4.3 MW. A steady heat release rate of about 3.4 MW was reached after about 150 seconds. The sprinklered experiments yielded no heat release rate measurements since the sprinklers quickly suppressed the fire after 25 seconds, a time shorter than the time lag discussed above.

Gas sample extraction probes 1.4 m above the floor were used to measure CO, CO_2, O_2 and HCN at the two location shown in Fig, 4-29. The gases were pulled through 9.4 mm ID tubing to chemical analyzers

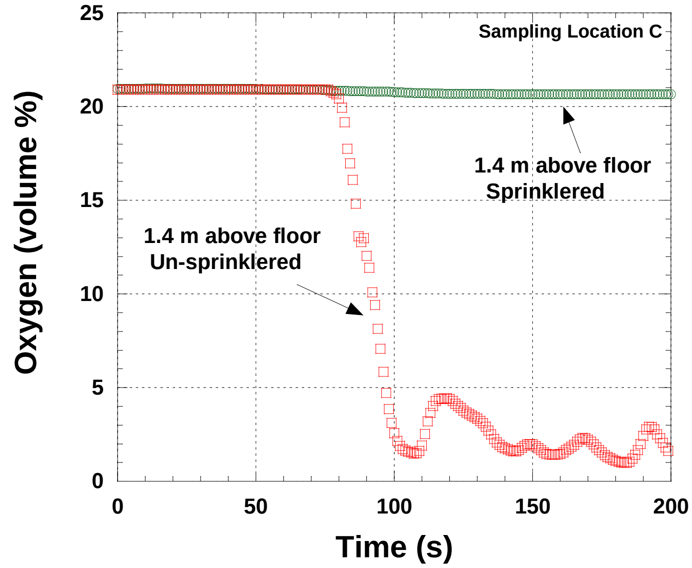


Figure 4- 30. Oxygen Volume Fraction vs Time for Unsprinklered and Sprinklered Mockup Test. Gas Sampling probe positioned on Main Floor (Location C) at 1.4 m (4.5 ft) above floor.

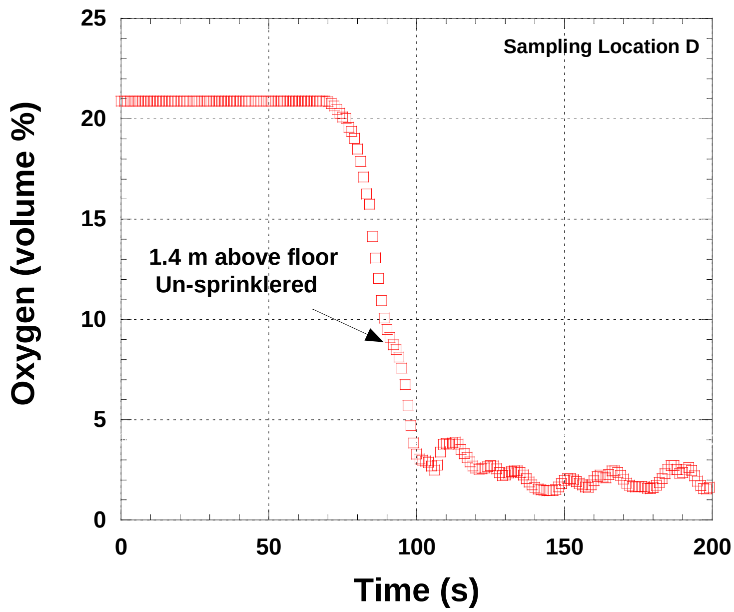


Figure 4-31. Oxygen Volume Fraction vs Time for Unsprinklered Mockup Test. Gas Sampling probe positioned on Main Floor (Location D) at 1.4 m (4.5 ft) above floor.

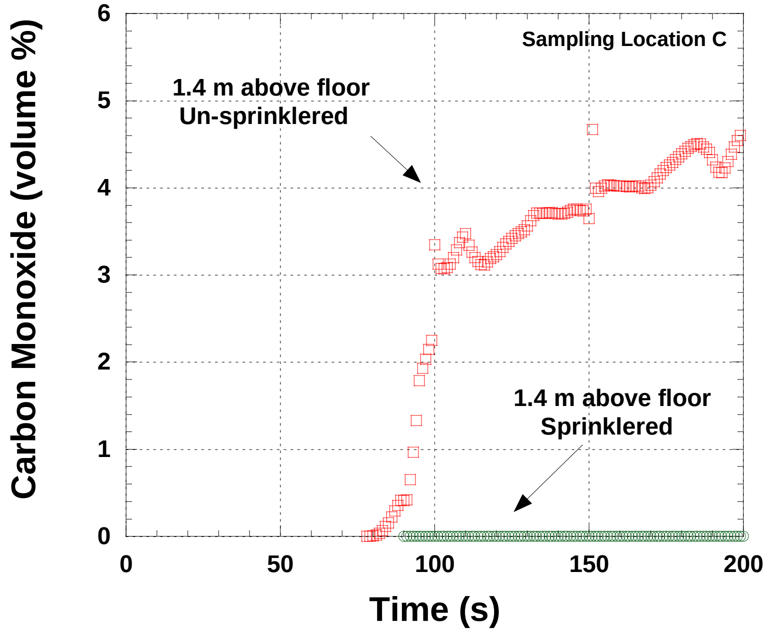


Figure 4-32. Carbon Monoxide Volume Fraction vs Time for Unsprinklered and Sprinklered Mockup Test. Gas Sampling probe positioned on Main Floor (Location C) at 1.4 m (4.5 ft) above floor.

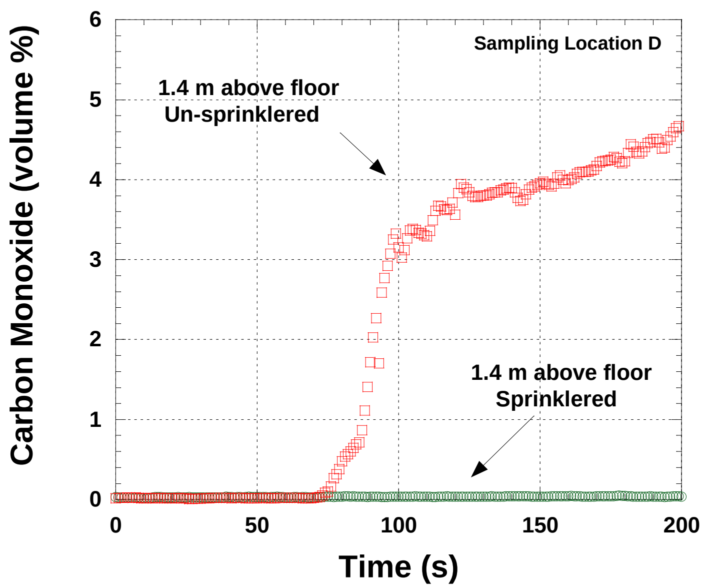


Figure 4-33. Carbon Monoxide Volume Fraction vs Time for Unsprinklered and Sprinklered Mockup Test. Gas Sampling probe positioned on Main Floor (Location D) at 1.4 m (4.5 ft) above floor.

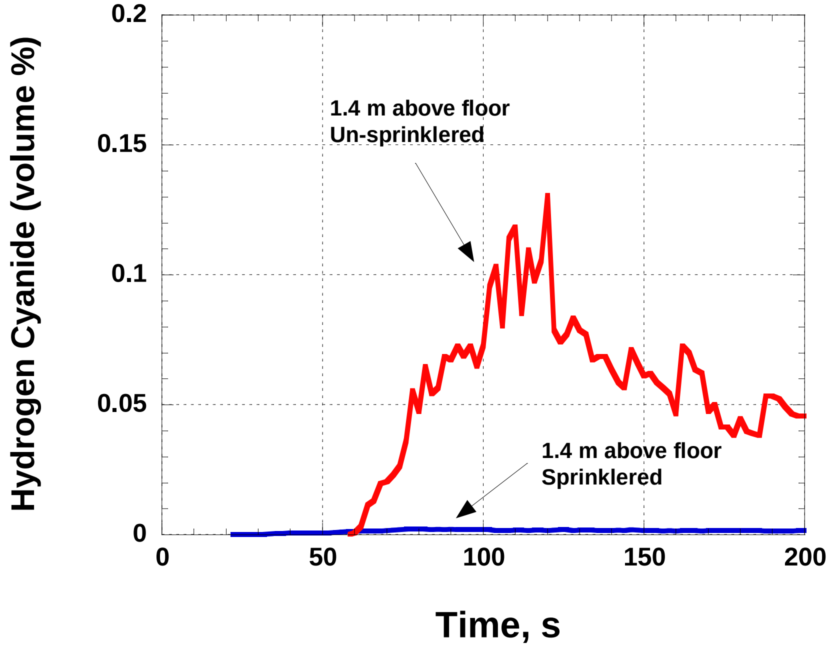


Figure 4-34. Hydrogen Cyanide Volume Fraction vs Time for Unsprinklered and Sprinklered Mockup Test. Gas Sampling probe positioned on Main Floor (Location C) at 1.4 m (4.5 ft) above floor.

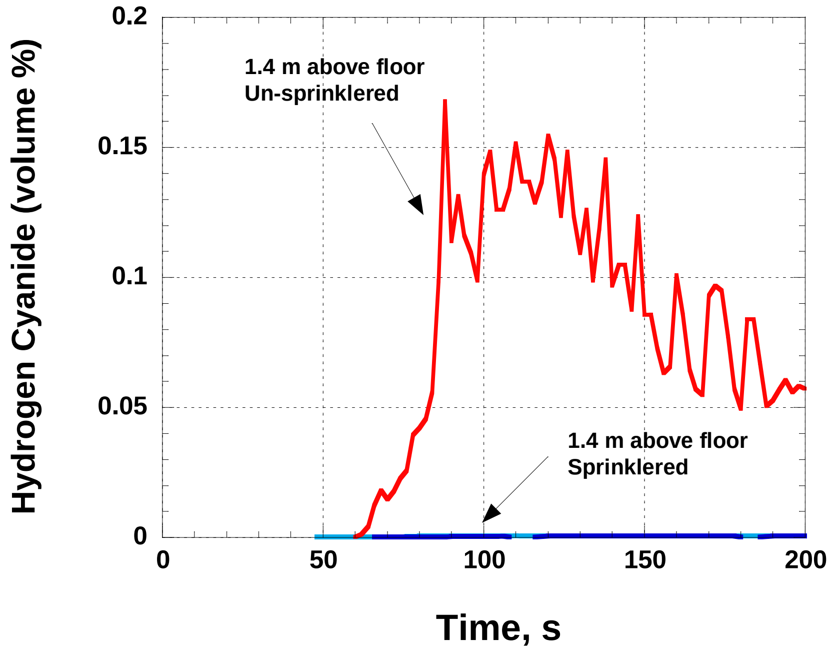


Figure 4-35. Hydrogen Cyanide Volume Fraction vs Time for Unsprinklered and Sprinklered Mockup Test. Gas Sampling probe positioned on Main Floor (Location D) at 1.4 m (4.5 ft) above floor.

after passing through moisture and particulate filters. Carbon monoxide and CO_2 volume fractions were monitored using non-dispersive infrared gas analyzers while the oxygen volume fractions were measured using paramagnetic analyzers. Hydrogen cyanide concentrations were monitored using impingers and real-time gas analyzers with cyanide combination electrodes. Each impinger utilized 0.1 M KOH as the trapping solution and samples were analyzed according to NIOSH Method 7904 [20].

During the sampling process, the gas sample for the oxygen, carbon monoxide, and carbon dioxide analysis was drawn through a cold trap which removed the water vapor. The oxygen, carbon monoxide, and carbon dioxide concentrations were recorded by each analyzer on a dry basis, and later corrected for the water removed by assuming that for every mole of carbon dioxide or carbon monoxide generated, one mole of water was also generated. By adding the water vapor back into the gas sample, the concentrations of oxygen, carbon monoxide, and carbon dioxide decreased. The hydrogen cyanide sample gas utilized a different sampling train and did not pass through a cold trap.

Gas volume fractions versus time are plotted for the unsprinklered and sprinklered tests in Figures 4-30 through 4-35 for O_2, CO and HCN. (Additional gas volume fractions measurements are discussed in Appendix G.) At both locations C and D, oxygen volume fractions did not begin to drop at the 1.4 m elevation until 70 seconds to 80 seconds after ignition for the unsprinklered mock-up experiments. At both locations, the oxygen volume fractions descended to less than 4 % in less than 100 seconds, then fluctuated between 1 % and 4 % . During the sprinklered test burns, the oxygen mole fraction at location C did not appear to drop much below ambient oxygen levels. (A malfunctioning oxygen analyzer prevented the oxygen concentrations from being monitored at location D during the sprinklered burns.)

At both locations C and D, volume fractions of carbon monoxide at the 1.4 m elevation did not begin to increase until 70 seconds to 80 seconds after ignition for the unsprinklered mock-up experiments, but then increased to 3 % in the next 20 seconds to 30 seconds and reached 4.5 % by 200 seconds after ignition. During the sprinklered test burns, the carbon monoxide concentration at neither location C nor location D appeared to increase much above ambient levels.

The volume fractions of hydrogen cyanide at the 1.4 m elevation began to increase 60 seconds after ignition for the unsprinklered mockup experiments. At location C, the HCN reached its peak value of 0.13 % in 120 seconds. The HCN increased slightly faster at location D, where it reached a peak volume fraction of 0.17 % in about 90 s. During the sprinklered test burns, the hydrogen cyanide concentration at locations C and D were barely above the measurable limit.

4.6.6 Heat Flux and Heat Detectors

Three elliptical radiometers were installed in the ceiling of the test cell viewing downward at location B, C, and D (Fig. 4-36). In addition to the radiometer at location B, a total heat flux gauge with an upward view was installed flush with the platform floor. At locations C and D, two additional total heat flux gauges were installed 1.5 m above the floor. One total heat flux gauge was position to have an upward view, while the other gauge had a view of the alcove. The heat flux sensors were water cooled Schmidt-Boelter type transducers.

For the unsprinklered compartment test, the output of the thermal radiation and total heat fluxes for the radiometer and heat flux gauges at locations C and D are shown in Fig. 4-37 and Fig 4-38. At location C, peak fluxes in excess of 50 kW/m^2 were reached about 70 seconds after ignition. Peak fluxes at location D were about 20 % lower than location C. At 100 seconds after ignition, radiation and heat flux at

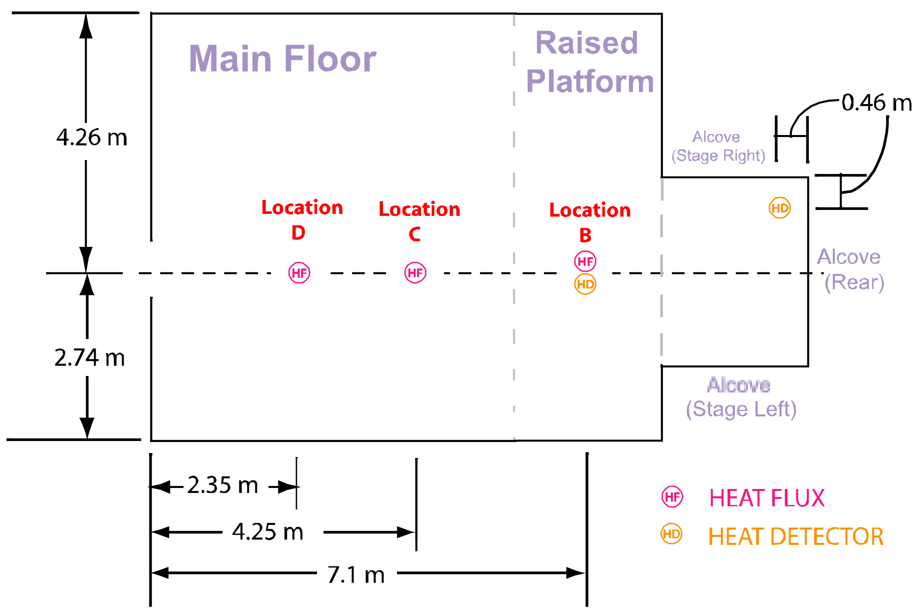


Figure 4-36. Schematic floor plan with heat flux and heat detector locations.

location C and the heat flux at location D decreased significantly to 20 kW/m^2 and appeared to remain relatively constant at both locations. The radiometer in the ceiling at location D dropped to 10 kW/m^2 before becoming relatively steady. (Additional plots of heat flux are shown and discussed in App. G.)

In the sprinklered test at locations C and D, neither radiation nor total heat flux reached levels much above the background. Only on the platform at location B was there a slight increase in radiation and total heat flux, starting around 20 seconds after ignition.

Two types of heat detectors were also installed: fixed temperature models with an activation temperature of 93 ºC, and a rate of rise/fixed temperature model which activated when the rate of temperature increase exceeded about 7 ºC /min or when the temperature reached 93 ºC. One pair of detectors was installed on the ceiling, adjacent to the thermocouple array on the raised floor, and the second pair of heat detectors was installed on the ceiling in the north-east corner of the alcove.

The responses of rate of rise heat detectors and fixed temperature detectors are plotted in Fig. 4-39 and Fig. 4-40, respectively. For both unsprinklered and sprinklered test burns, each of the rate of rise detectors activated in less than 20 seconds. Only in the unsprinklered experiments did the fixed temperature detectors activate. The fixed temperature detector in the alcove activated in about 20 seconds while the fixed temperature detector above the platform required almost 40 seconds to respond.

4.6.7 Sprinkler Activation

Five sprinkler heads were installed on a nominal 3.66 m spacing. One sprinkler was installed centered in the alcove, two were installed over the platform, and two over the main floor area. (See Figure 4-41.) The

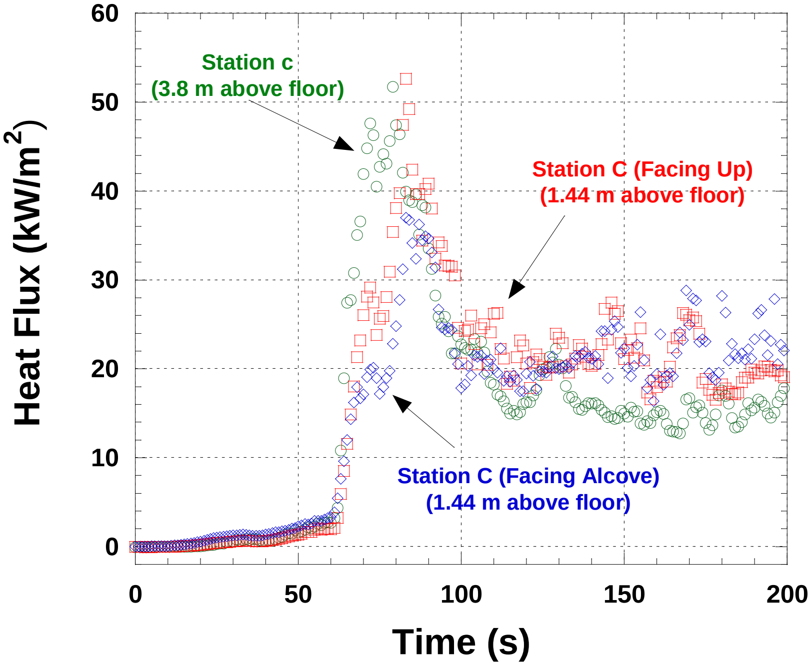


Figure 4- 37. Heat Fluxes versus time for unsprinklered mockup test. Radiometer positioned flush with ceiling (3.8 m above floor); heat flux gauges facing up (1.44 m above floor), and facing alcove (1.44 m above floor) at sampling location C.

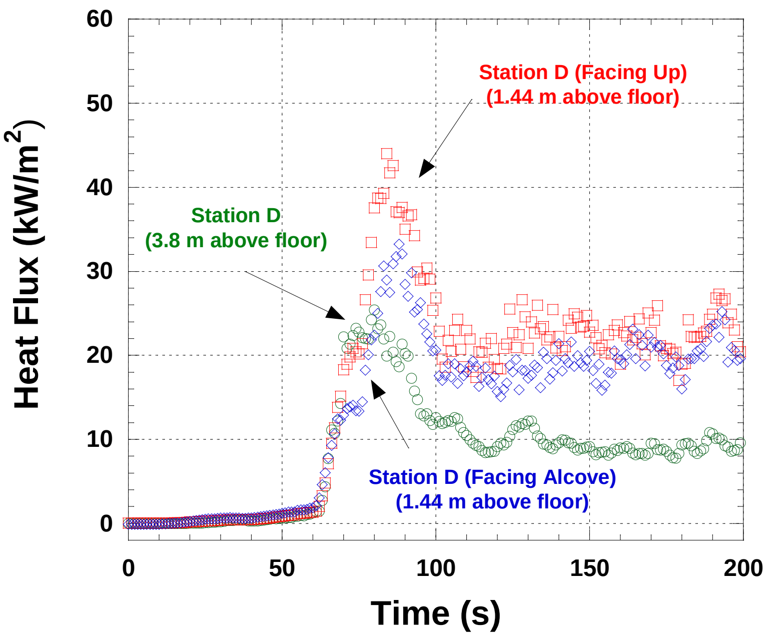


Figure 4- 38. Heat fluxes versus time for unsprinklered mockup test. Radiometer positioned flush with ceiling (3.8 m above floor); heat flux gauges facing up (1.44 m above floor), and facing alcove (1.44 m above floor) at sampling location D.

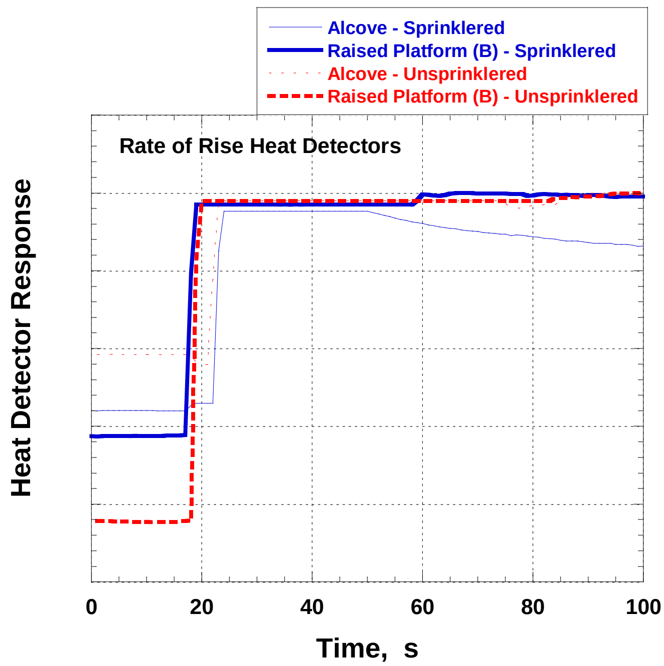


Figure 4- 39. Response of Rate of Rise Heat Detectors versus Time for Unsprinklered and Sprinklered Mockup. Detectors located in Alcove and at Location B.

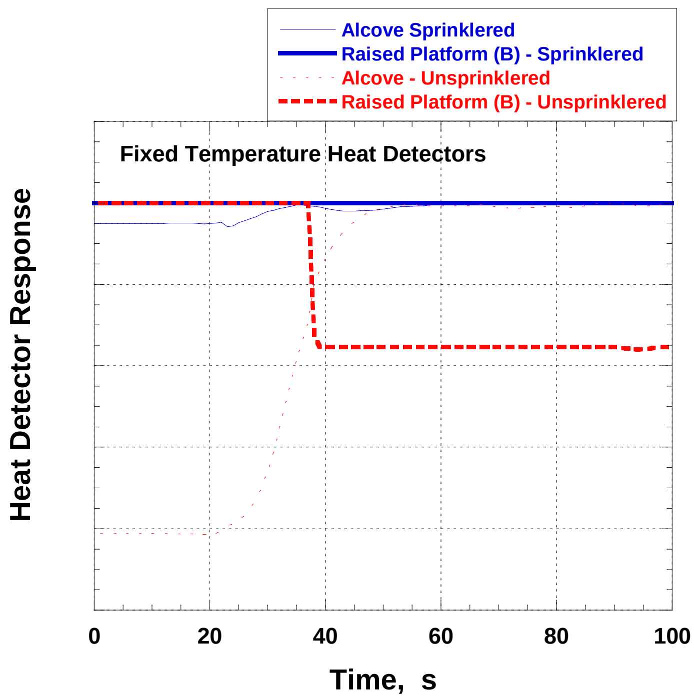


Figure 4- 40. Response of Fixed Temperature Heat Detectors versus Time for Unsprinklered and Sprinklered Mockup. Detectors located in Alcove and at Location B.

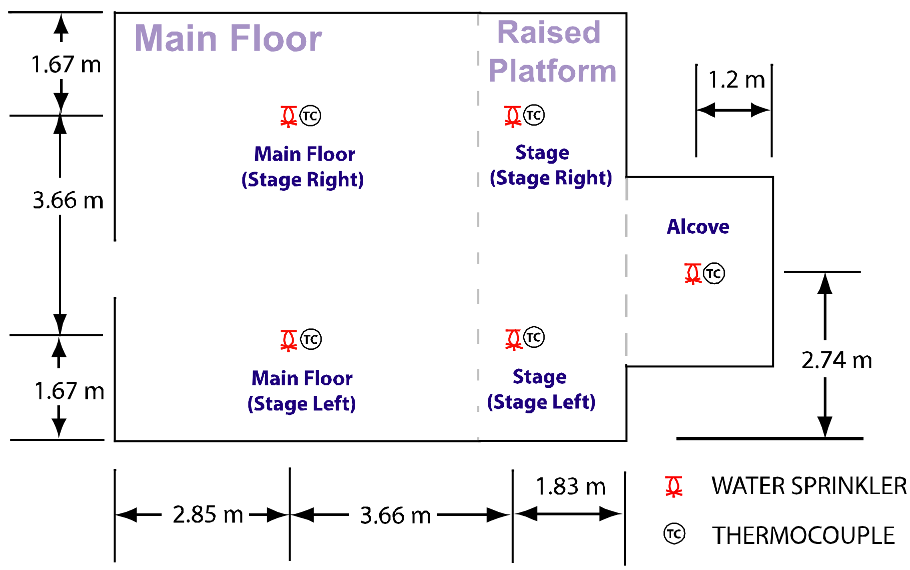


Figure 4- 41. Schematic Diagram of Sprinkler and Sprinkler Thermocouple Locations.

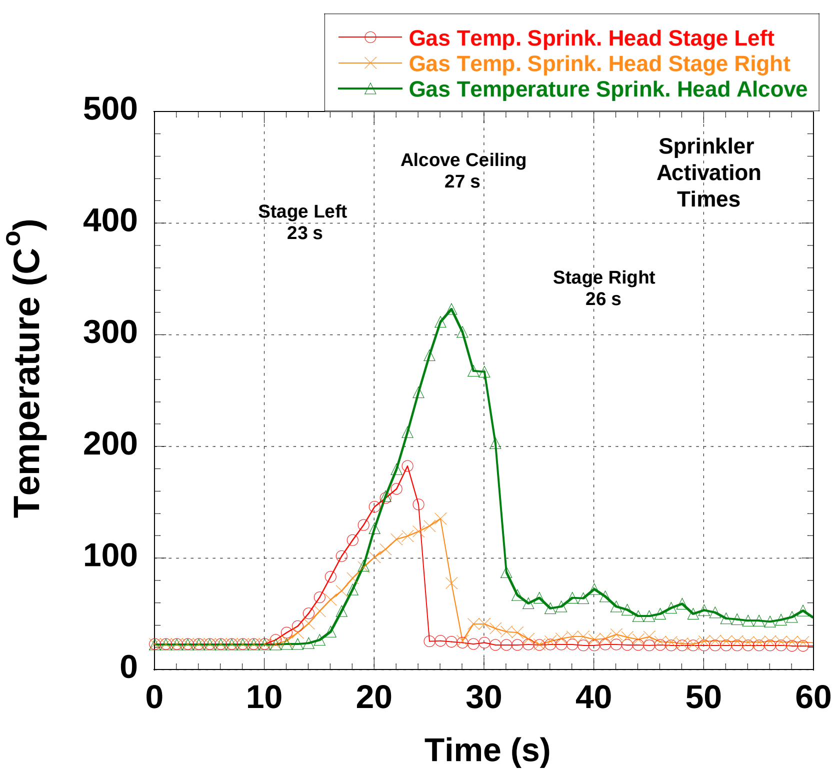


Figure 4- 42. Temperature versus Time for Sprinkler Thermocouples.

Table 4.5 Time to Reach Tenability Criteria, or maximum deviation obtained

	Temperature > 120 °C	Heat Flux > 2.5 kW/m²	Oxygen < 12 %	Hydrogen Cyanide > 0.02 %	Carbon Monoxide > 0.5 %
Sprinklered					
Location B	< 28 °C	not measured	not measured	not measured	not measured
Location C	< 24 °C	< 0.32 kW/m²	> 20.6 %	< 0.004 %	< 0.002 %
Location D	< 24 °C	< 0.21 kW/m²	not measured	< 0.0006 %	< 0.04 %
Unsprinklered					
Location B	71 seconds	not measured	not measured	not measured	not measured
Location C	76 seconds	61 seconds	87 seconds	71 seconds	82 seconds
Location D	71 seconds	61 seconds	85 seconds	75 seconds	92 seconds

sprinkler installation and water supply were based on a light hazard classification with 4.1 mm/min water spray density, in accordance with NFPA 13 [21]. The sprinklers used were commercially available pendent-type with a nominal 15 mm standard orifice. The listed activation temperature for all of the sprinklers used was 74 ºC. The temperatures monitored by a thermocouple that was positioned next to the sprinkler head are plotted versus time in Fig. 4-42. The first sprinkler, above the platform at stage-left, activated in 23 seconds. The sprinkler above the platform on stage-right was the next to activate at 26 seconds. One second later the sprinkler in the alcove activated. No other sprinkler was triggered.

4.6.8 Tenability

According to Purser [21] a room becomes untenable for people when any of the following occur: the temperature exceeds 120 °C (250 °F), a heat flux exceeds 2.5 kW/m^2, or the oxygen volume fraction drops below 12 %. These levels provide guidelines generally accepted by the fire protection engineering profession as leading to quick incapacitation, but may be tolerated for a short (unspecified) time. Hydrogen cyanide and carbon monoxide also represent significant hazards to humans. The lowest concentration of a material in air that has been reported to have caused death in humans is termed Lethal Concentration Low (LCLo). The LCLo (inhalation) for hydrogen cyanide is reported as 0.02 % for 5 minutes [22]. For carbon monoxide the LCLo (inhalation) is listed at 0.5 % for 5 minutes [22].

The upper portion of Table 4-5 summarizes the temperatures, heat fluxes, oxygen volume fractions, CO volume fractions, and HCN volume fractions measured at locations B, C, and D at an elevation 1.4 m above the floor(approximately head-height) for the sprinklered test. Also listed are the tenability criteria and LCLo levels. In the sprinklered test, conditions did not exceed any of the tenability criteria (temperature, heat flux, or oxygen volume fraction), or the LCLo volume fractions for either hydrogen cyanide or carbon monoxide during the entire duration of the test (> 200 seconds). The maximum values for temperature, heat flux, hydrogen cyanide and carbon monoxide as well as the minimum value for oxygen that were recorded during the sprinklered test are shown in the table.

In the test with the unsprinklered mock-up, the temperature criterion can be seen in Table 4-5 to have been exceeded in less than 76 seconds at all three locations. The thermal flux exceeded 2.5 kW/m^2 in about 60 seconds. At sampling location C and D, the oxygen concentration dropped below 12 % in less than 87 seconds. The hydrogen cyanide concentrations exceeded the LCLo in less than 75 seconds and the carbon monoxide concentrations reached its LCLo in less than 92 seconds.

Exceeding the tenability limit does not imply that any or all occupants who are present in that environment will succumb due to a particular limit exceeded. The length of time exposed, the rate of change of the environmental conditions, possible antagonistic effects, and the susceptibility of the individual all play a role. With this limited set of data from a single mockup experiment, it is not possible to determine whether an occupant of The Station nightclub would have first fallen victim to the high heat flux, to the high temperature, to the lack of oxygen, or to the hydrogen cyanide, carbon monoxide or smoke levels, or even to the crush of the crowd. (Note that NIST was unable to get access to the Rhode Island Medical Examiner's report due the ongoing criminal investigation, and was therefore unable to relate findings regarding the conditions in the nightclub to possible causes of death.) Given the rapid spread of the fire and combustion products, it is likely that the victims succumbed to multiple conditions. If conditions developed in The Station in the same manner as during this mock-up, most occupants likely would have had less than 90 seconds to escape under tenable conditions.

4.7 REFERENCES FOR CHAPTER 4

1. Duval, R., “Fires in Places of Assembly”, presented at NFPA Fall Education Conference, Miami, FL, November 14 – 17, 2004, National Fire Protection Association, Quincy, MA.

2. UL 94- Test for Flammability of Plastic Materials for Parts in Devices and Appliances, Fifth Edition, October 29, 1996, Underwriters Laboratories, Inc., Northbrook, IL, p. 34.

3. E-84-04 – Standard Test Method for Surface Burning Characteristics of Building Materials, ASTM Fire Standards, Sixth Edition, American Society for Testing and Materials, West Conshohocken, PA, pp 1000- 1018.

4. ASTM E 1354-04a, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*, ASTM International, West Conshohocken, PA, 2004.

5. ASTM D 1929 - *Standard Test Method for Determining Ignition Temperatures of Plastics*, ASTM International, West Conshohocken, PA, 2004.

6. *Society of Fire Protection Engineers’ Handbook of Fire Protection Engineering*, Third Edition, P.J. DiNenno, Editor-in-Chief, Society of Fire Protection Engineers, Bethesda, MD, pp. A-32 - A-42, 2002.

7. *Fire Protection Handbook, Nineteenth Edition*, A.E. Cote, Editor-in-Chief, National Fire Protection Association, Quincy, MA, pp. 8-38 – 8-39, 2003.

8. Troitzsch, J., “The Burning of Plastics”, Chapter 4 in International Plastics Flammability Handbook, Second Edition, Hanser Publishers, New York, NY, 1983, pp 16 – 30.

9. Ma, S., Venart, J.E.S., and Sousa, A.C.M., “Cone Calorimeter Measurements of Ignition and Fire Properties of Several Building Materials,” *International Conference on Fire Science and Engineering*, Hong Kong, March 15 – 16, 1995, pp. 629 –634.

10. ISO 1716, “Reaction to fire tests for building products-Determination of the heat of combustion,” *ISO*, Annex B, 2002.

11. Marchal, A., Yoshida, M., and Hasemi, Y., “Asia-Oceania ISO 5660 Cone Calorimeter Inter-Laboratory Trials,” in *Thirteenth Meeting of the UJNR Panel on Fire Research and Safety, March 13 – 20, 1996*, NISTIR 6030, National Institute of Standards and Technology, Gaithersburg, MD, 1997, pp. 173 – 214.

12. “Polyurethanes,” in *Fire Retardant Materials*, Edited by A.R. Horrocks and D. Price, Woodhead Publishing Limited, Cambridge England, 2001, pp.243-245.

13. *Fire Protection Handbook, Seventeenth Edition*, A.E. Cote, Editor-in-Chief, National Fire Protection Association, Quincy, MA, p. 3-111, 2001.

14. ASTM E 1354-04a, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*, ASTM International, West Conshohocken, PA, 2004.

15. *ASTM E84: Standard Test Method for Surface Burning Characteristics of Building Materials*, ASTM International, West Conshohocken, PA, 2002.

16. Omega Engineering Inc., (2000) *The Temperature Handbook*, Vol. MM, pages Z-39-40, Stamford, CT.

17. Blevins, L.G., "Behavior of Bare and Aspirated Thermocouples in Compartment Fires", *National Heat Transfer Conference, 33rd Proceedings*. HTD99-280. August 15-17, 1999, Albuquerque, NM, 1999.

18. Pitts, W.M., E. Braun, R.D. Peacock, H.E. Mitler, E. L. Johnsson, P.A. Reneke, and L.G.Blevins, "Temperature Uncertainties for Bare-Bead and Aspirated Thermocouple Measurements in Fire Environments," *Thermal Measurements: The Foundation of Fire Standards. American Society for Testing and Materials (ASTM). Proceedings*. ASTM STP 1427. December 3, 2001, Dallas, TX.

19. Bryant, R.A., Ohlemiller, T.J., Johnsson, E.L., Hamins, A.H., Grove, B.S., Guthrie, W.F., Maranghides, A., and Mulholland, G.W., *The NIST 3 MW Quantitative Heat Release Rate Facility*, NIST Special Publication 1007, National Institute of Standards and Technology, Gaithersburg, MD, 2003.

20. "Cyanides, Aersol and Gas, Method 7904," *NIOSH Manual of Analytical Methods*, Fourth Edition, 8/15/94.

21. NFPA 13 (2002), *Standard for the Installation of Sprinkler Systems*, National Fire Protection Association, Quincy MA.

21. Purser, D.A., “Toxicity Assessment of Combustion Products,” in Society of Fire Protection Engineers’ Handbook of Fire Protection Engineering, Third Edition, DiNenno,P.J., Editor-in-Chief, Society of Fire Protection Engineers, Bethesda, MD, 2002.

22. Lewis, R.J., Sax's *Dangerous Properties of Industrial Materials*, Ninth Edition, Van Nostrand Reinhold, New York, NY, 1995.

23. Zicherman, J.B., The Fire Incident at "The Station", Report FCA NO 04-5667, Fire Cause Analysis, 213 W. Cutting Blvd., Richmond, CA 94804, November 10, 2003.

Chapter 5
COMPUTER SIMULATION OF FIRE AND SMOKE SPREAD

The WPRI-TV video tape provided information to the investigation of the start and spread of the fire that was almost unprecedented in fire forensics. Supplemented with first person interviews and examination of the scene after the fact, a clear overall picture of the event emerged rather quickly. However, a number of important details could not be gleaned from the evidence, nor was it possible to examine the impact of the fire on the occupants. Both would have helped to understand the fire's effect on the evacuation process and to determine the relative importance of different contributors to the building failure.

Computer simulation has matured enough over the past five years to become credible when properly applied as a tool to help fill in critical details of the fire event, and to demonstrate the value of alternative building designs and fire safety measures. This chapter presents the results of numerical simulations and analyses of fire spread, smoke movement, tenability, and operation of fire protection systems that relate to the conditions in The Station on the night of Feb. 20, 2003.

The numerical models used in this investigation were the NIST Fire Dynamics Simulator (FDS) [1] and Smokeview [2]. The essential fire properties of the materials needed as input to FDS were generated from the small scale and real scale measurements described in Chapter 4. The following sections provide an overview of the models, describe how the testing was used to add credence to the simulations, and present the results of the full nightclub simulations.

5.1 NIST FIRE DYNAMICS SIMULATOR

The NIST Fire Dynamics Simulator is a computational fluid dynamics (CFD) model of fire-driven fluid flow. It solves numerically a form of the Navier-Stokes equations appropriate for low-speed, thermally driven flow with an emphasis on smoke and heat transport from fires [3]. Version 1 was publicly released in February 2000. The predictions performed here were made with the public pre-release version 4 of the model. Version 4 includes several new features, including multi-blocking, which were critical in performing the full night club simulations.

A CFD model requires that the room or building of interest be divided into small three-dimensional rectangular control volumes or computational cells. The CFD model computes the density, velocity, temperature, pressure and species concentration of the gas in each cell as it steps through time. Based on the laws of conservation of mass, momentum, species, and energy, the model tracks the generation and movement of fire gases. Radiative heat transfer is included in the model via the solution of the radiation transport equation for a non-scattering gray gas. All solid surfaces are assigned thermal boundary conditions, plus information about their burning behavior. Heat and mass transfer to and from solid surfaces is usually handled with empirical correlations. FDS utilizes material properties of the furnishings, walls, floors, and ceilings to compute fire growth and spread. A complete description of the FDS model is given in references [1,3].

Inputs required by FDS include the geometry of the structure, the computational cell size, the location of the ignition source, the energy release rate of the ignition source, thermal properties of walls, ceilings, floors, furnishings, and the size, location, and timing of door and window openings to the outside which critically influence fire growth and spread.

5.1.1 Geometry

FDS approximates the governing equations on a rectilinear grid. This three-dimensional grid represents the volume modeled by FDS. The grid is isolated from the surroundings, that is, all the smoke and heat generated by the fire stays within the grid and the air does not enter the grid. The user may, however, prescribe vents that allow smoke and heat to leave and air to enter the grid area. The user prescribes rectangular obstructions that are forced to conform to the underlying grid. Multi-blocking is a term used to describe the use of more than one rectangular grid or mesh in a calculation.

FDS predictions are sensitive to grid size; using a larger number of smaller cells will generally capture more features of the flow; however, the computation time increases more than linearly with the increase in number of grid cells. Computation times of one day on a fast computer are not uncommon but may increase to several months with a large number of grid cells. Therefore, it is important to use the smallest number of grid cells that still capture the important features of the fire. One way to reduce the number of grid cells is the use of multi-blocking. With multi-blocking, smaller grid cells that capture more detail are used near the fire and larger grid cells with less detail are used remote from the fire.

Building items such as walls, floors, windows, doors and furniture are described in FDS as rectilinear blocks. These blocks must have sides that are either horizontal or vertical and no sloped or curved surfaces are allowed. The blocks may be colored for identification and may be assigned material properties. The blocks may be entered into the simulation with exact measurements from the building. However FDS can only work with items that fall exactly on grid cell boundaries. FDS takes the input blocks and adjusts them to match the grid cell boundaries. As a result, items may either grow or shrink to match the grid. In most cases this does not have a major impact on the calculations, although it can result in walls with no thickness or walls with gaps at intersections. Usually these issues are resolved by adjusting the size of the blocks slightly to produce the desired geometry that matches the grid size.

5.1.2 Materials

When a wall, ceiling, floor, piece of furniture, or any other material is defined for use in the FDS model, it is given a set of physical and thermal properties that are used by the model. Some of these properties such as thermal diffusivity, thermal conductivity, density and thickness impact the heat transfer in the material. For materials that burn, additional parameters such as ignition temperature, heat of combustion, heat of vaporization and maximum burning rate are specified. The properties for the materials, to the extent they were available, were taken from standard references or fire experiments.

The combustion process is handled in two ways within FDS. In one version, the fuel gasification rate is related to the radiant heat flux imposed from the fire onto the material. The mass burning rates of these same materials are measured in a cone calorimeter (or similar) apparatus; hence, the importance of collecting these data as described in Chapter 4. An alternative way to handle the gasification of fuel in FDS is to base the fuel generation rate on a measured heat of vaporization and ignition temperature. Both versions utilize a mixture fraction combustion model, in which burning occurs in regions where the fuel and air are in stoichiometric proportion. The second approach was used in FDS to model both the mock-up experiments and the full nightclub fire.

The accuracy of either of these combustion models is related to the complexity of the fuel and the resolution of the numerical grid used during the simulation. A maximum burning rate is imposed to handle non-physical situations that can lead to excessive localized burning. To the extent that the heat release rates measured for the polyurethane foams by NIST and ATF differed, this had no effect on the calculations presented in this chapter since the same ignition temperature, heat of vaporization, and maximum burning rate were used for simulations of the experimental mock-up and the full nightclub fires.

5.1.3 Vents

Vents in FDS are openings from the model to ambient conditions outside the computational domain. Vents allow smoke and heat to leave the grid area and air to enter. Vents may be either simple openings that allow natural flow to occur based on the buoyancy of the hot gases, or vents may use a specified or forced flow rate such as the flow from a fan.

5.1.4 Openings Within the Grid

The placement of blocks within the grid forms the structure of the building and its contents. The hydrodynamic calculations performed by FDS allow air, hot gases, smoke and flames to flow through the simulated building. Thermal radiation travels by line-of-sight and may be intercepted by obstacles within the grid.

Normal buildings may appear tightly constructed, but there are many small openings or leaks within a building that allow for the flow of air or combustion products. Since objects can only exist at grid boundaries, small leaks may be created by either using a very small grid size, or by representing many small leaks by fewer large leaks.

During the course of a fire, some items within the building may be consumed by the fire or otherwise change position. FDS does not have the capability to calculate burn-through or collapse but the user can remove items during the course of the calculations. Items that are removed can represent objects that fall or are destroyed by fire, or objects that are changed by people such as doors or windows that are opened.

5.1.5 Smokeview

Smokeview is a scientific visualization program that was developed to display the results of an FDS model computation [2]. Smokeview allows the viewing of FDS results in three-dimensional snapshots or animations. Smokeview can display contours of temperature, velocity and gas concentration in planar slices. It can also display properties with iso-surfaces that are three-dimensional versions of a constant value of the property. Iso-surfaces are most commonly used to provide a three-dimensional approximation of the flame surface where fuel and oxygen are present such that flames may exist.

5.2 FDS SIMULATIONS OF THE FULL-SCALE MOCK-UP

The primary objective of the mock-up experiments was to observe the primary mode of flame spread and smoke movement under fire conditions that were similar to what likely existed early in The Station fire on Feb. 20, 2003. Along with the video record, measurements of heat release rate, temperature, heat flux, oxygen volume fraction, and gas velocity were used as a basis to judge the capability of FDS in a complex fire environment. The secondary objective was to examine the impact of automatic fire sprinklers under experimental conditions, again to provide a basis of comparison with FDS.

5.2.1 Computational Domain, Grid Size, Initial Conditions, and Boundary Conditions

Selecting the appropriate grid size required balancing the need to resolve critical dimensions and physical phenomena, and the need to budget enough time to perform the hundreds of computer runs necessary to assess the importance of different variables on the outcome. FDS was run on a Linux cluster with eight 3.2 MHz processors. To complete the estimated 100 simulations needed of 300 seconds actual time for the full nightclub fire in a six month window necessitated runs with a turn-around time of less than two days. Based upon the software needs and the hardware capabilities, this translated to a limit of about 2 million grid cells. The computational domain used to simulate the full nightclub measured about 22 m by 33 m by 4 m high, which led to a minimum grid size of about 145 mm.

Grid size sensitivity has been examined in several studies as noted by McGrattan [3]. For full-scale experiments involving a small compartment, 2.4 m (8 ft) by 3.6 m (12 ft) by 2.4 m (8 ft) high, with fires ranging from 55 kW to 110 kW, 100 mm grids were found to provide temperatures with 15% of the measured values. Based upon that work and the imposed time constraints, 100 mm was selected as the baseline grid size, with computational savings sought through multi-blocking and the physical evidence provided by the WPRI video and the real-scale mock-up experiments described in Chapter 4.

The choice of grid size influenced the selection of the appropriate values for the initial conditions, boundary conditions and material properties, including the size and energy of the ignition source, heat transfer at the boundaries, and burning properties of the fuel. With all other inputs kept constant, doubling the grid size did not lead to the fast growing fires seen in the video or mock-up experiments; halving the grid size led to a fire growth rate that was faster than the evidence (and a single run-time of 10 days). This implied that if the mock-up experiments were to be used to help inform the choice of parameters for the full nightclub, then the grid size should be the same, even though the mock-up required only 319,000 cells that were 100 mm on a side. Even so, about 17 hours was required to simulate 200 seconds of the mock-up experiments. While the simulations could not be shown to be grid size independent, the input parameters could be tuned to the 100 mm grid using the results of the mock-up experiments and then applied to the full nightclub simulation, with the WPRI video acting as a reality check.

For the real-scale mock-up, the platform area and the dance floor area to the west of the platform were located in a compartment that was 10.8 m east to west and 7.0 m north to south. The ceiling height over the dance floor was 3.8 m. The drummer's alcove, located to the east of the platform, was 3.1 m wide, 2.4 m deep, and 1.96 m high. The height of the drummer's alcove floor and ceiling relative to the dance floor were 0.74 m and 2.7 m respectively. The platform was 7.0 m wide and 2.4 m deep and 0.4 m high. Figures 5-1 shows the resulting FDS model in Smokeview based upon a 100 mm grid size. Refer to Fig. 4-16 through Fig. 4-17 for additional details on the mock-up design.

The exposed interior finish materials used in the experiment consisted of convoluted polyurethane foam, plywood paneling, gypsum board, and carpeting. In Fig. 5-1, the foam is shown as a dark gray surface, the paneling is depicted as the brown surface and the carpet is shown as a light blue surface. The remaining light gray surfaces are gypsum board. Foam, spruce, gypsum board and carpet material properties were used in conjunction with tabulated [1] and experimentally derived properties of polyurethane. The bottom of the domain was considered to be an inert, adiabatic solid.

The principal fuels in the mock-up were the convoluted polyurethane foam and plywood paneling. In the area of the platform and the drummer's alcove, the foam was installed over the plywood paneling. The complexity of this arrangement limited the extent to which the burning composite fuel could be modeled *a priori*. Therefore, several simplifications and assumptions were made in order to generate model results that were representative of the experimental data. The thickness of the convoluted polyurethane foam varied significantly as shown in Figure 5-3. Typical thickness variations ranged from 6 mm (0.24 in) valleys up to 30 mm (1.2 in) peaks in the "egg crate" configuration. Given that the thickness of two nested sheets was consistent at 36 mm (1.4 in), the foam was modeled as a uniform flat solid with an average thickness of 18 mm (0.7 in).

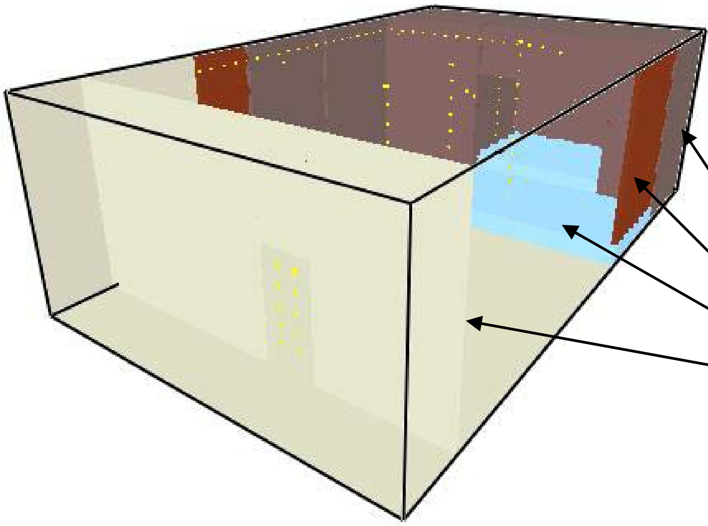


Figure 5-1. FDS model of mock-up in Smokeview

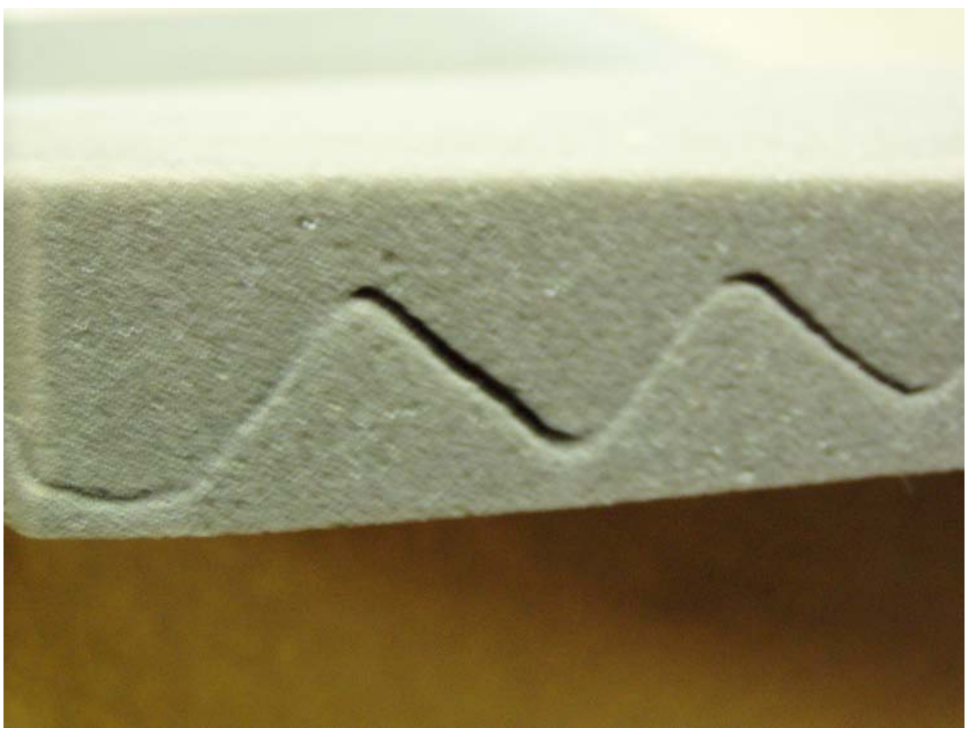


Figure 5-2. Photograph of the edge of two sheets of convoluted polyurethane foam.

Table 5-1. Polyurethane foam material properties used as FDS input.

Property	Value
Thermal Conductivity	0.034 W/m ºC
Specific Heat	1.4 kJ/kg ºC
Thickness	18 mm
Density	22 kg/m^3
Ignition Temperature	370 ºC
Heat of Vaporization	1350 kJ/kg
Maximum Burning Rate	0.008 kg/m^2 s

The other material properties used to describe the foam are given in Table 5-1. All of the foam material properties were derived from the experiments that were documented in Chapter 4, with the exception of the maximum burning rate. Given the complex nature of the foam over plywood composite, a series of simulations were conducted. The value of the maximum burning rate was varied from 0.004 to 0.028 kg/m^2 s. The maximum burning rate, which yielded the heat release rate results closest to the experimental results for the unsprinklered mock-up experiment was 0.008 kg/m^2 s.

The plywood paneling is based on the thermal properties of spruce [4] and is modeled as a charring material as described in [1]. The only modeled difference between the spruce material in the FDS database and the paneling is in the thickness of the material; 5 mm (0.2 in) was used to represent the paneling. The material properties of gypsum board and carpet were taken directly from the FDS 4 database with no changes [1].

Two 100 mm (4 in) wide by 200 mm (8 in) tall heat producing vents, simulating the heat feedback to the wall panels due to an ignition source, were located on the west side of the platform wall, at the north and south edge of the drummer's alcove. Two more heat inlet vents, 100 mm (4 in) square were located on the north and south walls of the drummer's alcove adjacent to the vents of the platform wall. The lower edge of the vents was located 1.50 m (5 ft) above the platform floor. The vents had a defined heat release rate per unit area of 1500 kW/m^2. These heat vents produced heat for the duration of the simulations.

The only opening within the grid of the model itself was the doorway in the west wall of the compartment, as shown in Figure 5-1. The doorway was 0.9 m (3.0 ft) wide and 2 m (6.6 ft) high. The computational grid extended outside the door 1.2 m to allow unrestricted flow into and out of the doorway.

Two simulations of the mock-up experiment are presented in the next section. The first simulation was unsprinklered. The second simulation examined the conditions resulting from the use of automatic fire sprinklers. The capability to model the sprinkler activation and the effects of suppression can not be done *a priori*. Several simulations were conducted by varying both the parameters that impacted the activation of the sprinklers and the parameters that impacted the suppression physics. The values which are presented in Table 5-2 provided the best fit to the data.

Three parameters are used in a lumped-mass model for the thermal element in the sprinkler: response time index (RTI), activation temperature, and conduction factor. This lumped mass sub-model is used to

Table 5-2. Sprinkler Properties Used as FDS Input

Property	Value
Sprinkler Type	Pendent
Operating Pressure	1.72 bar (25 psi)
K-factor	80 L/min/bar$^{1/2}$ (5.6 gpm/psi$^{1/2}$)
Response Time Index	16 m$^{1/2}$ s$^{1/2}$ (32.6 ft$^{1/2}$ s$^{1/2}$)
C-Factor	0
Activation Temperature	74 ºC (165 ºF)
Offset Distance	100 mm (3.9 in)
Size Distribution	Global Average
Median Volumetric Diameter	675 µm (0.03 in)
Minimum Spray Angle	75º
Maximum Spray Angle	105º
Speed	15 m/s (49 ft/s)

calculate the time of sprinkler activation. The values used represent a fast response sprinkler with an ordinary temperature classification. No conductive losses were considered.

The remaining sprinkler parameters describe how much water would be discharged, what the water droplet size distribution would be and the direction of the droplets discharge. The water flow rate is determined by the operating pressure and the discharge factor (or K-factor). As modeled, the water flow from each sprinkler was 94.6 L/min (28.0 gpm).

The water droplet size distribution is based on a median droplet diameter to which a size distribution is applied. A median droplet diameter of 675 µm (0.03 in) was used with the FDS default parameters of the Rosin-Rammler/log-normal distribution (γ= 2.4).

The droplets were distributed uniformly in the conical spray pattern emanating from the sprinkler deflector. The spray pattern is defined by the minimum and maximum spray angles. Relative to a sphere that is centered on the sprinkler, with a radius equal to the offset distance, the spray pattern ranged from 75º north of the south pole to 15º above the equator. Further discussion of the sprinkler properties are provided in section 5.2.3.

5.2.2 FDS Full-scale mock-up Simulation, Non-Sprinklered Results

The results of the non-sprinklered simulation are compared with the video record of the experiment, and the measurements of temperature, oxygen volume fraction, heat flux, heat release rate and gas velocity. Visual comparisons of the experiment and simulation are shown in Figures 5-2 through 5-11. Quantitative comparisons between the experimental data and the model predictions are given in Figures 5-12 through 5-18.

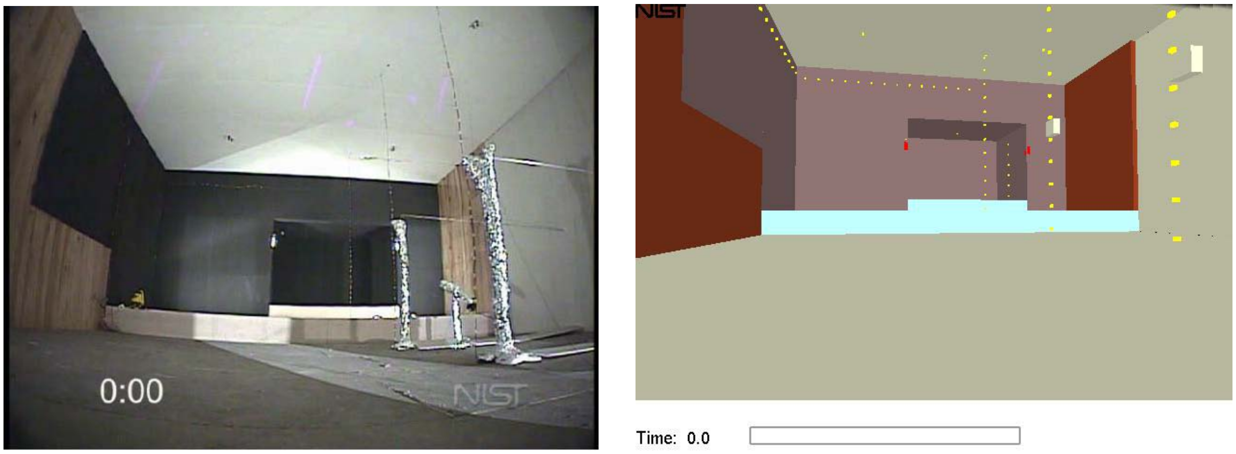


Figure 5-2. Ignition at the corners of the drummer's alcove, t = 0 s.

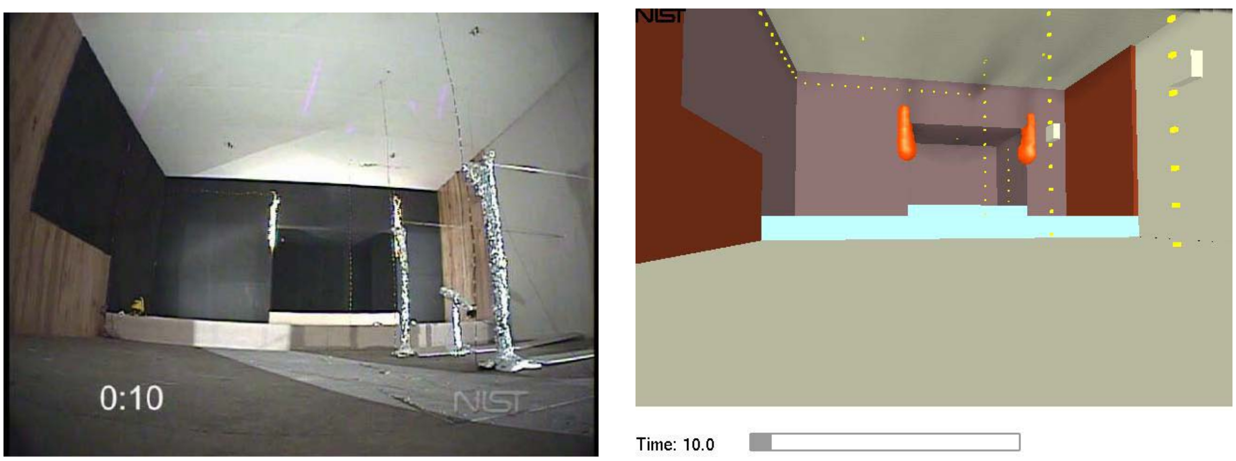


Figure 5-3. Flames spreading toward ceiling, t = 10 s after ignition.

(i) Visual Comparisons

Figures 5-2 through 5-11 are composed of pairs of images. The still frames, captured from video tape, appear on the left. The images on the right are rendered from Smokeview. Both images represent the same time after ignition. The pairs of images begin at ignition, or t = 0 seconds, and continue at 10 second intervals until 90 seconds after ignition, when most of the visibility from the video is lost.

Figure 5-2 shows the experiment and the simulation at the time of ignition. The video frame on the left shows the foam covered walls, the wood paneling, and the carpeted platform. Gypsum board covered the ceiling, floor and the remaining wall areas which were not covered with wood paneling or foam. Some of the instrumentation can be seen in the foreground of the video frame. In the image from the simulation, on the right, the comparable interior finishes can be seen. The instrumentation in the right figures is represented by colored dots. The thermocouples appear as yellow dots in evenly spaced arrays. The light gray blocks represent the locations of the heat flux sensors and the gas sampling locations, which were installed at approximately 1.5 m (5 ft) above the floor.

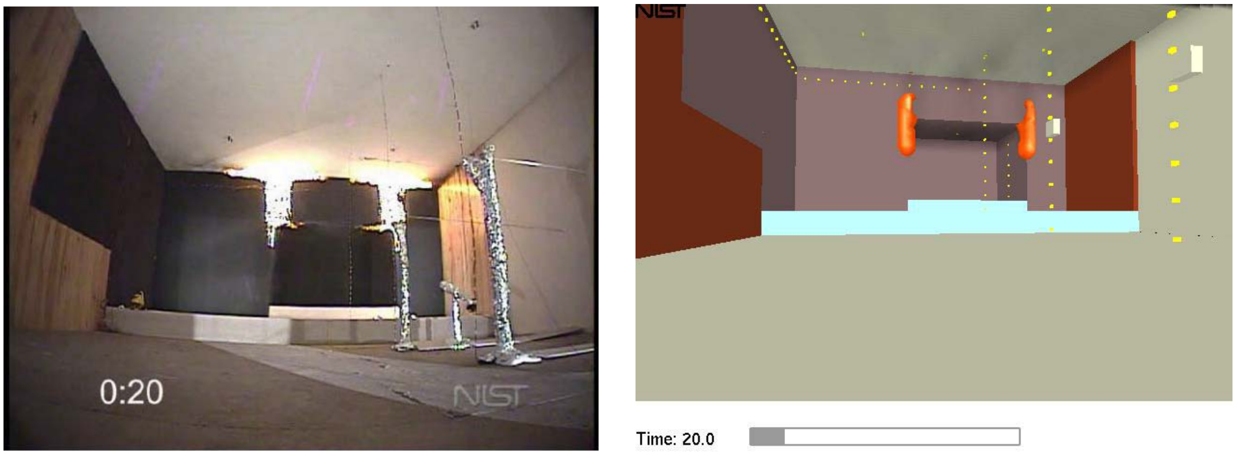


Figure 5-4. Flames impinging on ceiling, t = 20 s after ignition.

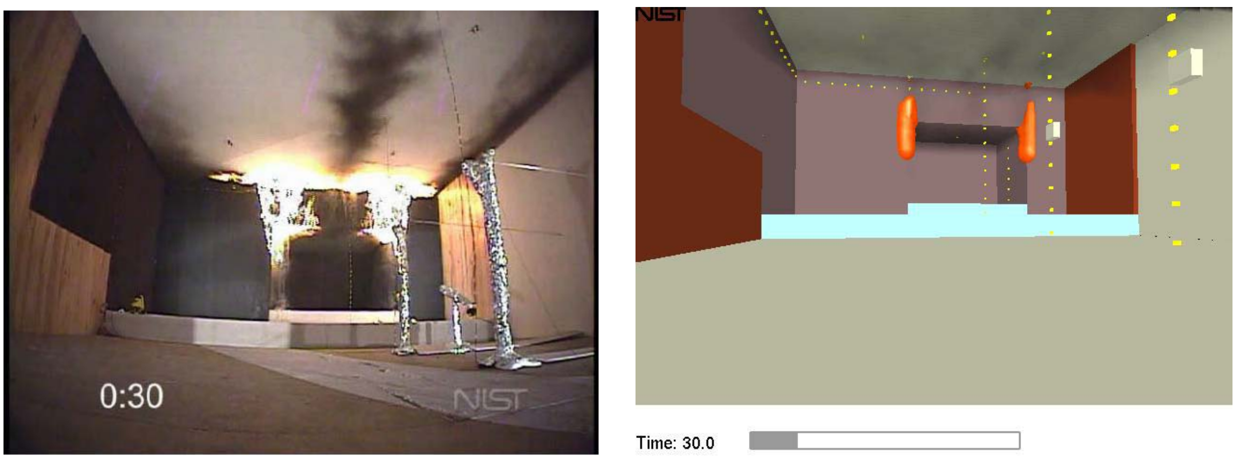


Figure 5-5. Visible smoke spreading across ceiling, t = 30 s, after ignition.

Figure 5-3 compares the fire development at 10 seconds after ignition. A flame is shown on both corners where the platform wall intersects with the drummer’s alcove. In the case of FDS, the area that appears to be involved with flames is based on the stoichiometric mixture fraction, where there is the ideal mixture of fuel and oxygen for a robust flame to exist. The heat release rate per unit volume represented by the simulated flames is 285.5 kW/m^3. The flames in the simulation appear wider due to the grid resolution, which is 100 mm (4 in) throughout the room.

The video frame to the left in Figure 5-4 shows flames 20 seconds after ignition growing vertically and impinging on the ceiling. The simulated flames on the right, however, have not yet reached the ceiling. As noted above, the simulated flame is constrained to grow in 100 mm (4 in) increments, both vertically and laterally. This may account for the wider flame and the accompanying redistribution of energy which would reduce the propensity for rapid vertical flame spread. Light smoke can be seen in both images along the ceiling of the alcove, with light wisps of smoke along the ceiling above the platform.

Figure 5-5 shows an increased amount of smoke flow across the ceiling at 30 seconds after ignition. The actual fire continues to grow at a faster rate than the simulated flames. In the video frame on the left the flames

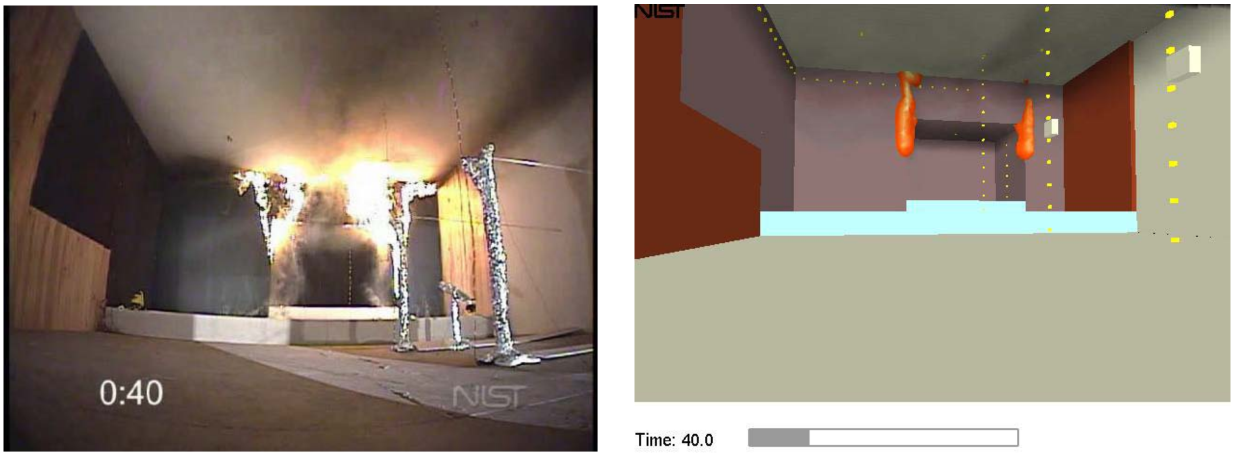


Figure 5-6. Flames continue to spread into alcove, t = 40 s, after ignition.

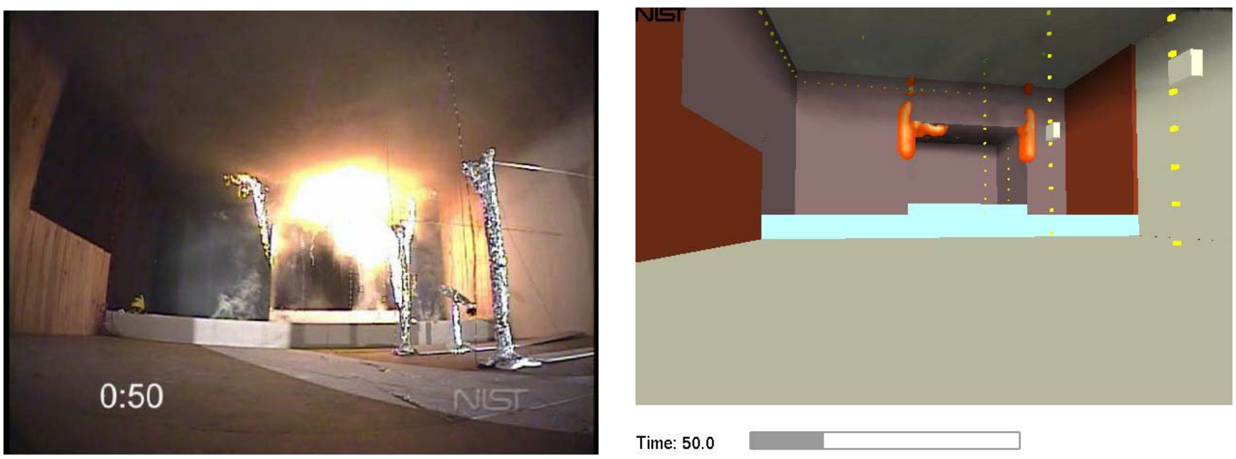


Figure 5-7. Ceiling of alcove fully involved in fire, t = 50 s, after ignition.

have formed twin V-patterns on each side of the alcove and the flames are spreading across the alcove ceiling. Notice the light smoke that is coming up from the carpeting below the two fire plumes. This is the result of foam melting and the burning foam droplets falling to the floor. This mode of flame spread is not accounted for within the FDS model. At 40 seconds after ignition, the video frame in Figure 5-6 shows areas of the foam on the platform wall have burned out (note the dark area directly above the point of ignition on the left side of the alcove). The actual flame fronts have continued to spread and into the alcove, where fire is visible on portions of the side walls and the ceiling of the alcove. The flames simulated with FDS have also grown, although at a slower rate. Both of the simulated flames have impinged on the ceiling.

Figure 5-7, has images captured at 50 s after ignition. In the experiment, it appears that the entire ceiling of the alcove is burning, as well as the area of the platform wall above the opening to the alcove. There is also more smoke from drop-down of the burning foam onto the carpet, both in the alcove and on the platform. In the simulation, the flames have moved into the alcove and are spreading across the ceiling. In both images, the smoke or hot gas layer has developed across the ceiling of the enclosure.

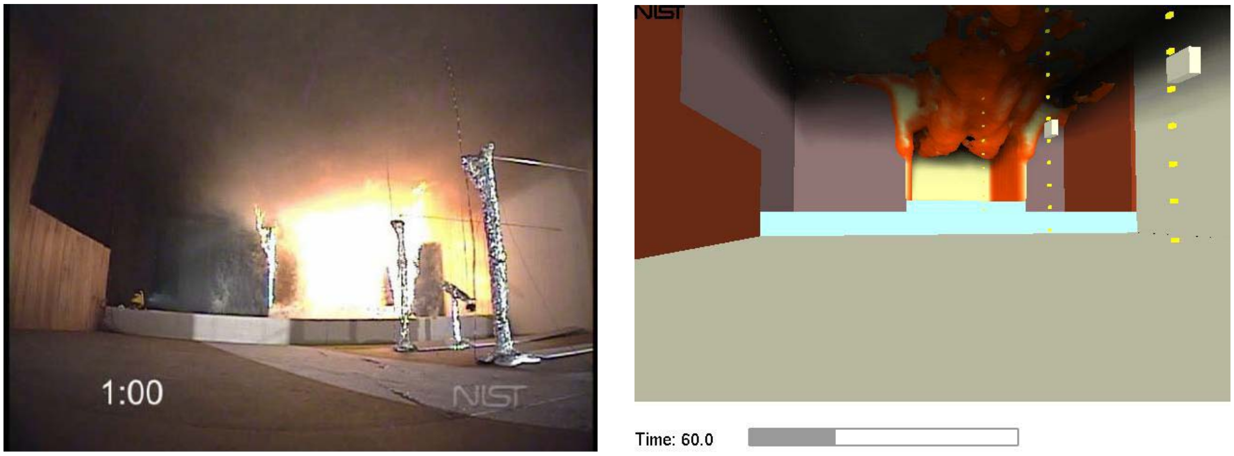


Figure 5-8. Flashover has occurred in alcove area, t = 60 s, after ignition.

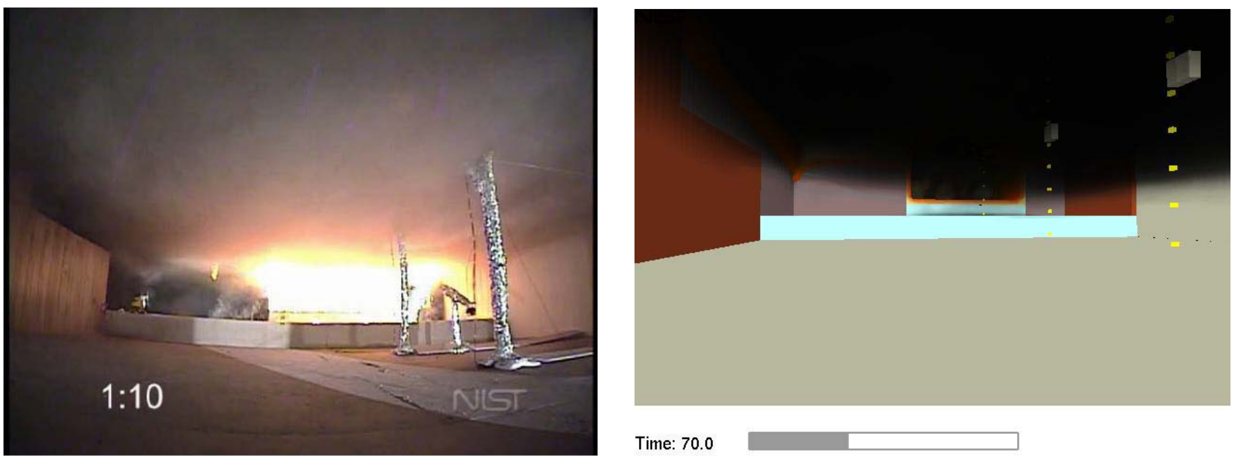


Figure 5-9. Smoke layer has dropped to 1.5 m above floor, t = 70 s after ignition.

In Figure 5-8, the ceiling and the walls of the alcove have become fully involved with fire in both of the images. At 60 seconds after ignition, flashover has already occurred in the experiment and flashover is about to occur in the simulation. In both cases, flames are extending out of the alcove across the ceiling and the smoke layer has become thicker and darker.

The images in Figure 5-9 show a significant increase in the amount of the smoke in the enclosure. The smoke layer has descended to within 1.5 m (5 ft) of the floor. The flames have spread along the wall behind the platform and can be seen at the lower edge of the smoke layer in both the video frame and the image from the simulation. The smoke in the experiment appears lighter in color than it actually is due to light that is being reflected from floor level halogen lights that were used to improve the visibility for the video cameras.

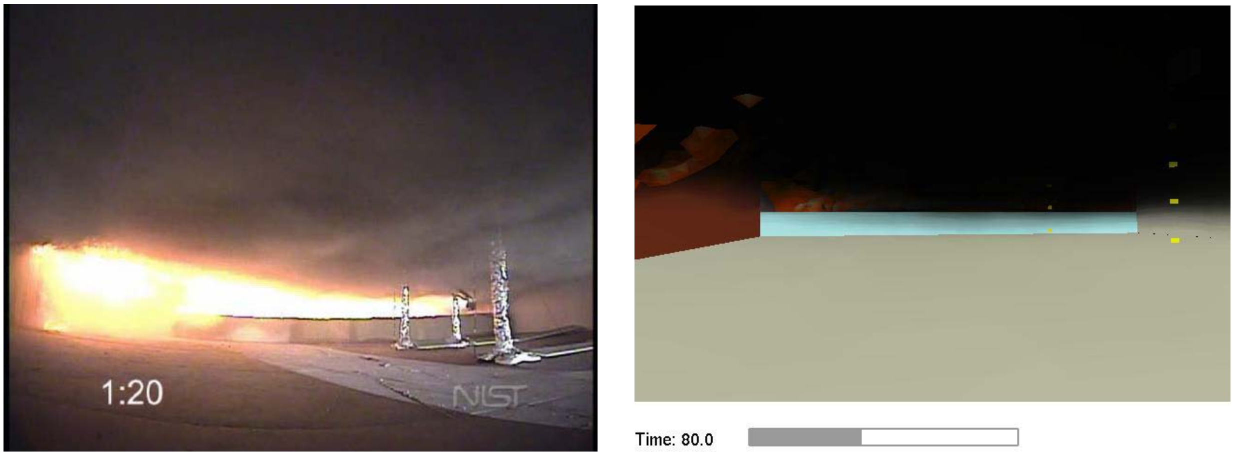


Figure 5-10. Fire continues to spread, t = 80s after ignition.

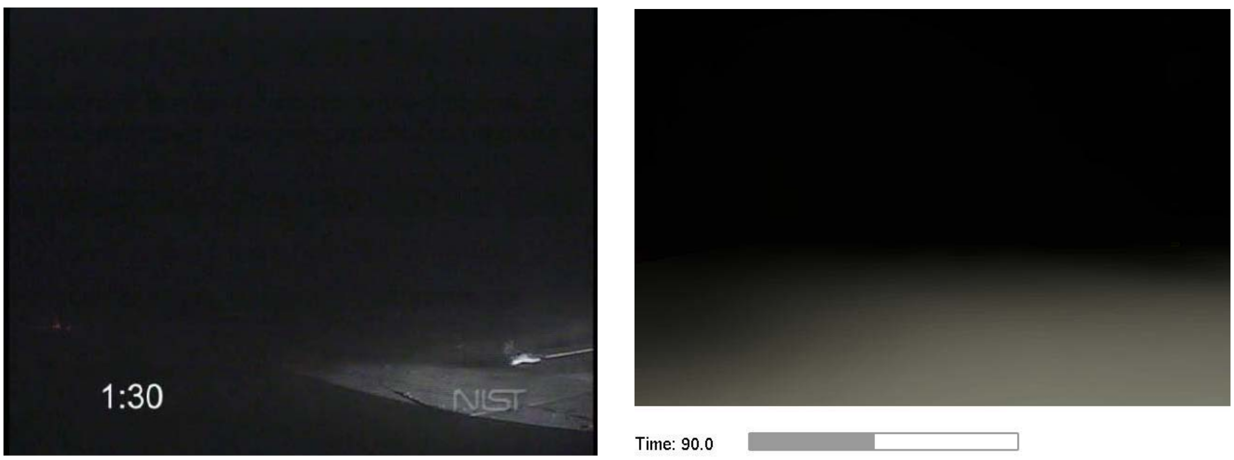


Figure 5-11. Visibility lost, t = 90 s after ignition.

The fire continues to grow in both the experiment and the simulation as shown in Figure 5-10. The smoke layer has continued to descend. The interface height of the smoke layer is approximately 0.75 m (2.5 ft) above the floor at 80 s after ignition for both the experiment and the simulation. Both images also show the flame extension on the left wall of the enclosure. The upper portion of the left wall near the platform had foam installed over the paneling.

The last set of images, Figure 5-11 demonstrate that most of the visibility in the enclosure has been lost due to smoke filling. A small layer of clear area can be seen near the floor in both the experiment and the simulation. This is due to fresh air being drawn into the fire enclosure through the open doorway.

The image pairs show that the simulation is not exact with respect to time, in reproducing the development and growth of the fire, especially during the initial growth stages of the fire. Based on the images during the first 40 seconds of the fire FDS appears to lag behind in fire growth by approximately 10 to 20 seconds. As the fire reaches the transition point of flashover, the simulation has reduced the time

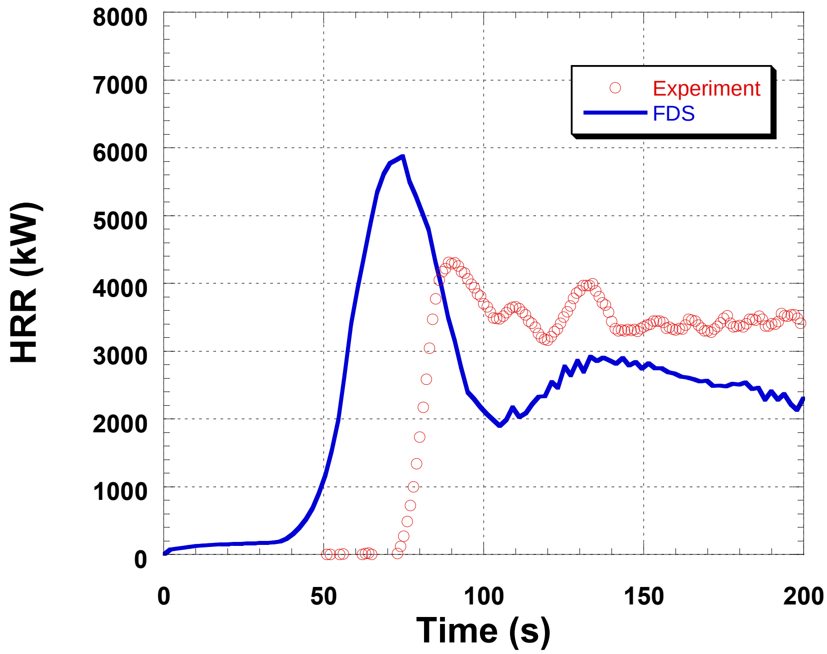


Figure 5-12. Power generated in experiment as measured outside of doorway, compared to FDS simulation of heat release rate from fire within compartment.

lag significantly. Post-flashover, the appearance of the fire progression and the smoke development for both the experiment and the simulation are more closely synchronized with each other.

(ii) Numerical Comparison

In this section, measurements of power generated, temperature, heat flux, oxygen volume fraction, and gas velocity from the full-scale mock-up experiments described in Chapter 4 are compared with the values generated by the FDS simulation.

The heat release rate of the fire is the source for the energy transfer which occurs throughout the fire environment. It is critical in fire protection engineering for assessing the development of a hazard due to a fire within a building. In addition, the heat release rate is a function of oxygen depletion. Therefore, differences in the heat release rate comparison also impact the comparison of the temperature, heat flux, oxygen, and velocity measurements.

Figure 5-12 compares the measured thermal power leaving the door of the experiment (based upon oxygen consumption) to the heat release rate from the fire within the compartment as predicted by FDS. For fires burning in the open under the laboratory hood, the thermal power measured by the oxygen depletion calorimeter is equal to the heat release rate from the fire. However, for a fire within an enclosure, the effluent from the room is a mixed average of the upper layer gases, and does not represent the instantaneous heat release rate of the fire. This means that a direct comparison between the experimental measurements and the numerical predictions cannot be made because the oxygen depletion calorimeter does not respond to a fire within an enclosure until the combustion products have had time to exit the door and become entrained into the hood. The heat release rate predicted by FDS in Fig. 5-12 represents the instantaneous heat release throughout the room. The heat release rate reaches a peak of

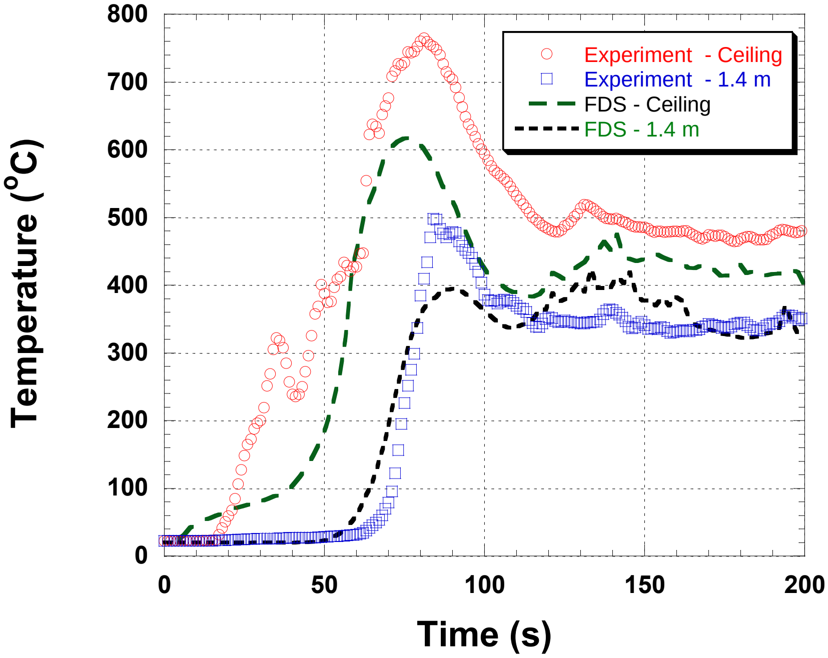


Figure 5-13. Temperature comparison between the un-sprinklered fire experiment and the FDS simulation at Station C.

approximately 6 MW about 70 seconds into the simulation, 20 seconds prior to the peak in thermal power measured in the oxygen depletion calorimeter. Both curves approach 3000 kW ± 300 kW approximately 150 seconds into the fire, again consistent with a ventilation limited condition. The heat release rates diverge at longer times as the model consumes the remaining interior finish fuels while the physical fire continues to burn at a reduced rate into the wood supporting the platform and walls. When the areas under the heat release rate curves were integrated, the resulting energies were found to agree within 10 %.

Figure 5-13 is a comparison of the temperatures predicted and measured 25 mm below the ceiling and 1.4 m above the floor at the thermocouple array located at Station C (4.25 m east of the door opening or 1.7 m from the platform). The FDS output has been smoothed by applying a Stineman function (a geometric weight applied to the current point ±10 % of the data range). The temperature data show reasonable agreement with the predictions, including an overshoot followed by a leveling off as the fire reaches a ventilation limit. The temperatures near the ceiling increase faster in the test; conversely, the lower level temperatures increase at a slower rate in the test.

Note that, unlike the heat release rate, the temperature measurements respond to the local environment within a second; hence, the experimental temperatures and FDS predictions can be compared directly. Initially, the experimental measurements near the ceiling increase more rapidly than predicted. This is probably due to the strong transverse temperature gradients associated with the ceiling jets created early in the fire (see Fig. 5-5), where small differences in position between the experiment and simulation can have a large change in temperature. The peak temperatures for the experiment and the simulation occur within 5 seconds of each other.

Figure 5-14 is a comparison of the temperatures predicted and measured 25 mm below the ceiling and 1.4 m above the floor at the thermocouple array located at Station D (2.35 m east of the door opening). Similar to the previous figure, the temperature data show reasonable agreement with the predictions. The

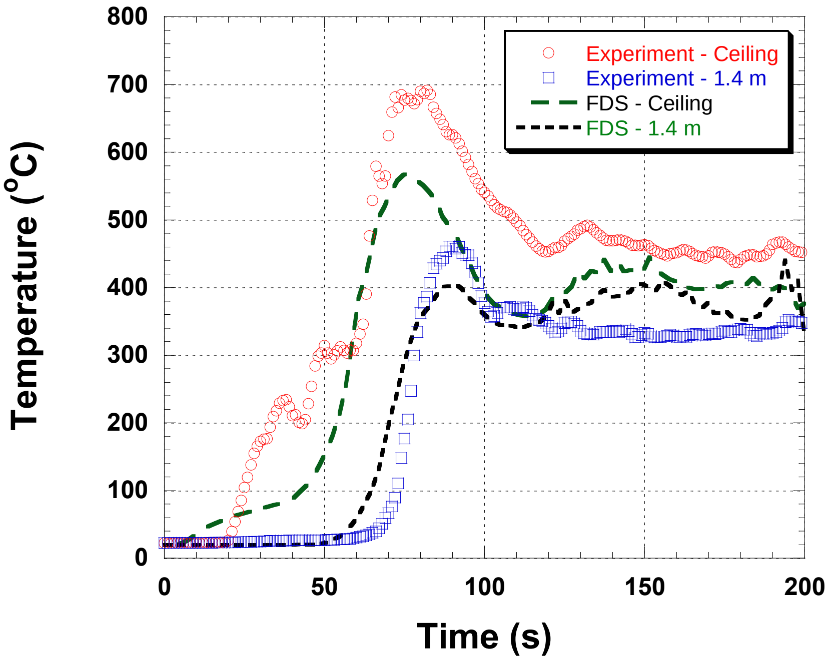


Figure 5-14. Temperature comparison between the un-sprinklered fire experiment and the FDS simulation at Station D.

trends are also similar and both of the measured temperatures and the predictions exhibit a reduction in peak temperatures relative to the values from Station C which is located approximately 2 m closer to the platform.

Figures 5-15 and 5-16 present the heat flux measurements taken at Stations C and D respectively. There were three total heat flux sensors at each position: one installed at ceiling level with the sensor aimed at the floor; and two sensors installed at approximately 1.5 m (5 ft) above the floor with one aimed at the ceiling and the other aimed toward the platform end of the enclosure. In both cases, the predictions follow the trends of the measured heat flux. Better agreement in terms of magnitude occurs at the ceiling level. The predicted heat fluxes 1.5 m above the floor are low by almost 50 % when compared with three out of four measurements.

Figures 5-17 and 5-18 represent the oxygen volume fraction comparisons between the measurements at Stations C and D and the predicted values from FDS. The measurements and the predictions were positioned at 1.5 m (5 ft) above the floor. The oxygen levels predicted by FDS dropped sooner but slightly less rapidly than the experimental measurements; both reached the same low value of about 2 %, confirming that the fire was close to ventilation-limited at this point.

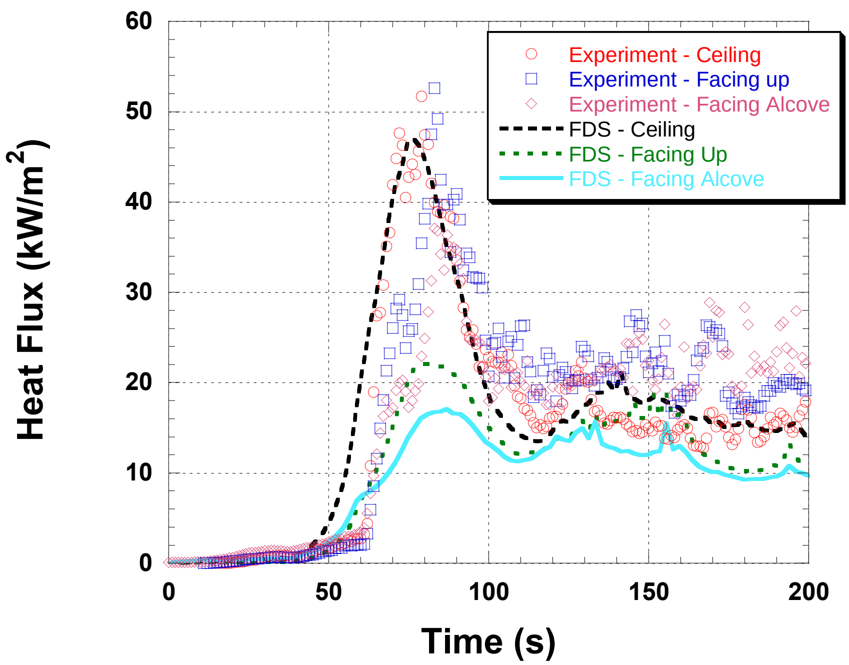


Figure 5-15. Heat flux comparison between the un-sprinklered fire experiment and the FDS simulation at Station C

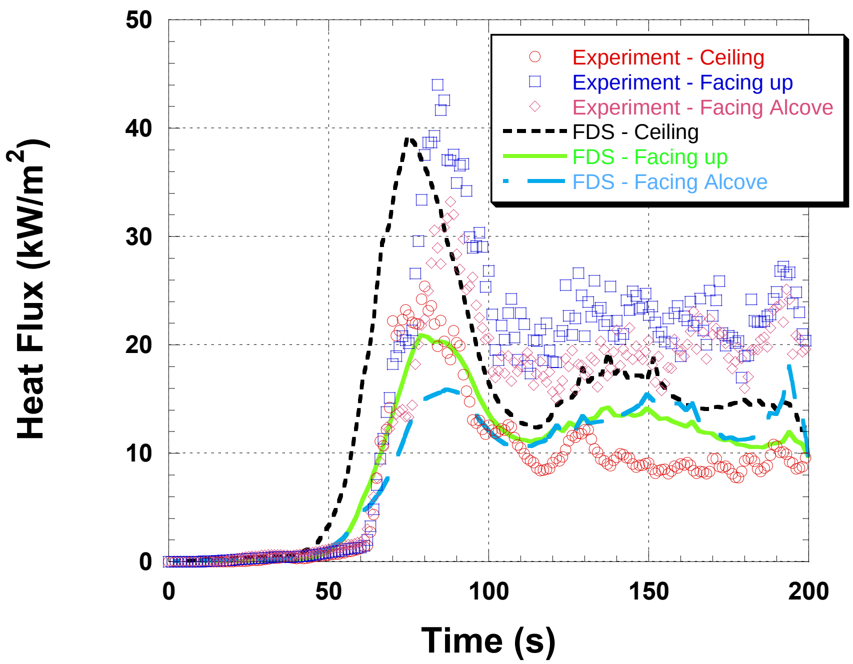


Figure 5-16. Heat flux comparison between the un-sprinklered fire experiment and the FDS simulation at Station D.

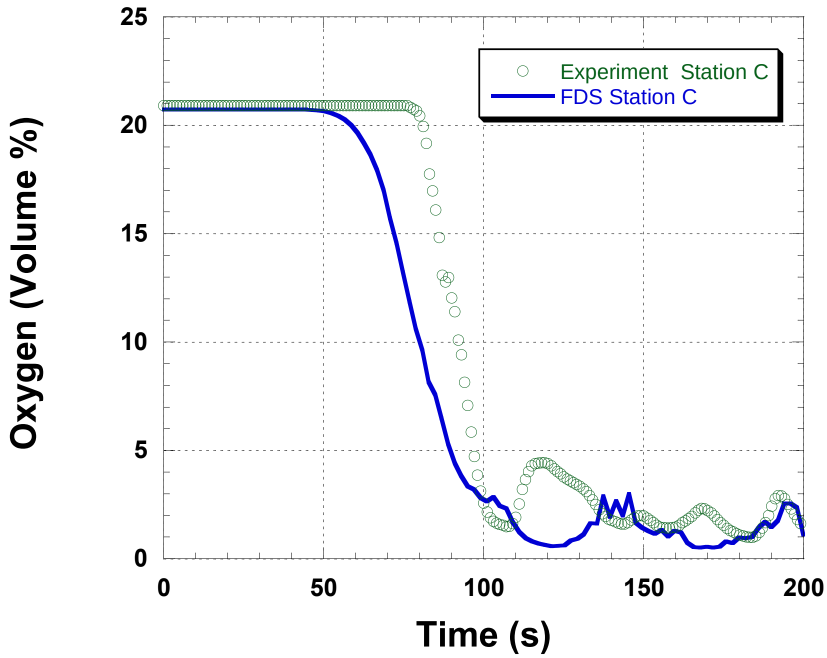


Figure 5-17. Oxygen volume fraction comparison between the un-sprinklered fire experiment and the FDS model at approximately 1.5 m above the floor at Station C.

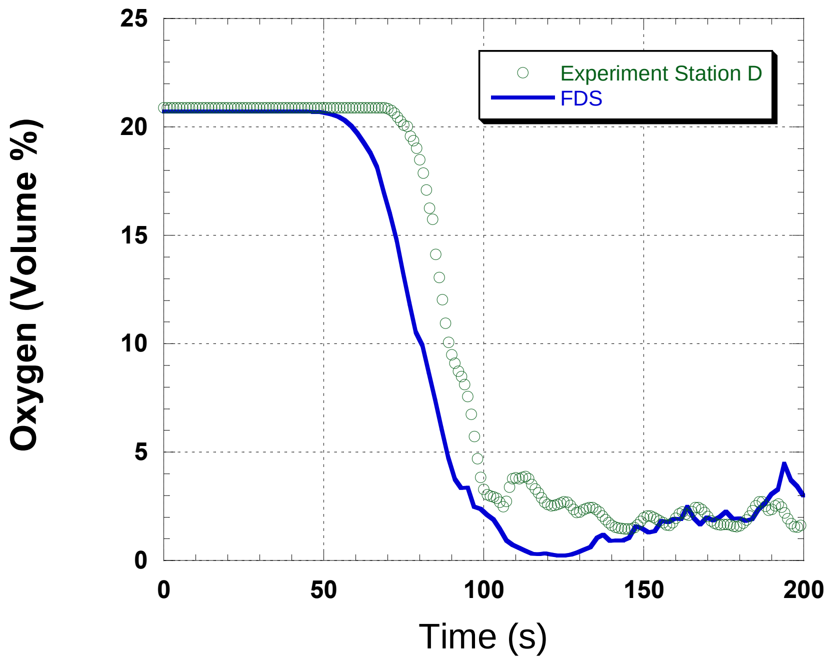


Figure 5-18. Oxygen volume fraction comparison between the un-sprinklered fire experiment and the FDS model at approximately 1.5 m above the floor at Station D.

Table 5.3 Time to reach tenability criteria at Location C, or maximum deviation obtained, in sprinklered and unsprinklered simulations, compared to experimental measurements

	Temperature > 120 °C	Heat Flux > 2.5 kW/m^2	Oxygen < 12 %
Unsprinklered			
Experiment	76 seconds	61 seconds	87 seconds
FDS	72 seconds	57 seconds	80 seconds
Sprinklered			
Experiment	< 24 °C	< 0.32 kW/m^2	> 20.6 %
FDS	< 22 °C	<0.15 kW/m^2	> 18.8 %

(iii) Tenability

Tenability limits based upon the work of Purser [5] were discussed in section 4.6.8. The time predicted by FDS to reach the limits of temperature, heat flux, and oxygen are summarized in the top portion of Table 5.3. The agreement between the simulation and experimental measurements at Location C is within 8 %, with both methods indicating the heat flux criteria is exceeded first, around one minute into the fire.

5.2.3 FDS Full-scale mock-up Simulation, Sprinklered Results

The results of the sprinklered simulation are compared with the video record of the experiment, and the measurements of temperature and oxygen volume fraction. Visual comparisons of the experiment and simulation are shown in Figures 5-19 through 5-27. Quantitative comparisons between the experimental data and the model predictions are given in Figures 5-28 through 5-32. Given the limited growth of the fire during the experiment, the oxygen depletion calorimeter did not register a significant rate of heat release.

The comparison of the sprinkler activation times from the sprinklered mock-up experiment and the FDS simulation of that experiment are given in Table 5-4. In FDS, the activation time of the first sprinkler was the result of adjusting the RTI in the simulation until the times were similar. The RTI which provided the best match, 16 $m^{1/2} s^{1/2}$ (32.6 $ft^{1/2} s^{1/2}$), was used as the RTI for the remaining sprinklers in both the mock-up and the full night club simulation. The order of sprinkler activation, and the number of sprinklers activated, were the same in the simulation and the experiment. The times to activation differed by no more than 6 seconds.

(i) Visual Comparisons

Figures 5-19 and 5-27 are composed of pairs of images. The still frames, captured from the video tape of the experiment, appear on the left. The images on the right are rendered from Smokeview. Both images represent the same time after ignition. The pairs of images begin at ignition or t = 0 seconds and continue at 10 second intervals until 60 seconds after ignition, when most of the fire in the experiment had been suppressed. Additional sets of images are included at 25 seconds after ignition to show the initial sprinkler just after activation and at 90 seconds to demonstrate the lack of significant fire spread after sprinkler activation. Figures 5-19 through 5-21 show a very similar progression in fire growth as the unsprinklered case for both the experiment and the FDS simulation between ignition and 20 seconds after

Table 5-4. Comparison of sprinkler activation times.

Sprinkler Location	Sprinkler Activation Times (seconds)	
	Experimental	Fire Dynamic Simulator
Southeast	24	23
Northeast	29	35
Alcove	30	36
Southwest	Did Not Activate	Did Not Activate
Northwest	Did Not Activate	Did Not Activate

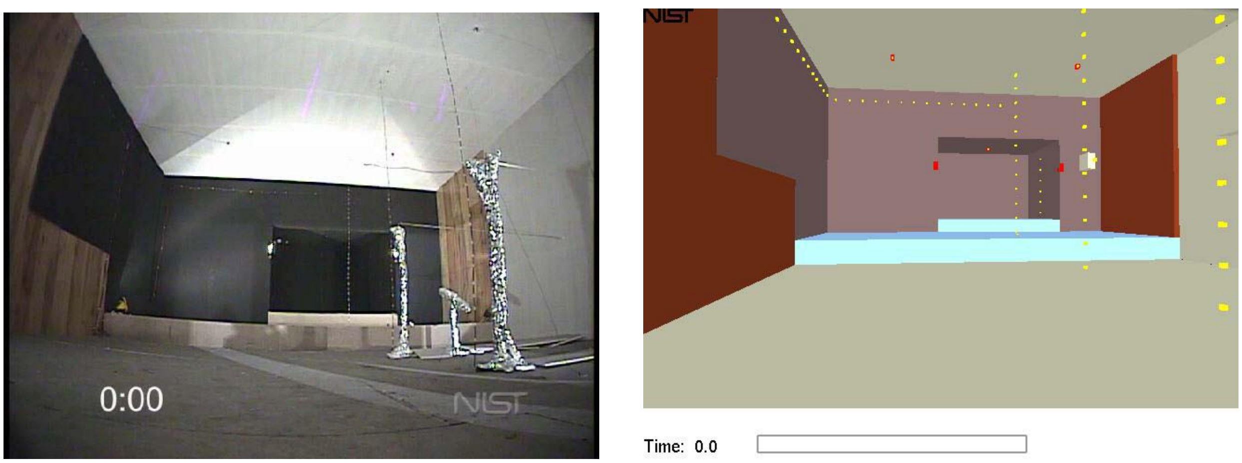


Figure 5-19. Ignition at the corners of the alcove, t = 0 seconds.

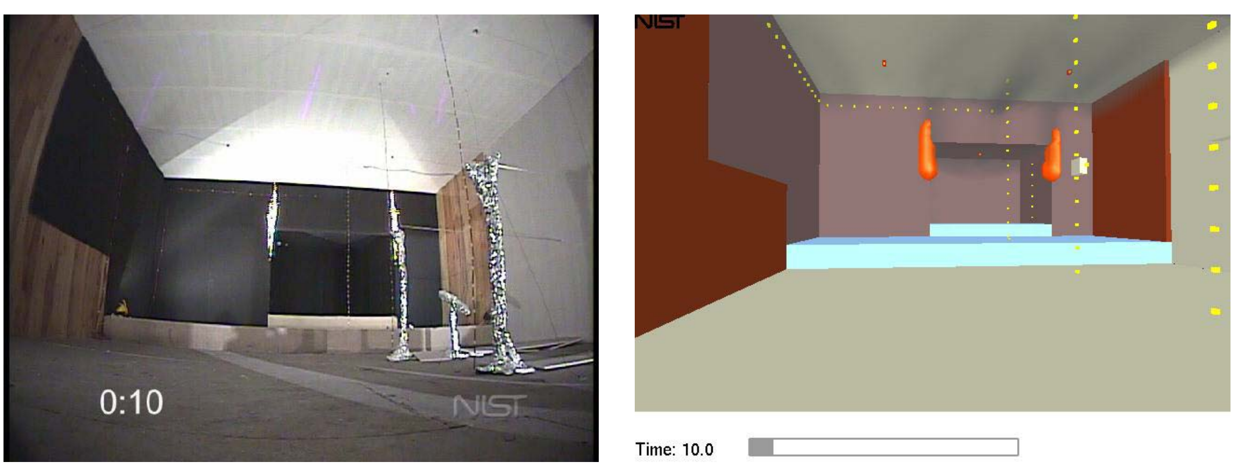


Figure 5-20. Flames spreading toward ceiling, t = 10 seconds after ignition.

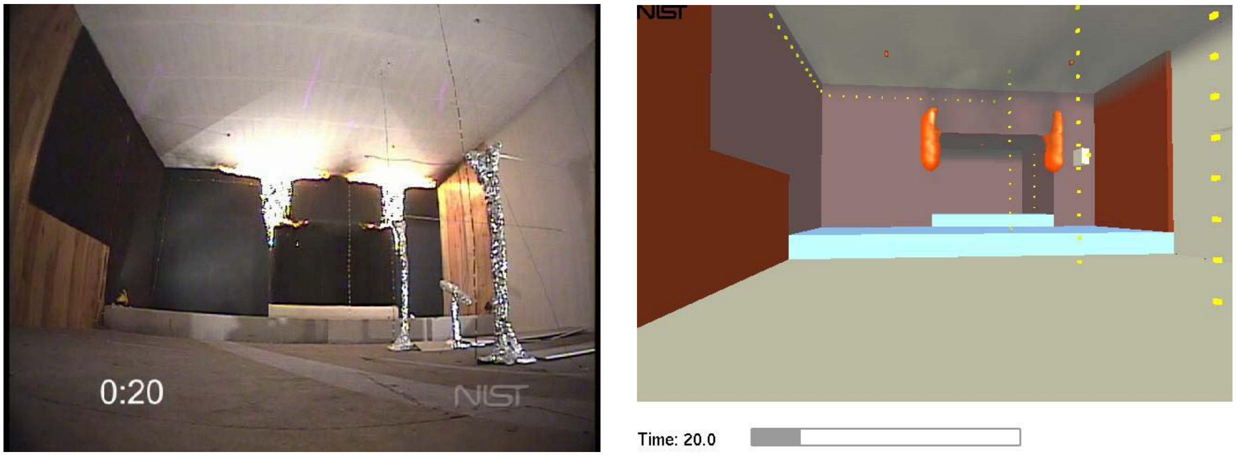


Figure 5-21. Flames impinging on ceiling, t = 20 seconds after ignition.

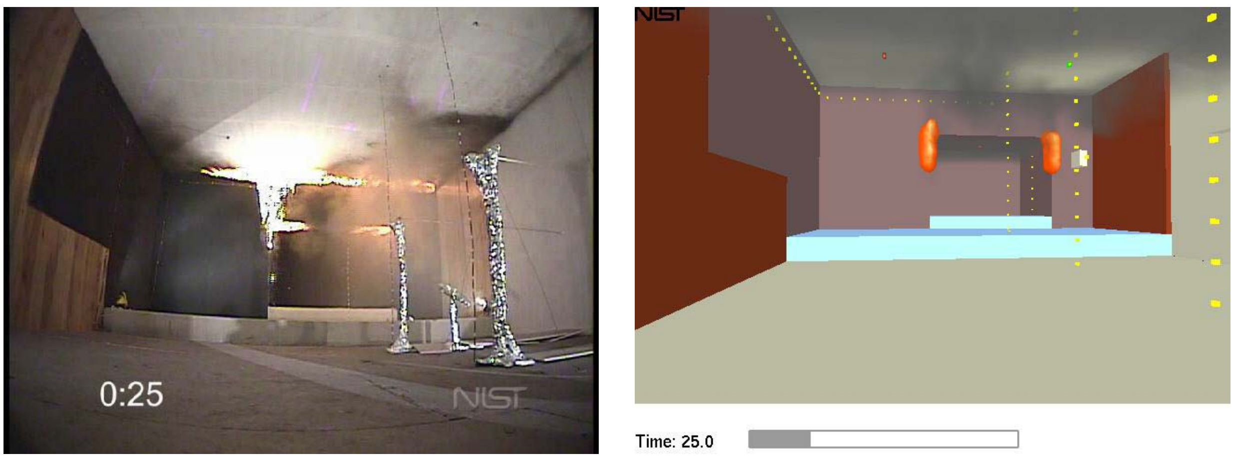


Figure 5-22. Initial sprinkler operating, t = 25 seconds after ignition.

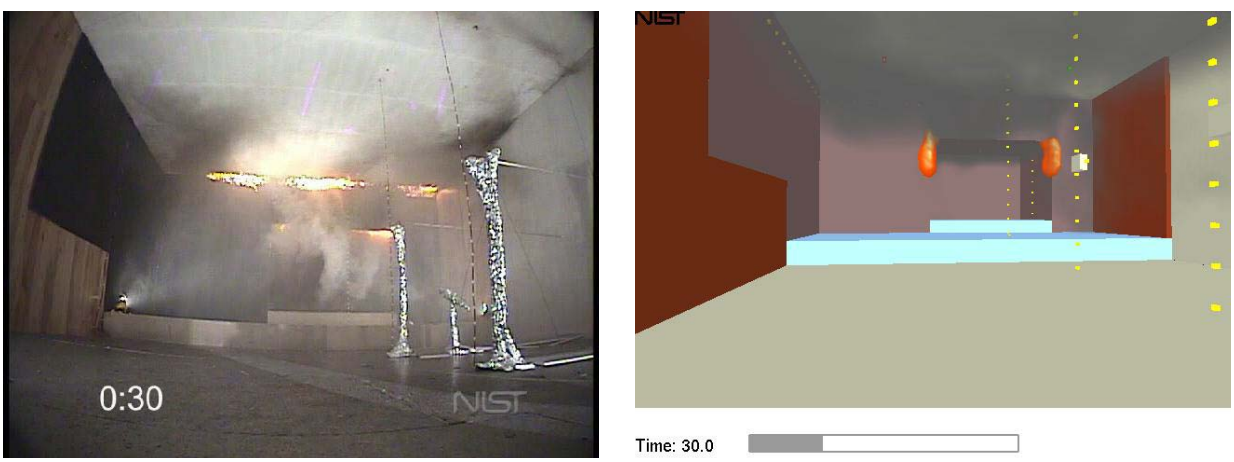


Figure 5-23. Third sprinkler operating in experiment, t = 30 seconds after ignition.

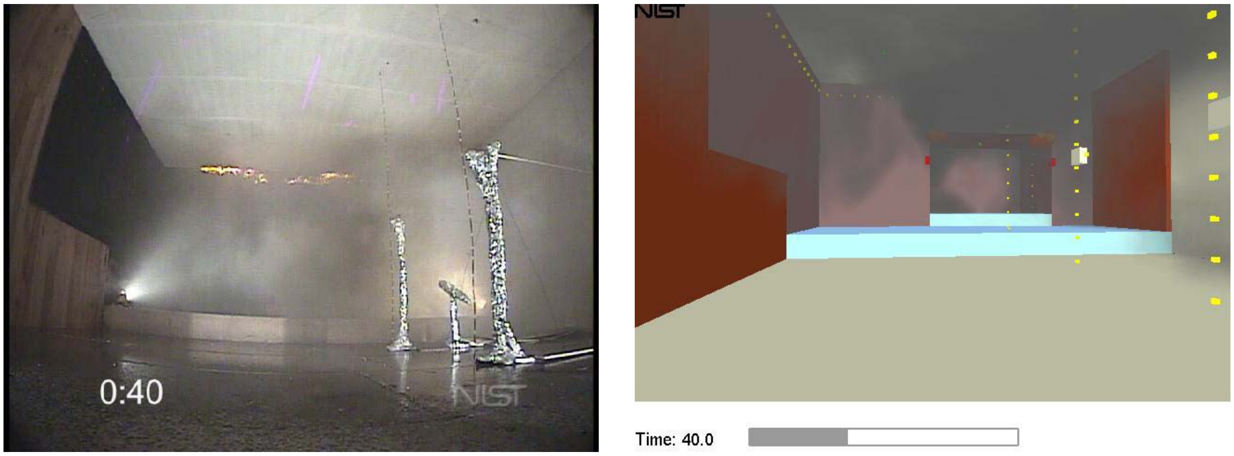


Figure 5-24. Suppression with three sprinklers operating in each case, t = 40 seconds after ignition.

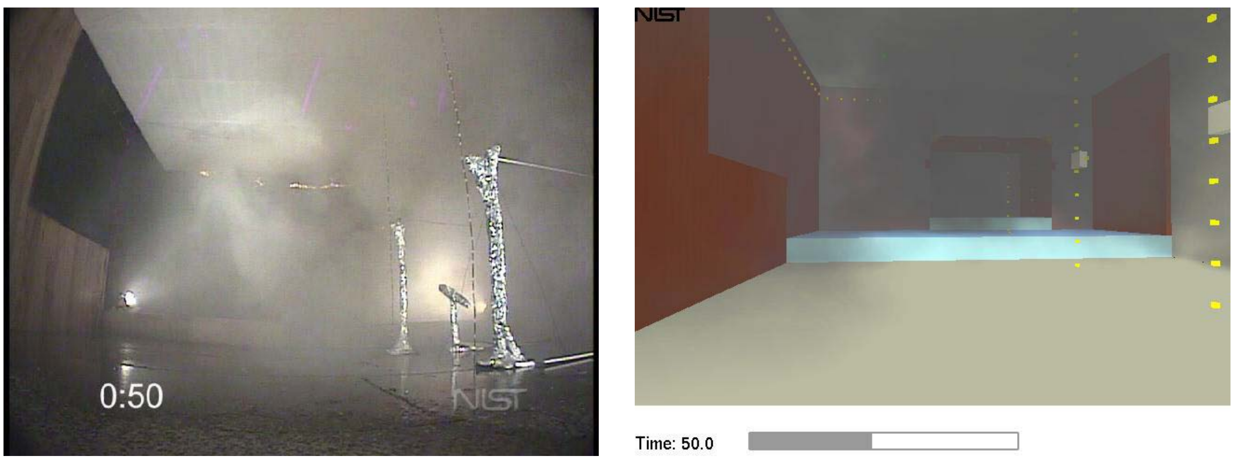


Figure 5-25. Fire suppression continues in both the experiment and the simulation, t = 50 seconds after ignition.

Figure 5-26. Fire controlled in both cases, t = 60 seconds after ignition.

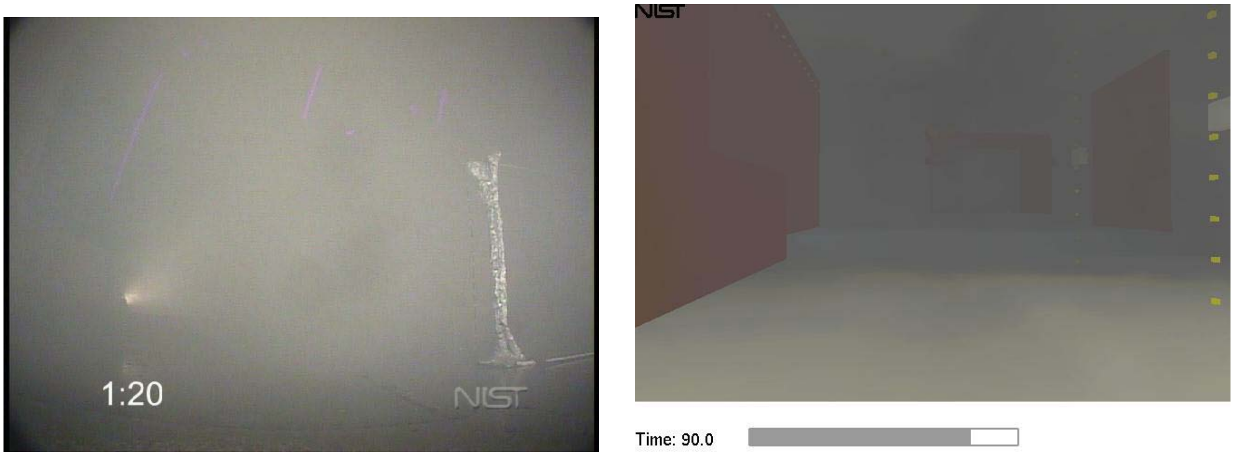


Figure 5-27. Fire controlled in both cases, t = 90 seconds after ignition.

ignition. Figure 5-22 was captured at 25 seconds after ignition, approximately 1 second after the first sprinkler activated in both the experiment and the simulation. With the experiment, the impact of the sprinkler can be seen as the fire on the right side of the platform wall is suppressed. In FDS the flame height on the right side of the alcove can be seen to be reduced.

By 30 seconds (see Fig. 5-23) the effect of both of the sprinklers above the platform operating as well as the sprinkler in the alcove is apparent. Burning continues at the intersection of the platform wall and the ceiling. This area is above where the water spray is hitting the wall. Also notice the flames on the ceiling of the alcove. This area is shielded from the water spray of the two sprinklers. The smoke being pushed out of the alcove is due to the activation of the sprinkler on the ceiling of the alcove. In the simulation, only one sprinkler is operating at this time. The fire growth on the right side of the alcove has been limited by the single sprinkler.

By 40 seconds after ignition, three sprinklers in the experiment and in the simulation have activated. The video frame in Figure 5-24 shows that the fire in the alcove has been suppressed and that the burning above the water line on the platform wall continues. With three sprinklers operating in FDS, the water spray is significantly reducing the visible flames. The flames on the platform wall have been suppressed. However, there are still flames visible at the intersections of the alcove ceiling and the alcove walls on both sides of the alcove. These areas are shielded from the water spray of the sprinklers over the platform and they are above the water impact line from the sprinkler in the alcove.

Figures 5-25 through 5-27 show continued fire suppression for both the experiment and the simulation. In both cases some flames exist in the ceiling area of the alcove. But clearly the rate of fire growth and the resulting hazard development has been reduced significantly when compared with the unsprinklered case.

Both the experiment and the computer model demonstrate that the sprinklers would prevent flashover and considerably mitigate the hazard from the fire. However, the degree to which the fire is controlled is different between the experiment and the model, since the simulation has more flame spread along the edges of the alcove ceiling after activation of the sprinklers.

(ii) Numerical Comparison

In this section, measurements of heat release rate, temperature, heat flux, and oxygen volume fraction from the full-scale mock-up sprinklered experiments conducted in Section 4 are compared with values generated by the FDS simulation.

Figure 5-28 shows the FDS predicted heat release rate for the sprinklered enclosure. The experiment failed to produce enough combustion gases for the oxygen depletion calorimeter to measure a heat release rate. This was due to the rapid sprinkler activation, the effective fire suppression and the large volume of the enclosure. This graph demonstrates that in the simulation the fire grew after the activation of the third sprinkler (all were operating by 36 seconds). The decrease in HRR at approximately 140 is when the shielded (dry) foam on the alcove ceiling burns itself out.

The comparison of the temperatures at Stations C and D are shown in Figures 5-29 and 5-30. In both cases FDS under predicts the temperatures near the ceiling. The FDS predictions in these two graphs have not been smoothed in order to show that the peak values near the ceiling are very close to the sprinkler activation temperature of 74 ºC. Typically the temperature of the fire gases surrounding a sprinkler at the time of activation are approximately twice the listed temperature.

Due to the continued burning of foam on the ceiling of the alcove prior to complete extinguishment,, the temperature in the simulated enclosure increases over the experimental temperatures. However, at the 1.4 m level above the floor the temperature never exceeds 35 ºC (95 ºF). This is well within the temperature tenability range.

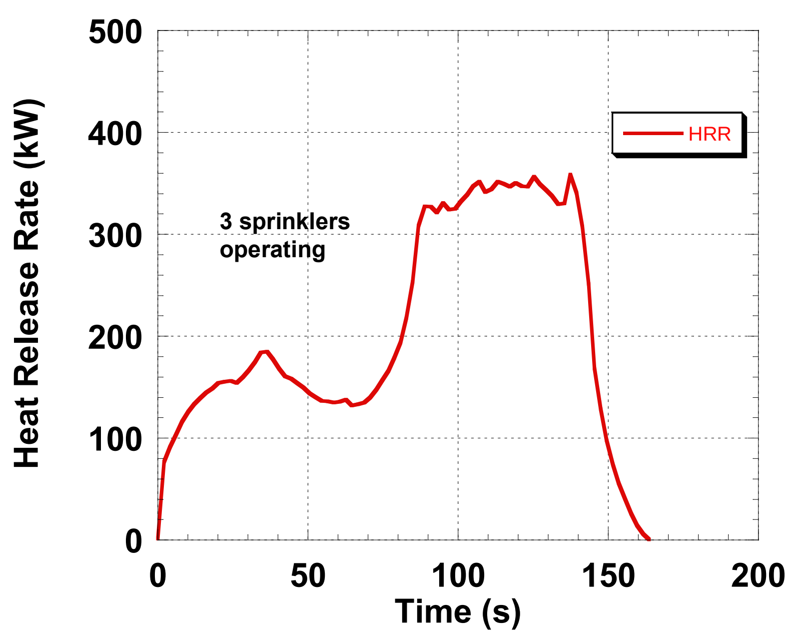


Figure 5-28. FDS predicted heat release rate for the sprinklered case.

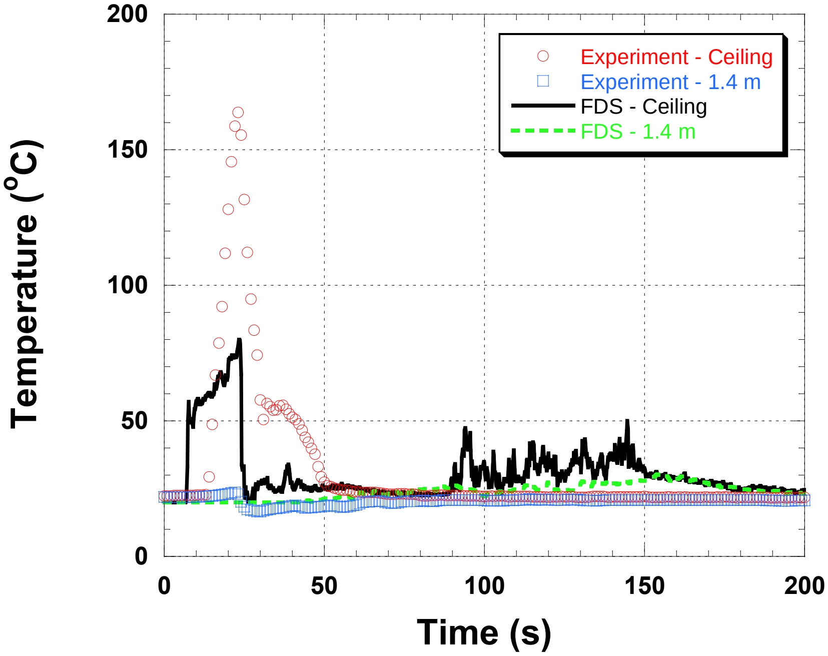


Figure 5-29. Temperature comparison between the sprinklered fire experiment and the FDS simulation at Station C.

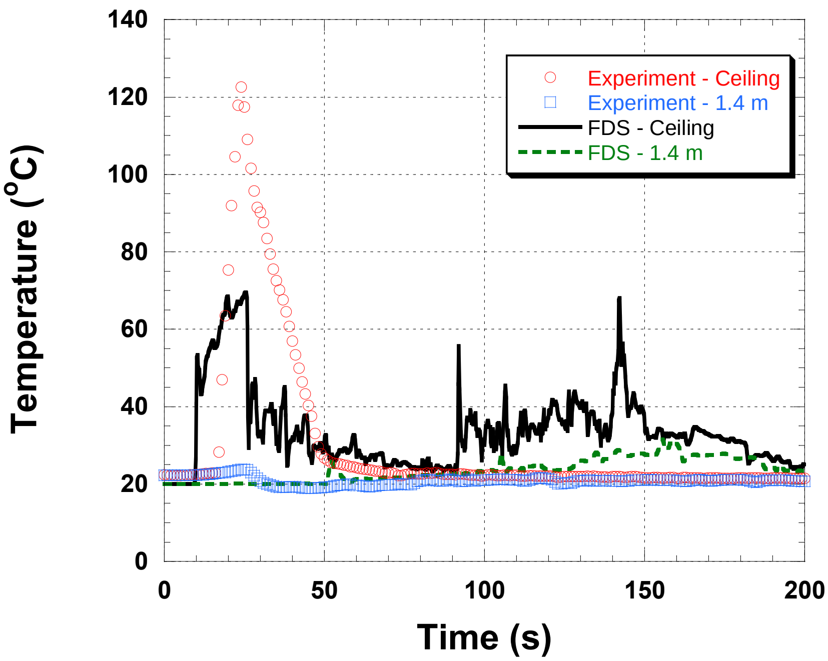


Figure 5-30. Temperature comparison between the sprinklered fire experiment and the FDS simulation at Station D.

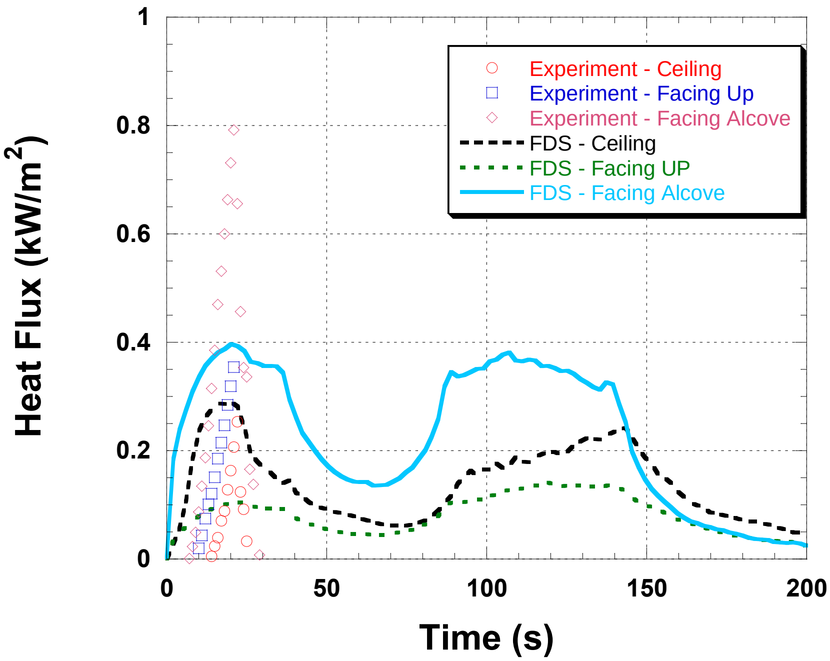


Figure 5-31. Heat flux comparison between the sprinklered fire experiment and the FDS simulation at Station C.

The comparison of the measured heat flux with the calculated heat flux is shown in Figures 5-31 and 5-32. Due to the limited fire growth and significant cooling by the water all of the heat flux values are less than 1 kW/m^2. One notable difference between the experiment and the simulation is after the sprinklers activate in the experiment, the measured heat flux goes to zero, while in the simulation small values heat flux energy continue to be shown.

Figure 5-33 exhibits the comparison of the measured and predicted oxygen concentrations at Station C. The measured oxygen concentration shows only a slight decrease during the 200 seconds, while the simulation shows a decrease of approximately 2 percent. This may be due to the continued burning of the foam along the ceiling of the alcove that is taking place in the simulation of the experiment.

(iii) Full-scale mock-up comparison - Summary

The visual and numerical comparisons demonstrate that the effects of an automatic fire sprinkler system on a fire can be successfully modeled by FDS and visualized with Smokeview. Both the experiment and simulation demonstrate that the sprinklers would prevent flashover and considerably mitigate the hazard from the fire in the test enclosure. However, the degree to which the fire is controlled is different between the experiment and the model, since the simulation has more flame spread along the edges of the alcove ceiling after activation of the sprinklers.

The temperature, heat flux, and the oxygen volume fraction comparisons show reasonable agreement between the experiments and the model in terms of both trends and range. Again some differences were caused by the increased burning after the start of suppression in the shielded areas, but that phenomena has been documented in other experiments as well [6]. Tenability limits were predicted never to be exceeded using FDS, consistent with what was observed in the full-scale mock-up experiments. The lower portion of Table 5.3 compares the extreme values of heat flux, temperature, and oxygen volume fraction predicted in the simulation to the measured values.

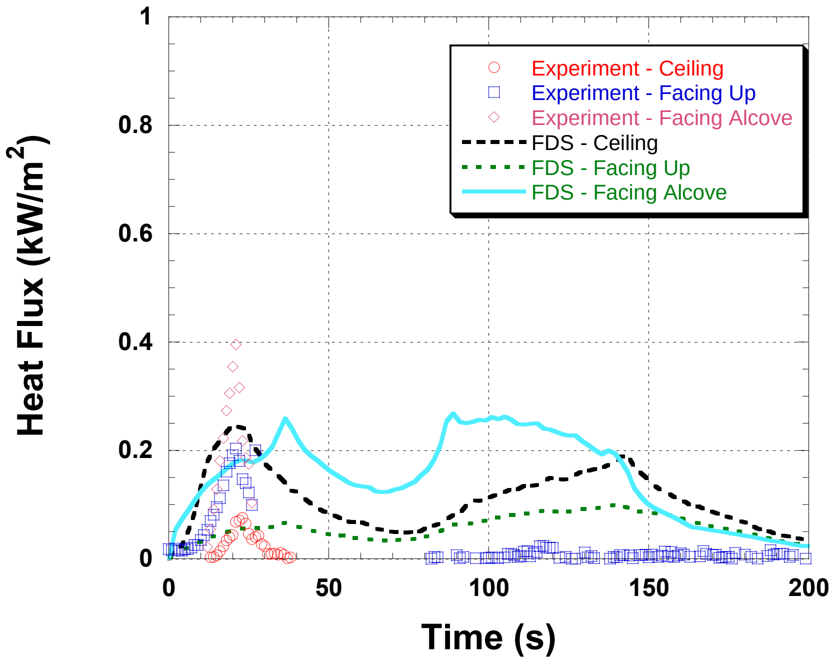


Figure 5-32. Heat flux comparison between the sprinklered fire experiment and the FDS simulation at Station D.

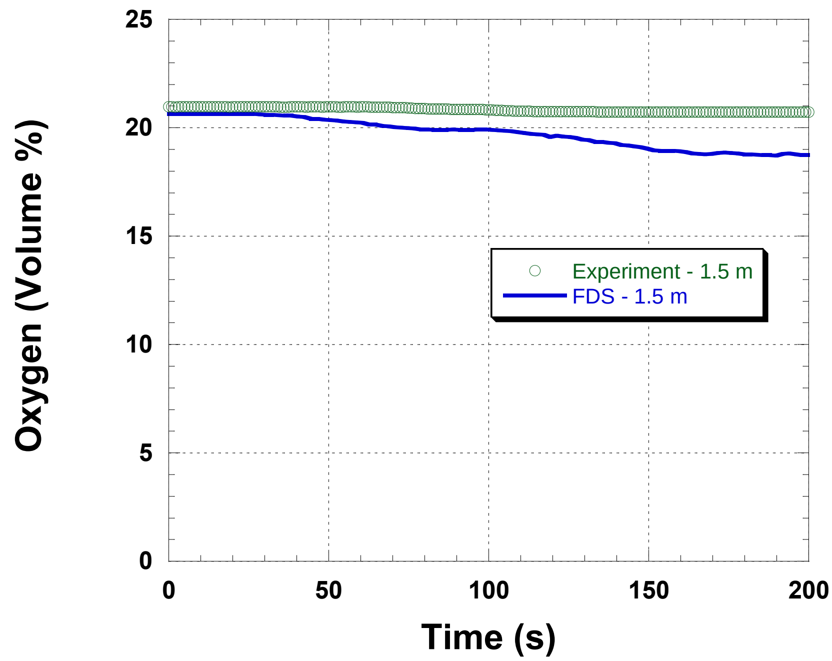


Figure 33. Oxygen volume fraction comparison between the sprinklered fire experiment and the FDS simulation at approximately 1.5 m above the floor at Station C.

5.3 FDS INCIDENT SIMULATION

5.3.1 Computational Domain and Materials

The computational domain used for the incident simulation consisted of eight adjoining rectangular meshes. Figure 5-34 shows an isometric view and Figures 5-35 and 5-36 show two different external views of the building. Each mesh was 4.1 m (13.5 ft) wide and the lengths varied from 10.8 m (35.4 ft) to 21.6 m (70.9 ft) based on the size of the structure and vent location. Each computational (or grid) cell was 100 mm (3.9 in) on a side. The input geometry for the Station night club including all wall, door and window sizes and locations was modeled based on the documentation provided in Chapter 2. Figure 5-37 is a plan view, Figures 5-38 shows the grid spacing used for the foam on the platform, and Figure 5-39 is a view looking toward the horseshoe bar and side exit from the center of the nightclub.

The interior finishes of the structure were simplified and modeled as five different materials: foam, wood, ceiling tile, gypsum board and carpet. The foam was prescribed with a wood backing due to the fact that the foam burns away leaving the wood paneling behind. Typically, FDS accounts for the burning of a single material; thus, the model was modified to allow the wood behind the foam to burn once the foam had burned away. The actual structure was lined with multiple types of wood such as paneling, wafer boards and bead board. In the simulation, all of these woods were prescribed with a single set of material properties. The ceiling tile, gypsum board and nylon carpet properties were based upon a combination of the cone calorimeter tests described in Chapter 4 and the FDS materials database. The view of the platform area seen in Figure 5-40 contains foam (grey), wood (brown and black), gypsum board (tan) and ceiling tile (tan).

The only difference in the material properties used in the simulation of the full night club vs the mock-up is the thickness of the foam and the paneling. Based on materials observed in the field, the foam recovered from the night club was thicker than the foam used in the mock-up; a value of 30 mm (1.2 in) was chosen. The paneling that remained in the night club was installed in two layers. Therefore the thickness of the paneling for the incident simulation was doubled relative to the mock-up. The ceiling tile, gypsum board, and carpet used the same values as the FDS database, which were the same values used in the mock-up simulation.

Table 5-4. Simulation Material Properties

Material	Thickness (m)	Ignition Temperature (°C)	Heat of Vaporization (kJ/kg)	Thermal Conductivity (W/m K)	Density (kg/m^3)
Foam	0.03	370	1350	0.034	22.0
Paneling	0.01	360	500	0.13-0.29	450
Ceiling Tile	0.016	NA	NA	0.0611	NA
Gypsum Board	0.013	400	NA	0.48	NA
Carpet	NA	280	3000	NA	NA

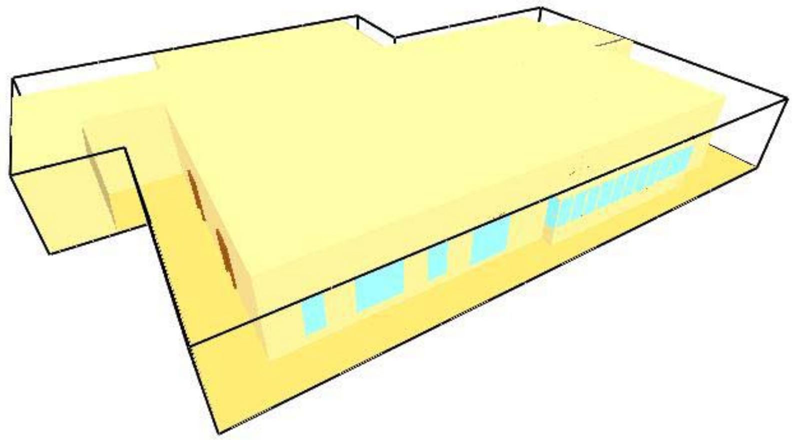


Figure 5-34. FDS computational domain of full nightclub

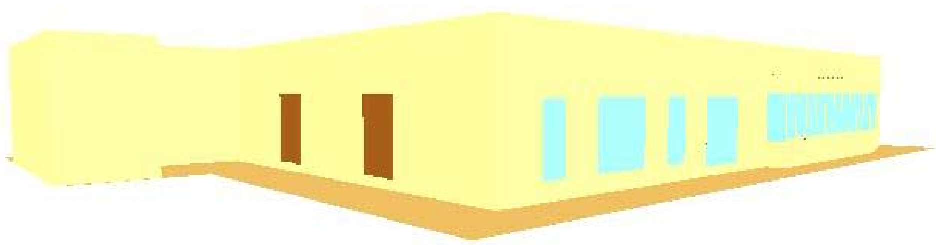


Figure 5-35. External view of nightclub from northeast corner

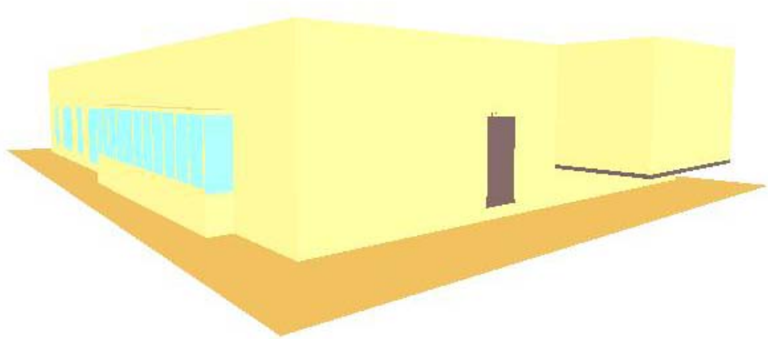


Figure 5-36. External view of nightclub from northwest corner

Figure 5-37. View from above with structure sliced 2.5 m above floor

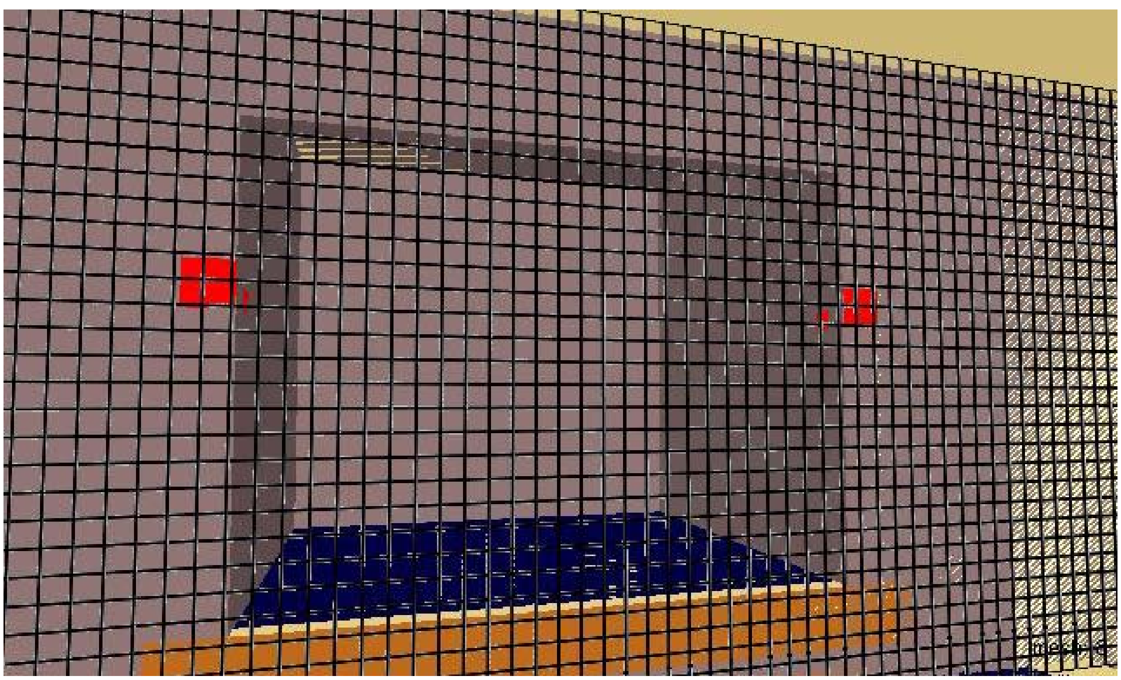


Figure 5-38. Numerical grid used for foam covered walls on platform. Red squares represent the points of ignition

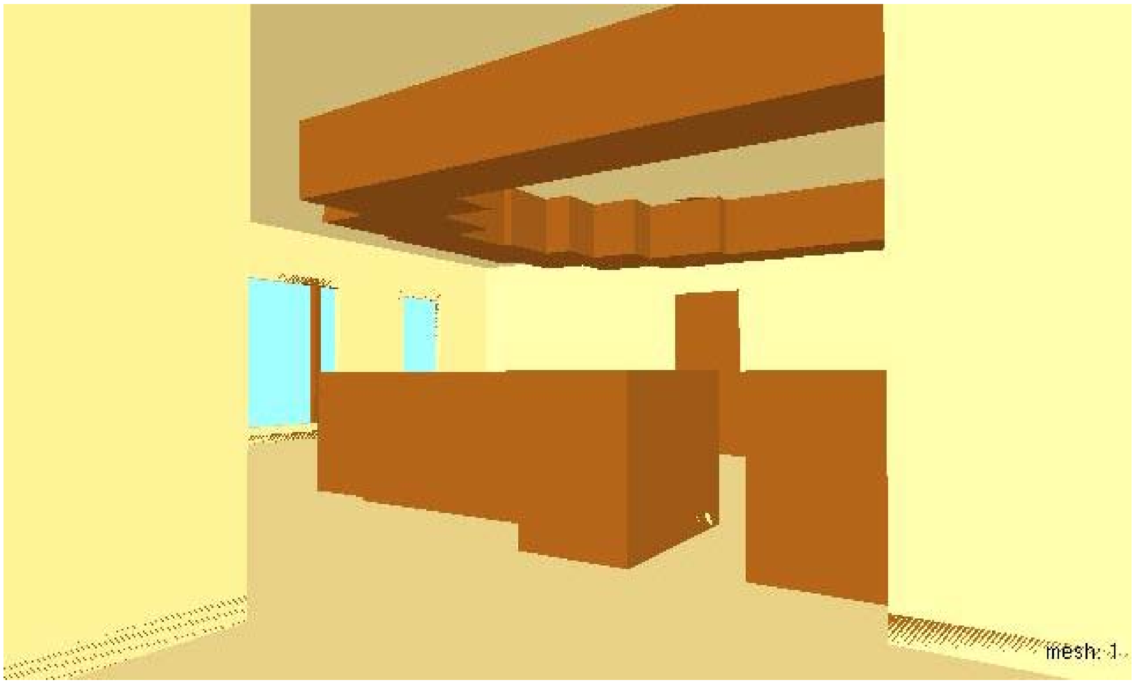


Figure 5-39. View from center of nightclub toward horseshoe bar, with side exit and front windows in background

Figure 5-40. View of platform and dance floor showing different materials

5.3.2 Vents and Openings

All four sides and the top of the computational domain were modeled as open to the environment outside of the domain to allow air to enter and combustion products to exit. The outside temperature was assumed to be the same as the initial temperature inside, and the wind was assumed to be calm[1]. The bottom of the domain was considered to be an inert, adiabatic solid. Four heat producing vents were modeled: two 200 mm (7.8 in) square vents on the front corner of the alcove, and two 100 mm (3.9 in) square vents located 100 mm (3.9 in) back from the corner, into the alcove. All of the heat producing vents were 1.24 m (4 ft) above the floor of the alcove. The vents have an energy flux of 1500 kW/m^2 and emit energy for 35 seconds beginning at t = 0 seconds.

The structure's doors and windows were opened during the simulation based on estimations from the WPRI video. The first door to open was the door adjacent to the platform. This door was observed opening in the video 29 seconds after ignition. The front double door was assumed to open shortly after the stage door at 30 seconds. This time was selected due to the crowd beginning to notice the fire and to move toward the front door. The side door near the main bar was opened at 45 seconds and the side door in the kitchen was opened at 60 seconds. These times were estimated by the crowd movement seen in the video and the remoteness of the doorways from the stage area.

At 78 seconds, the lower portion of one of the bay windows was removed. This appeared to occur as the cameraman passes by on his way to the rear of the structure. Portions of the windows located on the front of the structure, left of the main entrance were removed at 80 seconds. This included the lower half of each of the matching windows next to the large window in the center, the entire large window in the center, all of the thin window to its left and the lower half of the thin window to its right. Finally, more sections of the bay window, surrounding the portion that was removed at 78 seconds, were removed between 100 and 130 seconds. The side bay window facing the main entrance was seen open in the WPRI video and the three other windows between the side window and the lower portion of the window were removed at 78 seconds based on the sounds heard in the video. Vent opening times are summarized in Table 5-5 and visualized in Figure 5-41.

Table 5-5. Time of Openings for FDS Simulation

Location of Opening	Time of Opening (s)
Stage Door	29
Front Double Door	30
Side Door (near main bar)	45
Side Door (kitchen)	60
Front Bay Window (lower portion)	78
Front Windows	80
Left Side Bay Window	100
Three Bay Windows	110, 120, 130

[1] The temperatures recorded at T.F. Green Airport that night were in the high 20s (^{o}F) and the winds were light.

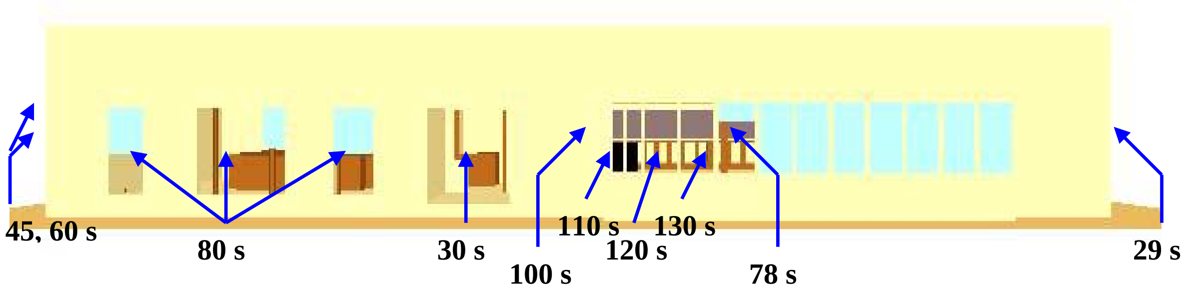


Figure 5-41. Visualization of Opening Times

5.3.3 FDS Simulation Results

The focus of this simulation was the examination of the conditions that may have been present in The Station night club during the early stages of the fire. Results from the bench-scale experiments and existing data were used to develop the input properties for the interior finish materials. The full-scale mockup results were used to compare against the FDS simulations to validate the implementation of the data in the model, and to determine the model's capabilities for this fire incident. Further, the sprinklered mock-up results were used to develop a means to model the sprinkler in the full nightclub simulation. Images from the WPRI video were utilized to develop model input to establish the location of the different interior finishes within The Station night club as well as being used as a general resource for confirming the physical arrangement of the nightclub. The simulation was run for 300 seconds to examine the time period from ignition to the approximate time of application of water by the fire department. The computation included simulated fire and smoke spread, potential temperatures, oxygen concentrations and visibility that may have existed in the actual incident. Each of these were compared to published tenability criteria.

In order to gauge the accuracy of the full night club simulation results, they were compared with the WPRI video record of the incident. In addition, analysis of the simulation considered published tenability criteria and the location of the victims within the night club.

(i) Heat Release Rate

The total heat released in the fire is plotted in Figure 5-42. The graph shows that after the alcove became fully involved with fire, at approximately 50 to 60 seconds, the heat release rate increased from approximately 2 MW to 54 MW in less than 50 seconds. Hence the rate of increase was more than 1 MW per second. As the fire spread throughout the structure and the fire became oxygen limited the heat release rate became steady at approximately 45 MW for approximately 150 seconds. After that time, the simulation began to deplete the fuel contained in the interior finish materials. The fire in the actual night club had spread into the structure and burned in and through areas of the roof and walls by this time. The simulation only provided fuel based on the interior finish and did not account for fuel being provided by structural elements and materials in building outer envelope.

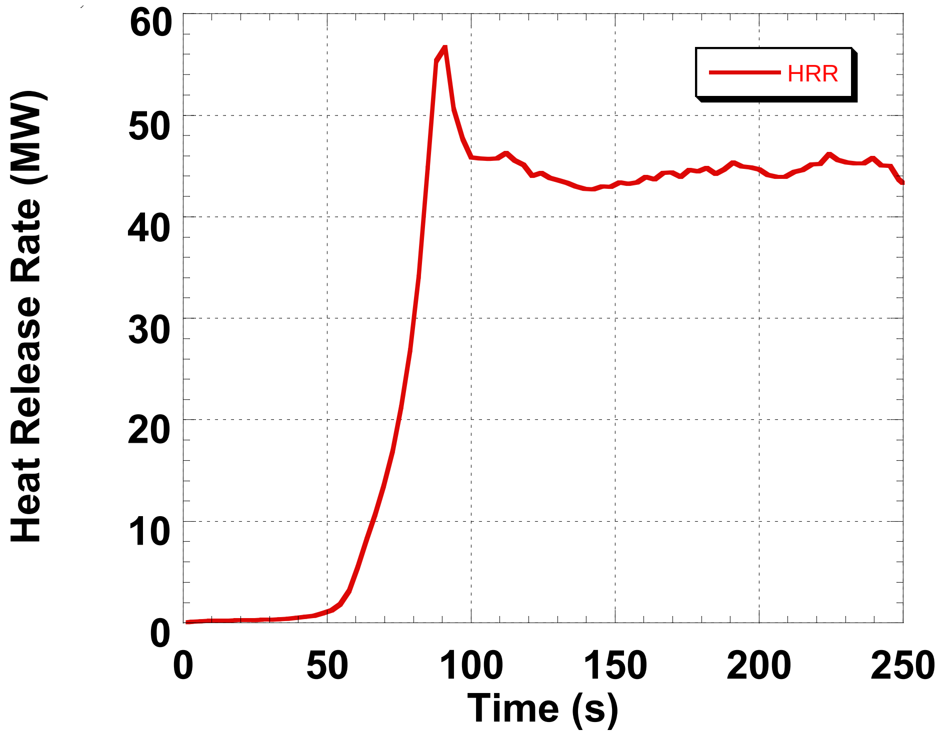


Figure 5-42. Total Heat Released in Building Fire Simulation as a Function of Time

(ii) Fire Growth and Smoke Spread

Images were selected from the WPRI video to compare with the FDS simulation results. Iso-surfaces of the heat release rate per unit volume and three dimensional smoke density parameters are displayed in the Figures 5-43 through 5-53. It should be noted that the orange color in Smokeview tracked the location of stoichiometric fuel and air mixture. If the temperature were high, then the orange surface could be thought of as a flame; if the temperature were below a threshold value, then no flame was actually present, just a non-burning mixture of fuel and air. Qualitative agreement can be seen between the pairs of images from the video and the simulation for both the initial growth prior to the videographer leaving the structure, and the outside view as the videographer walked around the structure. This similarity helped the investigation draw conclusions as to the conditions inside the structure even though the video was no longer recording inside.

Time "0" refers to the instant of ignition of the foam by the gerbs as documented in the WPRI video. All of the times that accompany the figures below are times after ignition. The times were chosen based on the image availability from the WPRI video. The images were chosen based on the visibility of the fire or the smoke from the fire. The last image set does not reflect the same time. The simulation stops at 300 s while the image from the video showing flames from the front of the night club was not recorded until 337 seconds after ignition. At this point in the fire, conditions were not changing as rapidly as during the fire development, so the comparison between the two images is reasonable.

The images from the video in Figures 5-43 and 5-44 capture the initial state of the fires on each side of the platform shortly after the gerb discharge had stopped. At 10 seconds after ignition, the fire can be seen burning on two surfaces at each of the corners; this is also considered in the simulation with the

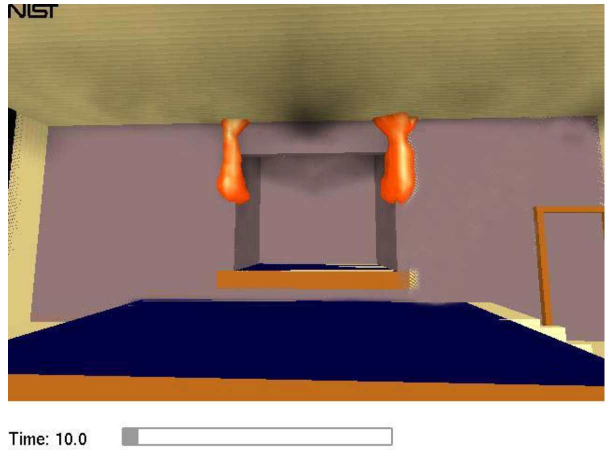


Figure 5-43. Initial growth of fire on foam at corner of the alcove (10 seconds)

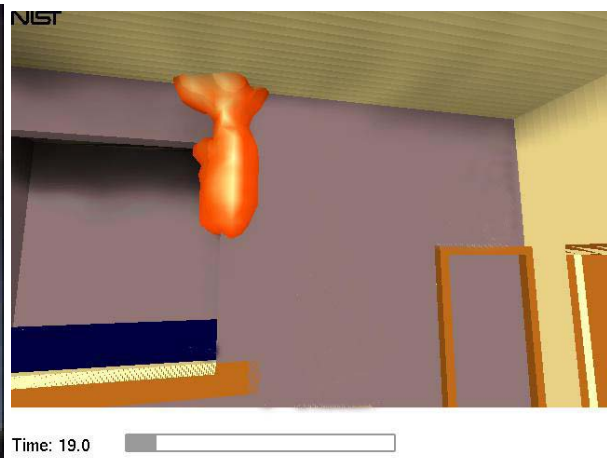


Figure 5-44. Flames impinging on ceiling (19 seconds)

placement of the ignition vents on both sides of the corner. In both the simulation and the actual incident the flames impinge on the ceiling within 20 seconds after ignition.

At 23 seconds after ignition, Figure 5-45, the videographer has begun to move toward the exit as have many in the crowd. Notice that many people are still facing the platform. The fire continued to grow and smoke has collected in the raised ceiling area over the dance floor. The smoke filling can be seen in the image from the simulation. (Note the black rectangular image on the floor is representative of the speaker cabinet, whereas the boundaries of the smoke layer are irregular.) At 53 s after ignition, the flames have grown and spread along the platform wall and into the alcove as shown in video image in Figure 5-46. In addition, the smoke is spreading across the lower level ceiling area toward the main exit. The flames have spread in the simulation as well and smoke is beginning to spill over from the dance floor area towards the exits and the main bar room, although it takes a few more seconds into the simulation for this to occur. Again the black rectangular objects on the floor are representative of speaker cabinets (near the platform) and the sound and lighting board (left side).

The videographer had exited the night club at approximately 70 seconds and headed toward the stage door. He then returns toward the main entrance and attempts to pass between the nightclub and the bus when he encounters a plume of black smoke pushing out of one of the window vents in the sunroom. The

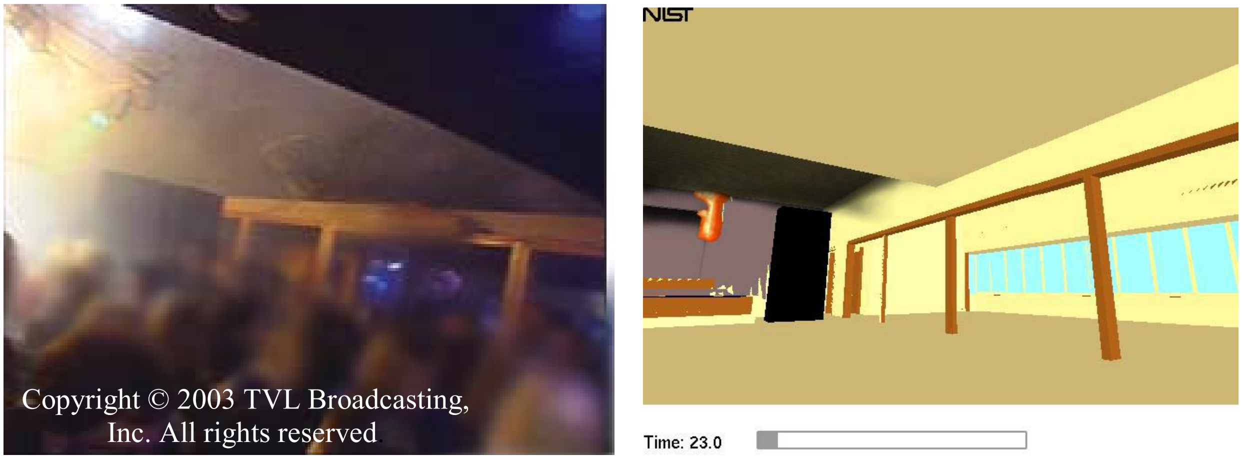


Figure 5-45. Videographer backing away from platform (23 seconds)

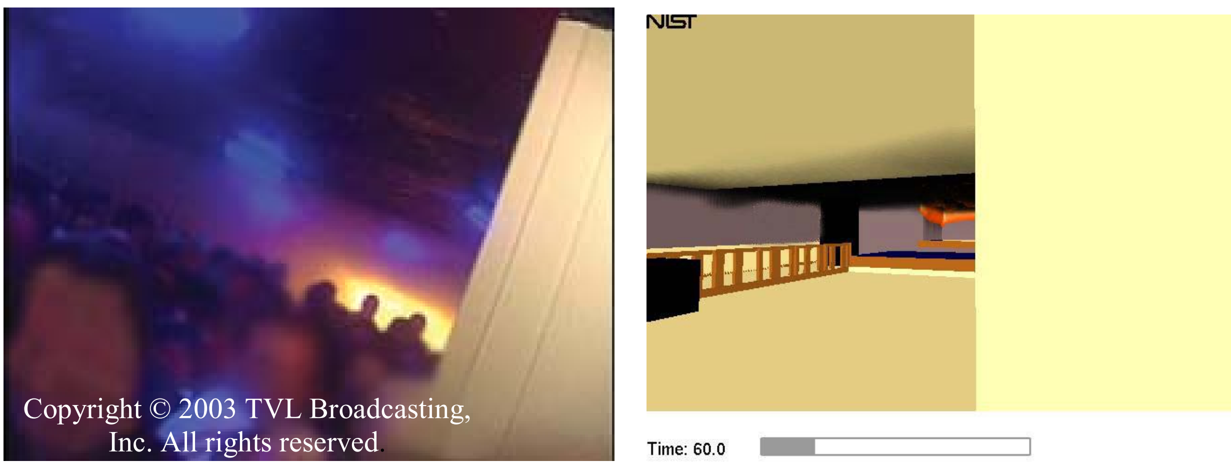


Figure 5-46. Smoke beginning to roll across ceiling (video 53 seconds, simulation 60 seconds)

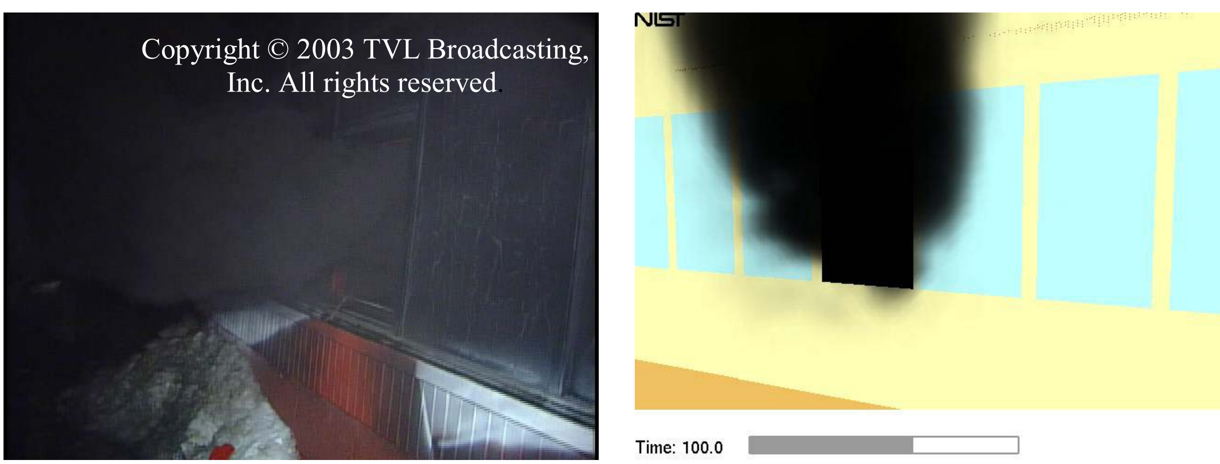


Figure 5-47. Smoke billowing outside from broken sunroom window (100 s)

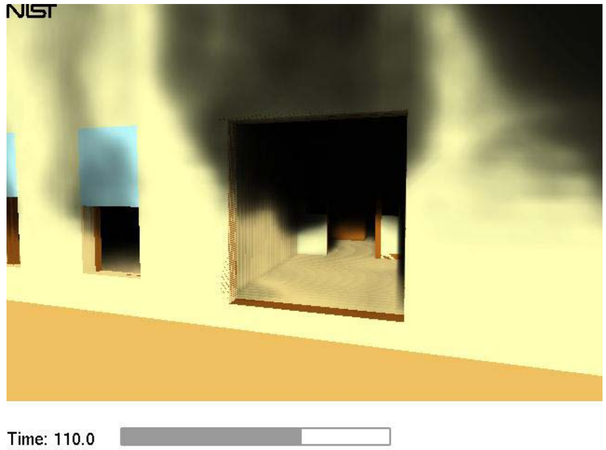


Figure 5-48. Light smoke emanating from front door of nightclub (110 seconds)

image from the simulation also shows a similar view. At approximately 110 s after ignition, smoke is flowing from the main entrance, the image from the simulation is given in Figure 5-48. The model did not account for people blocking the air flow into the doorway.

The Smokeview image in Figure 5-49 shows the smoke flow from the front door at 160 seconds after ignition in the simulation. In Figure 5-50, the simulated smoke flow from the main bar room windows is shown. More smoke is coming from the center window than the two side windows because the upper and lower portions of the center window have been removed while only the lower portion of the side windows are open in the simulation.

Figure 5-49. Heavy smoke leaving front door and open main bar window (160 seconds)

Figure 5-50. View of smoke plumes from front windows of horseshoe bar area (176 seconds)

The videographer moves around to the stage door again. The view inside the open door at approximately 289 seconds after ignition is shown in Figure 5-51 The image from the simulation agrees with the video image on the level of combustion products in the doorway. However without a comparison to the temperature in the doorway, the mixture fraction alone would indicate that more flames are in the area of the stage doorway than can be seen in the video image. The videographer continues around to the backside of the nightclub, at 300 s after ignition flames are coming through a small portion of the back wall (south wall) of the dance floor area and smoke is leaking from the bathroom hallway wall. The videographer moved toward the front of the night club again, at 309 seconds flames can be seen in the area of the front door. It takes another 25 seconds before he is in a position to record the images of the flames coming from the sunroom windows and the main door. The simulation stops at 300 s after ignition, short of the time that the entire night club reaches flashover conditions.

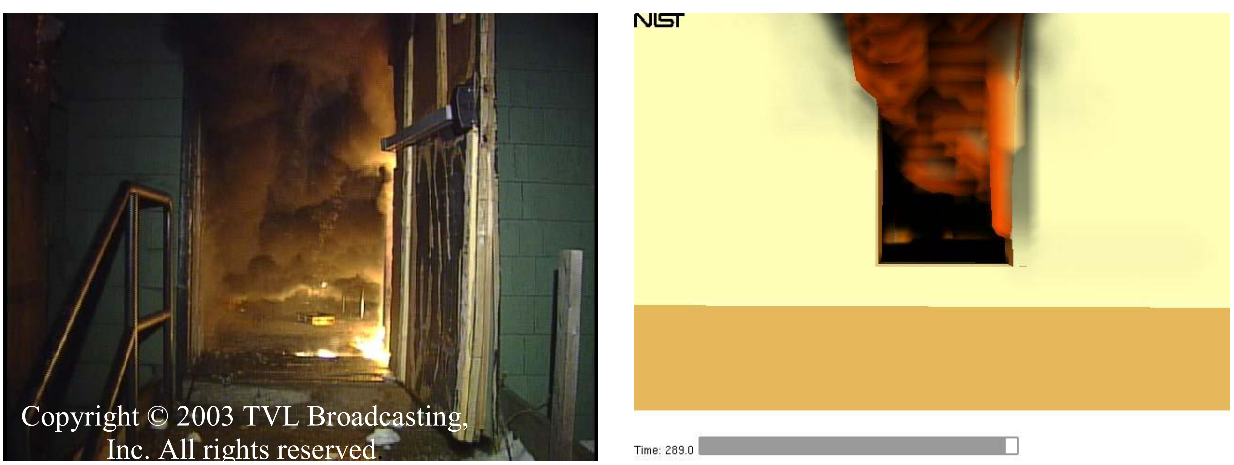


Figure 5-51. Looking into stage door exit (289 seconds)

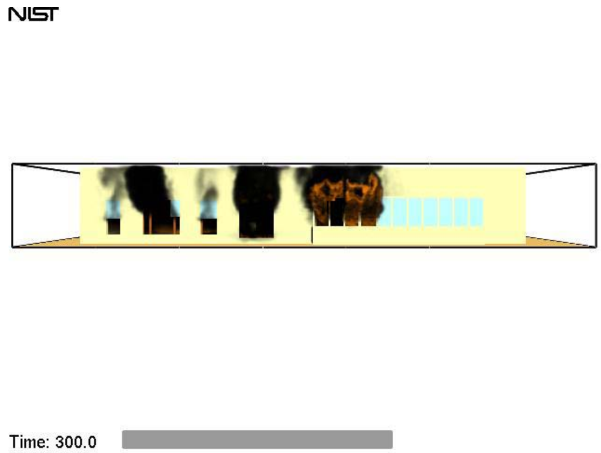


Figure 5-52. Flames breaking through front door and sunroom windows (337 seconds, video, 300 seconds simulation)

Smokeview images were rendered at certain time intervals from the view looking through the far side of the main bar to the platform area. (See Figures 5-53a,b.) This allowed for the conditions to be observed at several key locations: the platform area, the entrance to the main exit way and the main bar area. Many of the occupants traveled this path as either they were able to exit or were overcome by the conditions prior to being able to do so.

The fire developed quickly in the platform area as the foam burned and resulting in the alcove become fully developed with fire. Once that occurred the flames involved the entire rear wall and spread toward the main entrance, generating large amounts of smoke. At 70 s after ignition, the smoke can be seen in the area of the main entrance to the nightclub. This is consistent with the WPRI video. As the videographer leaves the nightclub, at approximately 70 s after ignition, smoke is flowing over the heads of people in the main entry foyer. However, even 80 seconds after ignition visibility remained high in the main bar room. This changed suddenly as the smoke and hot gases that were spilling out of the now-filled raised ceiling above the dance floor quickly spread to the main bar room. Based on the FDS simulation, within another 20 seconds, 100 s after ignition visibility was impaired, and remained so throughout the rest of the 300 second simulation. Flames can be seen in the last three images of Figure 5-53b as the surfaces in the main bar area began to burn.

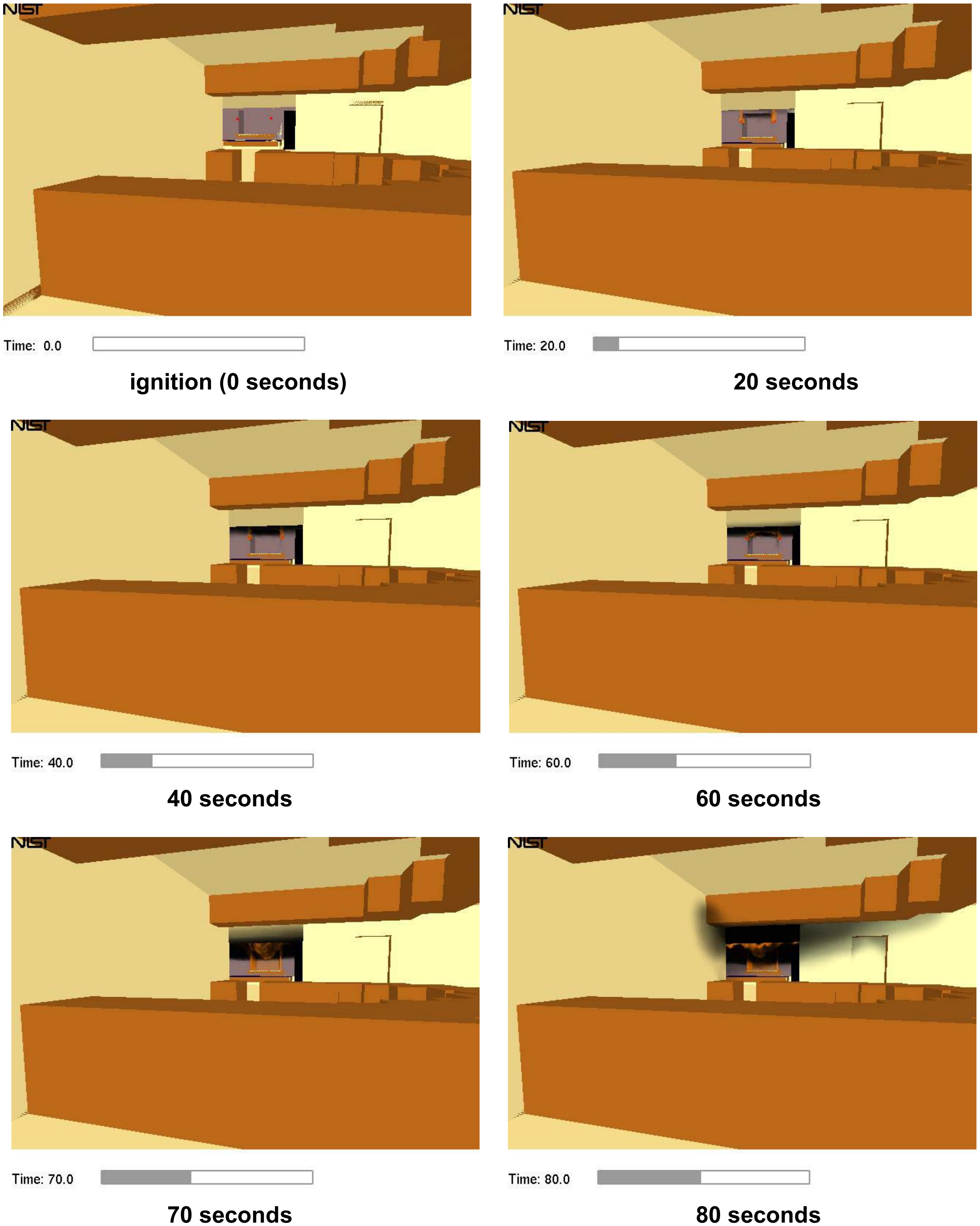


Figure 5-53a. View of fire from beyond horseshoe bar, looking at platform (0 s - 80 s)

85 seconds

100 seconds

200 seconds

250 seconds

Figure 5-53b. View of fire from beyond horseshoe bar, looking at platform (85 s - 250 s)

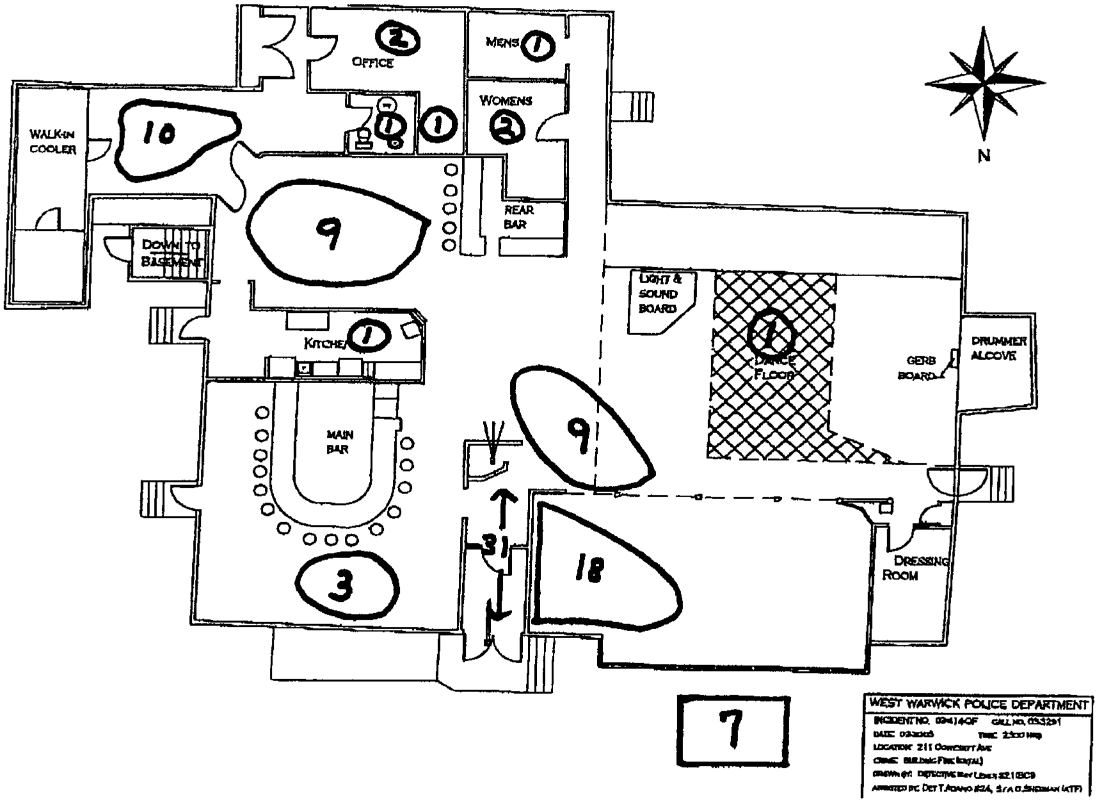


Figure 5-54. West Warwick Police Department Victim location diagram

(iii) Temperature

Temperature slices were examined to assess the tenability conditions that existed during the evolution of the fire. Horizontal slices were taken at both the 1.5 m (5 ft) and 0.6 m (2 ft) levels above the floor with the ceiling rendered transparent to examine the temperature distribution throughout structure as a whole. Vertical slices were used to analyze certain locations where groups of victims were located (See Figure 5-54). These locations included the main entrance as seen through the front door, the area leading into the exit area from the dance floor, and the left side of the sunroom and the open area adjacent to the side bar and kitchen. This analysis utilized 120 ºC (248 ºF) as the temperature tenability threshold [6]

Temperatures increase dramatically shortly after the alcove area reaches flashover conditions at approximately 65 seconds and then the platform area becomes fully involved in flames. The first two images in Figure 5-55a show the temperatures at 1.5 m (5 ft) above the floor at 80 and 85 seconds. Within that 5 second time interval the simulation predicts that dance floor area of the nightclub would have become untenable due to temperature. By 100 seconds after ignition, the simulation shows a large portion of the structure had become untenable due to temperature at the 1.5 m (5 ft) level. Figure 5-55b continues with the presentation of simulation temperature results from 160 second to 250 seconds after ignition. During this time interval temperatures continue to remain in the untenable range throughout the simulated night club, with the exception of areas that are considered closed off from the hot gas flow such

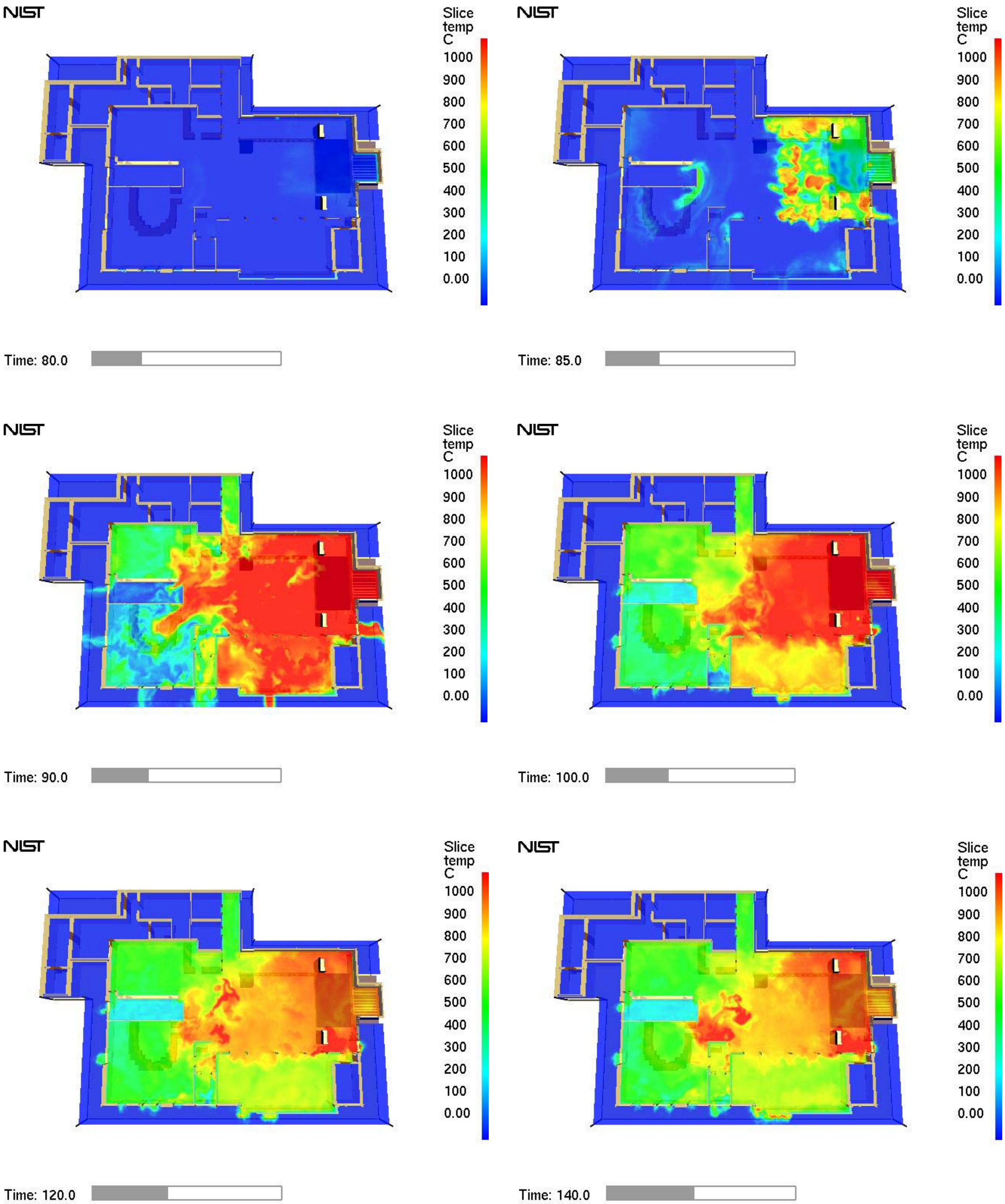


Figure 5-55a. Temperatures at 1.5 m (5 ft) above the floor, 80 seconds to 140 seconds

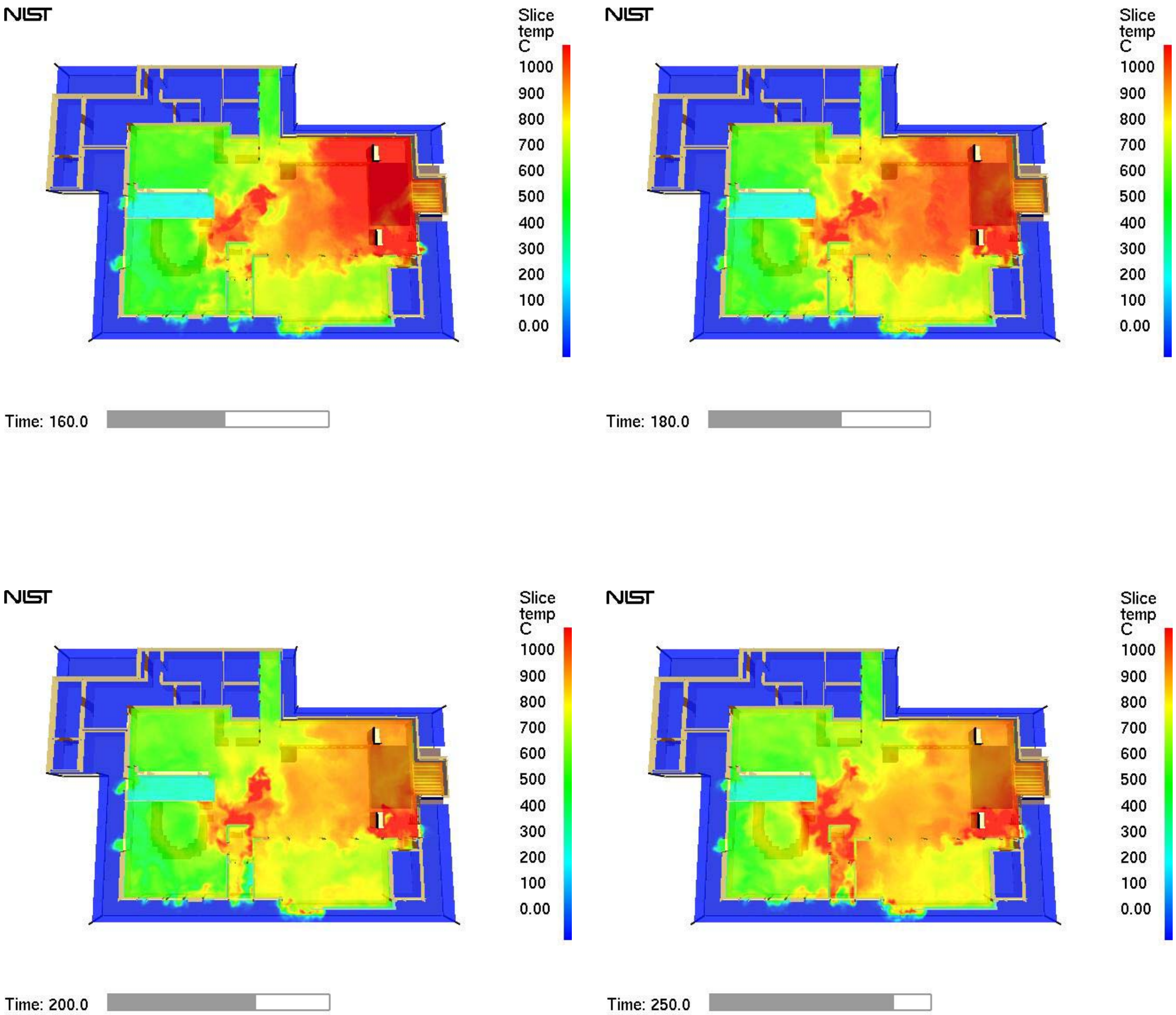


Figure 5-55b. Temperatures at 1.5 m (5 ft) above the floor, 160 seconds to 250 seconds

as the bathrooms, office and storage areas. These areas were assumed to be separated from the rest of the nightclub by closed doors, so they were modeled without a path for the gases to enter the spaces, hence they appear to remain in the tenable range. The kitchen area has an open door from the dart room and a open door that exits to the outside. The hot gas flow goes directly from the dart room to the exit doorway. This leaves the kitchen at a cooler temperature than the surrounding rooms.

At the 0.6 m (2 ft) height above the floor conditions remain tenable for a longer period of time than at the higher elevation. Figures 5-56a and 56b contain images captured at the same time intervals as in the previous figure. Figure 5-56a shows the dance floor and adjacent areas reach untenable temperatures in the simulation within 90 seconds after ignition. The sun room and dart room areas are predicted to reach untenable temperatures within another 10 seconds.

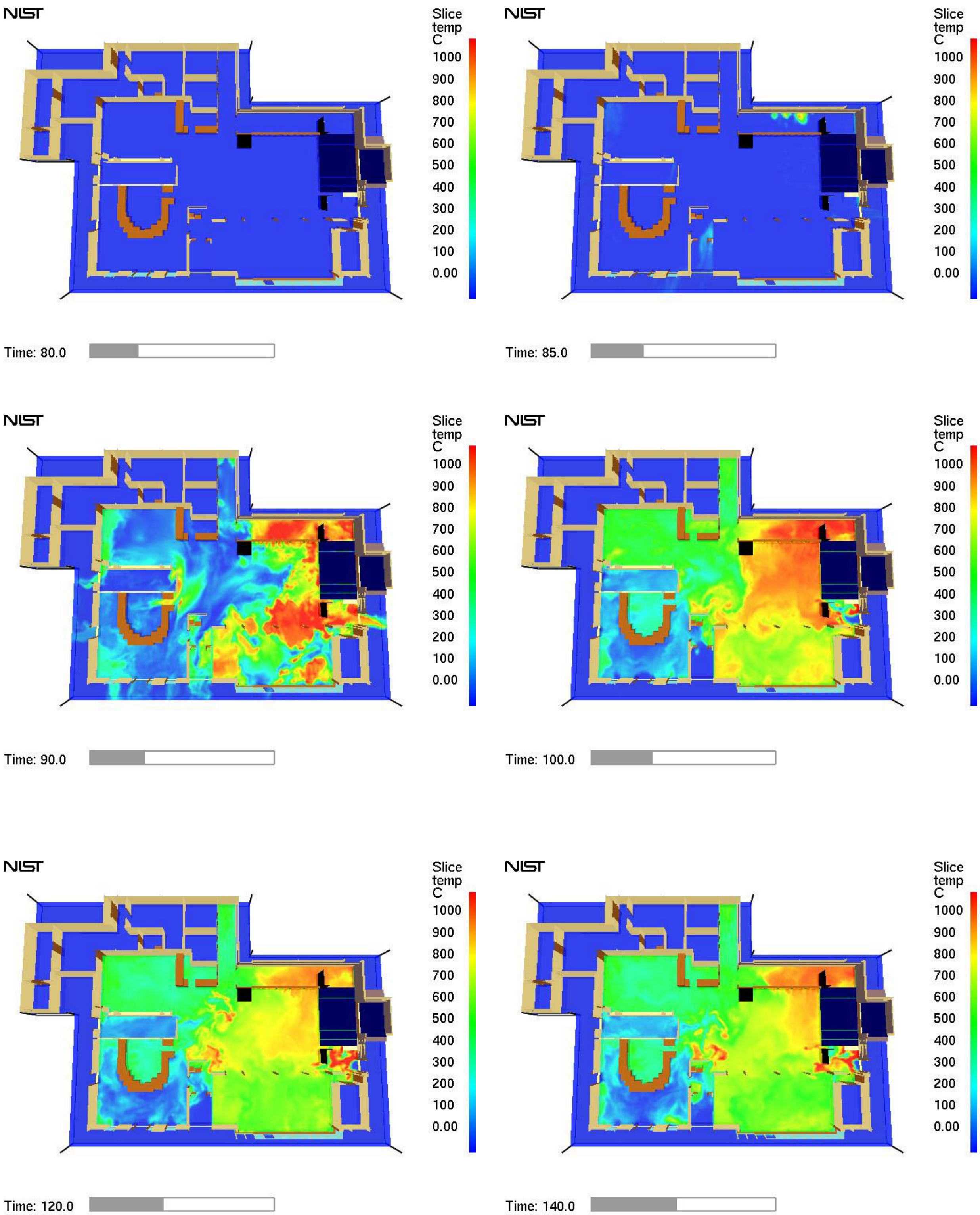


Figure 5-56a. Temperatures at 0.6 m (2 ft) above the floor, 80 seconds to 140 seconds

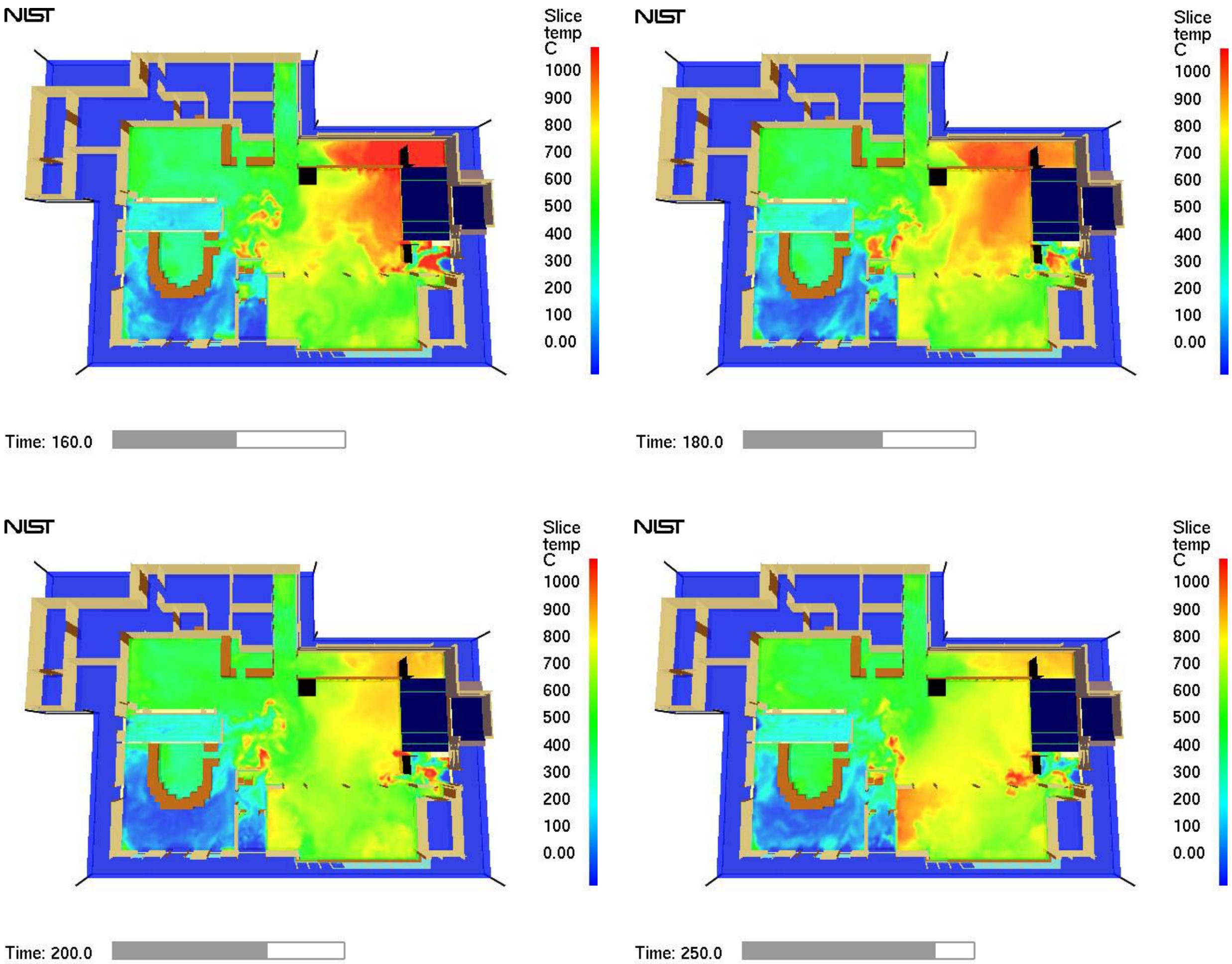


Figure 5-56b. Temperatures at 0.6 m (2 ft) above the floor, 160 seconds to 250 seconds

The significant differences in temperature between the 1.5 m (5 ft) elevation and 0.6 m (2 ft) occur in the main bar room and the main entrance. This area remains tenable at the lower level due to the inflow of fresh air through the open windows and open doorways. The cooler temperatures towards the floor at both the front door and main bar area explain why occupants were seen in the WPRI video escaping from the windows and doorway later into incident. The temperatures in Figure 5-56b do not change significantly regarding areas that have untenable conditions versus areas that remain tenable based on temperature only.

Figure 5-57a and 57b show the temperature predictions for the plane of data that is centered along the axis of the entry foyer. Temperatures just inside the front door, near the floor remain below the tenable limit because of the fresh air being drawn in through the doorway. This region of tenability decreases in a triangular orientation as the entranceway goes into the structure and gets smaller as the simulation continues. This simulation does not account for the occupants that accumulated in the doorway. Thirty-one victims were located in this area.

.

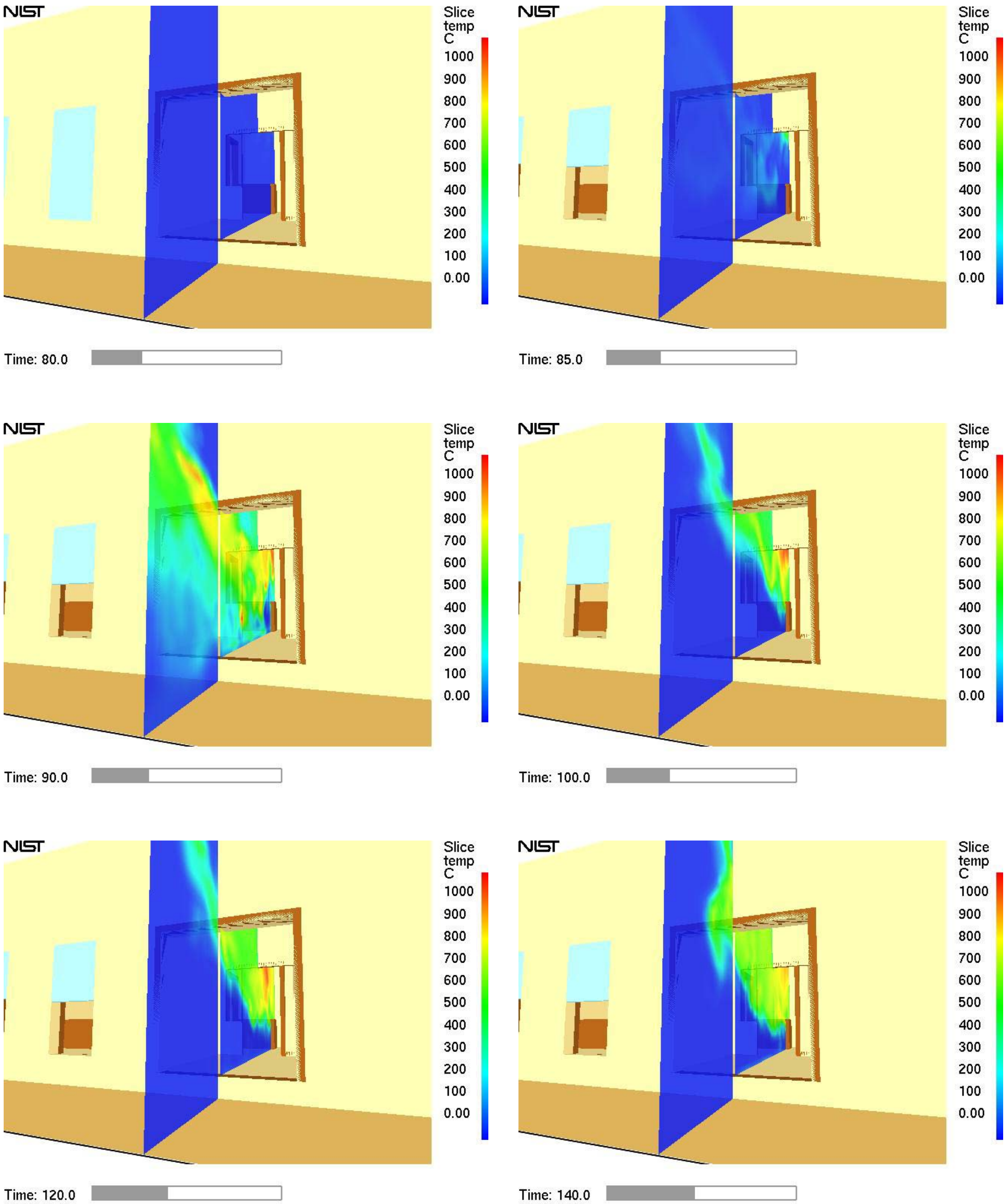


Figure 5-57a. Temperature profile through the center of the entry foyer, 80 seconds to 140 seconds

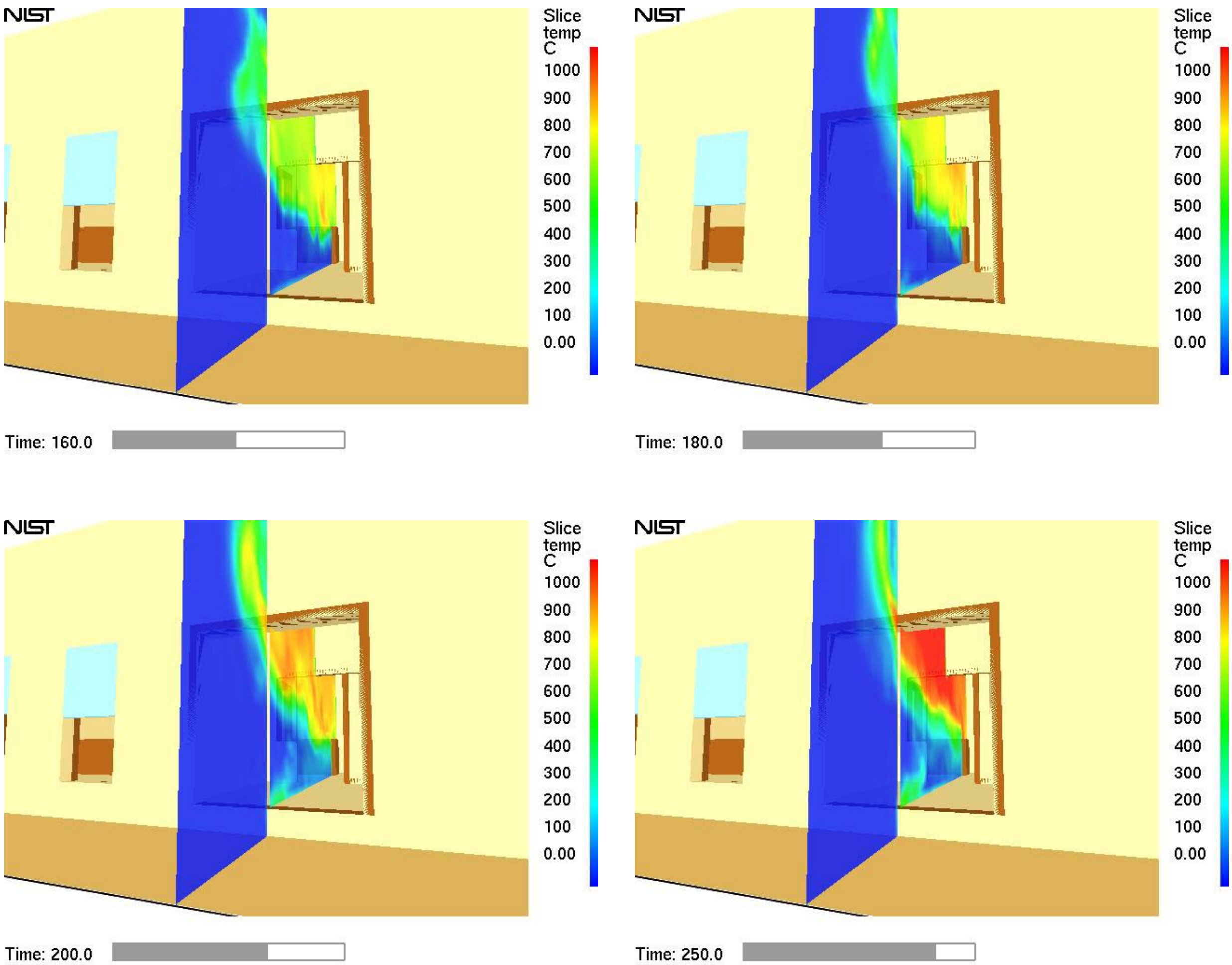


Figure 5-57b. Temperature profile through the center of the entry foyer, 160 seconds to 250 seconds

The area in the end of the sunroom adjacent to the entranceway was also a location that many victims were found. A vertical temperature slice through this area, shown Figures 5-58a and 5-58b, suggests that these victims did not have much time before the heat overcame them. Temperatures exceeded the 120 ºC (248 ºF) tenable threshold within 90 seconds after ignition. The simulation indicates that this change was rapid and extreme with temperatures in the upper portion of the space increasing from ambient conditions to flame temperatures on the order of 1000 ºC (1830 ºF) within 10 seconds. After the initial energy release due to the burning polyurethane foam (90 seconds), the predicted temperature decreased, but remained in the untenable range throughout the remainder of the simulation. Figure 5-58b shows that the temperatures increased again to 900 ºC (1650 ºF) at 250 s after ignition. The opening of portions of the bay windows between 78 seconds and 120 seconds after ignition had a minimal impact on reducing the temperatures in this part of the building. Eighteen victims were located in this area.

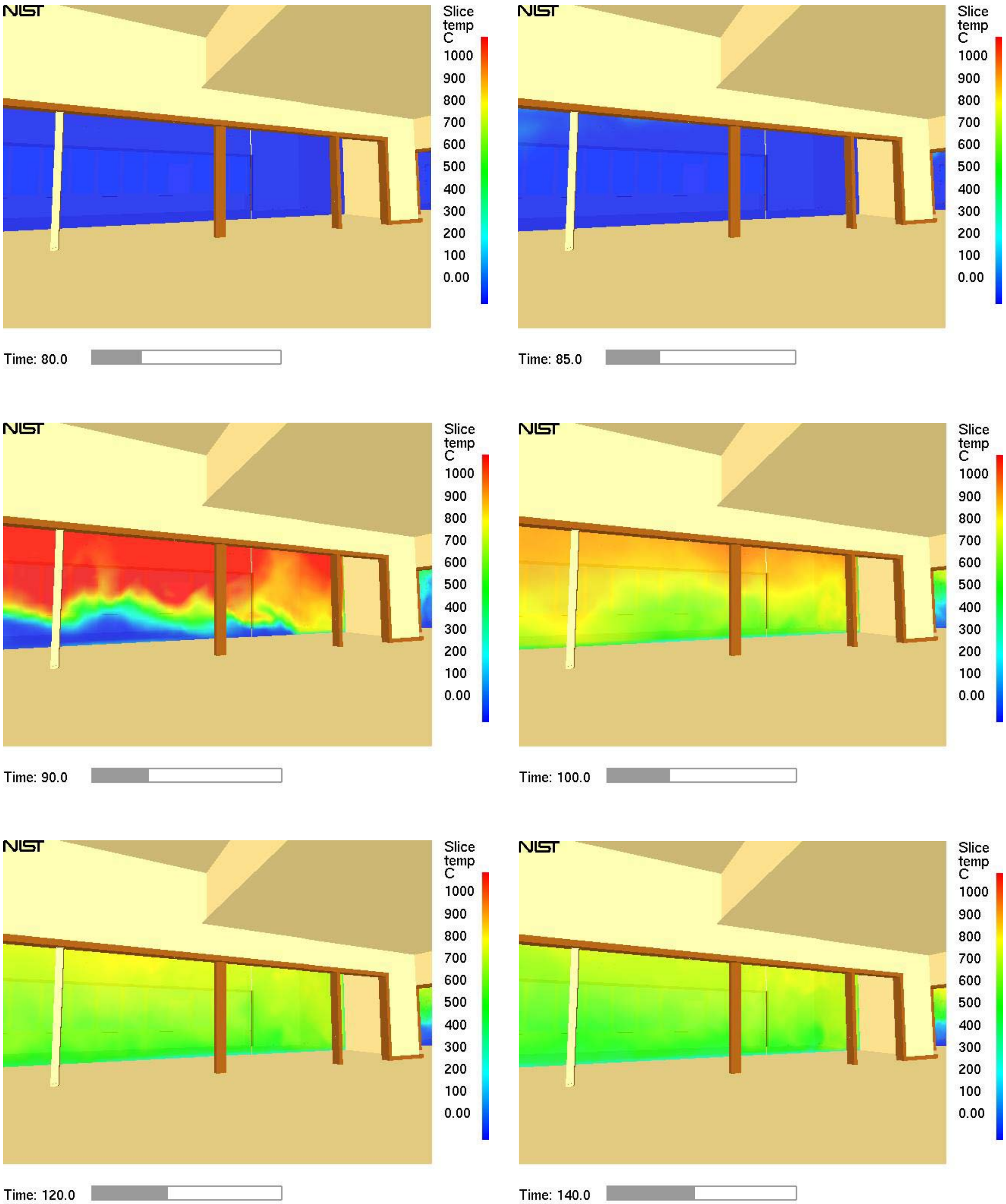


Figure 5-58a Temperature profile through the center of the sunroom, 80 seconds to 140 seconds

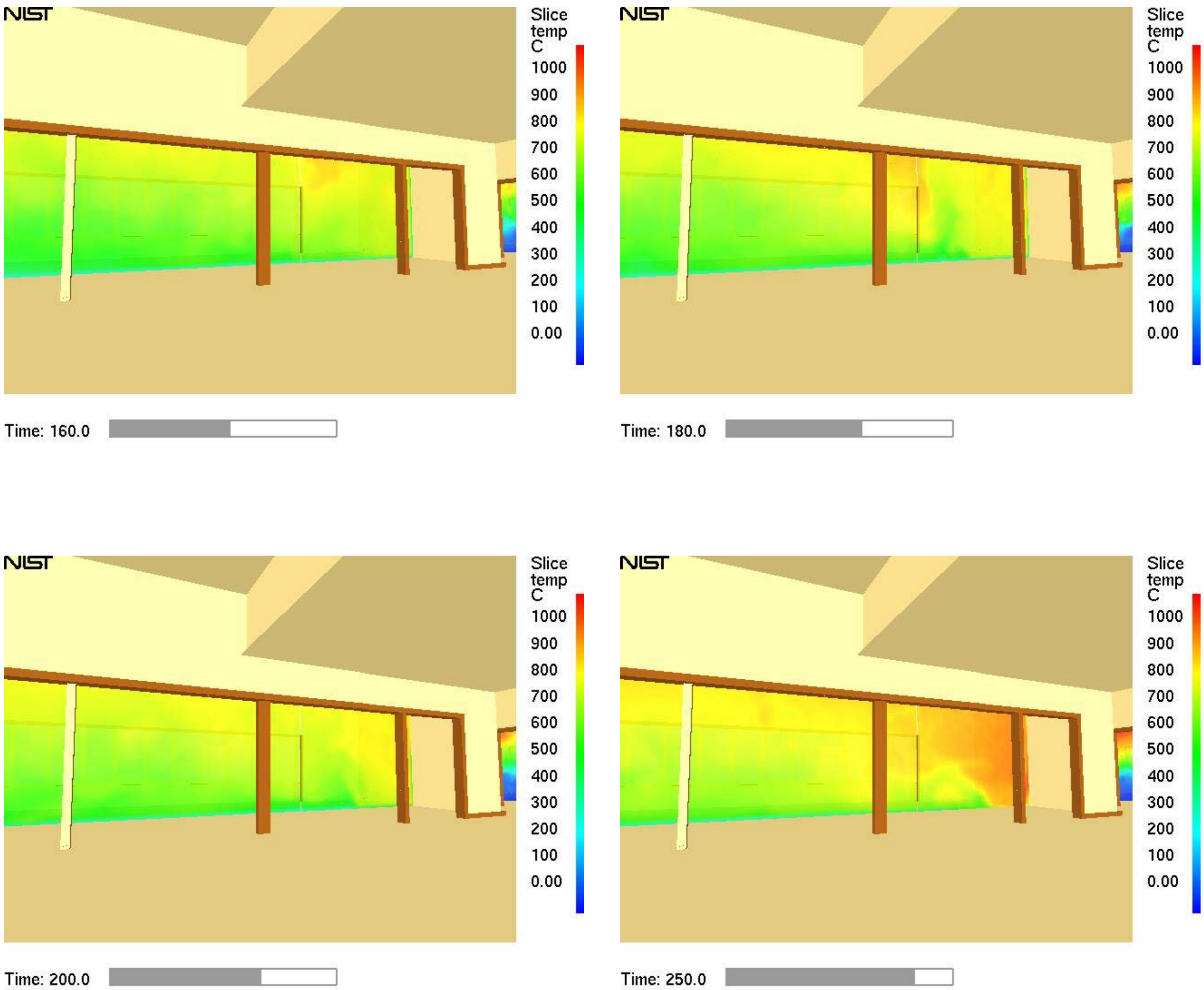


Figure 5-58b. Temperature profile through the center of the sunroom, 160 seconds to 250 seconds

Figures 5-59a and 5-59b depict the temperatures in the approaches to the main entry foyer. The vertical temperature slices cover the area at the end of the entrance foyer and next to the ticket booth. The view is from the dance floor area looking toward the main entrance (front door). What appears to be a pillar in between the intersection of the two vertical slices is a portion of the wall that separates the sunroom from the main entry foyer. The images demonstrate that temperatures were untenable outside of the entranceway and that if the occupants were not able to make it into the area of cool air coming in from the front doorway, they did not have a chance of survival. Temperatures near the floor exceeded 400 ºC (750 ºF) within 100 seconds of ignition. Nine victims were located in this area.

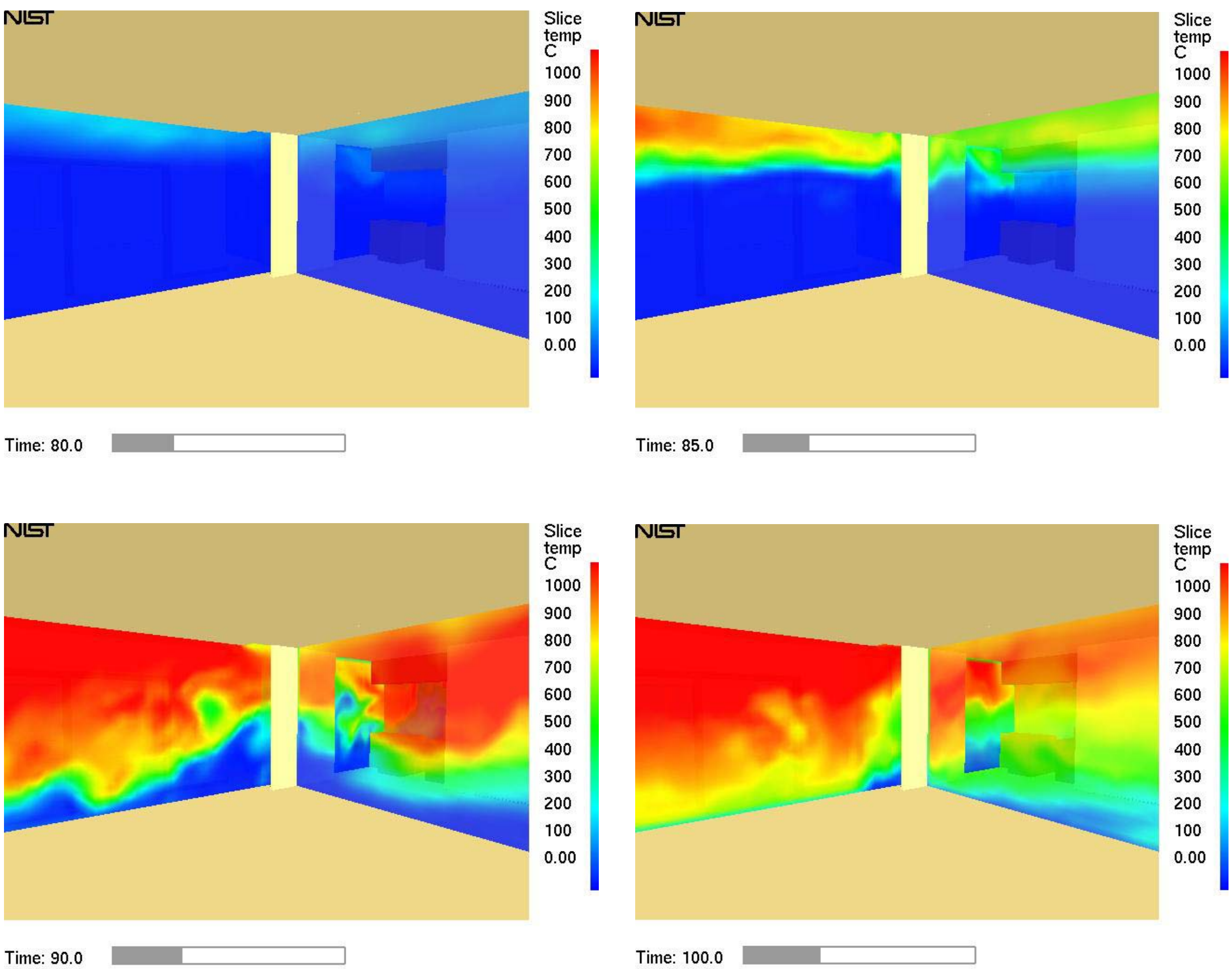


Figure 5-59a. Temperature profiles approaching main entry foyer, 80 seconds to 100 seconds

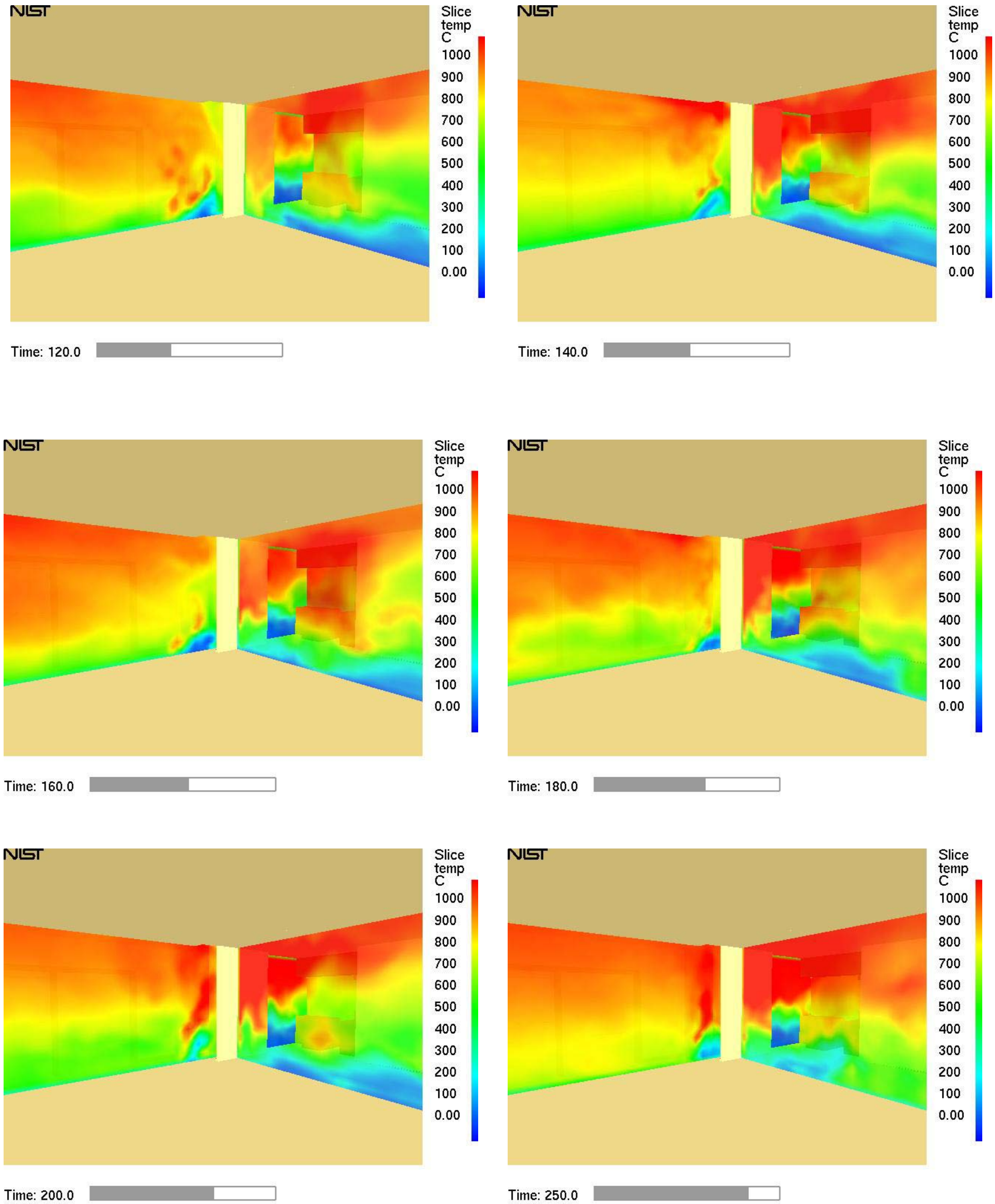


Figure 5-59b. Temperature profiles approaching main entry foyer, 120 seconds to 250 seconds

The area of the night club with the side bar and the dart room is shown in the simulated images with vertical temperature slices bounding the area to the north (toward the main entrance) and to the east (toward the storage/office area entrance). Figures 5-60a and 5-60b show the rapid change in thermal conditions between 80 seconds and 90 seconds after ignition. As in other parts of the night club simulation this significant increase in temperature was due to the burning of the polyurethane foam. Temperatures near the floor ranged from 200 ºC (390 ºF) to 600 ºC (1110 ºF) at 100 seconds. Figure 5-60b indicates that the temperatures remained in the untenable range throughout the rest of the simulation. In the incident, nine victims were found in this area.

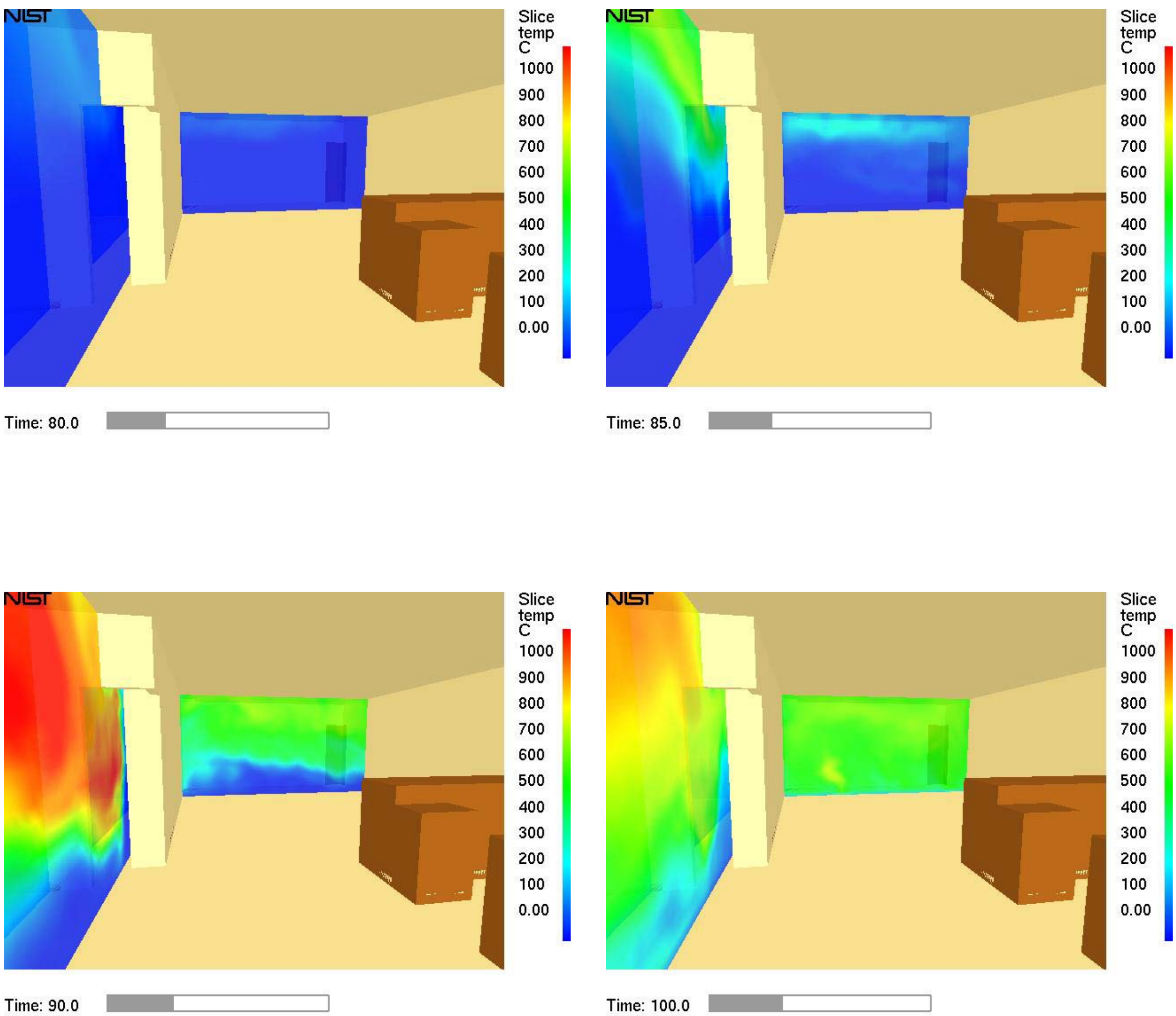


Figure 5-60a. Temperature profiles in the dart room, 80 seconds to 100 seconds

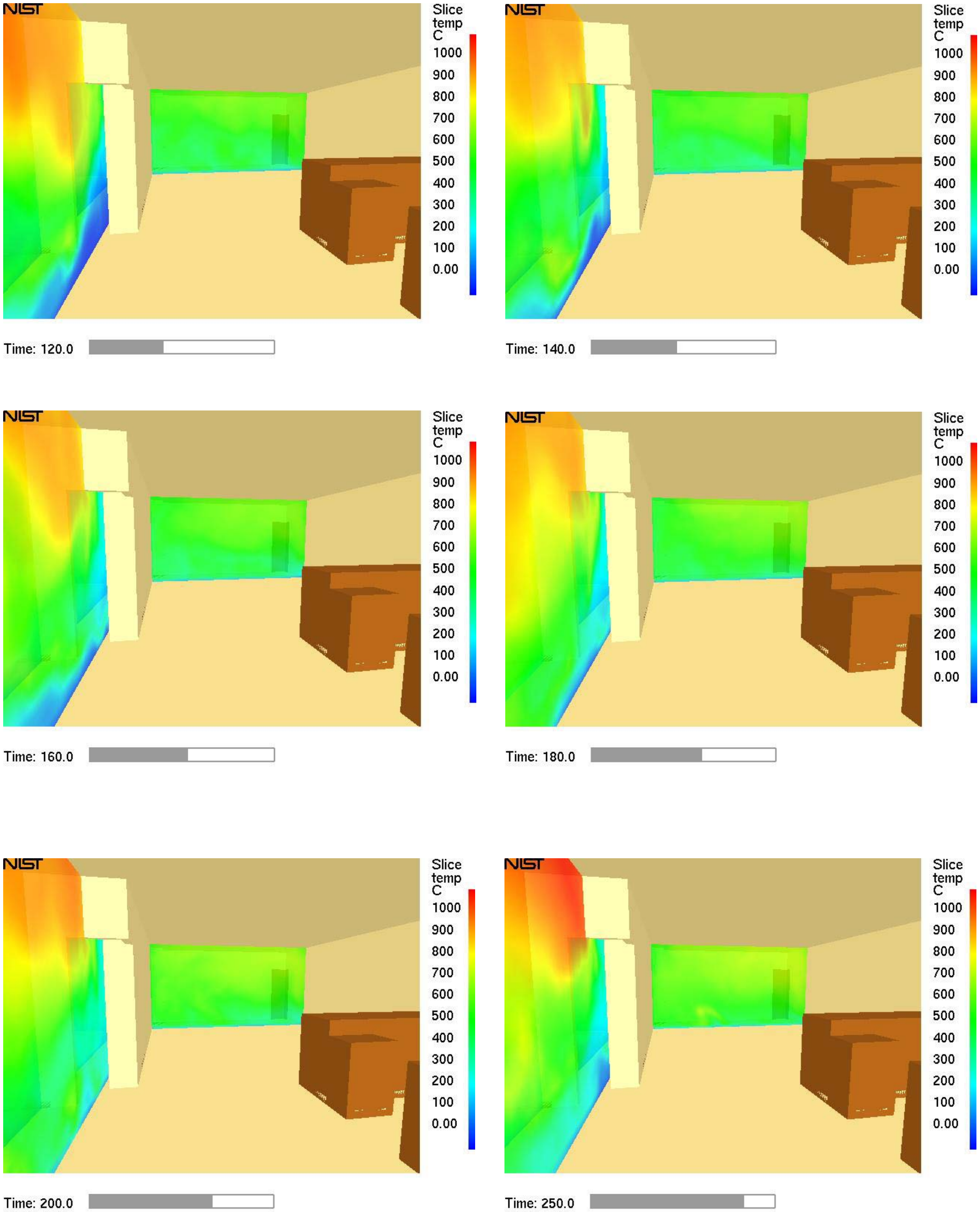


Figure 5-60b. Temperature profiles in the dart room, 120 seconds to 250 seconds

(iv) Oxygen

Oxygen volume fraction concentrations were also examined in the simulation to assess the tenability conditions that existed during the evolution of the fire. Horizontal slices were taken at both the 1.5 m (5 ft) and 0.6 m (2 ft) levels with the roof removed to examine the structure as a whole. This analysis will utilize a volume fraction of 12 % as the oxygen tenability threshold [6]. Based on that oxygen limit the following figures show that occupants would have had less than 100 seconds of tenable conditions.

Just as the temperature levels rose rapidly after the platform area became fully involved in flames, the oxygen levels drop proportionally. As shown by the three dimensional smoke output in the previous section, the smoke spreads quickly through the structure. Figure 5-61a contains four images ranging from 80 seconds after ignition to 100 seconds after ignition. This sequence has the most dramatic changes in oxygen concentration. Beyond 100 seconds the entire structure is untenable at the 1.5 m (5 ft) height. Tenability exists for the longest duration in the main bar area. Figure 5-61b shows the progression of the oxygen levels through the end of the simulation at 250 seconds. Most of the building, including the platform and dance floor areas, the dart room, the main entry foyer and the main bar room, is shown by the simulation to be significantly depleted of oxygen to less than 2 %.

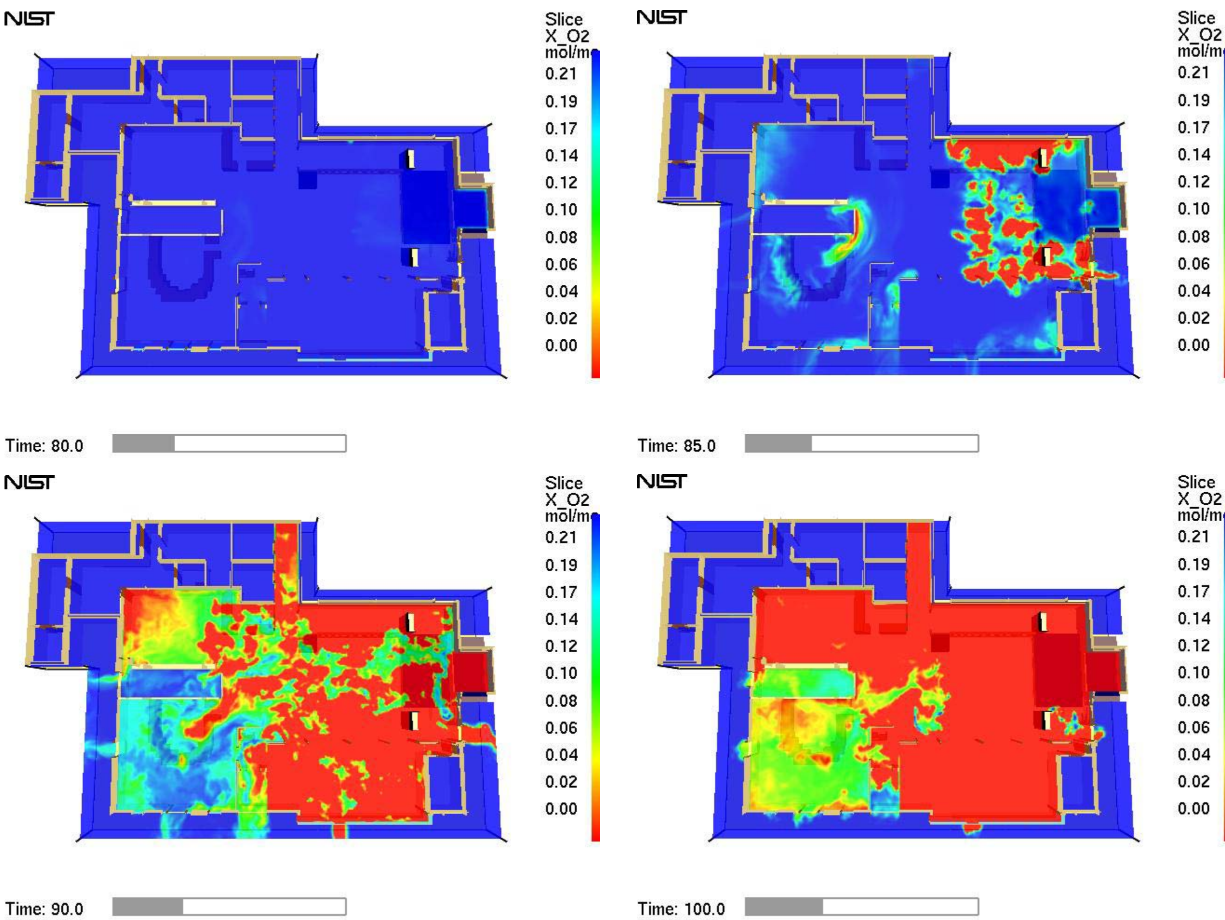


Figure 5-61a. Oxygen volume fractions at 1.5 m (5 ft) above the floor, 80 seconds to 140 seconds

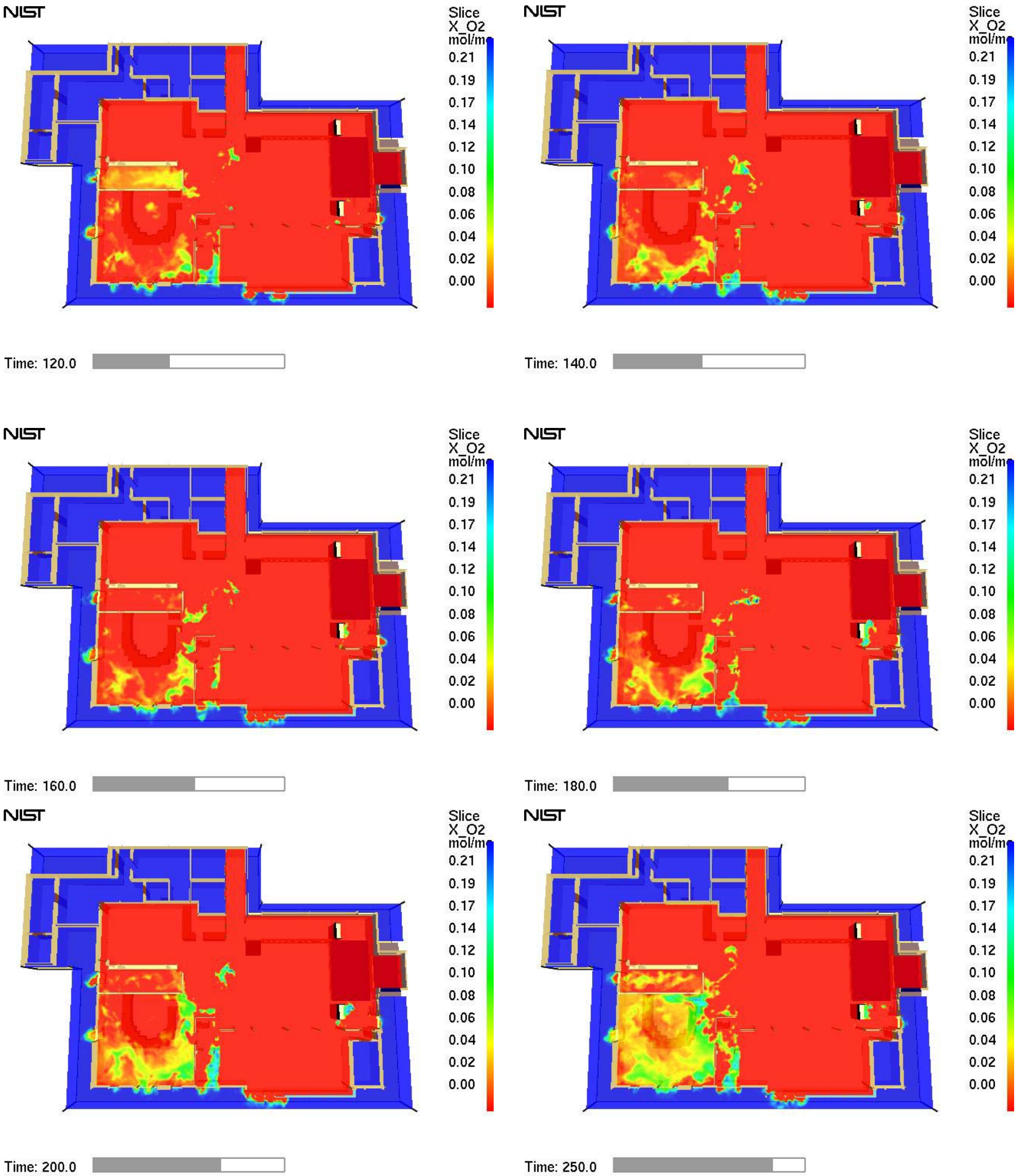


Figure 5-61b Oxygen volume fractions at 1.5 m (5 ft) above the floor, 120 seconds to 250 seconds

Figures 5-62a and 5-62b show the predicted oxygen volume fraction 0.6 m (2 ft) above the floor, beginning at 80 seconds after ignition through 250 seconds after ignition. At this lower level it is apparent that tenability is also not likely in any area other that the main bar area and the entranceway right inside the front door. The opening of the windows at the front of the main bar room creates a more tenable atmosphere, probably saving the lives of occupants as they can be seen being pulled from the windows in the WPRI video. Occupants that stayed low in the main bar area had a better chance of survival.

The images in Figure 5-62b, once again show a rapid decrease in tenable conditions due to oxygen depletion throughout most of the simulated nightclub with the exception of the main bar room and the main entry foyer. Due to the open doors and windows in these areas, the simulation indicates that sufficient fresh air was drawn in to maintain a level of tenability with respect to oxygen in the areas adjacent to the open windows and the main entry way. This trend is shown to continue through the end of the simulation. In the WPRI video, the last person recorded being assisted through a window from the main bar room occurs at 250 s seconds after ignition. This is consistent with the predicted oxygen concentrations near the windows.

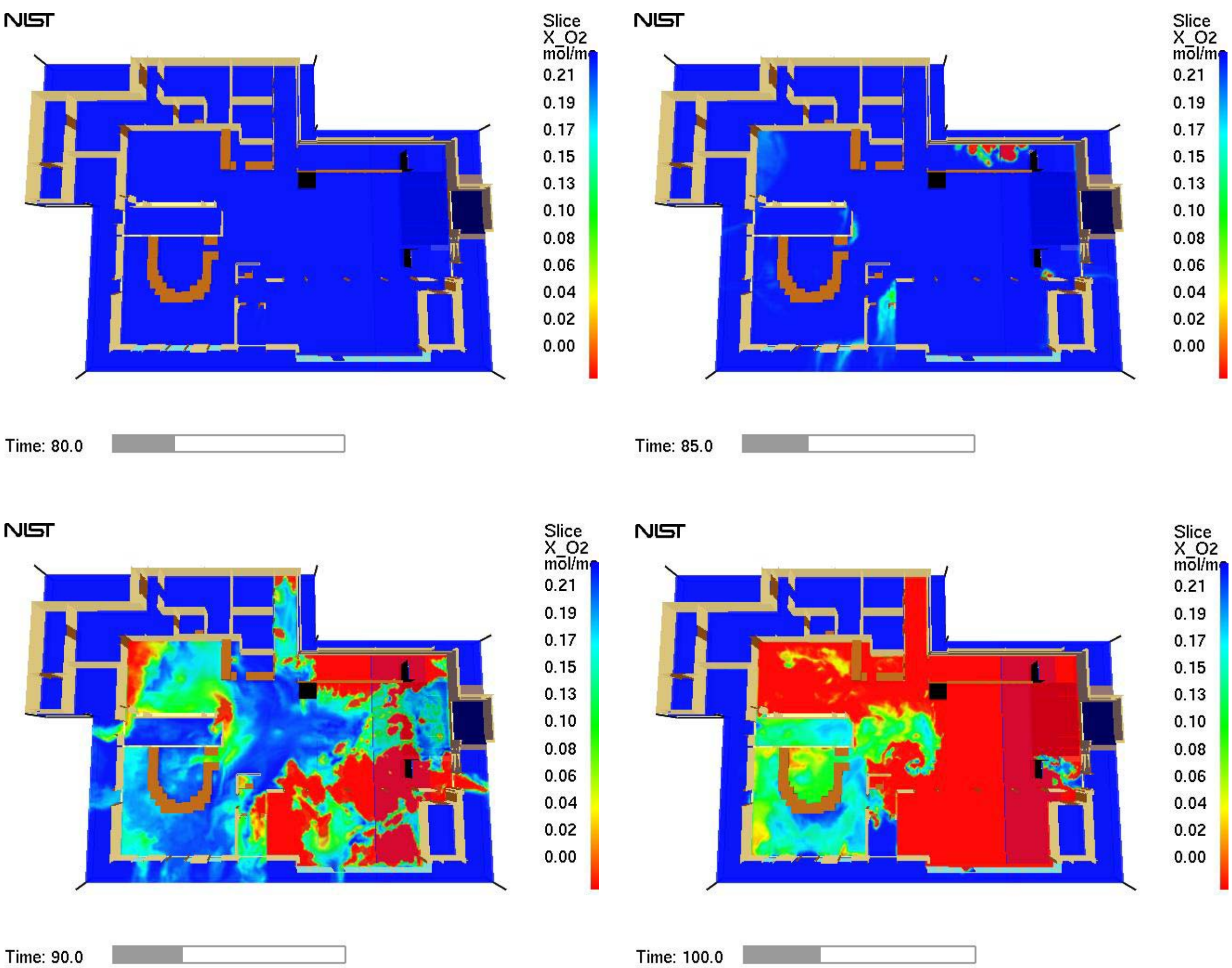


Figure 5-62a Oxygen volume fractions at 0.6 m (2 ft) above the floor, 80 seconds to 100 seconds

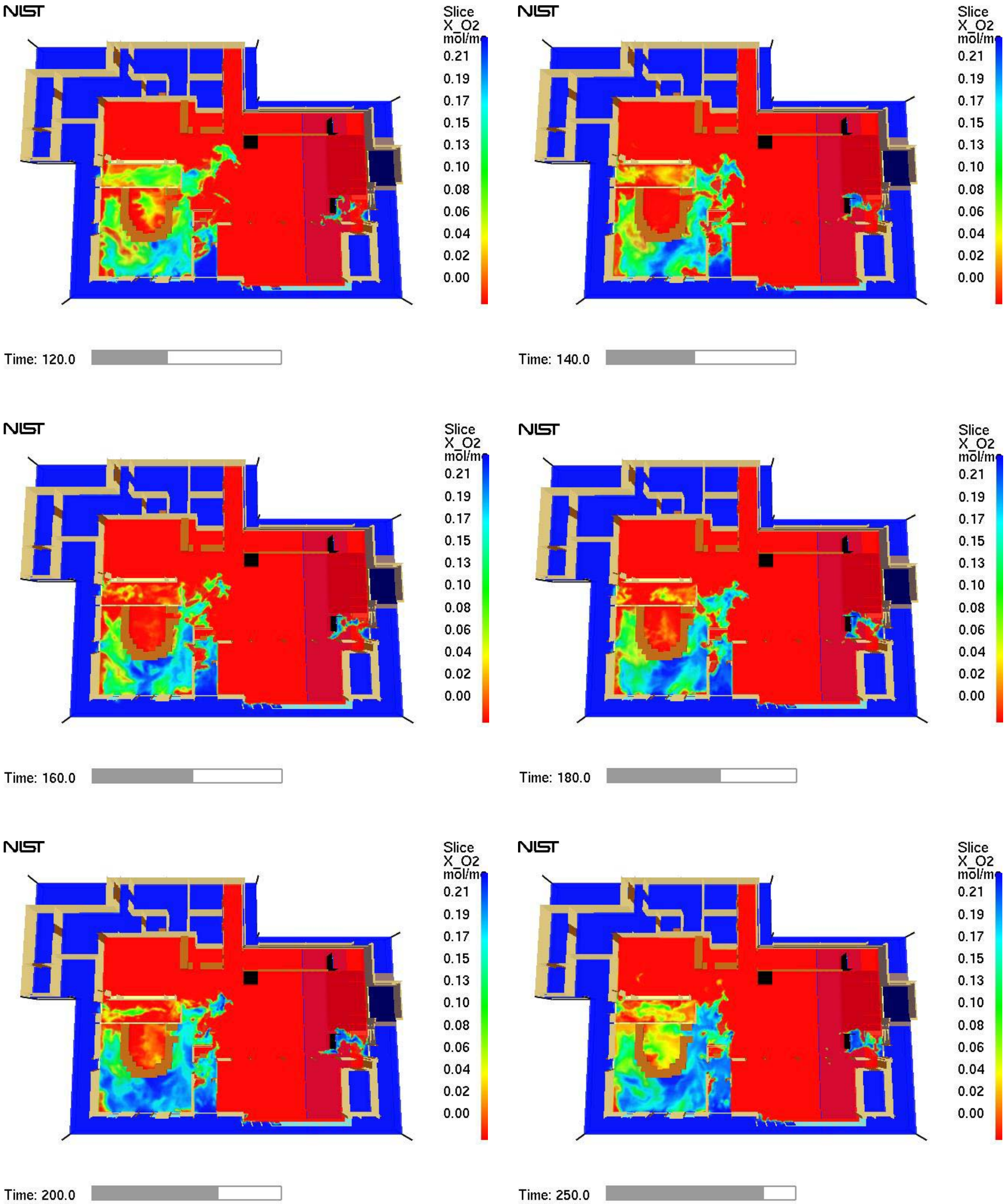


Figure 5-62b Oxygen volume fractions at 0.6 m (2 ft) above the floor, 120 seconds to 250 seconds

5.3.4 Simulation of full nightclub equipped with sprinklers

Another simulation of the full night club was completed in order to examine the effects that sprinklers may have had on the fire and the environment. The input from the FDS incident simulation was combined with the sprinkler input from the FDS sprinklered full-scale mock-up simulation. Five sprinklers were placed in the simulation. One was located in the center of the alcove and the other four were placed using 3.6 m (12 ft) spacing. The west sprinklers were 1.8 m (6 ft) north and 1.8 m (6 ft) south of the alcove sprinkler and 1.8 m (6 ft) east of the platform wall. The east sprinklers were also 1.8 m (6 ft) north and 1.8 m (6 ft) south of the alcove sprinkler and 12 ft east of the west sprinklers.

The sprinkler activation times from the sprinklered FDS simulation are given in Table 5-7. The sprinklers used in the FDS simulation are identical to those used in the full-scale mock-up FDS simulation. The properties of each sprinkler can be found in Table 5-2.

Table 5-7. FDS Predicted Sprinkler Activation Times

Sprinkler Location	FDS Sprinkler Activation Times (seconds)
Southwest	20
Northwest	16
Alcove	29
Southeast	Did Not Activate
Northeast	Did Not Activate

(i) Visualization

Figures 5-63a and 5-63b are rendered from Smokeview to examine the flame and smoke spread and the effect of the sprinklers. The images begin at ignition or t = 0 seconds and continue until 100 seconds after ignition. The first image in Figure 5-63a shows the two sprinklers over the platform area and the two sprinklers over the dance floor as small red dots along the ceiling. The larger red areas on the platform walls represent the location of the ignition burners. The sprinkler located on the ceiling of the alcove is hidden from view. The second image rendered at 20 seconds shows smoke being pushed away at the first sprinkler, which activated at 16 seconds after ignition. By 30 seconds after ignition, three of the sprinklers had been activated. This caused some of the smoke to be pushed down to the floor. The two sprinklers over the dance floor area did not activate during the simulation. Figure 5-63b has images from 70 seconds to 150 seconds after ignition. During this period the fire was significantly suppressed. The series of images show the smoke disbursing. The fire was extinguished fully at approximately 114 seconds. The smoke continued to spread and is diluted by fresh air entering the area.

Figure 5-64 provides another means of looking at the simulation. This image, rendered at 2 seconds after the first sprinkler activated, includes the visualization of the sprinkler droplets but does not include the visualization of the smoke. Notice that the activated sprinkler has changed color from red to green.

Figure 5-63a. Simulation of nightclub with sprinklers, 0 seconds to 60 seconds

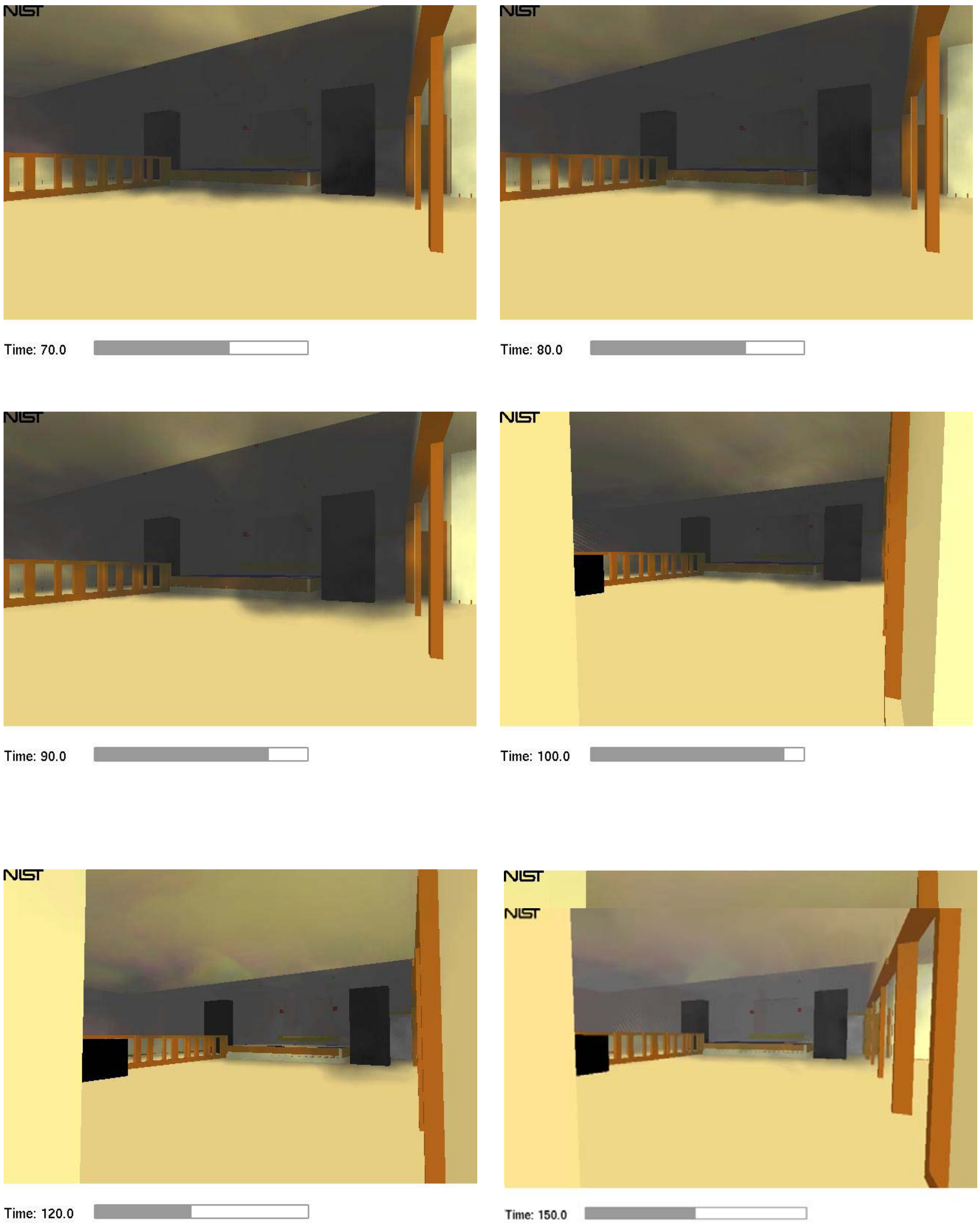


Figure 5-63b. Simulation of nightclub with sprinklers, 70 seconds to 150 seconds

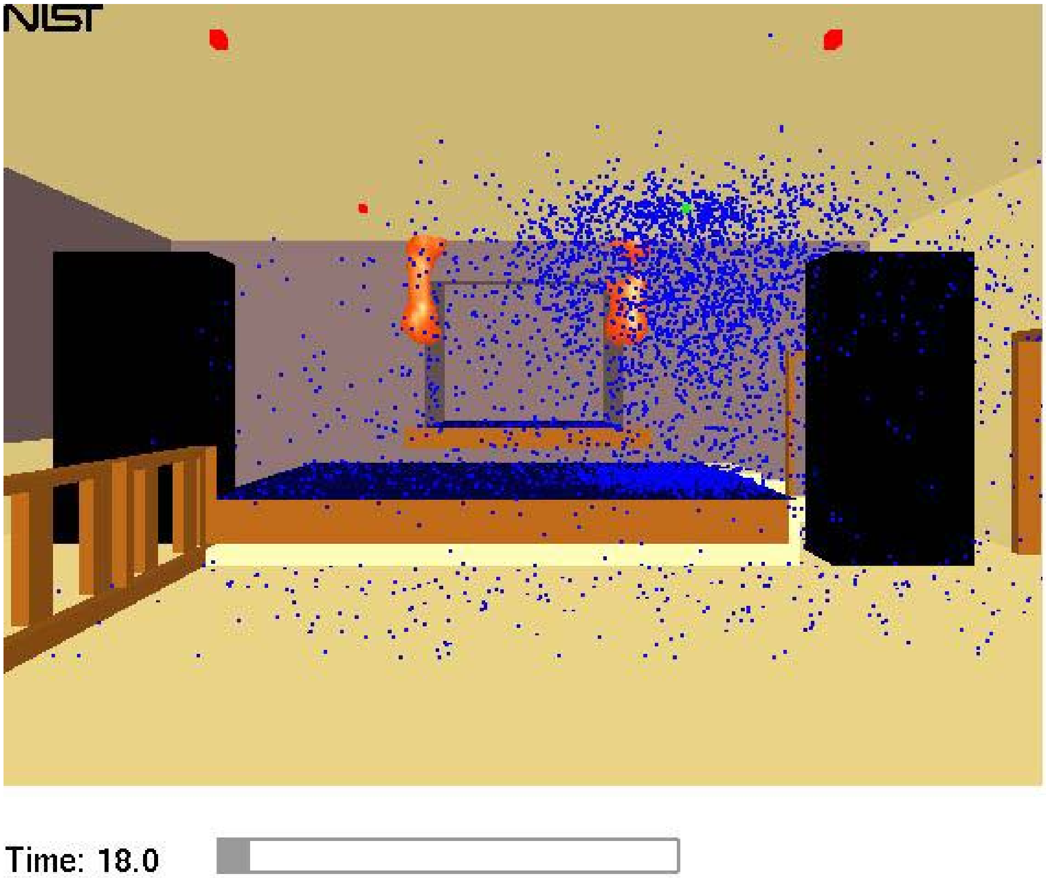


Figure 5-64. Simulation of northwest sprinkler activation 18 seconds after ignition, showing water flow with smoke "turned off."

(ii) Numerical Output

In this section, predictions of heat release rate, temperature, and oxygen volume fraction from the FDS sprinklered incident simulation are presented and compared to the non-sprinklered simulation and tenability criteria.

Figure 5-65 shows the FDS predicted heat release rate for the sprinklered simulation. The heat release rate reached its maximum of approximately 220 kW at 20 seconds. This heat release rate quickly declined as the three sprinklers activated and suppressed the fire.

Isothermal plots are shown in Figures 5-66a and 5-66b to assess the tenability conditions based on temperatures that were predicted during the simulation of the fire. The figures show horizontal isothermal images 1.5 m (5 ft) above the floor from the time of ignition (t = 0) to 100 seconds in 10 second intervals, and an image at 150 seconds. Due to the rapid activation of the sprinklers (three sprinklers were operating by 30 seconds after ignition), the temperatures at the 1.5 m (5 ft) level remain well below the temperature tenability threshold of 120 ºC (248 ºF) [6].

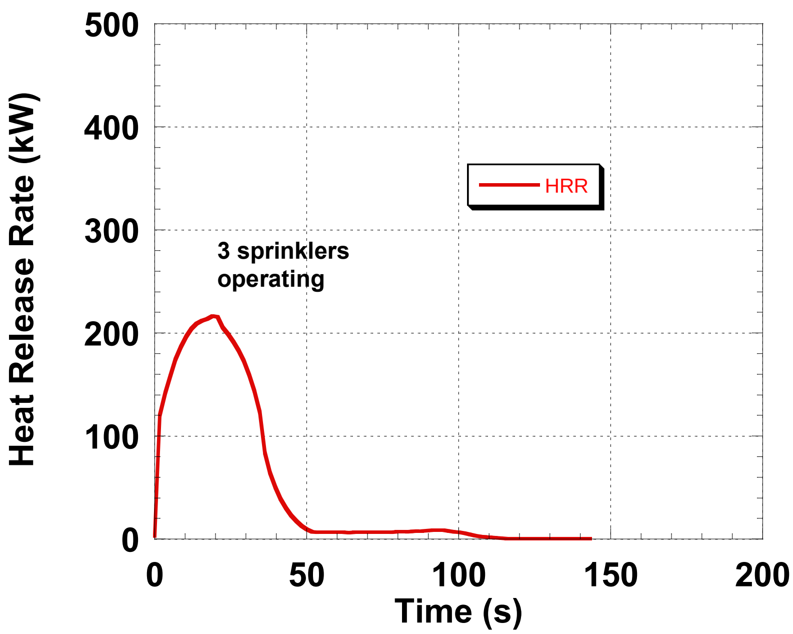


Figure 5-65. FDS predicted heat release rate for the sprinklered case.

The comparison between the temperatures 1.5 m (5 ft) above the floor in the non-sprinklered simulation (Figs. 5-55a and 5-55b) and in the sprinklered configuration (Figs. 5-66a and 5-66b) show dramatically different thermal conditions. (Note the large difference in color scales.) During the non-sprinklered simulation temperatures exceeded 1000 ºC (1830 ºF) in the platform and dance floor areas, and in the main bar room they exceeded 500 ºC (930 ºF) within 100 seconds. In the sprinklered simulation, the temperature exceeds 25 ^{o}C at head height only near the platform; following sprinkler activation around 20 seconds, the thermal environment remains close to ambient up until the time the fire is fully extinguished at 120 seconds.

Given the limited fire spread and the resulting tenable gas temperatures, the heat flux tenability criteria was never exceeded in the sprinklered case.

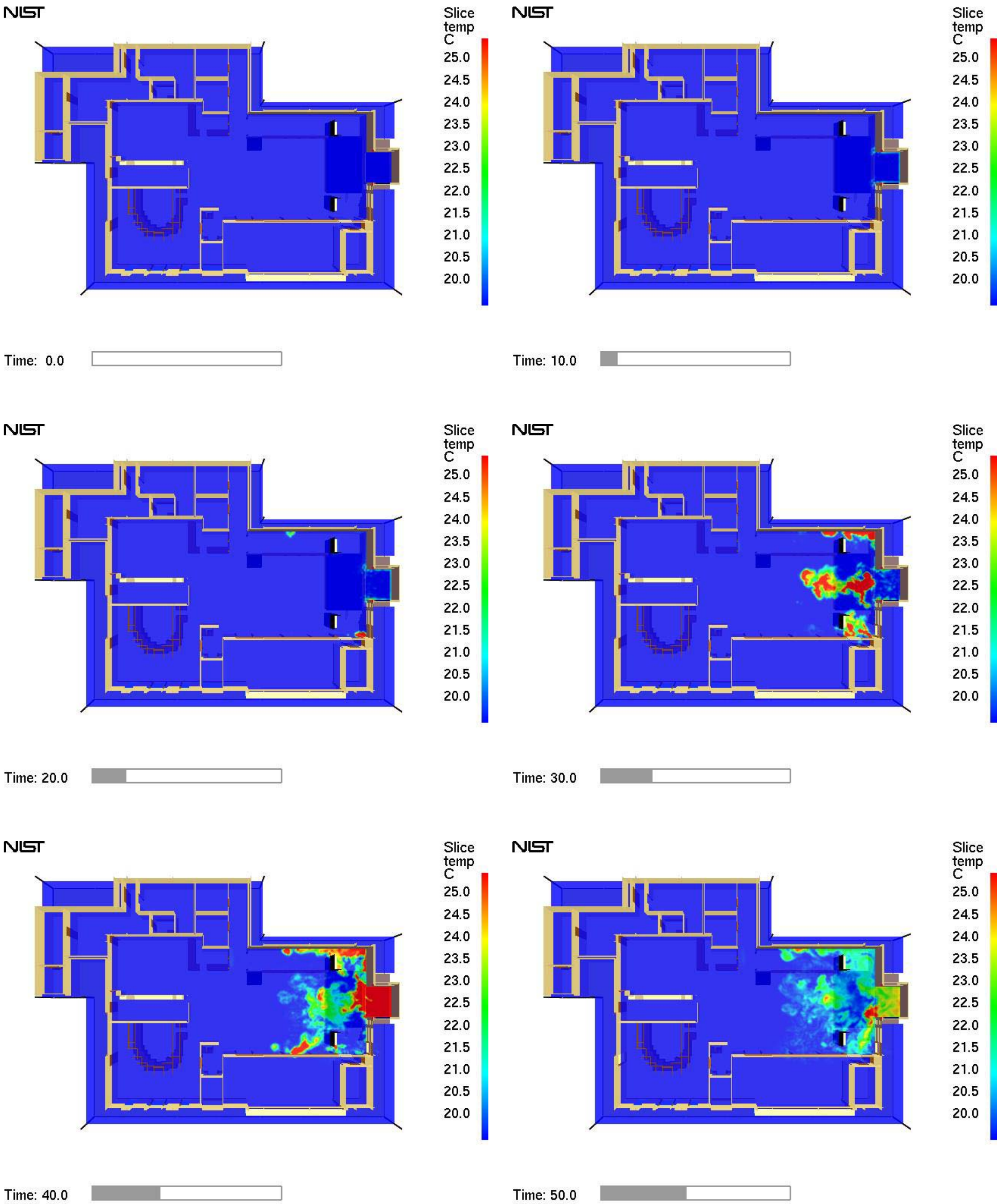


Figure 5-66a. Temperatures at 1.5 m (5 ft) above the floor, 0 seconds to 50 seconds

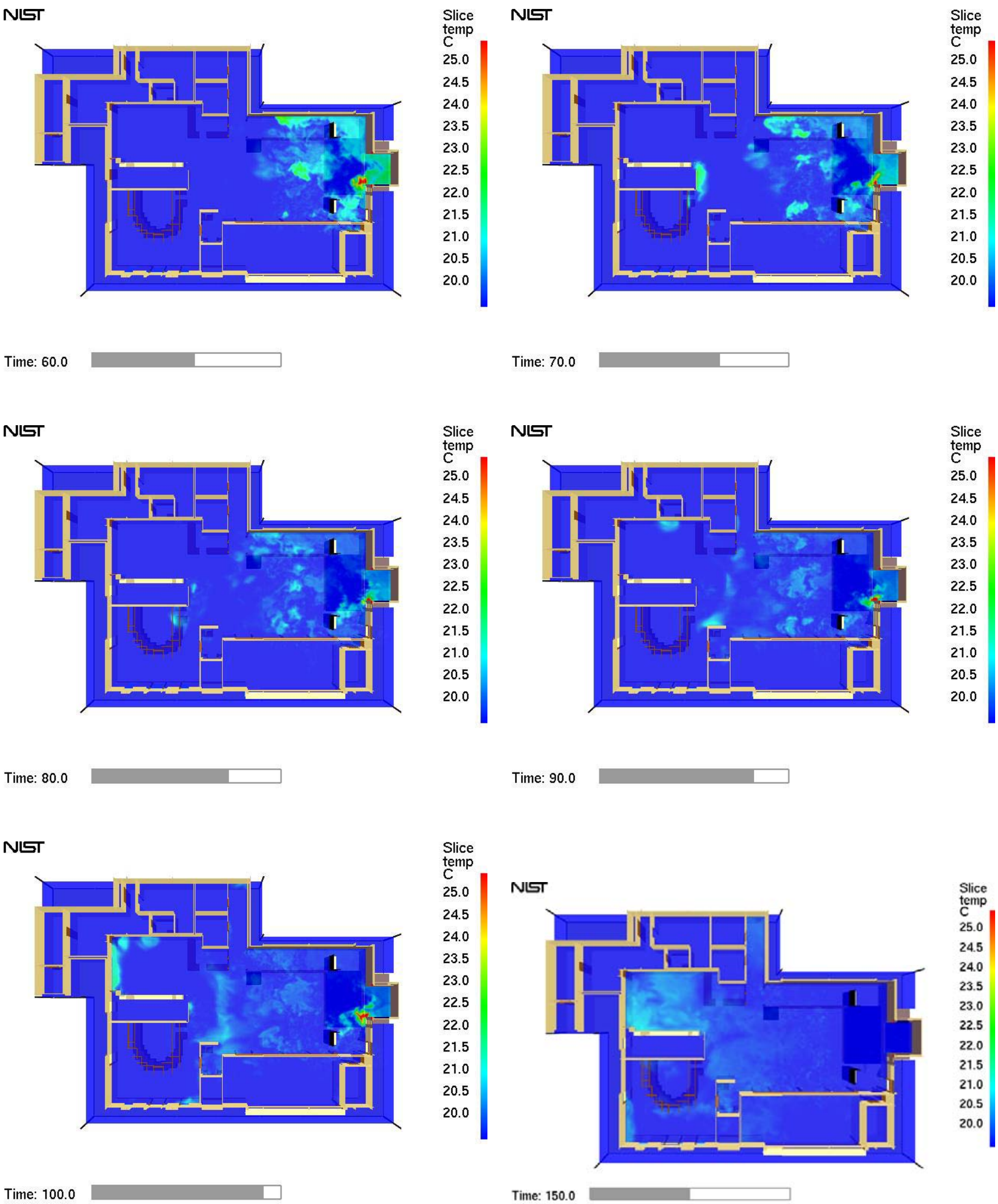


Figure 5-66b. Temperatures at 1.5 m (5 ft) above the floor, 60 seconds to 150 seconds

(iii) Oxygen

Oxygen volume fractions were also examined in the sprinklered simulation to assess the tenability conditions that existed during the evolution of the fire. Horizontal slices were taken at the 1.5 m (5 ft) level with the roof removed to examine the structure as a whole. This analysis will utilize a volume fraction of 0.12 as the oxygen tenability threshold [6]. Based on that oxygen limit, Figures 5-67a through 5-67c demonstrate that the atmosphere remained tenable during the entire duration of the simulation. In contrast, the non-sprinklered simulation predicted oxygen levels below 0.12 at the 1.5 m (5 ft) elevation throughout the building at 100 seconds after ignition and then continuing at untenable concentrations during the remainder of the simulation.

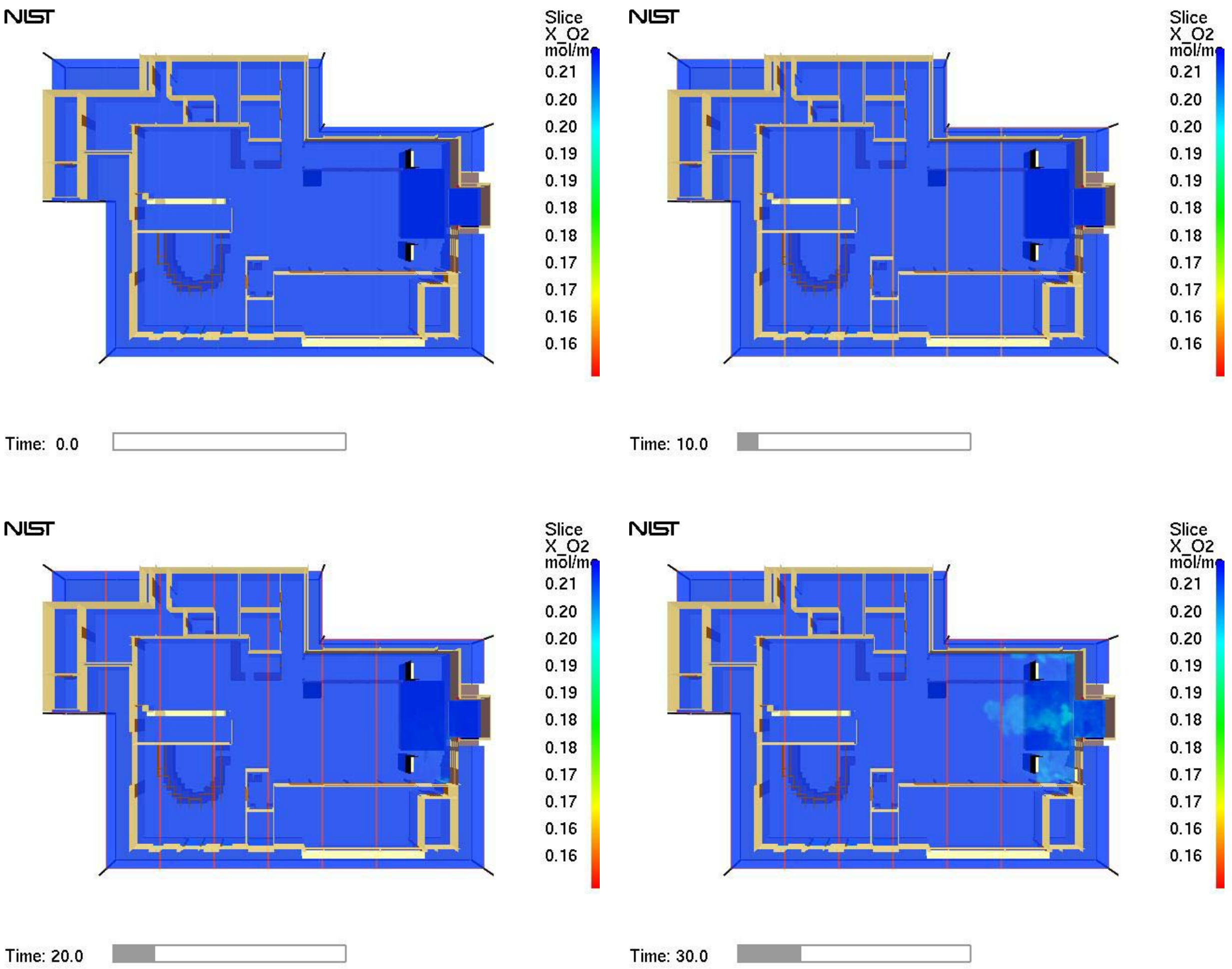


Figure 5.67a. Oxygen volume fractions at 1.5 m (5 ft) above the floor, 0 seconds to 30 seconds

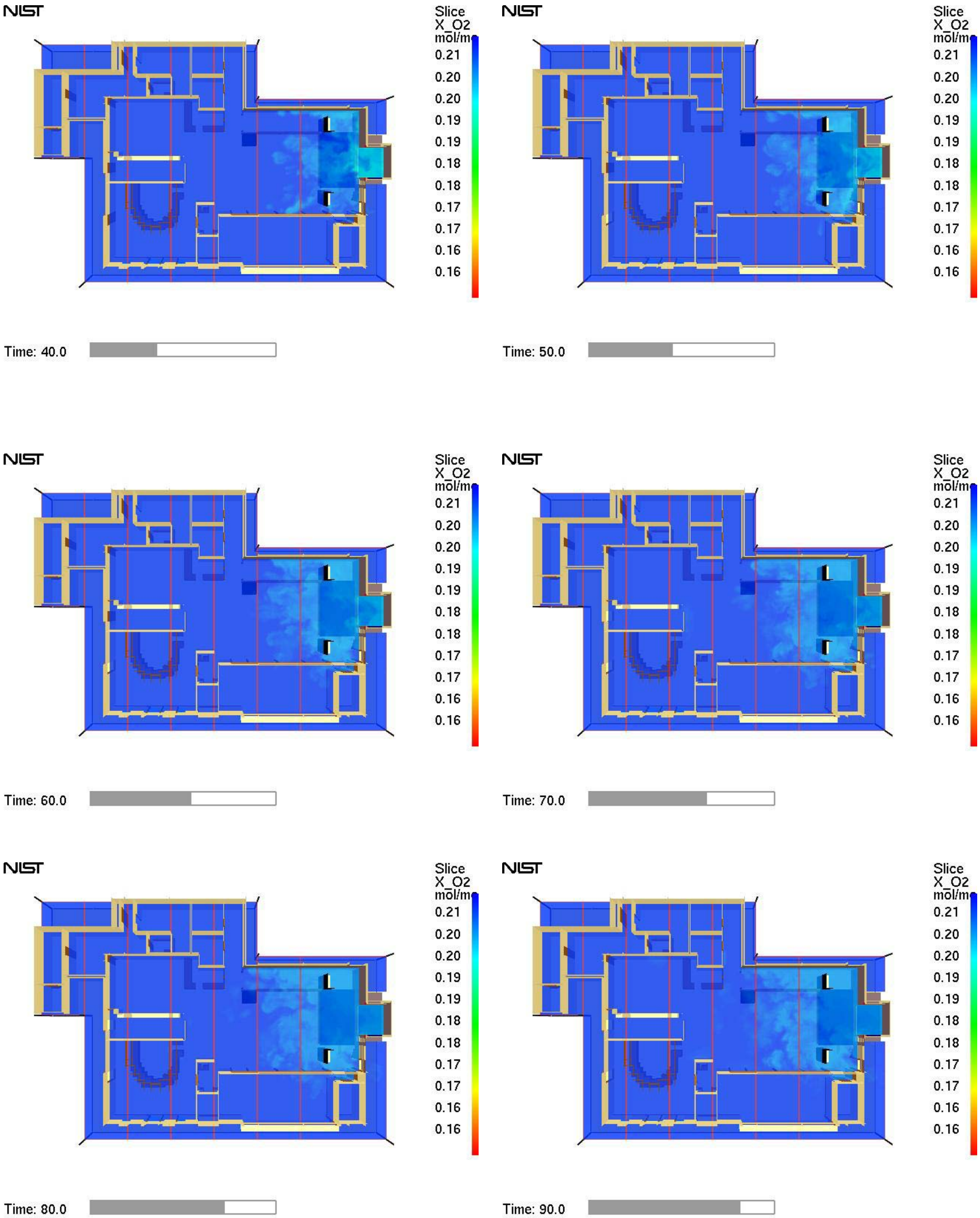


Figure 5.67b. Oxygen volume fractions at 1.5 m (5 ft) above the floor, 40 seconds to 90 seconds

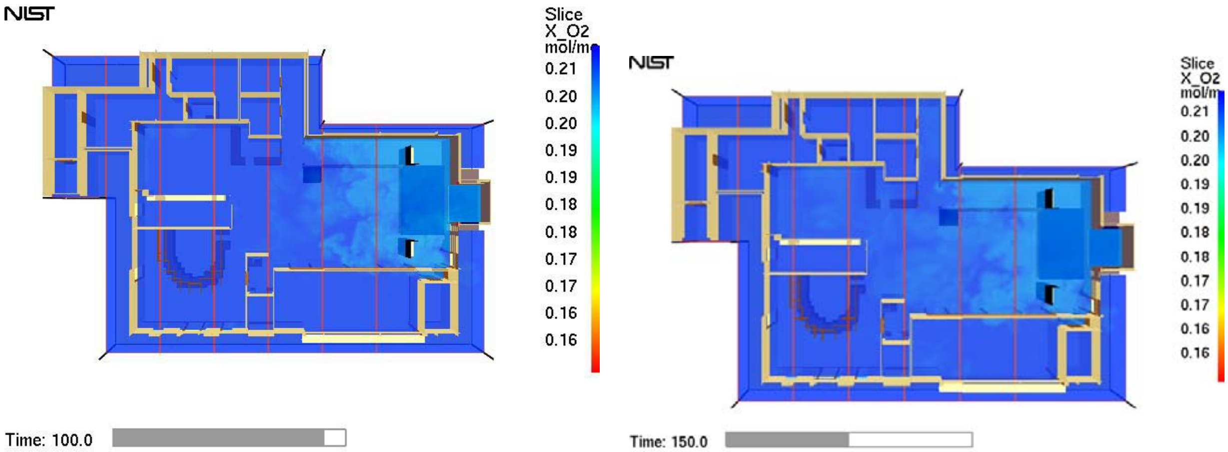


Figure 5-67c. Oxygen volume fractions at 1.5 m (5 ft) above the floor, 100 and 150 seconds

5.4 SUMMARY

Images from the WPRI video were utilized to develop model input to establish the location of the different interior finishes within The Station nightclub as well as used as a general resource for confirming the physical arrangement of the nightclub. The simulation was run for 300 seconds to examine the time period from ignition to the approximate time of flames throughout most of the nightclub as recorded by WPRI. The computation included simulated fire and smoke spread, and potential temperatures, heat flux and oxygen concentrations that may have existed in the actual incident. Each of these parameters were compared to published tenability criteria.

Results from some of the bench-scale experiments described in Chapter 4 and existing data were used to develop the input properties for the interior finish materials. The key parameters were the combustion properties of the foam/plywood wall: ignition temperature, heat of vaporization, and maximum burning rate. The results from the cone calorimeter tests of the polyurethane foam were not used directly in the simulation because of the composite nature of the foam-plus-plywood fuel on the wall and the limitations in grid resolution created by the sheer number of computational cells (of the order of 3 million) required to simulate the entire nightclub. As a consequence, the differences in heat release rate of the polyurethane foam measured by NIST and ATF had no impact on the simulation results.

The visual and numerical comparisons between the experiments and the FDS simulations of the experiments demonstrated reasonable agreement. The visual comparisons indicated a lag in fire development in the simulation relative to the experiments, but once the simulated fire grew large enough the growth rate and smoke development were consistent with the experiments. The temperature, heat flux, and the oxygen concentration comparisons show reasonable agreement between the experiments and the model in terms of both trends and range.

To gauge the accuracy of the full nightclub simulation results, they were compared with the WPRI video record of the incident and the map of victim locations. The FDS simulation predicted rapid fire growth due to the burning of the convoluted polyurethane foam. The simulation is consistent with the video record during the early stages of fire development. The conditions in the actual nightclub transitioned from a fire within a compartment to a fully-involved wood structure fire burning in void spaces, the attic area, structural elements, and roofing materials. In the computer simulation, such regions and materials were not included, which led to a diminishing of the fire after 250 seconds as the fuel was consumed.

According to the computer predictions, many of the occupants had less than 90 seconds after ignition to exit the structure. The quickly spreading fire and rapid production of smoke led to high temperatures and low oxygen levels throughout most of the simulated nightclub. The exceptions were a few areas near the open windows of the main bar room and the open doorway to the main entry foyer. In these areas air from outside the structure was being drawn in providing a more tenable environment and more time for escape.

The effects of an automatic sprinkler system on a fire were modeled to a useful degree by FDS and visualized with Smokeview. Both the experiment and the FDS simulation demonstrate that the sprinklers would prevent flashover and considerably mitigate the hazard from the fire in the test enclosure. However, the degree to which the fire is controlled is different between the experiment and the model. The simulation has more flame spread along the edges of the alcove ceiling after activation of the sprinklers. While the ability of FDS to predict fire suppression is simplified and cannot capture all of the physics involved in the process, FDS is able to predict the trends in reasonable agreement with the measured temperatures, heat fluxes and oxygen volume fractions.

In the simulation of the full nightclub equipped with sprinklers, examination of the predicted temperature and the oxygen volume fractions shows tenable conditions would have existed over the duration of the simulation (300 seconds), as the fire was fully extinguished approximately 114 seconds after ignition.

5.5 REFERENCES FOR CHAPTER 5

1. McGrattan, Kevin; Forney, Glenn; "Fire Dynamics Simulator (Version 4) – User's Guide," National Institute of Standards and Technology, Gaithersburg, MD, NIST SP 1019, September 2004.

2. Forney, G. P. and McGrattan,K.B., "User's Guide for Smokeview Version 4 - A Tool for Visualizing Fire Dynamics Simulation Data," NIST SP 1017, National Institute of Standards and Technology, Gaithersburg, MD, August 2004.

3. McGrattan, K., ed., "Fire Dynamics Simulator (Version 4), Technical Reference Guide," NIST SP 1018, National Institute of Standards and Technology, Gaithersburg, MD, September 2004.

4. Heitaniemi, J., Hostikka, S., and Vaari, J. FDS Simulation of Fire Spread – Comparison of Model Results with Experimental Data. Technical Report VTT Working Paper 4, VTT Building and Transport, Espoo, Finland, 2004.

5.. Purser, D.A., "Toxicity Assessment of Combustion Products." *SFPE Handbook of Fire Protection Engineering, 3rd ed.* DiNenno, P.J., et. al. (eds). NFPA Quincy, MA, 2002.

6. Madrzykowski, D., and Vettori, R.L., "A Sprinkler Fire Suppression Algorithm," *Journal of Fire Protection Engineering, Vol. 4*, No. 4, 1992, pp 151-164.

Chapter 6
ANALYSIS OF BUILDING EGRESS

6.1 INTRODUCTION

Chapter 6 documents, to the extent possible, life safety egress features present in the building at the time of the fire on Feb. 20, 2003. A summary of previous incidents in which a significant number of lives have been lost is provided in Appendix C, as well as emergency evacuations that can be classified as successful.

A contract was let to Ove Arup & Partners Massachusetts, Inc. to help document the egress process and life safety features in the building. This chapter is based upon portions of their final report [1], although any conclusions and findings that are presented are solely those of NIST.

The analysis and observations presented depend primarily on the following sources:

- *Providence Journal* – all pertinent published documents;
- *Boston Globe* – all pertinent published documents;
- Town of West Warwick, RI, Building Department – public information on file at the Office of the Town Clerk;
- Town of West Warwick, RI, Fire Department – public information on file at the Office of the Town Clerk;
- National Fire Protection Association (NFPA) – published fire investigations, and historical Life Safety Codes, code handbooks and commentaries;
- International Code Council (ICC) – historical building codes and code commentaries; and
- Rhode Island Attorney General's Office – public information available regarding the indictments.

Additional information was provided by individuals directly to NIST via email, mail, and telephone calls in response to an appeal to the public.

6.2 ANALYSIS OF EVIDENCE

Chapter 2 of this report provides a timeline for the evacuation based upon the WPRI-TV video. Additional photographic records, documents, and witness statements have been analyzed to gain a more complete picture of the egress process and associated activities.

6.2.1 Lighting

While the camera operator was evacuating, the fluorescent "black lights" mounted on the ceiling of the club remain on, as do various other lights that are visible on the video. Thus, main power within the club was still on when the camera reached the exterior. The video did not provide evidence as to when the lights inside the club went out. This information would have aided in coordinating some of the eyewitness statements provided later in Chapter 6.

Lights mounted on the eaves outside of the building were seen to be illuminated throughout the duration of the video up until 0:12:36 video time (0:06:14 fire time). The video did not depict these as illuminated after 0:12:36 video time (0:06:14 fire time). It is not clear if the circuit powering these lights turned off, or if individual fixtures turned off as a direct result of the fire in their vicinity.

6.2.2 Occupant Tracking

A great deal of analysis was carried out to attempt to track occupants as they evacuated the building. The goal was to determine if specific portions of the crowd were able to escape more readily than others and to gain insight as to the pile-up at the front door. The main sources for locating occupants within the building for this analysis were the WPRI video footage panning across the crowd facing the platform, video footage taken while the camera operator evacuated the facility, and video of occupants escaping through windows.

Efforts were made to track individuals from their location in the club when the fire ignited until they had evacuated. One male occupant, shown facing the camera in Figure 6-1, was tracked through evacuation. The time of this still frame is 0:06:51 video time (0:00:29 fire time). The occupant's face has been blurred in the figures below in order to preserve his anonymity; his facial features were not critical for the identification analysis.

After the ignition of the fire, the camera operator began moving towards the main exit before most other occupants did. The camera passed the occupant shown in Figure 6-1 before this individual had begun to evacuate, and he can be seen still facing the platform. At 29 seconds after the ignition of the fire, this individual was seen to turn and to begin moving towards the door. At this point, the camera was approximately two rows of people behind this man (between him and the main exit). This occupant can be seen reaching and crossing the main exit at 0:07:31 video time (0:01:09 fire time), 39 seconds later, in Figure 6-2.

It appears that whether an occupant choosing to exit through the main exit was able to escape or not depended on a combination of two factors: (1) when the occupant decided to begin to evacuate, and (2) where the occupant was located when he/she decided to evacuate. Based on analysis of the video, it appears that the camera operator was located approximately three to six rows back from the platform, chose to evacuate 18 seconds after the ignition of the fire, and was able to exit safely 53 seconds later. The male occupant discussed above was located significantly farther away from the platform (given that the camera operator was seen to pass him in the video), but his evacuation decision was delayed until 29 seconds after the ignition. Because he was farther from the platform and closer to the main exit, he was able to escape safely 39 seconds after he began to evacuate. These observations indicate that generalizations regarding the success of peoples' evacuation attempts cannot be made based purely on either their time to commence evacuation or their location at the beginning of their evacuation efforts. These two factors must be considered in concert.

Figure 6-1. Occupant at Start of Evacuation [2]

Figure 6-2. Occupant Exiting the Building [2]

A number of people were seen early in the video within the club and, after the ignition of the fire, at the exterior. However, based upon the limited video footage of the crowd facing the platform at the start of the concert and during the evacuation, attempting to track other occupants initially located further inside the club was unsuccessful. This is mainly due to the fact that many of the occupants exiting through the vestibule were not originally located in the view of the camera.

6.2.3 Gap in Front Door Egress

Although Figure 6-3 is of poor quality because the camera was in motion at the time, this video frame depicts a series of occupants evacuating through the main exit (note that the white surface at the lower right corner of the frame is one of the open exterior doors). The video time of this still frame is 0:07:33 (0:01:11 fire time). A male and a female are visible near the center of the frame; however, occupants cannot be seen immediately behind them. It would be expected that the occupant density ahead of these

Figure 6-3. Evacuating Occupants [2]

individuals would be similar to the occupant density behind them, given that much of the crowd in the video frames leading up to this frame is noted to be moving towards this door. The lack of occupants visible behind these individuals may suggest that some event occurred to slow or stop further egress. The camera angle shifts away from this door after 0:07:33 (0:01:11 fire time) and does not return to the front door until 0:08:04 (0:01:42 fire time). When the camera returns at 0:08:04 (0:01:42 fire time) a pile-up of occupants is visible. Details regarding how the pile-up occurred are not available from the WPRI-TV video; however, the gap in evacuating occupants during this 31-second period provides insight as to when the pile-up initiated.

6.2.4 Occupants Within Crowd-Crush

Attempts were made to relate individuals observed in the build-up at the main exit door to their locations at the start of the evacuation for the purpose of gaining additional information regarding how and when the pile-up occurred. Due to the limited views afforded by the WPRI video, most individuals could not be tracked. However, the male occupant shown in Figure 6-4 (attempting to evacuate) was also be seen in the video near the bottom of the pile-up of occupants shortly later. This occupant was identified by the color of his clothing, gold chain and hairstyle. It appears that this occupant waited at the sidelight of the interior vestibule door (see Figure 6-4), so it is unclear when he was able to join the stream of evacuating occupants. There appears to be one person below him in the pileup of people, implying that he was directly behind or close to the first occupants who tripped or otherwise fell to the ground. According to an interview conducted with the *Providence Journal* [23], the person who appeared to be this occupant

> "got into entry hall, it was chaotic with people coming from two directions into foyer, like a funnel. The smoke came in. [The occupant] started pushing and shoving his way to front; 'I could feel myself walking over' people; he could feel the heat on his back. Front doors were open. He was almost out when he tripped over someone who had fallen, and was laying perpendicular to front door. [The occupant] caught himself but as he was halfway up, people behind him fell on top of him. 30-35 people on him. Half his body was out of the door. His waist was where the door was. [He] felt himself being yanked back in. Grabbed bottom metal bar [outside the main entrance]... Finally, [on the] third or fourth pull, [the occupant's] other shoe popped off and he came sliding out."

Figure 6-4 Occupant Attempting to Evacuate [2]

Forty-one seconds elapsed between Figure 6-4 (0:01:02 fire time) and when the occupant was first seen near the bottom of the pile. Because the camera operator moved to the side of the building immediately upon exiting through the main exit, it is not known when the individual shown in these figures reached the door and fell to that position.

A second survivor of the crowd-crush gave the following account, as reported by the *Providence Journal* [41]:

> "As the mass followed the most direct route to the doors, [the survivor] detoured around a free-standing wall, and rejoined the river of people on the other side. The force of the crowd behind him was growing. He almost made it to the exit. He tried to stay upright by putting his hands on the person in front of him, but the pressure from behind overwhelmed him. He fell to the floor, two feet from the door. He rolled over to his side and curled up into the fetal position. 'People were piling up on top of me and I could feel the press of people,' he said…. He could breathe in cool, fresh air. He wasn't even hot. But he couldn't move. 'It felt like a football pileup,' he said…'I didn't want to move because I didn't want the pile to topple on me,' he said. 'I had air and I didn't feel any heat. I wasn't crushed or feeling crushed. I was in a relaxed state. I just felt calm and focused… I knew it was bad because we were stuck there, but I didn't know how bad,' he said. Finally, he felt the load above him lighten as firefighters searched for survivors. He saw a firefighter's boot and reached for it. The firefighter gripped him and wouldn't let go… It took a couple of tugs and [he] was freed."

6.2.5 Eyewitness Statements

Statements from approximately 30 individuals were reviewed for this analysis; those that are relevant to this project are summarized in the following sections. The accounts presented here are quoted from those compiled and published by the *Providence Journal, Boston Globe*, Associated Press, and various other sources. In addition, NIST provided an anonymous toll free hotline and an email address for voluntary input from the general public, which generated another 25 communications, none of which contradicted the published accounts.

(i) General accounts of the fire

The statements in this Section refer to the development of the fire and any occupant actions in response to the fire, other than evacuation.

Paul Vanner – Club Employee [3]

After the fire started on the sides of the stage, Vanner moved to the sound control booth towards the back of the concert space and picked up a fire extinguisher that was stored there: "I hit the pin, hit the trigger just to make sure I got something coming out of it. Then I'm heading for the stage. …a fire extinguisher has no chance against this. We've got to get out of here right now."

Vanner then exited via the kitchen exit, bringing several occupants along with him.

(Note: The *Providence Journal* reported that Kimberly Phillips, a club patron, recalls being hit on the leg by a fire extinguisher as a club employee carried it past her. It is not known if the employee was Vanner, but this confirms that at least one employee obtained a fire extinguisher and advanced towards the stage with it.)

Mario Giamei, Jr. – Former Club Employee [4]

Giamei described the actions of the club's manager in attempting to re-enter the building to help occupants: "He tried to run back in but he couldn't; he got knocked back with smoke."

Robert Riffe – Club Patron [5]

Riffe was attending the concert with a friend on the night of the fire: "I believe I heard someone screaming fire, and I recall someone in the band throw a cup of water on the flames, which of course did nothing."

Riffe also described the development of the fire that he observed as he evacuated: "Within about 5 seconds of us heading to the door, the flames were already about half way through the first room, and the black smoke had filled the entire club." It is expected that the "first room" Riffe refers to is the main event space where the stage is located.

(ii) General accounts of the evacuation

This section provides general eyewitness statements of the evacuation of The Station subsequent to the fire. The statements in this section do not refer to any specific portion of the building or its exit components.

Christopher Travis – Club Patron [6]

Travis was somewhere in the middle of the crowd when the fire started: "Nobody wanted to give up their spot. People felt like it would just be put out." Travis did not start to evacuate until after the lights in the club had gone out.

Andrea Stewart – Club Patron [7]

Stewart was in the crowd about ten rows back from the stage when the fire started: "It happened so fast. I saw the top of the stage catch on fire… People started to run. All of a sudden, bam! People were pushing me so hard." Stewart was knocked down and landed in the middle of a pile of people just before the lights in the club went out.

Mark Knott – West Warwick, RI, Police Officer [8]

Officer Knott was located near the club's main entrance door when people began to evacuate. He was pushed out of the door by the evacuating occupants, and subsequently radioed to the police dispatcher: "Stampede."

(iii) Accounts of evacuation via the main exit

Many of the occupants of The Station exited (or attempted to exit) through the main exit door at the front of the building. This Section provides several statements describing the evacuation at this location. The Providence Journal reported that 90 occupants exited through the main exit [9].

Robert Riffe – Club Patron [5]

Riffe was attending the concert with a friend on the night of the fire. Upon noticing the growing fire, he and his friend began to evacuate: "We both turned and headed for the main door, which…was the only door we knew of."

They made their way to the main door: "Just as we reached the point where the two hallways came to one, the thick black smoke just completely filled the room. I couldn't see, I couldn't breathe… As I got within inches from the front door way, I just came to a complete stop."

Once out of the building, Riffe attempted to assist others in evacuating: "I tried pulling on one man and could not get him to even budge the tiniest bit. I grabbed onto a woman who was trapped at the bottom, and could not get her to budge either."

He eventually left the area of the main entrance and observed the scene from the parking lot:

"…we could see people coming out of the windows…"

Raul Michael Vargas – Club Patron [10]

After deciding to evacuate the club, Vargas states that he encountered numerous people who were not moving and were still watching the stage: "I just picked people up as I went so I wouldn't trip over them."

It is unclear if by "picked people up" Vargas means that he got people to evacuate along with him, or if he encountered people who had fallen and lifted them from the floor.

(iv) Accounts of the evacuation via the exit by the main bar

An exit was provided in the main bar area of the club. Numerous eyewitness statements are available describing evacuation efforts in this area, as provided below. The *Providence Journal* reported that 46 occupants exited through the exit by the main bar [9].

Deborah Lemay – Club Patron [11]

Lemay had been in the club several times prior to the night of the fire, and knew of the exit door by the main bar. When the fire broke out, she decided to exit via this door. However, she claims to have experienced difficulty in opening this door. “There was no push bar and I’m looking for a handle and I remember there not being anything to open the door.”

This is contrary to the statements of Robin Petrarca and the video taken inside the club before the fire.

Robin Petrarca – Club Patron [12]

Petrarca, who was a frequent patron of The Station, was located in the main bar area of the club when the fire started. She and a number of her friends escaped through the exit door near the main bar: “Only because we know where the door is…”

Petrarca did not imply that her friend had any trouble in opening this door. Petrarca was pushed out of the door and fell down some stairs: “So many people were just pushing that bodies started coming down the stairs on top of me."

Rick Sanetti – Club Patron [11]

Sanetti was among the occupants who chose to exit through the door near the main bar area: “It was totally pitch black and you had about 20 of us pushing, and you’re in a state of panic pushing at that door, and it wouldn’t open. The door was functional, but whoever it was [trying to open it] was having a problem getting it open. The door was jammed with people. Had it opened, I assure you, had it opened easily, another 30 or 40 people would have gotten out that door.”

Jason Williams – Band Member of Opening Band *Trip* [13]

Upon noticing the fire, Williams, who had been near the main bar, moved towards the exit door in the main bar area. There, he encountered a crowd, and he attempted to calm people down: “I said something about Chicago, people getting trampled. People seemed to kind of relax for a second. Then, a flood of people came over the bar, flying toward me… the smoke came right behind them, just really fast.”

In the above quote, Williams is referring to a February 18, 2003 incident in a Chicago nightclub in which 21 people were killed and 55 were injured attempting to evacuate through a single door.

Just after the lights in the club went out, Williams decided to back away from the door where people were bunching up, and covered his mouth until he saw an opening to the outside: “As soon as I saw a little glimmer of light, I ran for the door and made it through.”

(v) Accounts of evacuation via the platform exit

A third exit door was located next to the performance platform in the club. The statements below describe evacuation efforts using this exit. The *Providence Journal* reported that 20 occupants exited through the platform exit [9].

Paul Vanner – Club Employee [3]

Vanner had warned band personnel against placing objects in the path to the door by the stage:

"…you've got to move this stuff. That's a fire exit."

Walter Castle – Club Patron [11]

Castle attempted to use the door by the stage early in the fire's development. His statement indicates that he was told by a club employee that the exit was for band members only: "Come to find out it was a band exit....I ended up throwing him out of the way."

(vi) Accounts of evacuation via the kitchen exit

While technically not an exit per code, a door to the exterior was available in the kitchen area of the club, and several occupants (mostly employees) utilized this door during the evacuation. The statement below describes this door. The *Providence Journal* reported that 12 occupants exited through the kitchen exit [9].

Mario Giamei, Jr. – Former Club Employee [11]

Giamei described the exit located near the club's kitchen: "It had an exit sign, but unless you're back in that area, you wouldn't know it. The way the club was shaped, it was out of the way."

(vii) Accounts of evacuation through windows

Numerous eyewitness statements suggest that a significant number of occupants escaped through the club's windows. The *Providence Journal* reported that 79 occupants exited through windows [9].

Anthony Bettencourt – West Warwick, RI, Police Officer [8]

Officer Bettencourt was pushed out of the main exit of the club by the initial rush of people. Once outside, he apparently heard people kicking at windows, and proceeded to break some of these windows with his baton. He and other officers helped numerous people, both conscious and unconscious, exit through the windows.

Eventually, the officers could no longer reach people immediately inside the windows, and began to call for occupants: "Come to the window."

According to Bettencourt, one occupant ran through one of the windows: "He opened up a nice hole."

Robert Riffe – Club Patron [5]

After being stopped at the main entrance by the build-up of people, he was able to struggle free from the pile and to get out of the building. He observed the scene from the parking lot.

"…we could see people coming out of the windows, and people scattered throughout the parking lot. Some…were all bloodied from jumping out of the windows and onto the pavement."

Paul Vanner – Club Employee [3]

After deciding against attempting to fight the fire with a fire extinguisher, Vanner evacuated through the kitchen door. He then moved around towards the front of the building.

"All of a sudden, I heard smash-smash-smash, people kicking out the windows. It was like black oozing smoke when they started kicking those windows out."

(viii) Accounts of when the lights failed

Several accounts suggest that the lighting failed after the pile-up occurred.

Andrea Stewart – Club Patron [7]

Stewart was in the crowd about ten rows back from the stage when the fire started.

Stewart was knocked down and landed in the middle of a pile of people just before the lights in the club went out.

Deborah Lemay – Club Patron [11]

Lemay had been in the club several times prior to the night of the fire, and knew of the exit door by the main bar. When the fire broke out, she decided to exit via this door.

"When the lights went off. I was almost at the door. I remember turning around and seeing the black smoke rolling in. Then I became engulfed in smoke."

6.2.6 Summary of Additional Evacuation Analysis Observations

The analyses of the WPRI video and the available eyewitness statements have generated numerous observations in addition to the fire and evacuation timeline presented above. These are summarized below.

- It is apparent that many people did not immediately move upon first noticing the flames. This may have occurred because people initially believed that it was "part of the show" or wished to maintain their locations within the crowd for the rest of the show. This may also have occurred because the occupants were apparently not instructed by the club's staff to begin evacuation. People appear to have initially felt that the fire would be controlled. These factors caused a significant delay in the evacuation of many occupants.
- Some of the occupants seem to have known of the existence of the side exit door near the main bar. The *Providence Journal* identified survivors of the February 20, 2003 fire at The Station [14]. According to this article, approximately 46 occupants used this exit. However, difficulty in opening this door, for unknown reasons, was reported by several survivors (but not all survivors that exited through this door reported difficulty). In the WPRI video, this door appears to have panic hardware and to swing in the direction of egress. Eyewitness statements confirm that occupants were able to evacuate through this door.
- Some occupants who used the side exit near the main bar reported falling down a series of stairs immediately after passing through the door. Video footage or photographs of the evacuation efforts at this location are not available; however, this door exits onto a landing with steps to grade.
- A small number of occupants (approximately 20 - mainly those associated with the band or the club, as reported by the *Providence Journal* [14] used the exit near the platform early in the fire. It is apparent from the WPRI video that this exit rapidly became impassable; the camera observed significant flames in the area of this door when the camera operator first made his way to the side of the building at 1 minute 25 seconds after the start of the fire. Thus, it is likely that smoke and

flames blocked this exit within 1 minute 25 seconds of the start of the fire. At 4 minutes 30 seconds after the start of the fire, dense smoke and flames could be seen down to the floor level just inside of the platform exit.

- Multiple survivors described the evacuation as "panicked" or likened it to a "stampede." [6-8].
- Many survivors indicated that they were not aware of any exit doors other than the main front door.
- Numerous occupants (approximately 79) exited the building through its windows. Many were assisted by individuals, including police officers, on the outside of the building.
- Some attempts were made at initiating manual extinguishment of the fire. One band member attempted to douse the flames with a bottle of water, while another ran for a fire extinguisher (but never actuated it). Based upon eyewitness statements and observations from the WPRI-TV video regarding the fire growth, manual extinguishment efforts when initiated were ineffective against the fire.

6.3 ESTIMATES OF OCCUPANT LOAD

Based upon the 2003 editions of the IBC and NFPA 5000 model building codes, the estimated permitted occupant load for a building similar to The Station in area and use varies (See Section 7.3.11), but is equal to 420 people when limited by egress from properly functioning doors at the main entrance, platform, and bar exits.

Several public documents from the Town of West Warwick were found that referred to occupant loads in The Station or its previous incarnations. One, dated Nov. 21, 1981 [16], was an Application for Variation under the Fire Safety Code to omit completely enclosing the boiler room, which identified an occupant load of 225 for the building as it was being used at the time. The West Warwick Fire Department, in a memorandum dated Dec. 30, 1999 [17], identified the occupant load as 253 occupants; however, an allowance was given to increase the occupancy to 317 by removing tables and chairs from three lounge areas and providing standing room only in those areas. No other distribution for the memorandum is indicated on the document. A third document was an unsigned memorandum on blank bond without letterhead from the West Warwick Fire Department, dated Mar. 2, 2000 [18], addressed to Chief Peter Brousseau. Again, no other distribution is shown. The memorandum identified the occupant load as 258 when tables and chairs were set up in the four designated seating areas; however, an allowance was given to increase the occupancy to 404 by removing all tables and chairs. The memorandum also stated that a uniformed firefighter should be on the premises if this higher occupancy were to be applied. No explanation has been obtained for why the memorandum was written, nor does NIST know if either of the memoranda was made available to the owners of the building.

Published articles were reviewed in an attempt to develop estimates of the number of occupants at The Station during the incident. The *Providence Journal* identified the names of 100 people who died as well as the names of the survivors of the Feb. 20, 2003 fire at The Station [14]. Survivors are listed by source of identification. According to the *Providence Journal*, 208 survivors were interviewed; of those interviewed, 59 were identified by other survivors, 46 were identified by lawyers, 10 were identified by relatives, 5 were identified by hospital staff and two photographers were taking pictures in the club. The *Providence Journal* lists ages, town of residence, and state of residence for 274 of these people, list a total 430 occupants in October 2003 [14], 432 in December 2003 [9], and 440 in Feb. 2004 [40]. Independent information was not available to confirm this total.

To the degree possible, the WPRI-TV video taken in The Station on the night of the incident [2] was used to provide an alternative estimate of the actual number of occupants within the club; however, several factors limited the accuracy and comprehensiveness of the count:

- A camera has a limited view, or "cone of vision." As the operator moved around, he was only able to capture occupants within the camera's view; and thus, in many cases additional occupants at the periphery of the camera's view were not recorded.
- A single sequence in which the camera pans in a full circle and thus shows the entirety of the club at a given time was not available. Thus, at any given time, the camera is only showing the occupants of one portion of the club, and the occupant load conditions in the rest of the club are unknown.
- The first part off the video was recorded over an unknown amount of time, and includes several "cuts" or stop points when the camera was turned off for an unknown portion of time. During such cuts, occupants were likely to have moved around the club, and new occupants likely entered.
- The dark conditions of the club through most of the evening created shadows in areas distant from the light of the camera. Occupants located in these shadows were generally not visible.

With the above limitations in mind, a series of still frames that provide a panning view of the club's performance assembly area were obtained from the WPRI-TV video. These frames are shown in sequence in Figures 6-5 through 6-8 as the camera pans from right to left. The occupants shown in these still frames were counted in an effort to derive an approximate occupant load for the area shown. Orange dots have been used to represent counted occupants. The yellow lines in these Figures represent the boundaries where the frames overlap. A total of 144 occupants can be seen in these four figures.

Figure 6-5. Occupant Load Count, Part1 – 45 Occupants

Figure 6-6. Occupant Load Count, Part 2 – 42 Occupants

Figure 6-7. Occupant Load Count, Part 3 – 37 Occupants

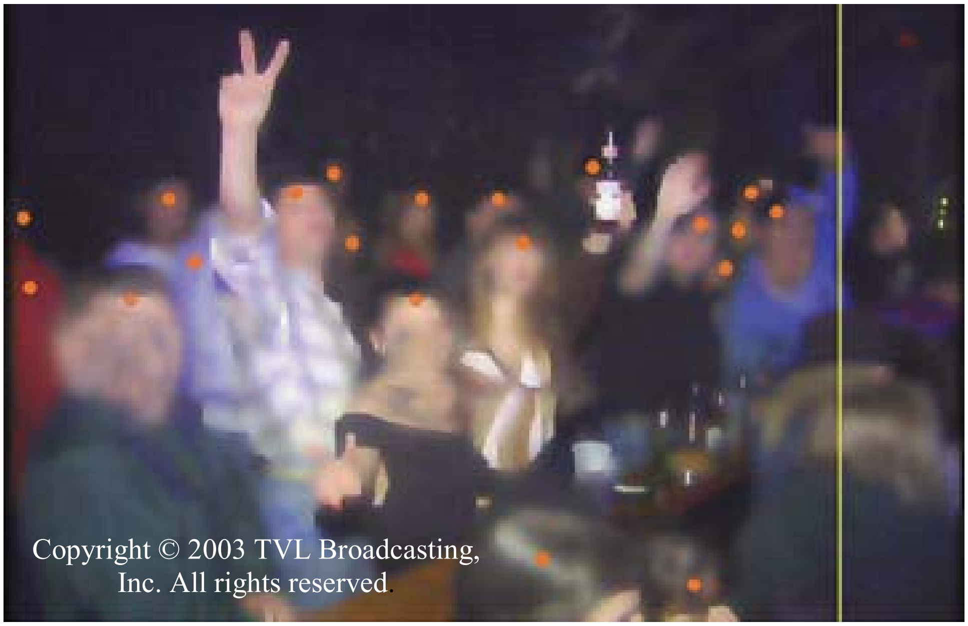


Figure 6-8. Occupant Load Count, Part 4 – 20 Occupants

It is not clear at what time in relation to the start of the concert this video sequence was recorded. If it was recorded well before the main musical act, then it is likely that many occupants were located outside of the main platform viewing area at this time (i.e., many occupants may have been near one of the bars, in the pool room, or in the restrooms). Conversely, if this sequence was recorded immediately prior to the start of the primary musical act, then it is likely that the majority of the club's occupants would have moved towards the platform and into the performance assembly area. For these reasons it is not possible to extrapolate to a total building occupant load from this analysis. However, these figures can be helpful in estimating possible ranges of the number of occupants that may have been within the main platform viewing area.

6.4 LIFE SAFETY FEATURES

Multiple data sources were reviewed to assist in determining the life safety features present at The Station at the time of the fire on Feb. 20, 2003. The following section documents the results of this effort. The information is divided into three categories:

- Public Documentation Evidence: This includes data from Fire Department Inspections, Fire Alarm Company Sketches and Reports, and other publicly available documentation.
- Photographic Evidence: This includes information obtained from a review of the digital photographs and scanned images received from NIST.
- Video Evidence: This includes information extracted from the WPRI video footage of the incident.

6.4.1 Floor Surfaces

It has been claimed that floor surfaces in The Station were uneven [22]. NIST has no independent information to confirm or contradict this claim.

6.4.2 Exit Doors

Egress through the main entrance to the building was limited by a single interior door (LSF 6 in Figure 6-10) not the double doors that could be seen from outside the building.

The West Warwick Fire Department Inspection Report dated Nov. 10, 2001, commented that the exit door near the platform cannot swing inward [24]. The building owner was instructed to call when ready for re-inspection. Note that these comments were checked and deemed "OK"; however, the re-inspection signature is blank.

In a West Warwick Fire Department Inspection Report dated Nov. 20, 2002 [25], the following comments were made:

- Platform exit door swings in the wrong direction;
- Panic hardware on platform door is broken.

The building owner was instructed to call when ready for re-inspection. These comments were checked and deemed "OK"; however, the re-inspection signature is blank.

6.4.3 Exit Signs

Numerous West Warwick Fire Department reports were issued to previous businesses on this site regarding the exit signs. In reports dated Sept. 25, 1993 [26], Nov. 17, 1994 [27], Oct. 2, 1995 [28], Sept. 25, 1996 [29], and Nov. 22, 1998 [30], the condition, arrangement, and operation of the exits signs were noted as "OK". These reports did not require re-inspection.

The West Warwick Fire Department Inspection Report dated Nov. 10, 2001 [24], commented that the exit sign near main entrance needs bulbs. The building owner was instructed to call when the building was ready for re-inspection. Note that this issue was checked and deemed "OK", although re-inspection signature on the report is blank.

The West Warwick Fire Department Inspection Report dated Nov. 20, 2002 commented that the exit signs were not working [25]. The building owner was again instructed to call when the building was ready for re-inspection. Note that these issues were checked and deemed "OK", although the re-inspection signature is blank on this report as well.

6.4.4 Emergency Lighting

The West Warwick Fire Department inspected the emergency lighting within the building under previous ownership on numerous occasions. In Inspection Reports dated Sept. 25, 1993 [26], Oct. 2, 1995 [28], Sept. 25, 1996 [29], and Nov. 22, 1998 [30], the condition and operation of the emergency lighting within the building were noted as "OK" and re-inspection was not called for.

In a West Warwick Fire Department Inspection Report dated Nov. 17, 1994, the kitchen emergency lighting was noted as not working. The owner was instructed to notify the Fire Department when the repairs were completed; note that the re-inspection signature is blank [27].

The West Warwick Fire Department Inspection Report dated Nov. 10, 2001, commented that the emergency lighting units at main entrance and at platform were not working [24]. The building owner was instructed to call when the building was ready for re-inspection. These issues were rechecked and deemed "OK", although the re-inspection signature on the report is blank.

6.4.5 Suppression

The West Warwick Fire Department carried out numerous inspections of the manual suppression equipment in businesses at this site. The Fire Department issued reports on Sept. 25, 1993 [26], Nov. 17, 1994 [27], Oct. 2, 1995 [28], Sept. 25, 1996 [29], and Nov. 22, 1998 [30], deeming the condition and location of the existing fire extinguishers "OK", and re-inspection was not required.

The West Warwick Fire Department Inspection Report dated Nov. 10, 2001, commented that the fire extinguishers must be hung [24]. The building owner was instructed to call when the fire extinguishers were ready for re-inspection. This issue was rechecked and deemed "OK", although the re-inspection signature on the report is blank.

6.4.6 Fire Alarm and Detection

(i) Fire alarm company information

An inspection report from RI-CONN Fire Systems, Inc. [31] verifies the testing of the following system components:

- four heat detectors in the kitchen and basement;
- two manual stations – one at the kitchen exit and one at the bar;
- the kitchen hood suppression system was also tested.

Fire alarm sketches prepared by New England Custom Alarms [32], indicate existing system devices and various device additions to upgrade the fire alarm system at The Station. This work was permitted on Mar.8, 2000; it appears that this work was completed.

The existing drawings located the following life safety devices:

- two heat detectors in the space between the Kitchen and the Employee Restroom Area;
- one heat detector in the Employee Restroom;
- an Ansul system in the kitchen (presumably protecting cooking appliances);
- one alarm horn near the kitchen door adjacent to the large bar;
- one alarm horn in the greenhouse near the pool tables;
- one alarm horn adjacent to the platform exit door;
- two heat detectors in the basement.

The upgrades included on the Mar. 6, 2000, drawings resulted in the following:

- a new Fire Alarm Control Panel inside the main entrance doors.
- one existing heat detector in the space between the kitchen and the employee restroom/prep area (one of the heat detectors was to be removed);

- one heat detector in the prep area (moved from the employee restroom);
- an existing Ansul system in the kitchen (presumably protecting cooking appliances);
- one new heat detector below the platform;
- one new heat detector above the platform;
- one new heat detector backstage;
- one existing alarm horn near the kitchen door adjacent to the large bar;
- one existing alarm horn in the greenhouse near the pool tables;
- one existing alarm horn adjacent to the platform exit door;
- one new alarm horn in the hallway to the restrooms.
- four new manual pull stations (inside front door, at platform door, at left side bar area door, and at light/sound control area);
- two existing heat detectors in the basement.

An NFPA 72 Inspection and Testing form [33] lists the following fire alarm system components:

- three manual stations;
- six heat detectors;
- one Ansul tie-in;
- four horns;
- five strobes;
- one speaker.

The device testing section of the same form [33] confirms that the following initiating and supervisory devices were inspected and tested:

- one heat detector in the Kitchen;
- one heat detector in the Prep Area;
- one heat detector in the Dining Area;
- one heat detector in the Employee Restroom;
- two heat detectors in the Basement;
- two pull stations (location is not specified);
- Ansul system was visually inspection and its operation was simulated.

6.4.7 Interior Finish

In letters dated May 22, 2003 [34] and May 23, 2003 [35], the West Warwick Fire Chief and the West Warwick Building Official, respectively, responded to the West Warwick Town Clerk regarding requests for permits or inspections from The Station for the use of decorative or acoustic materials. No information was found by either individual with regard to a request from The Station for permitting or inspection of decorative or acoustic material usage.

6.4.8 Identification of In-place Life Safety Features

Table 6-1 summarizes all identified life safety features within The Station prior to the fire. Refer to Figure 6-9 for the locations of these features within the building. Specific devices and features are shown

Table 6-1. Summary of Identified Life Safety Devices

Image ID	Description
LSF 1.	Main double doors with ramp and stairs. (Note that egress was limited by the single interior door (LSF 6), not the main double doors.)
LSF 2.	Exterior stairs from the left-side main bar area indicating location of exit door.
LSF 3.	Exterior stairs from the kitchen area indicating location of exit door.
LSF 4.	Exterior stairs from the platform area indicating the location of exit door.
LSF 5.	Site view indicating the location of the doorway from the main bar area to the ticket area.
LSF 6.	Door leading from the interior ticket area towards the outer vestibule.
LSF 7.	Exit door from the left side of the main bar area to the exterior concrete stairs. Panic hardware was provided on this door.
LSF 8.	Exit door adjacent to the platform to the exterior concrete stairs. Panic hardware was provided on this door. Note that it appears there was foam attached to this door and that there was an additional interior door that swung against the egress direction.
LSF 9.	Exit sign located near the rear bar; it appears to be pointing toward the kitchen exit door.
LSF 10.	Exit sign above the door that leads from the ticket area to the front vestibule.
LSF 11.	Exit sign above the platform door. Note that in this image the sign is clearly illuminated.
LSF 12.	Exit sign above the platform door on February 20, 2003. Note that in this image the sign does not appear to be illuminated. NOTE: This is a duplicate of LSF 12, but was included to show that the exit sign may not have always been illuminated.
LSF 13.	Two exit signs. One located in the main floor area with an arrow towards the ticket area and another above the ticket area doors leading to the front vestibule.
LSF 14.	Exit sign over the left side main bar area exit door.
LSF 15.	Exit sign located in the front vestibule above the main double exit doors. This location is based upon similar wall and ceiling features observed in the WPRI video.
LSF 16.	Emergency light located near the rear bar.
LSF 17.	Emergency light above and to the right of the platform exit door.
LSF 18.	Emergency light on the wall adjacent to the kitchen by the main bar facing into the main floor area.
LSF 19.	Emergency light above and to the right of the left side exit door from the main bar area.
LSF 20.	Fire extinguisher located behind the rear bar.
LSF 21.	Detector (heat) located above the lighting grid on the ceiling near the platform.
LSF 22.	Fire alarm strobe adjacent to the exit sign above the platform exit door.
LSF 23.	Fire alarm strobe on the ceiling to the left and in front of the platform.
LSF 24.	Fire alarm strobe on the wall adjacent to the exit sign in the main floor area pointing toward the ticket area.

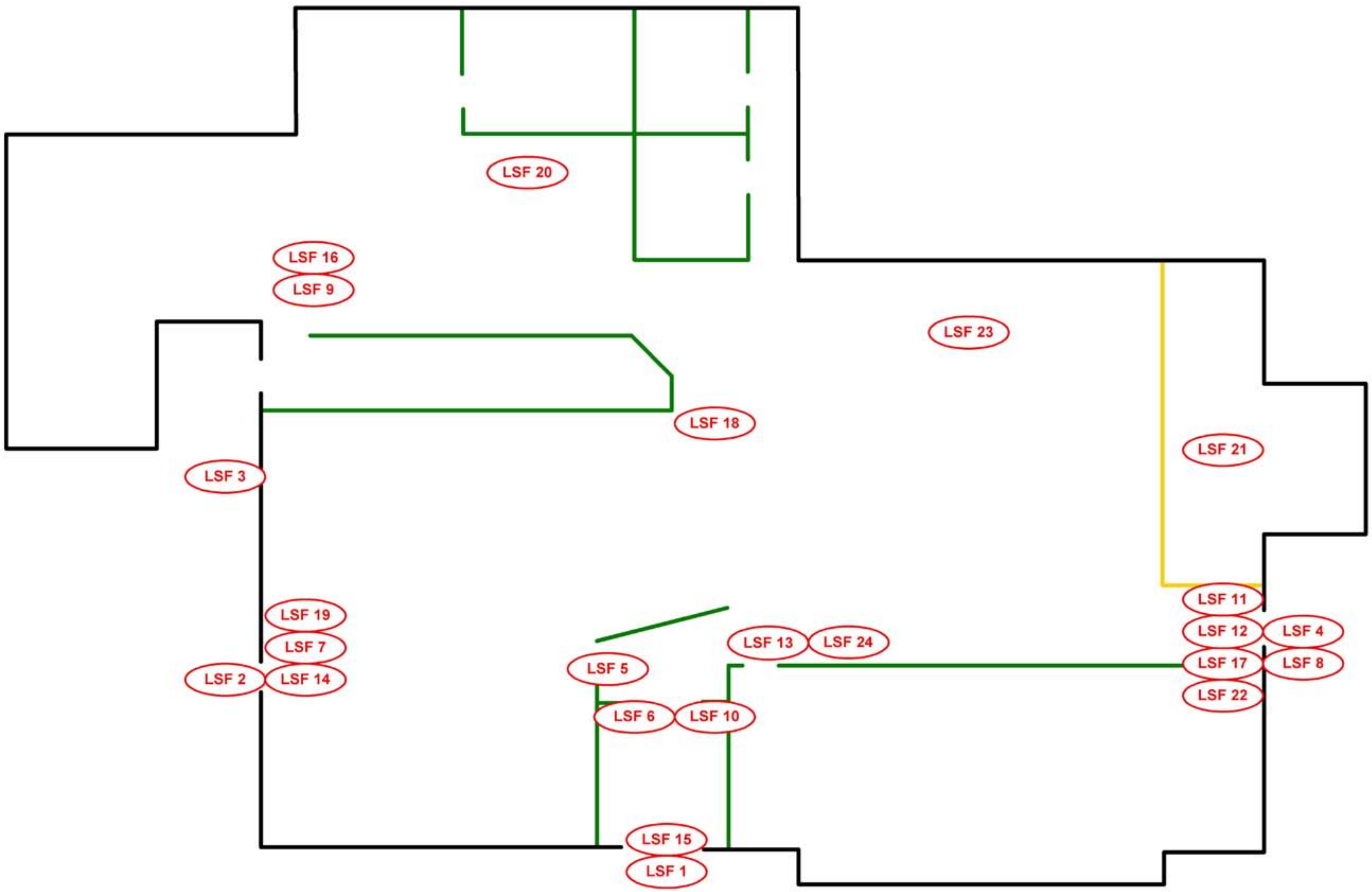


Figure 6-9. Locations of life safety features listed in Table 6-1.

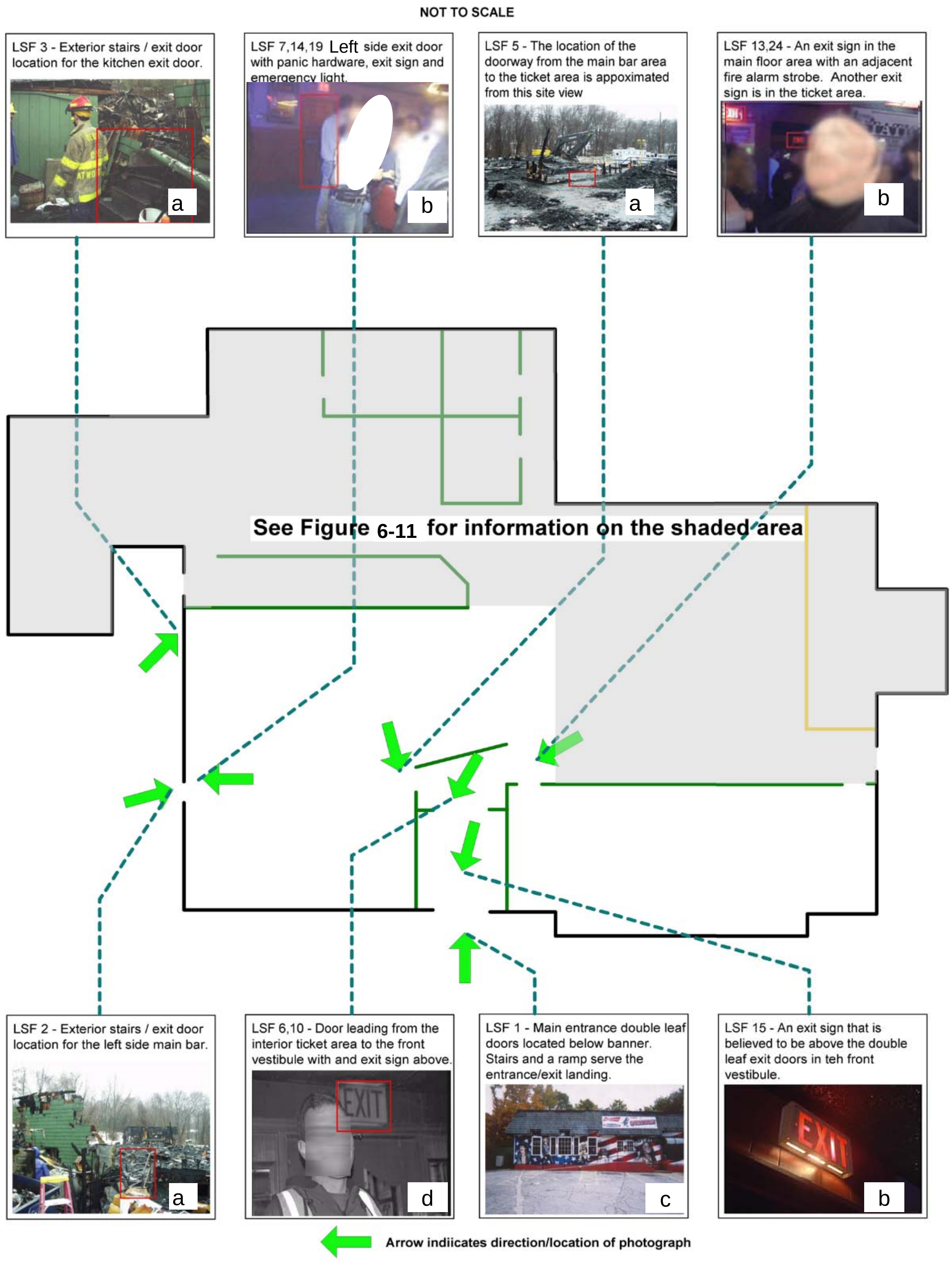


Figure 6-10. Summary of Life Safety Features – Part 1

a - photo by NIST; b - Copyright © 2003 TVL Broadcasting, Inc. All rights reserved.

c - photo with permission of A. Baldino, III; d - photo with permission of K. Corbin

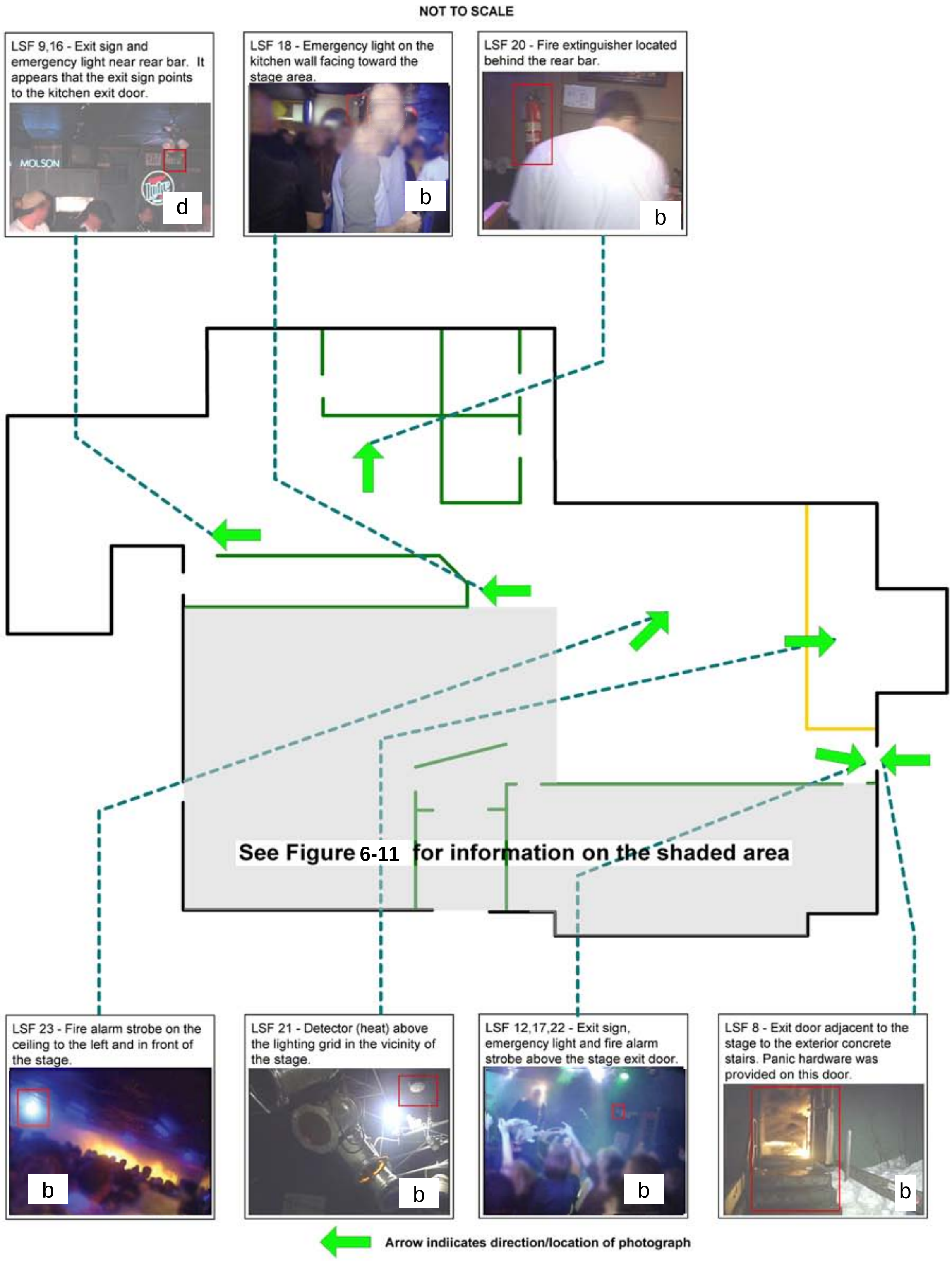


Figure 6-11. Summary of Life Safety Features – Part 2

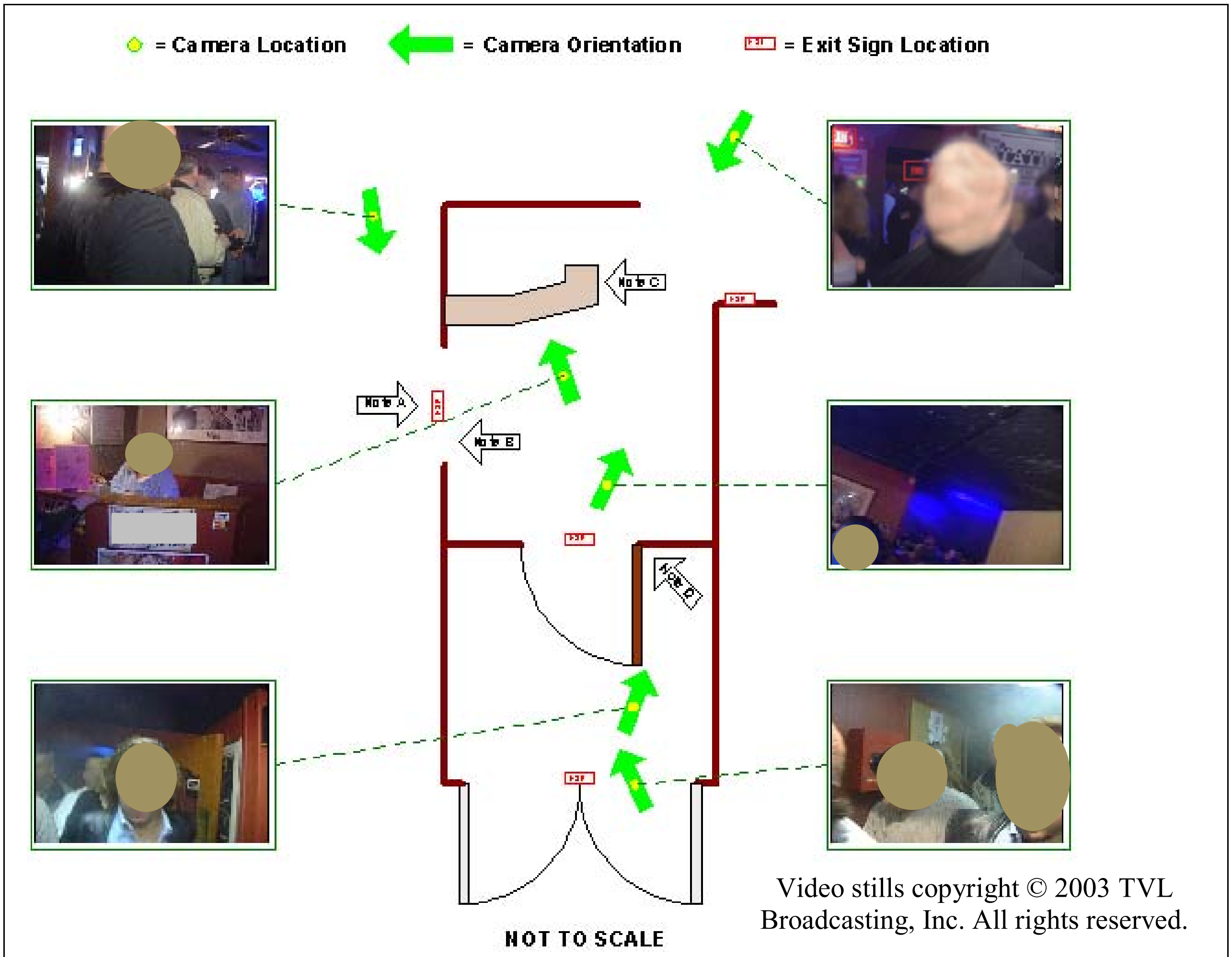


Figure 6-12. Detail of Main Exit Vestibule Area (Video frames copyright © 2003 TVL Broadcasting, Inc. All rights reserved)

Note A: Photograph or video evidence specifically showing the exact location of this exit sign above the secondary vestibule doorway was not available. However, the sign was observed in the WPRI video in a reflection in the mirror behind the main bar.

Note B: Photograph or video evidence specifically showing the exact location and size of the secondary vestibule doorway was not available. This representation is approximate based upon the video evidence available.

Note C: The dimensions of the ticket counter are not known. This representation is approximate based upon the video evidence available.

Note D: The dimensions of the associated sidelights are not known, although the orientation shown here is accurate based upon video evidence. Note that the single inner door provides the limit to egress, not the exterior double doors.

The uncertainty in the transverse position of the camera is estimated to be +/- 1 ft; it is not possible to estimate the uncertainty in position of the camera along the direction of the arrow since the zoom setting is unknown.

Figure 6-13. Exit Door Near Platform [2]

in Figures 6-10 and 6-11, taken from video stills or photographs taken at the site on Feb. 22, 2003. (Large format copies of the photos are included in Appendix B.) Additional details, such as manufacturer names, model numbers, or other descriptions of the devices were not available.

Several additional observations were made regarding the main exit vestibule area and the exit door near the platform. Figure 6-12 provides an approximate representation of the orientation and layout of the main exit vestibule area. It also shows the video evidence that was used to formulate this representation. The notes provided with this Figure give some additional observations related to this exit. Figure 6-13 shows the exit door located in the vicinity of the platform. Based upon this video still and other frames from this portion of the WPRI video, it appears that this exit included two doors:

- an exterior door, which swung outward, or with the direction of egress travel, and
- an interior door, which swung inward, or against the direction of egress travel.

The presence of the interior door is evident from the inward-swinging hinges seen on the doorframe. The edge of this door is visible as well. As can be seen in Figure 6-14 the exterior door was equipped with panic hardware. The hardware installed on the interior door is unclear. Additional examination of this figure reveals what appears to be adhesive on the inside of the exterior door.

6.5 LOCATION OF VICTIMS RECOVERED FROM THE SCENE

The Rhode Island Attorney General's office released a diagram of the approximate location where the rescuers recovered the 96 people who died a the scene of the fire [36]. (See Figure 6-14.) Based upon interviews with witnesses reported by the *Providence Journal* and the distribution of the victims shown in Figure 6-14, about 2/3 of the occupants appear to have attempted to leave through the main entrance in the front of the building; however, only about 40% of those who successfully evacuated escaped through the main entrance.

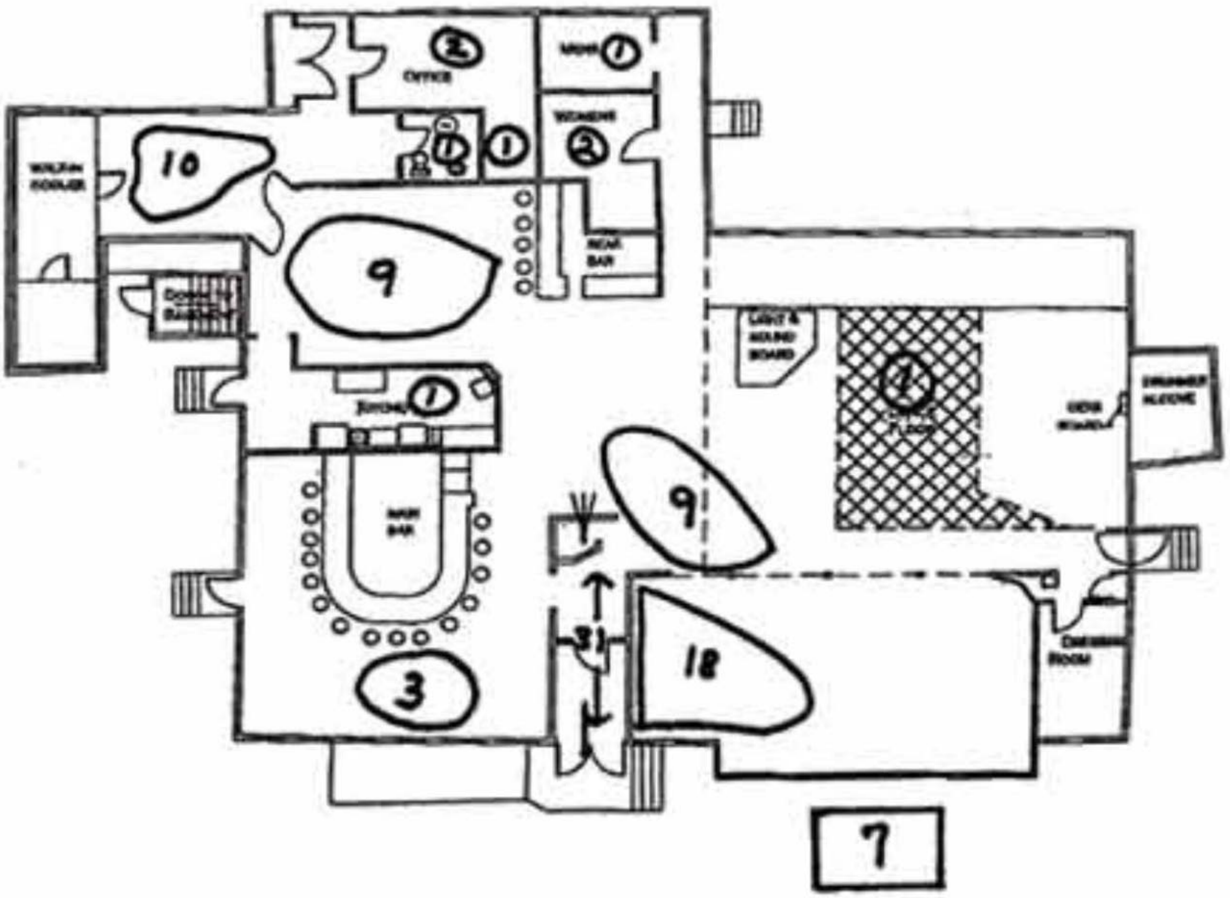


Figure 6-14. Location of Recovered People Who Died at Scene [36]

A little over half of all people who successfully escaped via the doors (main entrance plus main bar plus kitchen plus platform door) exited via the main entrance. The windows in the main bar room and the sunroom appear to have become the secondary routes of escape once the main entrance became impassible, and accounted for over 1/3 of the successful evacuations.

The small number of victims found in the main bar room suggests that the main bar room exit door and windows provided open routes to escape for a time period about as long as it took to reach untenable conditions in that area of the building. By contrast, the high number of victims found in the sunroom relatively close to the windows suggests that the environment there became untenable quickly, eliminating the option of a secondary route through the sunroom windows once the platform door and main entrance became unusable. Both of these conclusions are consistent with the environmental conditions predicted in the FDS simulations discussed in Chapter 5.

A significant number of victims were found in the dart room, storage area, and office, suggesting either that they were unfamiliar with the building and hoped to find a safe exit in that region, or that they became disoriented while heading for the side exit of the main bar room (or possibly the kitchen exit). It is unclear whether the seven people identified in Figure 6-14 as being recovered from the front of the building outside of the sunroom died as they escaped or were pulled from the sunroom by rescuers.

6.6 ALTERNATIVE SIMULATIONS OF NIGHTCLUB EVACUATION SCENARIOS

The following questions were posed by the investigation team regarding the evacuation from the nightclub:

1. How long would it take to evacuate a building similar to The Station with no fire present assuming exit numbers, exit widths, and occupancy limits were consistent with current national model building codes (see chapter 7 for details)?
2. How long would it have taken to evacuate The Station assuming the platform door became impassable in 30 seconds and the main entrance in front became blocked in 90 seconds?
3. How long would it take to evacuate a building similar to The Station assuming that the doorway near the ticket-taker was the same width as the double doors leading to the outside and that it did not become blocked, but that the platform door became impassable in 30 seconds?

The first question is important to answer since it forms the basis of model code provisions. The second question is a challenge to our ability to predict reality when it comes to an emergency evacuation. The third question provides insight into the effectiveness of a possible change in model code requirements.

The Station had four exit paths: through the main entrance, the main barroom, the kitchen, and the platform area. Based upon current model codes, the kitchen door was not accessible to the patrons. As mentioned in Chapter 6.3 and discussed in more detail in Chapter 7.3, the occupancy limit based upon current model code provisions for safe egress from the building as it was used on Feb. 20, 2003, was 420. With these data as input, and the floor plan from Chapter 1, the evacuation time was estimated using two commercial software packages, Simulex [36, 37] and buildingEXODUS [38].

To run these models it was necessary to distribute the 420 occupants throughout the building. It was assumed that the dance floor and area around the platform were at the maximum density permitted by the current national model codes described in chapter 7, 2.17 persons/m^2 (5 ft^2/person), that the sunroom and raised area around the dance floor had a density of 1.56 persons/m^2 (7 ft^2/person), that the main barroom and back room were populated at 0.72 persons/m^2 (15 ft^2/person), and that the 36 remaining occupants were scattered about the kitchen, behind the bar, restrooms, storage area, dressing room, and corridor. Simulex and buildingEXODUS also needed to have a pre-movement time assigned as well as an algorithm for selecting exits. For all cases examined the pre-movement time was assumed to be zero, and the occupants were instructed to always select the closest exit.

Table 6-2 summarizes the results of the simulations. The scenario number in column one corresponds to the questions posed above. The total times to evacuate and the number of people through each of the

Table 6-2. Summary of calculated evacuation times (seconds) and total occupants out each exit

Scenario	Total Evacuation Time	Occupants to Front Door	Occupants to Platform Door	Occupants to Kitchen Door	Occupants to Main Bar Door	Total Remaining at 90 s
1 (Simulex)	188 s	213	184	3	20	166
1 (EXODUS)	202 s	214	180	4	22	208
2 (EXODUS)	330 s	91	32	3	273	271
3 (Simulex)	198 s	358	39	3	20	173
3 (EXODUS)	194 s	363	33	4	20	201
2* (Simulex)	308 s	356	39	3	22	256
2* (EXODUS)	341 s	364	32	4	20	274

available doors are listed in the other columns, corresponding to the scenarios and the simulation model used in column 1. *For a building meeting current national model code requirements at maximum occupant load* (scenario 1), the time needed to evacuate with no fire or smoke present was calculated to be 195 seconds ± 7 seconds for the two simulations. The flow through the various exits was about the same for both calculation methods, with just over 50 % of the occupants evacuating through the front door.

buildingEXODUS was used to evaluate the scenario in question 2, in which the *platform door became impassable in 30 seconds and the front entrance became blocked at 90 seconds*. This scenario was the closest to the condition that occurred on Feb. 20, recognizing that the simulations did not account for any impairment of movement associated with high temperatures, smoke and toxic gas levels that were produced in the actual fire. The time for total evacuation increased to 330 seconds, with the bulk of the people forced to evacuate through the only (known) exit in the main barroom. (No provision was made to allow escape through broken windows). In this case, only 91 people used the front entrance and 35 used either the platform door or the kitchen door, numbers that were consistent with those reported by the *Providence Journal*. The total number of people evacuated in this scenario was only 399 since it was assumed that the 21 occupants who were in the entrance corridor when it became blocked at 90 seconds were trapped.

Scenario 3 investigated the impact of *doubling the width of the most restrictive element at the front entrance*. Figure 6-15 is one frame grabbed from the Simulex computer simulation indicating the initial

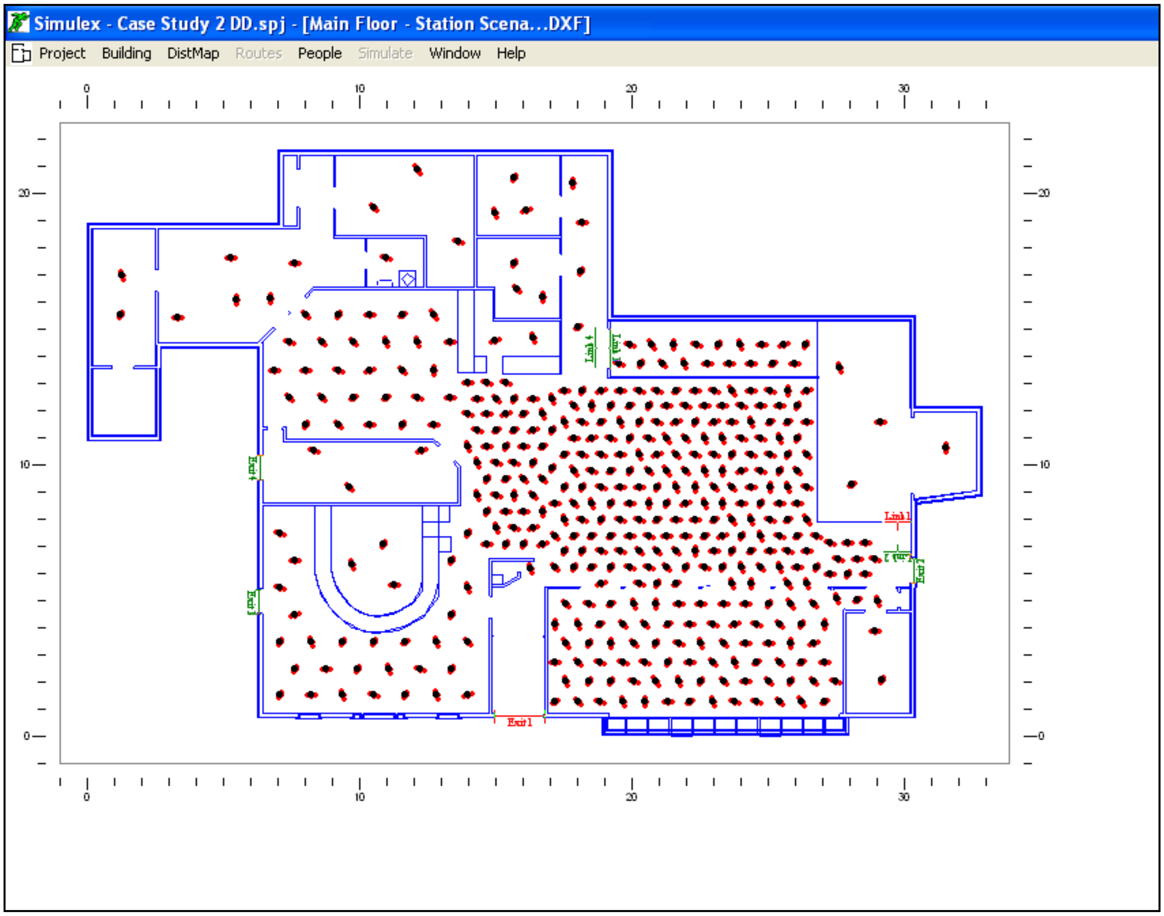


Figure 6-15. Initial distribution of 420 simulated nightclub patrons and employees

population and distribution of patrons and employees. (This was typical of the initial conditions for all of the simulations.) The purpose was to see how this affected the evacuation time in the event that one of the other exits became blocked (e.g., due to construction, negligence or a criminal act). Simulex and buildingEXODUS calculated a total egress exit time of 196 seconds ± 2 seconds, almost identical to the baseline case in scenario 1. The main difference in the outcome for scenario 3 was the larger number of occupants using the front entrance to escape, about 87 % of the total. Assuming that doubling the width of the restrictive front entrance would also have reduced the possibility for a crowd crush to develop, this change would bring the level of safety equivalent to what was implied by the current model codes.

The last row in Table 6-2 applies to a modified form of scenario 2 (Scenario 2*), in which it was assumed that *the main door did not become blocked by the crush of the crowd (in spite of the single door width at the entrance to the ticket taker area), and that the platform door became impassable after 30 seconds*. It is interesting to see that while the distribution of occupants through the different doorways is essentially the same as was calculated for scenario 3, the total evacuation time increased to between 308 seconds and 341 seconds. This results from the decision algorithm that required occupants to choose the closest exit, even if the queue was long. One could argue that many of the people waiting to go out the front door would have chosen the barroom door (which remained clear for most of the evacuation period) as a logical alternative, even though it may have been a bit more distant. The counter argument is that the barroom exit sign could have been obscured by smoke, making that door a reasonable alternative only for those familiar with the nightclub.

Figures 6-16 and 6-17 compare the cumulative population that was evacuated as a function of time for the scenarios described above, based upon the results of buildingEXODUS [39] and Simulex [37, 38] respectively. If one draws a vertical line up from the time scale at 90 seconds, the total number of people who remained in the nightclub at that time can be determined.

Ninety seconds had significance on Feb. 20 because that was about the time the front entrance became blocked and, according to the fire dynamics simulations, was a point where the conditions were becoming untenable throughout the building. The last column in Table 6-2 lists the population remaining for both the buildingEXODUS and Simulex simulations. Note that buildingEXODUS, when compared to Simulex, consistently provided a more conservative (i.e., a slower) rate of egress, which is consistent with the conservative flow rates chosen for the exit doors in buildingEXODUS.

Somewhere between 166 and 208 people were calculated to remain in the building 90 seconds after the fire began for the scenario in which the building met current national model code requirements. This number jumped to 271 for scenario 2, with the platform door blocked (recall that the front door remained open during the first 90 seconds). Doubling the entrance door width in scenario 3 brought the number of people remaining in the building 90 seconds into the fire back down to the range calculated for scenario 1. Finally, since the crowd-crush had not occurred prior to 90 seconds, the calculation for the 2* scenario is essentially the same as for scenario 2.

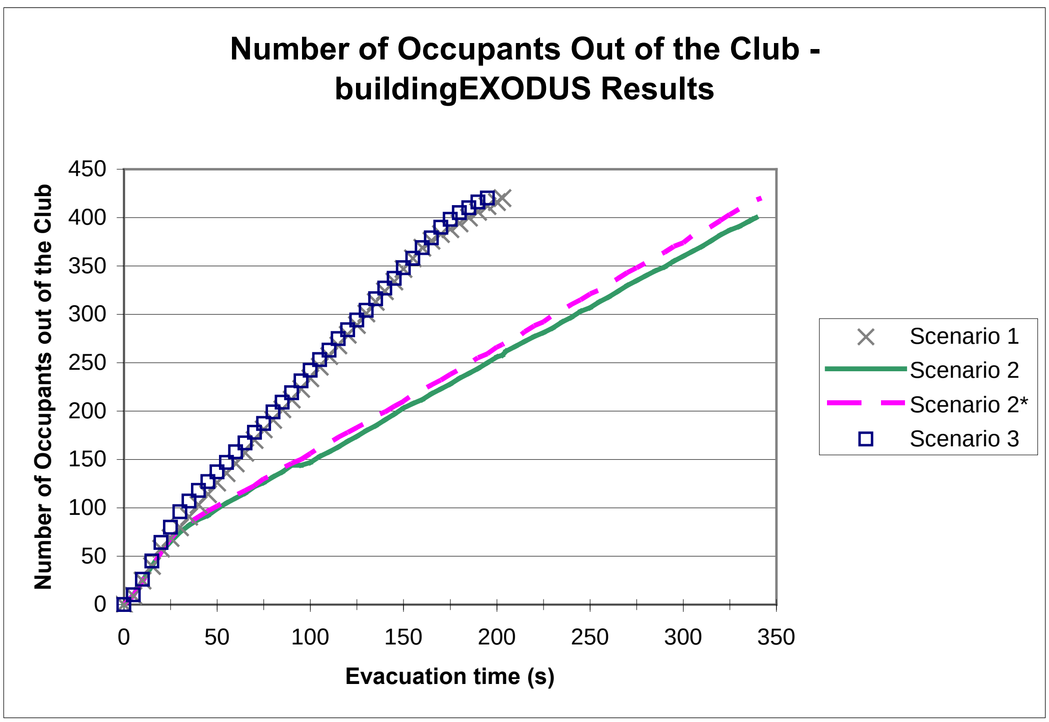


Figure 6-16. Cumulative plot of evacuation from building for different scenarios calculated from buildingEXODUS [39]

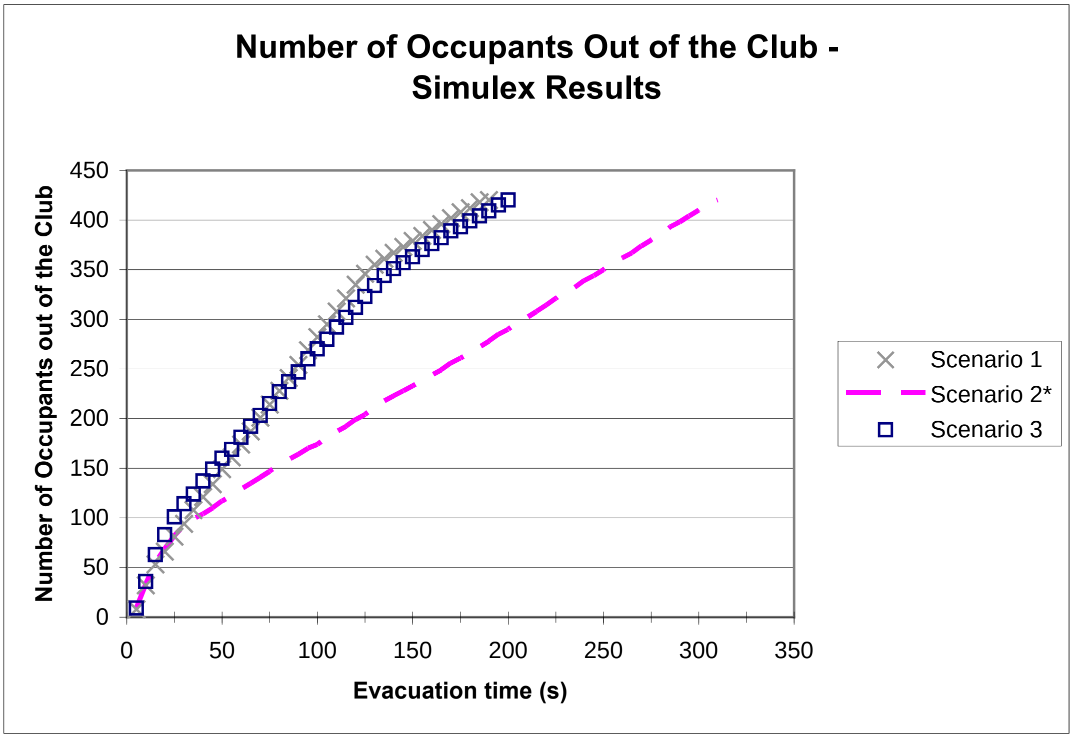


Figure 6-17. Cumulative plot of evacuation from building for different scenarios calculated from Simulex [37, 38]

6.7 REFERENCES FOR CHAPTER 6

[1] "Evaluation of Limitations to Egress through Doorways in Emergency Situations," vol. 1, Ove Arup & Partners Massachusetts Inc., Job number 32979, Westborough MA, Feb. 18, 2004.

[2] Butler, Brian, Video by WPRI-TV, Channel 12, Feb. 20, 2003.

[3] Parker, P.E. and Anderson, E. "Stage manager: Pyrotechnics not unusual at club." *Providence Journal*, Feb. 26, 2003.

[4] Parker, P.E., Levitz, J., and Anderson, E. "Witness describes placement of fireworks just before blaze." *Providence Journal*, Feb. 27, 2003.

[5] Riffe, R. "A first-person account from a survivor." *Providence Journal,* Feb. 24, 2003.

[6] Patinkin, M. "You just make plans for the end." *Providence Journal,* Feb. 23, 2003.

[7] Carbone, G. "Survivor reflects on life: Tell those you love, I love you." *Providence Journal*, Mar. 4, 2003.

[8] Mooney, T. "Saving lives at the open gates of hell." *Providence Journal,* Apr.13, 2003.

[9] Corkery, M. and Parker, P.E. "Forged by Fire, Day 7: Life and Death." *Providence Journal*, Dec. 21, 2003.

[10] Crowley, C. "A survivor's story: Saved by a pileup." Providence Journal, Mar. 10, 2003.

[11] Levitz, J. and Breton, T. "No easy way to escape." Providence Journal, May 5, 2003.

[12] Bramson, K. "Friends lost during frantic escape." Providence Journal, Feb. 23, 2003.

[13] Anderson, E. "Opening band: A 'little button' set off sparks that started fire." *Providence Journal*, Feb. 28, 2003.

[14] *Providence Journal*, "In the Fire." Oct. 5, 2003.

[15] "Analysis if Model Building and Fire Codes and Practices," Koffel Associates, Inc., Ellicott City, MD, 2004.

[16] Application for Variation under the Fire Safety Code, submitted to the State of Rhode Island by D. S. Kelly, Triton Industries, Inc. Nov. 21, 1981.

[17] Larocque, D., letter to Chief P. Brousseau of West Warwick Fire Department, dated Jan. 30, 1999, signed by D. Larocque, West Warwick Fire Marshall.

[18] Letter from West Warwick Fire Department to Chief P. Brousseau of West Warwick Fire Department, dated Mar. 2, 2000.

[22] Horgan, Daniel J., Ralph J. Monaco, John J. Nazzaro & Robert I. Reardon, Jr. United States District Court District of Connecticut, Civil Action Indictment. June 5, 2003.

[23] database compiled by *Providence Journal,* provided to NIST, Jan. 23, 2004.

[24] West Warwick Fire Department Inspection Report, dated Nov. 10, 2001, signed by D. Laroque.

[25] West Warwick Fire Department Inspection Report, dated Nov. 20, 2002, signed by D. Laroque.

[26] West Warwick Fire Department Inspection Report, dated Sept. 25, 1993, signed by R. Ouellette.

[27] West Warwick Fire Department Inspection Report, dated Nov. 17, 1994, signed by Capt R. Ouellette.

[28] West Warwick Fire Department Inspection Report, dated Oct. 2, 1995, signed by BC R. Ouellette.

[29] West Warwick Fire Department Inspection Report, dated Sept. 25, 1996, signed by R. Ouellette.

[30] West Warwick Fire Department Inspection Report, dated Nov. 22, 1998.

[31] RI-CONN Fire Systems, Inc. Inspection Report, dated Apr. 3, 1991 by inspector #9776.

[32] New England Custom Alarms, Fire Alarm Sketches, dated Mar. 6, 2000.

[33] New England Custom Alarms NFPA 72 Inspection and Testing Form, dated Mar. 3, 2000, completed by J LaFontaine (License #BF 09863).

[34] West Warwick Fire Chief, letter regarding requests for permits or inspections for the use of decorations or acoustic materials, dated May 22, 2003.

[35] West Warwick Building Official, letter regarding requests for permits or inspections for the use of decorations or acoustic materials, dated May 23, 2003.

[36] Rhode Island Attorney General's Office, Aug. 2004.

[37] IES, "Simulex User Manual, Evacuation modeling software," Integrated Environmental Solutions, Inc., Glasgow, UK, Mar. 2001.

[38] IES, "Simulex Technical Reference, Evacuation modeling software," Integrated Environmental Solutions, Inc., Glasgow, UK, Nov. 2000.

[39] Galea, E.R., Gwynne, S., Lawrence, P.J., Filippidis, L., Blackshields, D., and Cooney, D., "buildingEXODUS V4.0 User Guide and Technical Manual," Fire Safety Engineering Group, University of Greenwich, London, UK, 2004.

[40] *Providence Journal*, “In the Fire,” p. B4, Feb. 20, 2004.

[41] Crowley, C.F., The Station Nightclub Disaster - A survivor's story: Saved by a pileup; *Providence Journal*. Providence, R.I.: Mar 10, 2003. pg. A.01

Chapter 7 MODEL CODES, STANDARDS AND PRACTICES

7.1 INTRODUCTION

A contract was issued to Koffel Associates, Inc. of Ellicott City, Maryland, to identify the current model building and fire codes relevant to a structure such as The Station nightclub, as well as to identify the model building codes in place at the time modifications were made to the structure. This chapter reproduces information supplied NIST by the contractor [1], much of it verbatim and without further attribution, although any conclusions and findings that are presented are solely those of NIST.

7.2 CODE HISTORY

Since the 1946 original construction of the building at 211 Cowesett Avenue in West Warwick, RI, numerous model codes have come and gone. Prior to 2000, most model codes were limited to regional adoption. Tables 7-1 and 7-2 summarize the model fire and building codes that were relevant to the structure over its history.

From the 1940's through the 1960's, the prevalent regional model building code in Rhode Island was the National Board of Fire Underwriters, later the *American Insurance Association (AIA) National Building Code (NBC)*, last published in 1976. AIA also published the *Fire Prevention Code (FPC)*, which was the prevalent model fire code in the region.

From the 1970's through the end of the century, the Building Officials Congress of America (BOCA) building code was the leading model code in the region. The BOCA fire code dominated during this period. The BOCA codes were originally named the *Basic Building Code (BBC)* and *Basic Fire Prevention Code (BFPC)*. In the 1980's, BOCA purchased the rights to the AIA codes. BOCA renamed their codes the *National Building Code (NBC)* and the *National Fire Code (NFC)*. While the names were that of the AIA codes, the content was that of the BOCA documents.

In 2000, the International Code Council (ICC) published the first *International Building Code (IBC)* and first *International Fire Code (IFC)*, both now published in 2003 editions [2, 3]. The ICC was formed by the merger of the three regional code writing organizations. As such the IBC replaced the NBC and the IFC replaced the NFC. From 2000 until the appearance of the NFPA building code, the IBC was the only model building code that was being developed and maintained in the United States.

The National Fire Protection Association (NFPA) has published a fire code since 1971 and began publishing a building code in 2003. The NFPA fire code, originally named the *Fire Prevention Code*, was renamed the *Uniform Fire Code* for the 2003 edition [4]. The NFPA building code, Building Construction and Safety Code, is a second model code developed and maintained in the United States. As such, it is included in the code analysis. The Building Construction and Safety Code is commonly known as *NFPA 5000* [5].

The older editions of the BOCA building code treated restaurants and nightclubs differently. To many, a restaurant and a night club may seem to pose similar risks; however, prior to 2000, the codes viewed restaurants and night clubs differently. Even though the codes classified nightclubs and restaurants in different occupancies, it is not always easy to distinguish between restaurants and nightclubs. Below are BOCA definitions of class A-1 and class A-2 structures [6]:

Table 7-1. Applicable Model Fire Code

Bldg. Permit Date	Description of Work	BOCA: Fire Code	NFPA 101	NFPA 1
July 27, 1967	Install paneling; rebuild two porches; install new sign	Basic Fire Prevention Code 1965	Life Safety Code 1967	
May 18, 1970	Roofing Paneling ect	Basic Fire Prevention Code 1970	Life Safety Code 1970	
October 18, 1971	Alterations and remodeling	Basic Fire Prevention Code 1970	Life Safety Code 1970	
November 15, 1974	Interior paneling and partitions	Basic Fire Prevention Code 1970	Life Safety Code 1973	
April 29, 1975	Exterior Alterations and Renovations	Basic Fire Prevention Code 1975	Life Safety Code 1973	
July 1, 1975	Addition 330ft^2	Basic Fire Prevention Code 1975	Life Safety Code 1973	
November 21, 1981	Request of Variation Under Building Code, not enclose stair to basement	Basic Fire Prevention Code 1981	Life Safety Code 1981	
Feburary 20, 1985	Remodel and renovation to existing restaurant	Basic/National Fire Prevention Code 1984	Life Safety Code 1985	Fire Prevention Code 1982
December 9, 1999	Notice of Construction without a permit	National Fire Prevention Code 1999	Life Safety Code 1997	Fire Prevention Code 1997
June 19, 2001	Repair front from car	National Fire Prevention Code 1999	Life Safety Code 2000	Fire Prevention Code 2000

Table 7-2. Applicable Model Building Code

Building Permits Dates	Description of Work	BOCA Building Code
July 27, 1967	Install paneling; rebuild two porches; install new sign	1965 Basic Building Code
May 18, 1970	Roofing Paneling ect	1970 Basic Building Code
October 18, 1971	Alterations and remodeling	1970 Basic Building Code
November 15, 1974	Interior paneling and partitions	1970 Basic Building Code
April 29, 1975	Exterior Alterations and Renovations	1975 Basic Building Code
July 1, 1975	Addition 330ft^2	1975 Basic Building Code
November 21, 1981	Request of Variation Under Building Code, not enclose stair to basement	1981 Basic Building Code
Feburary 20, 1985	Remodel and renovation to existing restaurant	1984 Basic/National Building Code
December 9, 1999	Notice of Construction without a permit	1999 National Building Code or IBC 2000
June 19, 2001	Repair front from car	1999 National Building Code or IBC 2000

303.3 Use Group A-2 structures: This use group includes all buildings and places of public assembly, without theatrical *stage* accessories, designed for occupancy as dance halls, nightclubs and for similar purposes, including all rooms, lobbies and other spaces connected thereto with a common *means of egress* and entrance.

303.4 Use Group A-3 structures: This use group includes all buildings with or without an auditorium in which persons assemble for amusement, entertainment or recreation purposes as well as incidental motion picture, dramatic or theatrical presentations, lectures or other similar purposes without theatrical *stage* other than a raised *platform*; and which are principally occupied without permanent seating facilities, including art galleries, exhibition halls, museums, lecture halls, libraries, restaurants other than nightclubs, and recreation centers; and buildings designed for similar assembly purposes, including passenger terminals.

Facilities that have seating at tables and chairs for all patrons and serve food are typically considered as restaurants. Facilities that may have some seating and food service, but offer standing and gathering space are typically considered to be nightclubs. Either occupancy may have entertainment and a dance floor. As a tool to assist in determining if an establishment is a nightclub or restaurant, historically, local jurisdictions have compared amounts of food and alcohol served. The ratio of food to alcohol to be classified as one or the other varies between localities.

Converting from one to the other would trigger the change of occupancy provisions of the codes. Historically, the change of occupancy provisions of the BOCA codes required that the building meet the intent of the code for the new occupancy and not pose a greater hazard.

The 1955 National Building Code made no distinction between restaurants and nightclubs. The Code stated the following: "The provisions of this code based on occupancy also apply to conversions of existing buildings and structures or portions thereof from one occupancy classification to another, which would not apply to change from restaurant to nightclub."

It is clear that the proper classification of The Station at the time of the fire was as a nightclub. However, as of the writing of this document, the Town of West Warwick has not made either the historical, or most current, use and occupancy permit for the bar available. It is not possible to determine how the facility was being regulated. Also, it is not possible to determine how the facility was classified when changes occurred to the building. Without accurate knowledge of how the building was classified, assumptions regarding occupancy classification could lead to incorrect conclusions.

7.3 MODEL CODE ANALYSIS

The model code analysis was based upon the *International Building Code (IBC)* 2003 [2] edition and *Building Construction and Safety Code (NFPA 5000)* 2003 edition [5]. A comparison of the relevant sections of these codes is included as Table K-1 in Appendix K. In areas were the codes had dissimilar requirements the impact of both requirements were evaluated.

The *Life Safety Code (NFPA 101)* 2003 edition [7] is a code that addresses life safety issues primarily through regulation of egress and fire safety systems. The provisions of new construction in *NFPA 101* aligned with the requirements of *NFPA 5000*. The *International Fire Code (IFC)* [3] and the *Uniform Fire Code (NFPA 1)* [4] are compared section by section in Appendix K, Table K-2.

Details on the changes to *NFPA 101*, the *Uniform Building Code*, the *Standard Building Code*, and the *BCMC* over the life of The Station and its previous incarnations were also tabulated in the final report from Arup Fire [8].

NIST's technical investigation did not focus on compliance or non-compliance with the specific state or local regulations in effect at the time of the fire, nor did it seek to find fault. Rather, the focus was on model codes and standards and how the design and operation of The Station compared with the guidance provided within them. The findings and recommendations from the NIST investigation are expected to be useful across the nation.

Relevant aspects of the national model building codes are discussed in this section, followed by comments (in italics) on the conditions in The Station that were documented during the analysis. ***It should be noted that the building code evaluation utilizes current building code requirements, which generally are not applied to existing buildings.***

7.3.1 Administration

IBC §105.1 mandates permits for enlarging, altering, repairing, or changing of the occupancy of any building. NFPA 5000 §1.7.6.1.1.1 maintains similar requirements.

> *Comment: Over the life of this building, it was rehabilitated numerous times. A number of the projects were permitted. Typically, descriptions of work included on building permits included Roofing Paneling [9], Alterations and remodeling [10], Addition 30.6 m^2 (330 ft^2) [11]*

Both IBC §109.1 and NFPA 5000 §1.7.6.6.1.3 demand any work that is required to have a permit issued to be inspected.

> *Comment: Limited inspection records for the building were available for review. The inspection records are of fire department inspections, not inspection records for the building department. The reports appear to be from inspections related to renewal of the bar's liquor license.*

NFPA 5000 §1.7.6.6.4 requires the records be maintained for each inspection. IBC §104.7 also mandates that reports of inspections be maintained for the period of time required for public records by the local authority.

7.3.2 Occupancy Classification

IBC §303.1 classifies the occupancy as a Group A-2. NFPA 5000 §3.3.371.1 classifies the space as an Assembly Occupancy.

> *Comment: The use of The Station is consistent with the IBC and NFPA 5000 occupancy classifications of Group A-2 and Assembly, respectively.*

7.3.3 Construction Type

IBC §602.5 classifies the building as Type VB construction. NFPA 5000 §7.2.6 classifies the building construction as Type V (000).

> *Comment: The construction of the building was unprotected wood frame.*

The requirements, IBC Table 602 and NFPA 5000 Table 7.3.2.1, for fire resistance rating of exterior walls are consistent in both codes. In instances were the building is more than 3.05 m (10 ft) from the property line, exterior walls are not required to have a fire resistance rating. For a separation distance between the building and the property line of less than 3.05 m (10 ft), the codes require the exterior wall to have a 1-hour fire resistance rating.

Comment: The building was more than 3 m (10 ft) from the property line.

7.3.4 General Building Heights and Area

Both codes regulate the height and area of buildings based on occupancy of the building and construction type. IBC Table 503 limits the area of the Group A-2 Type VB buildings to 557 m^2 (6000 ft^2) and one story. NFPA 5000 Table 7.4.1 limits Assembly occupancies with occupant loads greater than 300 and less than 1000 persons of Type V (000) construction to 511 m^2 (5500 ft^2) and one story.

Comment: West Warwick tax records indicate the main floor of the building was 416 m^2 (4484 ft^2) and the basement was 78 m^2 (840 ft^2) [12]

Both codes allow an increase in the area based on open perimeter. The IBC also allows an increase in the height of the building based upon sprinkler protection. NFPA 5000 does not allow the increase in height for sprinklers in this instance.

Comment: The building was not sprinkler protected.

7.3.5 Interior Finish

Both model codes regulate interior finish materials based upon flame spread, smoke production, location in the building, and type of use or occupancy of the space. The IBC, Chapter 8 contains interior finish provisions; in NFPA 5000, they are contained in Chapter 10. ASTM E-84 [13] (or NFPA 255 [14]) is the principal test method used by both codes to characterize flame spread and smoke development. Both codes also allow for large scale testing of interior finishes in lieu of E-84. Tests such as NFPA 286 [15] meet the requirement for large scale testing.

IBC Table 803.6 and NFPA 5000 §16.3.3.3 require interior finishes such as wood paneling, wood sheathing boards, and bead board to have a flame spread rating equal to or less than 75 and a smoke development index equal to or less than 450. In sprinkler protected buildings, both codes allow the flame spread index to go up to 200.

In the IBC, plastics used as interior finish are regulated by IBC §2604. In NFPA 5000, cellular or foamed plastics used as interior finish are regulated by §10.4.3. The IBC requires foam plastics used as interior finish to be labeled, to have a flame spread index not to exceed 75, to have a smoke development index not to exceed 450, and to pass full scale testing. The large scale testing shall be related to the actual use configuration.

NFPA 5000 §10.4.3.1 requires large scale fire tests for foam plastic insulation. The tests must be representative of actual use conditions. The requirement does not make a distinction between foam plastic insulation that is used as interior finish and foam plastic insulation that is used within a wall cavity.

In 1949, no combustible wall or ceiling finish was permitted in public buildings and places of assembly and exits there from that would “spread flame over its surface more rapidly than over one-inch (nominal) wood boards covered with ordinary paint or varnish.” This rather loose standard was replaced in the 1955 NBC by the E-84 test discussed above.

The interior finish requirements have changed little since the 1955 edition. The most significant change in 1967 tightened a previous exception for business occupancies by reducing the allowable flame spread in rooms or spaces less than 139 m^2 (1500 ft^2). In 1976, the allowable flame spread of exits in assembly occupancies was reduced, and dwellings were regulated for the first time. A separate section was added on floor coverings based upon a "flame propagation index". Neither smoke production nor toxicity has been regulated.

Comment: As would be expected, the interior finish materials of the building varied greatly. The interior finish material was mapped and is shown in Figures 7-1 and 7-2. The interior wall finishes included wood paneling, bead board, painted gypsum, wafer board, and ceramic tile. Interior finishes were identified from photographic and video records. The finishes identified were estimates based on a video and photographs taken in the building. The finishes referred to as painted gypsum may be either gypsum wall board or plaster. Neither samples of products nor model and manufacture information were available. Accordingly, conclusions regarding flame spread ratings are based upon broad product categories. The ceramic tile and gypsum do not pose potential interior finish flame spread issues.

It appears that there were multiple types of wood paneling installed in the building. Portions of the wood paneling and bead board were painted. Wood paneling is manufactured with different flame spread ratings ranging from Class A to Class C. Many wood panelings are plywoods. Flame spread indexes for plywood range from 70 to 160 [16, 17]. Without knowledge of the specific paneling installed, it is not possible to determine the interior finish classification of the wood paneling at its time of installation. The natural aging and surface treatments applied after installation can dramatically affect the flame spread index of products. The bead board is subject to the same variations in flame spread index due to aging and surface treatments. Without samples to test the class of the interior finish, the flame spread index cannot be definitively stated for either the bead board or paneling. Untreated red oak flooring has a Class C interior finish rating (100 flame spread index).

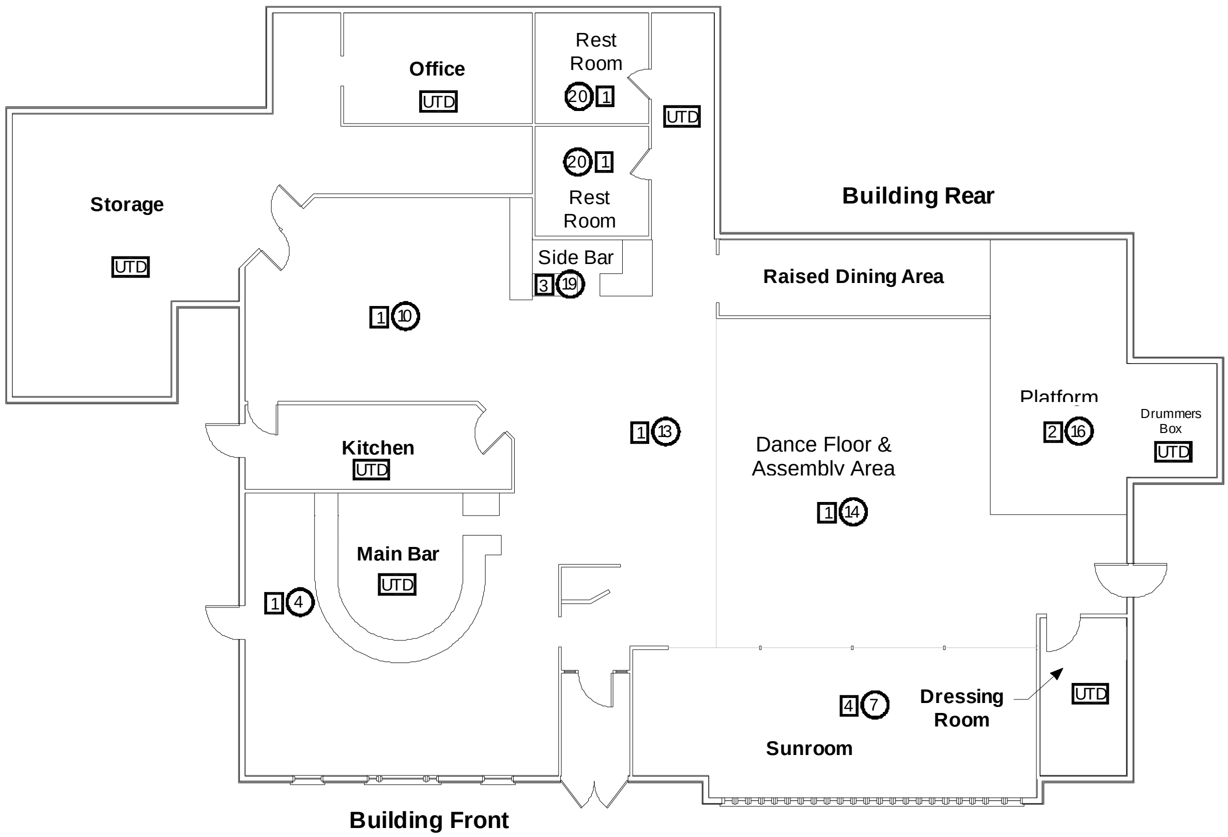
The walls surrounding the stage and the wall to the left of the stage were covered in expanded foam plastic insulation. Additionally, a portion of the ceiling over the stage and the ceiling in front of the stage were covered with expanded foam plastic insulation. The model codes allow foam plastic installation as an interior finish only after large scale testing has been conducted and successfully completed.

7.3.6 Plastics

IBC regulates plastics in Chapter 26. Chapter 26 has provisions that complement the interior finish provisions in Chapter 8. NFPA 5000 Chapter 48 regulates all plastic materials used in or on buildings.

Comment: The tie between Chapters 48 and 10 is not as concise as with IBC. The provisions of IBC and NFPA 5000 are the same. The organization of these codes differ; however, the requirements are the same.

Foam plastic used as an interior finish shall be the tested in accordance with NFPA 286. During the NFPA 286 test, the room may not flashover nor may flames exit the enclosure. Additionally, total smoke production (a measure of the total surface area of the smoke particles per kg of fuel consumed) shall not exceed 1000 m^2. In the IBC, the requirements for foam plastic to be used as an interior finish are found in §2604.1. §2604.1 requires testing in compliance with §2603.8. §2603.8 requires large scale testing and compliance with Chapter 8 flame spread provisions. NFPA 5000 §48.4.4 contains the same provisions as IBC §2603.8.



* Refer to Appendix _ for details
** Blank Indicates No Wall Exists
*** UTD - Unable To Determine

Legend

Ⓧ Bibliography of Photos

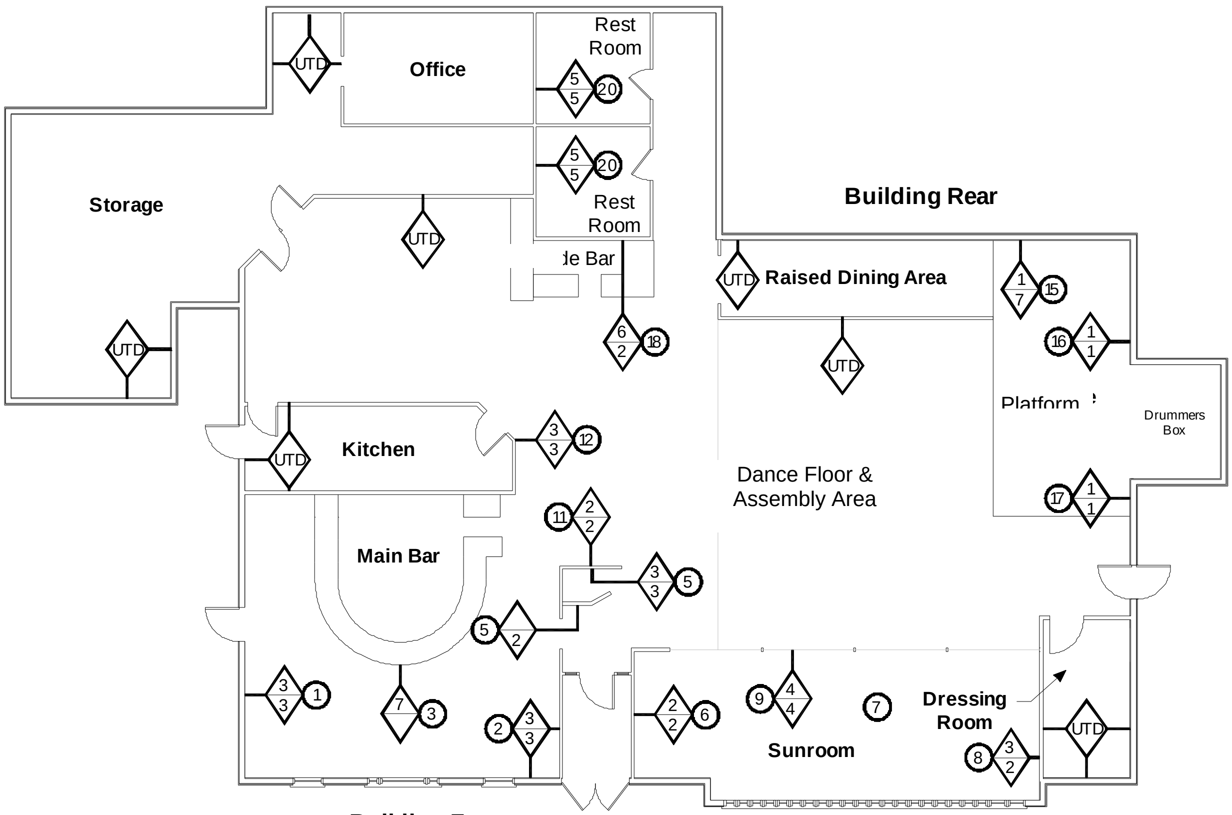
☒ Indicates Ceiling Type*

Legend of Ceiling Types

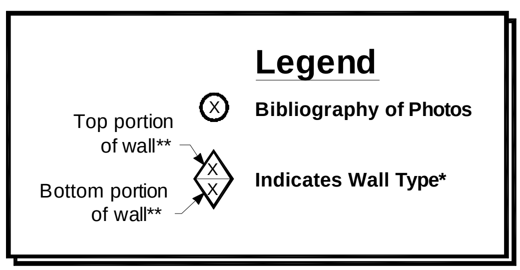
1 Acoustical Ceiling Tile
2 Foam
3 Wood Lattice
4 2x4 Rafters

Figure 7-1. Station Night Club Ceiling Interior Finish

Comment: The model codes prohibit the use of foam plastic insulation as an interior finish that does not pass a large scale test replicating end-use conditions. There is no indication that the foam used on the walls of The Station was tested.



* Refer to Appendix _ for details
** Blank Indicates No Wall Exists
*** UTD - Unable To Determine



Legend of Wall Types

1	Foam
2	Paneling
3	Gypsum
4	Waffer Boards
5	Cermic Tile
6	Stucco
7	Bead Board

Figure 7-2. Station Night Club Wall Interior Finish

7.3.7 Automatic Sprinkler System

For new construction, IBC §903.2.1.2 requires Group A-2 uses to be protected by automatic sprinklers if any of the following are exceeded:

- fire area > 1114 m^2 (12,000 ft^2)
- occupant load > 300 persons
- fire area located on other than the floor of exit discharge

NFPA 5000 §16.3.5.1.1 mandates automatic sprinkler protection for assembly occupancy serving more than 300 persons. Several exceptions are allowed. None of the exceptions are relevant to The Station.

> *Comment: The model codes trigger sprinkler protection for buildings based on a combination of factors including occupancy, building area, construction type, building height, location relative to exit discharge, and occupant load.* ***For new construction*** *of this type of building, the model codes require sprinklers for an occupant load. in excess of 300 persons. The building was not equipped with an automatic sprinkler system.*
>
> *The BOCA National Building Code would have required sprinkler protection* ***(for new construction)*** *based on the area and construction type of the building. The largest Type 5B Use Group A-2 building the BOCA National Building Code would have allowed is 390 m^2 (4200 ft^2), which is less than the area of The Station.*

7.3.8 Fire Alarm

IBC §907.2.1 requires manual fire alarm systems in Group A occupancies with occupant loads exceeding 300 persons. IBC §907.2.1.1 requires voice notification for Group A occupancies with occupant loads greater than 1000 persons.

NFPA 5000 §16.3.4 requires manual fire alarms in Assembly occupancies with occupant loads exceeding 300 persons. The fire alarm shall be activated by manual pull station, smoke detectors, the sprinkler system, and heat detectors in hazardous locations.

> *Comment: The building was equipped with a manual fire alarm. Manual pull stations were located adjacent to Door 3 and behind the main bar. Heat detectors were located in the area behind the kitchen. Heat detectors were present above and below the platform area. Fire alarm horns were located behind the main bar and in the front room near the pool tables.*

7.3.9 Festival Seating

NFPA 5000 §3.3.474.1 defines "Festival Seating" as a form of audience/spectator accommodation in which no seating, other than a floor or ground surface, is provided for the audience/spectators gathered to observe a performance. NFPA 5000 §16.2.4.1 allows festival seating for assembly occupancies with less than 1000 occupants. IBC does not address festival seating.

> *Comment: At the time of the fire, the nightclub was arranged for festival seating, permitting more occupants than had the building been arranged for fixed seating.*

7.3.10 Exits

There were four exit routes from the building, as numbered in Figure 7-5: (1) the front main exit, (2) the main bar exit on the side, (3) the kitchen exit, and (4) the platform exit. The model codes govern their number, size, placement, and other details of design, as discussed in this section

(i) Doors

Doors shall provide a clear opening of at least 0.81 m (32 in), IBC §1008.1.1 and NFPA 5000 §11.2.1.2.4. Doors shall swing in the direction of egress travel when serving spaces with more than 50 persons, IBC §1008.1.2 and NFPA 5000 §11.2.1.4.2.

> *Comments: All doors exceeded the 0.81 m (32 in) minimum, and all door leaves swung in the direction of egress travel with the exception of the interior leaf at exit 4. (See Fig. 1-5.)*

(ii) Panic Hardware

IBC §1008.1.9 and NFPA 5000 §16.2.2.2.3 mandate panic hardware on doors in the means of egress for assembly occupancies with an occupant load greater than or equal to 100 persons.

> *Comments: When viewed from the exterior, the right leaf of the front doors was not equipped with panic hardware. There was no visible hardware on either door. As of this writing, the type of hardware on the swinging door immediately inside the double exterior doors is undetermined.*
>
> *The door to exit 2 was equipped with panic hardware. As of this writing the type of hardware with which the door at exit 3 was equipped has not been determined. The inward swinging leaf of the door at exit 4 was fitted with standard knob style hardware. The outward swinging door was equipped with panic hardware.*

(iii) Floor Level and Landings

IBC §1008.1.4 and NFPA 5000 §11.2.1.3 mandate that the floor level on both sides of a door shall be at the same level. IBC §1008.1.5 and NFPA 5000 §11.2.2.3.2 also requires that the landing be at least as wide as the stair or door being served and the door when fully open may not reduce the required width of the landing by more than 0.18 m (7 in).

> *Comments: Based on photographic evidence and review of the video, the floor was level on both sides of the main door at exit 1. It could not be determined if the floor was level on both sides of the doors at exits 2 and 3. The floor was not level on both sides of door at exit 4. The first riser was in line with the plane of the closed door.*
>
> *There was not a landing at the exterior of exit 4. The photos of exit 2 indicate a landing outside the door, however, it cannot be determined if a step existed at the door. The photos indicate a stair at Door 3, but it could not be determined if a landing or risers were present at the door.*

(iv) Exit Signs

Exit signs are required at exits other than obvious main exits, and at other locations where exit access is not obvious, per IBC §1011.1. NFPA 5000 §11.10.1.4 and §16.4.7.5 not only require elevated exit signs, but also require floor proximity exit signs.

Comments: The only difference between IBC and NFPA 5000 requirements is that NFPA 5000 requires floor proximity exit signs in assembly occupancies. The nightclub was equipped with exit signs over each of the four doorways.

(v) Travel Distance

Both IBC §1018.1 and NFPA 5000 §16.2.6 require the travel distance to exits (the maximum distance from any place in the building to an exit) not exceed 61 m (200 ft). In the 1955 NBC travel distance in assembly occupancies was increased to 45.7 m (150 ft), up from 30.5 m (100 ft). In 1967 it was changed back to 30.5 m (100 ft).

Comment: The travel distance in this building was less than 61 m (200 ft).

(vi) Common Path of Travel

IBC §1013.3 states the common path of travel shall not exceed 22.8 m (75 ft). NFPA 5000 §16.2.5.1.2 limits the common path of travel to 6.1 m (20 ft) or less. Common path of travel is the portion of the means of egress that must be traversed until such a point that at least two independent means of egress to at least two exits are available.

Comment: The common path of travel from the raised seating area and the hallway leading to the rear restroom was greater than 6.1 m (20 ft). If all doors to the exterior were considered exits, all other areas complied with the model codes' common path of travel provisions.

If exit 4 is not considered an exit, over 50% of the sun room and dance floor area have a common path of travel greater than 6.1 m (20 ft).

Not considering exit 3 as an exit does not create additional common path of travel issues.

(vii) Exit Separation

NFPA 5000 §11.5.1.4 and IBC §1014.2.1 requires the exits to be separated by at least one half the length of the maximum overall diagonal dimension of the building area served.

Comments: The diagonal of the area served was 25.3 m (83 ft). The model codes require a separation of 12.6 m (41.5 ft). Exit 1 and exit 2 were 10.4 m (34 ft) apart.

(viii) Dead Ends

IBC §1016.3 states that dead ends in relation to corridors shall not exceed 6.1 m (20 ft). NFPA 5000 §16.2.5.1.3 has the same limit.

While the passage way to the restrooms created a dead end 7.6 m (25 ft) long and the access aisle to the raised seating area was a dead end 7.3 m (24 ft) in length, neither were associated with corridors. No other dead ends existed.

7.3.11 Occupant Load Limits

The model codes compute the occupant load limits in two ways: based upon area, and based upon egress capacity. The limit is set by the calculation that leads to the smaller number. Both of these approaches are described here using the IBC and the NFPA 5000 criteria.

(i) Area Basis

Occupant load factors are expressed in terms of square meters (feet) per person. Dividing the area of the space by the occupant load factor yields the allowable occupant load. The model codes use occupant load factors to determine the allowable number of persons given an area. The relevant occupant load factors from IBC Table 1004.1.2 and NFPA 5000 Table 11.3.1.2 are detailed in the following table.

Table 7-3. Occupant Load Factors, m^2/person (ft^2/person)

Occupancy/Use	IBC Table 1004.1.2 Occupant load factor	NFPA Table 11.3.1.2 Occupant load factor
Assembly, Concentrated (chairs only not fixed)	0.65 (7) net	0.65 (7) net
Assembly, Stand space	0.46 (5) net	no provision
Assembly, Unconcentrated (tables and chairs)	1.39 (15) net	1.39 (15) net
Business area	9.28 (100) gross	9.28 (100) gross
Kitchens commercial	18.6 (200) gross	9.28 (100) gross
Stages and Platforms	1.39 (15) net	1.39 (15) net
Warehouse	46.4 (500) gross	no provision

Table 7-4. Computed Occupant Loads Based Upon Model Codes and Areas Shown in Figures 7-3 and 7-4

Use	Area, m^2 (ft^2)	IBC capacity	NFPA 5000 capacity
Assembly Standing	251 (2709)	542	387
Business	25 (270)	3	3
Platform	35 (373)	25	25
Kitchen	16 (171)	1	1
Storage	64 (690)	3	3
Assembly T/C	15 (161)	11	11
Total	**406 (4374)**	**585**	**430**

IBC §1004.2 allows the occupant load to be increased above the calculated number provided the other egress provisions are met and the occupant load does not exceed 0.46 m^2/person (5 ft^2/person). NFPA 5000 §11.3.1.3 and 16.1.6 contains similar provisions.

Both model codes allow the occupant load to be based on capacity of the means of egress provided each person has 0.46 m^2 (5 ft^2) of floor space. This calculation for available floor space shall be made on net space. Net space excludes restrooms, passageways, and space assigned for other uses such as the space behind the bars and the kitchens.

DRAFT

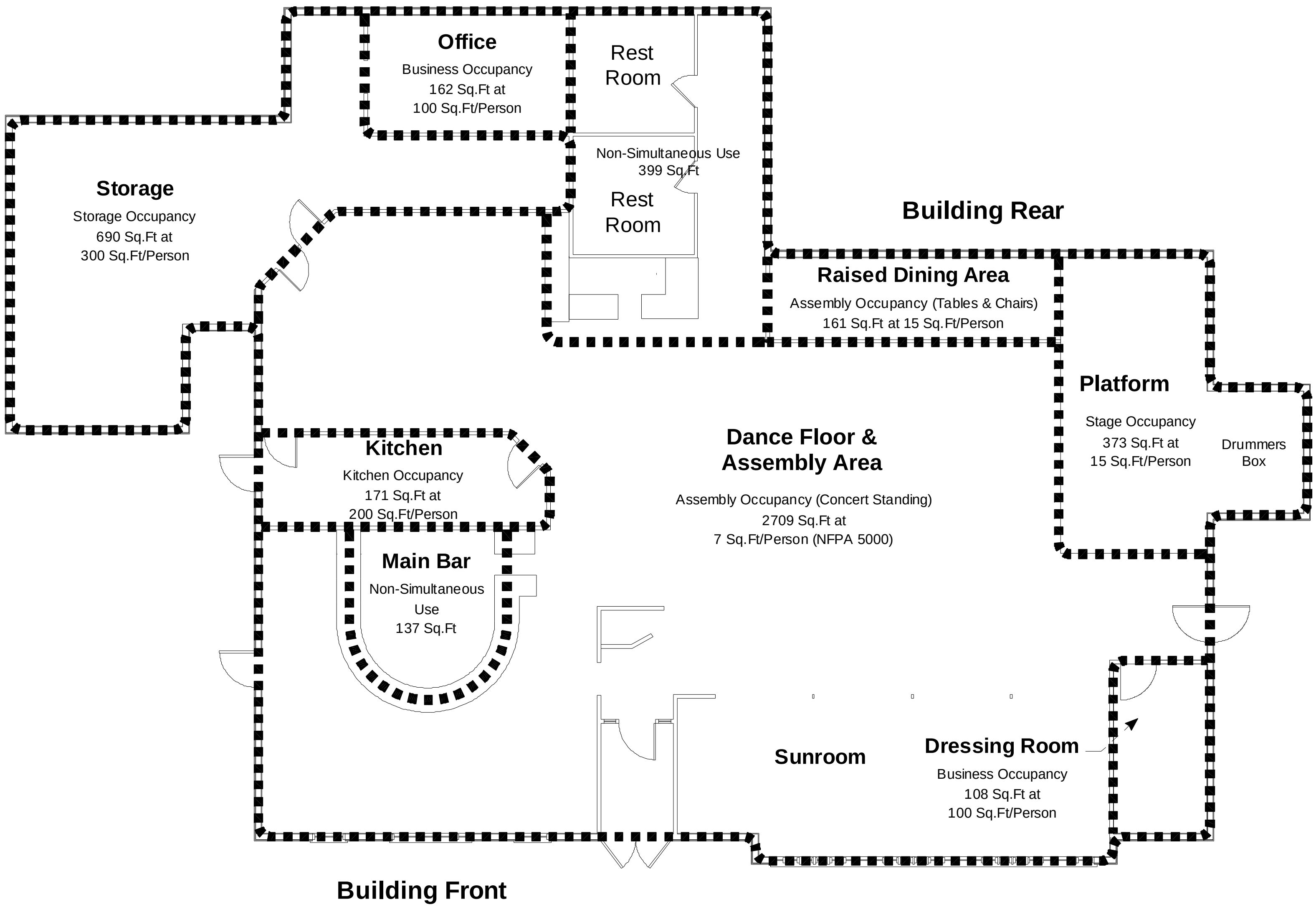


Figure 7-3. Station Nightclub (NFPA 5000) Use Area Designations

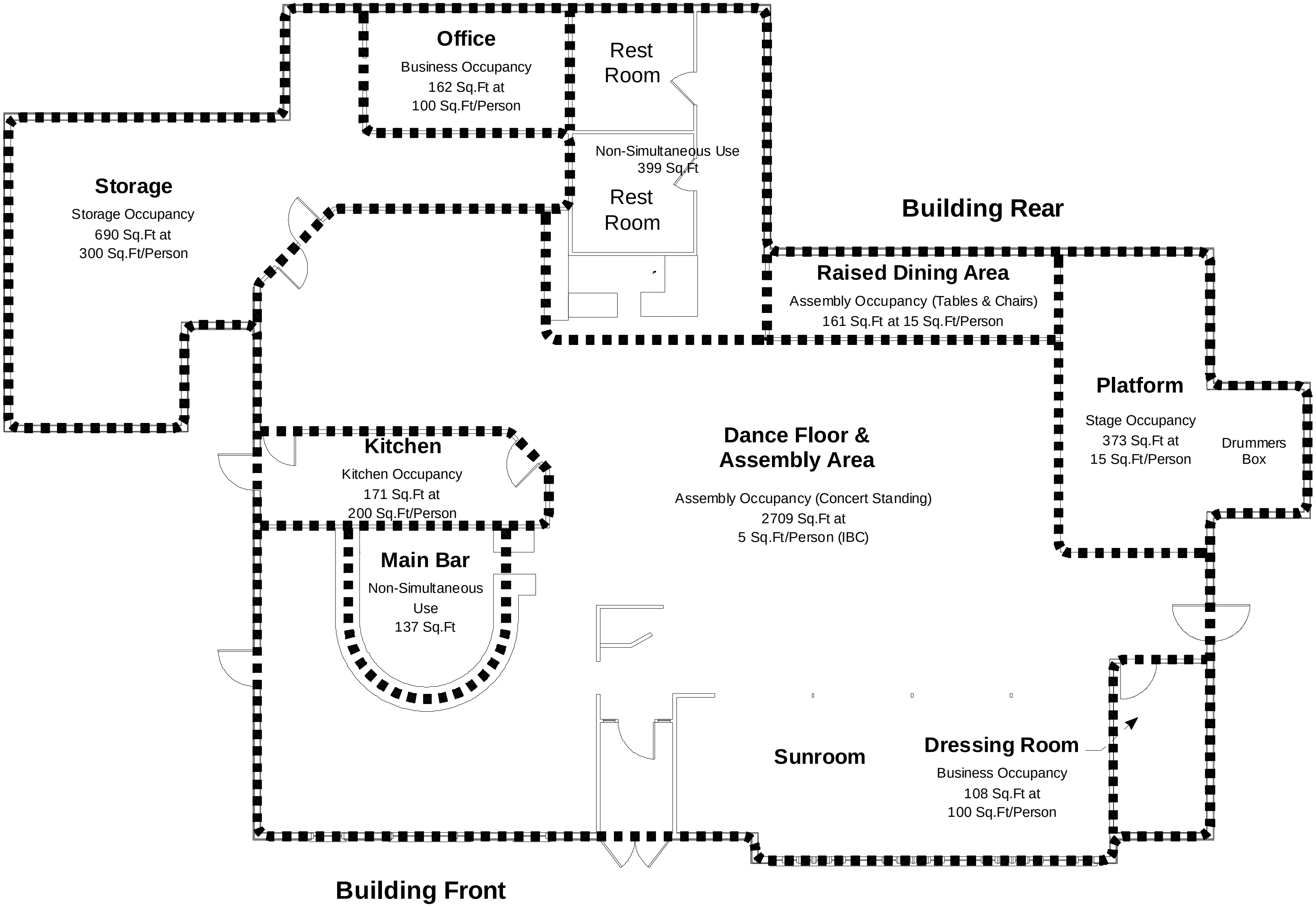


Figure 7-4. Station Night Club Fire (IBC) Occupancy Area Designations

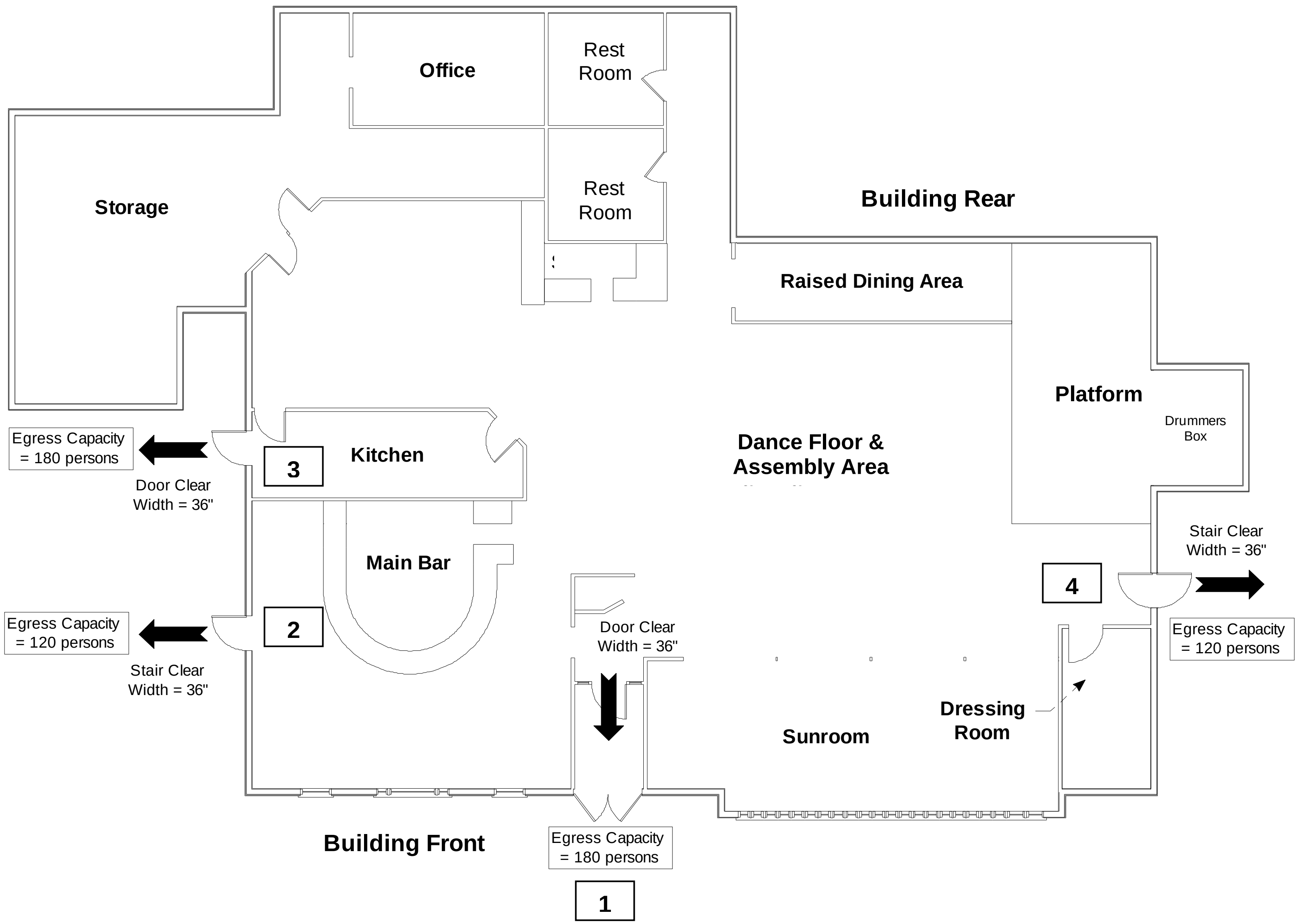


Figure 7-5. Station Nightclub Egress Capacity

Comment: Refer to Figure 7-3 and Figure 7-4 for the use of spaces within the Station as defined by the model codes. Based upon those uses, the maximum load for each space is computed in Table 7-4. The total maximum occupancy of a building similar to The Station, according to IBC, would have been 585 persons; a similar calculation based upon the NFPA 5000 occupant load factors yields a total maximum population of 430 persons. The significant differences arise from NFPA 5000 allowing the use of 0.65 m^2/person (7 ft^2/person) for concentrated assembly occupancy. IBC uses 0.46 m^2/person (5 ft^2/person) for standing assembly space. NFPA 5000 does have a provision that allows the occupant load to be increased to match the available egress capacity. Typically, the table value of 0.65 m^2/person (7 ft^2/person) is used. Both codes would allow these occupant loads, if the exit capacity were available.

(ii) Egress Basis

Egress capacity factors are related to the minimum clear width required for exit pathways in order to ensure timely egress, and are expressed in terms of mm/person (in/person). The egress capacity factors for level egress components and ramps are smaller than factors for stairways. IBC Table 1005.1 and NFPA 5000 Table 11.3.3.1 contain the capacity factors for egress elements. Clear widths are divided by egress capacity factors to yield the maximum capacity for that particular egress element. The IBC reduces the required width when a building is fully sprinkler protected, as shown in Table 7-5. IBC and NFPA 5000 require the number of occupants to be less than the capacity of the available egress width, and both codes require two means of egress for buildings with a total occupant load of less than 501 persons. IBC §1008.1.2 and NFPA 5000 §11.2.1.4.2 contain requirements that doors swing in the direction of egress travel in the path of egress from assembly occupancies serving occupant loads of greater than 50 persons .

Comments: The building was not sprinkler protected.

See Table 7-6 and Figure 7-5 for capacities of each exit. As required by both model codes, the element with the smallest capacity in each path of egress was considered to be the limiting element. The limiting element dictated the capacity of each egress path.

For the main entrance, exit 1, the interior 914 mm (36 in) door was the limiting element, resulting in a capacity of 180 persons for the main entrance exit. For exit 2, the side door out of the main bar area, the exterior stairs leading from the door were the limiting element, resulting in a capacity of 120 persons. Exit 3, from the kitchen, was also limited by an exterior stair; however, both codes prohibit egress by patrons through the kitchen (IBC §1013.2 and NFPA 5000 §11.5.2.1) Exit 4 adjacent to the platform had two doors installed on the same jam, one swinging in the direction of egress travel and one swinging opposing the direction of travel. Excluding the kitchen exit and including the exit adjacent to the platform, the occupancy limit based upon egress capacity would have been 420 according to both model codes. (See Table 7-6.)

Table 7-5. Egress Capacity Factors

Occupancy	Without Sprinkler System, mm/person (in/person)		With Sprinkler System, mm/person (in/person)	
	IBC Table 1005.1	NFPA 5000 Table 11.3.3.1	IBC Table 1005.1	NFPA 5000 Table 11.3.3.1
Level Components and Ramps	5.1 (0.2)	5.1 (0.2)	3.8 (0.15)	5.1 (0.2)
Stairways	7.6 (0.3)	7.6 (0.3)	5.1 (0.2)	7.6 (0.3)

Table 7-6. Egress-limited Occupant Load Calculations

Element	**Width, mm (in)**	**Clear Width, mm (in)**	**Capacity Fac., mm/person (in/person)**	**Capacity, persons**	**Limiting Element**
Exit 1 - main					
Front Door	1829 (72)	1727 (68)	5.1 (0.2)	340	no
Interior Door	914 (36)	914 (36)	5.1 (0.2)	**180**	**yes**
Stairs (4 risers)	2540 (100)	2438 (96)	7.6 (0.3)	320	no
Ramp	2540 (100)	2438 (96)	5.1 (0.2)	480	no
Exit 2 - bar					
Side Door	914 (36)	914 (36)	5.1 (0.2)	180	no
Stairs (4 risers)	1016 (40)	914 (36)	7.6 (0.3)	**120**	**yes**
*Exit 3 - kitchen**					
Side Door	*914 (36)*	*914 (36)*	*5.1 (0.2)*	*180*	*no*
Stairs (4 risers)	*1016 (40)*	*914 (36)*	*7.6 (0.3)*	*120**	*yes*
Exit 4 - platform					
Side Door	914 (36)	914 (36)	5.1 (0.2)	180	no
Stairs (4 risers)	965 (38)	914 (36)	7.6 (0.3)	**120**	**yes**
			total egress limit	**420***	

* Model codes exclude exiting through a kitchen when computing occupancy limit

7.4 REFERENCES FOR CHAPTER 7

[1] "Code Analysis of the Station Nightclub," KA 03732-004, Koffel Associates, Inc., Ellicott City, MD, June, 2004.

[2] *2003 International Building Code*, International Code Council, Inc., Country Club Hills, IL.

[3] *2003 International Fire Code*, International Code Council, Inc., Country Club Hills, IL.

[4] *NFPA 1, Uniform Fire Code*, National Fire Protection Association, Quincy, MA, 2003.

[5] *NFPA 5000, Building Construction and Safety Code*, National Fire Protection Association, Quincy, MA, 2003.

[6] *The BOCA National Building Code/1993, Twelfth Ed.*, Building Officials and Code Administrators, Inc., Homewood, IL.

[7] *NFPA 101, Life Safety Code*, National Fire Protection Association, Quincy, MA, 2003.

[8] "Evaluation of Limitations to Egress through Doorways in Emergency Situations," vol. 2, Ove Arup & Partners Massachusetts Inc., Job number 32979, Westborough MA, Feb. 18, 2004.

[9] West Warwick, Rhode Island, Building Permit May 18, 1970.

[10] Building Permit October 18, 1971.

[11] Building Permit July, 1, 1975.

[12] West Warwick, Rhode Island Commercial /Industrial Property Record Card May 30, 2001.

[13] *ASTM E84-00a, Standard Test Method for Surface Burning Characteristics of Building Materials,* American Society for Testing & Materials, West Conshohocken, PA, 2001.

[14] *NFPA 255, Standard Method of Test of Surface Burning Characteristics of Building Materials*, National Fire Protection Association, Quincy, MA, 2002.

[15] *NFPA 286, Standard Methods of fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth*, National Fire Protection Association, Quincy, MA, 2002.

[16] American Wood Council. Design for Code Acceptance. awc.org/publications/dca/dca1/dca1.pdf

[17] Canadian Wood Council. Cwc.ca/design/tech_topics/fire/spread_ratings.html

Chapter 7

Chapter 8
SUMMARY, FINDINGS AND RECOMMENDATIONS

8.1 SUMMARY OF INVESTIGATION

Under the authority of the National Construction Safety Team Act, a team was formed by the NIST Director on Feb. 27, 2003 to investigate the failure seven days earlier of The Station nightclub in West Warwick, Rhode Island. The objectives of the investigation were the following:

- to establish the likely technical cause or causes of the building failure;
- to evaluate the technical aspects of evacuation and emergency response procedures;
- to recommend, as necessary, specific improvements to building standards, codes, and practices based on the findings made pursuant to the duties listed above; and
- to recommend any research and other appropriate actions needed to improve the structural safety of buildings, and improve evacuation and emergency response procedures, based upon the findings of the investigation.

The following activities were undertaken by the team to reach the first two objectives and to establish the basis for the remaining two:

- identification of technical issues and hypotheses requiring investigation through consultations with experts in fire protection engineering, emergency evacuation, and members of other teams investigating The Station fire;
- data collection from local authorities, contractors and suppliers, building and fire protection design documents, records, plans, and specifications, video and photographic data, telephone and radio transmissions, field data, a limited number of interviews and other oral and written accounts from building occupants and emergency responders, and other witnesses as reported by the news media;
- analysis and comparison of national model building and fire codes and practices, as well as review and analysis of practices used in operation of the building;
- simulation and analysis of phenomena (with associated uncertainties), including fire spread, smoke movement, tenability, occupant behavior and response, evacuation issues, and operation of active and passive fire protection systems; and
- testing to provide additional data and validate computer simulation predictions.

The previous seven chapters of this final report describe the methodology used to conduct the investigation, detail what occurred on the night of Feb. 20, 2003, review the history of the building and the model codes and standards that would have applied to a building of this type, and present the results of testing and simulations. The key findings from the investigation are summarized in the following section. Recommendations for improving model building and fire standards, as well as codes, and practices are listed in Section 8.3; Section 8.4 describes actions already taken by local authorities and code making organizations. Research recommendations and other appropriate actions are provided in Section 8.5.

8.2 FINDINGS

During the course of the investigation NIST examined the life safety systems that were part of the building design; the materials used as part of the structure, as finish products and as building contents; the egress process; the response of the fire department to the incident; and relevant model building and fire codes. NIST developed new information or confirmed published reports as to the initiating event, the reasons for the very rapid spread of fire and smoke, the difficulties encountered by the occupants during egress, and the mass casualty situation confronted by the fire department. Many of the findings summarized in this section had a direct bearing on the tragic outcome of this specific event; others had a peripheral role but are important to capture because of the potential to positively influence the outcome of future events. All findings are presented in various categories below, with the key findings highlighted in bold.

8.2.1 Materials

- **A non-fire retarded foam sample purchased by NIST ignited within 10 seconds when exposed to a pyrotechnic device (15x15 gerb) in an arrangement similar to the set up on the platform of the nightclub. When a plywood panel with fire retarded polyurethane foam was exposed in a similar manner to a 15 x 15 gerb, no ignition of the panel occurred, nor did the plywood ignite with no foam present.**
- **As could be seen in the WPRI video, flames spread rapidly over the foam in the nightclub, generating smoke and enough heat (calculated to be almost 60 MW at its peak) to ignite the wood paneling underneath and adjacent to the foam. The wood paneling in the nightclub was estimated to contain over 95 % of the fuel load, so that once most of the foam was consumed (estimated to be around two minutes after ignition of the foam), the fire transitioned to a wood frame building fire, with a steady heat release rate calculated to be around 45 MW.**
- **There was no fire resistant barrier between the interior of the nightclub and foam thermal insulation which had been installed in the stud space on the interior side of external walls of the drummer's alcove.**
- **In the reconstruction of the *platform area fire* conducted at NIST, within 90 seconds after ignition of the non-fire retarded polyurethane foam conditions near the middle of the dance floor at head height (1.5 m, or 5 ft, above the floor) were lethal. (Temperature exceeded 460 ^{o}C (860 ^{o}F), carbon monoxide volume fractions reached 1 percent, hydrogen cyanide levels exceeded 0.07 percent, oxygen volume fraction fell to 9 percent, and radiant heat flux exceeded 40 kW/m^{2}.)**
- **NIST could not obtain samples of the foam that actually had been applied to the nightclub walls to conduct a chemical analysis to determine if the polyurethane material contained fire retardants; however, the ignition behavior of the foam exhibited on the WPRI video was consistent with the behavior observed in the NIST testing with a non-fire retardant foam.**
- Model codes require that foamed plastic material used as an interior finish pass large-scale fire tests that substantiate the combustibility characteristics of the material related to the actual end use.

- Model codes permit the use of pyrotechnic devices in nightclubs if certain precautions are taken and with the approval of the authority having jurisdiction.
- The average heat flux from the gerbs purchased by NIST impinging on a surface was determined to be much less than the average heat flux from the fire to the foam surface, once ignition of the foam had occurred.
- The heat release rate from foam samples found at the site and representative materials purchased by NIST ranged between about 250 kW/m^2 and 1100 kW/m^2 when exposed to radiant fluxes between 20 kW/m^2 and 70 kW/m^2 in a cone calorimeter.
- The carpet and furnishings contributed a relatively small amount to the fire, and the ceiling tiles a negligible amount.

8.2.2 Fire Protection Systems

- **Experiments conducted at NIST in a reconstruction of *the platform area* fire demonstrated that a water sprinkler system installed in the test room in accordance with NFPA 13 [1] was able to control the fire initiated in non fire retarded polyurethane foam panels and maintain tenable (survivable) conditions at head height in the test room for the duration (over five minutes) of the experiment. This was in contrast to the reconstruction of the platform area fire with no sprinklers present, which led to likely fatal conditions at head height in the test room in about 1-1/2 minutes. A computer simulation of the full nightclub with and without sprinklers led to a similar positive result for the sprinklered scenario.**
- **Automatic fire sprinklers were not installed in The Station nightclub, nor were they required for such existing structures under the 2003 editions of the model codes.**
- **A heat detection/fire alarm system was installed in The Station nightclub, which activated (sound and light strobe) 41 seconds after ignition of the polyurethane foam, by which time the crowd had already begun to move toward the exits.**
- Several hand-held fire extinguishers were located on the premises, at least one of which was used in an attempt to extinguish the fire on the platform.
- Standard exit signs were located above each exit.
- The building was equipped with emergency egress lighting.
- The kitchen was equipped with a dry powder fire suppression system above the stove.

8.2.3 Occupant Load and Egress

- **The first patrons recognized the fire danger about 24 seconds after ignition of the foam; the bulk of the crowd began to evacuate shortly after that, around the time the band stopped playing (30 seconds).**
- **The rate of egress from the main entrance at the front of the building was limited by the single doorway inside the vestibule, not the double doors visible from the outside.**
- **About 2/3 of the occupants appear to have attempted to leave through the single main entrance in the front of the building; many were unsuccessful.**

- **Prior to 1-1/2 minutes into the fire, a crowd-crush occurred in the front vestibule which almost entirely disrupted the flow through the front exit. The precise event which led to the crowd-crush likely was related to the arrangement of the single interior door with merging streams of traffic and the pressure to escape the rapidly deteriorating conditions in the main area of the nightclub.**
- **Measurements of temperature, heat flux and gas species in a reconstruction of the platform area fire at NIST and computer models of the NIST experiment and the full nightclub suggest that the conditions around the platform, dance floor, sunroom, and dart room would have led to severe incapacitation or death within about 1-1/2 minutes after ignition of the foam for anyone remaining standing, and for not much longer even close to the floor.**
- **The number of building occupants at the time of the fire was reported by the Providence Journal to be 440 [2].**
- The Station had three doors suitable for exit by occupants.
- The main area of the nightclub around the platform was open with very few chairs, stools or tables, consistent with a festival seating arrangement. Based upon the arrangement, the geometry of the exits, and the floor area, the occupant limit for a similar building would be 420 persons according to both NFPA 5000 [3] and the International Building Code [4].
- For more than a minute into the fire, the crowd moved in an orderly fashion at an egress rate estimated to be a bit faster than 1 person/second through the main entrance of the building.
- It was reported by the Providence Journal that a little over half of all people who successfully escaped via the doors (main entrance plus main bar plus kitchen plus platform door) exited via the main entrance.
- The windows in the main bar room and the sunroom became the secondary routes of escape once the main entrance became impassible, and, according to reports, they accounted for over 1/3 of the successful evacuations.
- The high number of victims found relatively close to the windows in the sunroom suggests that the environment became untenable more quickly than the victims were able to find a secondary route (e.g., through the sunroom windows) once the platform door and main entrance became unusable.
- The small number of victims found in the main bar room suggests that the main bar room exit door and windows provided open routes of escape up to the point where conditions in that area of the building became untenable.
- A computer model of The Station nightclub fire suggests that the conditions in the main bar area near the floor may have been survivable for more than three minutes after ignition, which is consistent with the WPRI video that showed people being assisted through the main bar windows up to 4 minutes after the start of the fire.
- A significant number of victims were found in the dart room, storage area, and office near the back of the building, suggesting that they (i) were unfamiliar with the building and hoped to find a safe exit in that region, (ii) did not realize that an exit existed inside the kitchen, or (iii) became disoriented while heading for the side exit of the main bar room.

- An interior door which opened inward was located at the platform exit, but the orientation of the door did not play a role in delaying the evacuation process since the rapid fire growth in that vicinity discouraged patrons from attempting to escape via the platform door exit.
- A preexisting exit adjacent to the lavatories at the back of the structure had been eliminated during some previous construction.
- The Team found no evidence of a written emergency action plan, a written fire prevention plan, or employee training to assist safe and orderly evacuation.
- No evidence was found that a uniformed firefighter was on the premises at the start of the fire; however, at least two off-duty West Warwick police officers were present, including one who called in the fire from within the building.

8.2.4 Emergency Response

- The first 911 call reporting a fire was before 11:09 pm, less than 40 seconds after ignition of the foam.
- **West Warwick police officers on the scene reported the fire about one minute after ignition of the foam, leading to the dispatch of four engines with six fire fighters and three fire officers, a tower-ladder truck with two fire fighters, a rescue unit with two attendants, and a battalion chief.**
- **The first fire engine, staffed with one firefighter and a fire officer, was confirmed on-scene less than five minutes after the first 911 call was received, which was well within the limits of the NFPA standard [5] that states the fire department should be able to respond to a call within six minutes at least 90 percent of the time.**
- NFPA standards [5] recommend a minimum staffing level of four firefighters on both engine and truck companies, which was not achieved. Additional firefighters on scene at the crucial initial phase of the response would have benefited the rescue and firefighting efforts, although NIST is unable to say how the outcome might have been altered.
- Rhode Island's fire/rescue, emergency medical services and law enforcement agencies were confronted with the largest life loss fire incident in the State's history.
- Mutual aid agreements with neighboring jurisdictions were effective in bringing the necessary resources (equipment and emergency responders) to the scene of the incident.
- A mass casualty plan was implemented capably within about 10 minutes of arrival of the first engine on the scene, such that within two hours of the start of the fire, all occupants needing medical attention had been evacuated from the scene and transported to medical facilities.
- Because of the ongoing criminal investigation, the medical examiner's reports that may have revealed the likely causes of death of the 100 victims of the fire were not available to NIST.
- Communications challenges resulting from limited radio equipment capabilities and the high volume of traffic substantially hampered the Incident Command's effective coordination of fire ground and triage operations, as well as the routing of responding EMS units to area hospitals.

8.2.5 Public Building Record-keeping Practices

- Records were not found of the initial building design. Records of modifications -- when located -- lacked sufficient detail to track the changes to the structure.
- Neither the historical nor most current use and occupancy permit for the building was located; however, the use of The Station was consistent with the IBC and NFPA 5000 occupancy classifications of "Group A-2" and "Assembly," respectively.
- The main deficiencies of the building identified during the history of inspections by the Town of West Warwick related to the location of the fire extinguishers, non-functioning exit signs and emergency lights, broken panic hardware on an exit door, and the direction of swing of an exit door.
- On numerous reports, deficiencies identified by the inspectors were later annotated as "OK," but with no official re-inspection signature.
- No Town of West Warwick or State of Rhode Island documents prior to Feb. 20, 2003 were located that mentioned foam materials on the walls of the nightclub, nor the use of pyrotechnics similar to those used on Feb. 20, 2003.

8.2.6 Referenced Codes and Standards

Tables 8-1, 8-2, and 8-3 list, respectively, the model codes and standards in the areas of materials, fire protection systems, and occupant load and egress that relate to the findings of the NIST investigation team. Table 8-4 summarizes the issues surrounding applications of the code, and building and fire safety practices. References are to the appropriate sections/paragraphs in the current International Building Code [4], the Life Safety Code [7], NFPA 5000 [3], and the standards contained therein. (The relevant sections in the International Fire Code and the Uniform Fire Code can be linked to the corresponding sections in the International Building Code and NFPA 5000 through the Tables provided in Appendix K.) The last column indicates the relevance of the issue to the outcome on Feb. 20, 2003. Based upon the computer simulations and other findings from the investigation, an "H" was assigned to issues that, properly addressed, were highly relevant and would almost certainly have reduced substantially the loss of life (these are also highlighted in bold); an "L" implies a low likelihood that addressing the issue would have reduced the loss of life for this particular incident; and "M" implies moderate relevance to the specifics of this particular incident. Consideration by the model code organizations and the building and fire safety professions for those actions marked as "L," while not linked tightly to the outcome of The Station fire, is still warranted. In some cases, actions may be called for that are not even addressed in the model codes as currently written; the code sections identified in Tables 8-1 through 8-4 are not meant to be inclusive.

Table 8-1 Findings Concerning Materials Relevant to Model Codes and Standards

Issue	References	Relev. H	M	L
Polyurethane foam used as sound insulation on platform and walls. Foam thermal insulation unprotected in back platform wall.	**ASTM E84 [9]**	**X**		
	NFPA 255 [11]	**X**		
	NFPA 286 [10]		**X**	
	IBC:2604 [4]		**X**	
	5000:10.4.3.1 [3]		**X**	
Pyrotechnic devices were used as part of the theatrics. **Little guidance provided to AHJ* regarding appropriate use of pyrotechnics.**	**NFPA 1126 [12]**	**X**		
Unknown fire rating on wood paneling.	IBC:803.6 [4]			X
	5000:16.3.3.3 [3]			X

* Authority Having Jurisdiction

Table 8-2 Findings Concerning Fire Protection Systems Relevant to Model Codes and Standards

Issue	References	Relev. H	M	L
Automatic sprinklers not required due to grandfather clause.	**101:13.3.5.1 [7]**	**X**		
	5000:16.3.5.1.1 [3]	**X**		
	IBC:903.2.1.2 [4]	**X**		
	101.12.3.5.1 [7]			X
Fire alarm system unable to alert people to hazard quickly enough to avoid trapping occupants in building.	IBC:907.2.1 [4]		X	
	5000:16.3.4 [3]		X	
Portable fire extinguishers ineffective/not used early in fire.	NFPA 10 [8]		X	

Table 8-3 Findings Concerning Occupant Load and Egress Relevant to Model Codes and Standards

Issue	References	Relev. H	M	L
Main entrance did not have capacity to handle 50% of the occupants on the night of the fire, and 50% would have been insufficient to safely evacuate all occupants in time (1-1/2 minutes).	**IBC:1024.2 [4]** **5000:16.2.3.3 [3]**	**X**		
Trained crowd managers not required for occupant loads < 1000.	**101:12.7.5 [7]** **101:13.7.5 [7]**		**X** **X**	
Festival seating increased the number of occupants permitted.	5000:16.2.5.4.1 [3] 101:12.2.5.4.1 [7] 101:13.2.5.4.1 [7] 5000:16.2.4.1 [3]		X X X X	
Higher occupant load factor permitted in IBC.	**IBC:1004.2 T [4]** **5000:11.3.1.2 T [3]**		**X** **X**	
Lower egress capacity factor permitted in IBC if sprinklers are installed.	**IBC:1005.1 T [4]** **5000:11.3.3.1 T [3]**		**X** **X**	
Location of alternative exits not obvious to patrons unfamiliar with nightclub, in spite of proper exit signs above doors.	IBC:16.4.7.5 [4] 5000:11.10.1.4 [3]		X X	
Longer common path of travel allowed in IBC.	IBC:1013.3 [4] 5000:16.2.5.1.2 [3]		X X	
Interior leaf of platform door did not swing in direction of egress.	IBC:1008.1.1 [4] 5000:11.2.1.4.2 [3]			X X
Stairs and landings at side exits may not have been at same level on both sides of doors.	IBC:1008.1.4 [4] 5000:11.2.1.3 [3]			X X
Main entrance double doors not equipped with panic hardware.	IBC:1008.1.9 [4] 5000:16.2.2.2.3 [3]			X X

Table 8-4 Findings Relevant to National Practices

Issue	References	Relev.		
		H	M	L
Automatic sprinklers not required due to grandfather clause.	**IBC:903.2.1.2 [4] 5000:16.3.5.1.1 [3]**	**X X**		
Polyurethane foam used as sound insulation on platform and walls.	**education, practice**	**X**		
Model codes can provide a meaningful level of safety only when adopted, practiced, and enforced by local jurisdictions.	**policy, practice**	**X**		
Model codes do not guarantee safety of occupants in all anticipated situations.	**policy**		**X**	
Criteria for optimum allocation of resources among routine inspections, prevention programs, and emergency response not established.	policy, practice, research		X	
Inspection reports not maintained.	**101:12.7.1 [7] 101:13.7.1 [7]**		**X X**	
	IBC:104.7 [4] 5000:1.7.6.6.4 [3]			X X
Portable fire extinguishers ineffective/not used early in fire.	training, practice			X
Stairs and landings at side exits may not have been at same level on both sides of doors.	IBC:1008.1.4 [4] 5000:11.2.1.3 [3]			X X
Main entrance double doors not equipped with panic hardware.	IBC:1008.1.9 [4] 5000:16.2.2.2.3 [3]			X X
Details of work not included in permits, or permits not obtained.	IBC:105.1 [4] 5000:1.7.6.1.1 [3]			X X
No indication that building was inspected following completion of work.	IBC:109.1 [4] 5000:1.7.6.6.1.3 [3]			X X

8.3 RECOMMENDATIONS FOR IMPROVING MODEL STANDARDS, CODES AND PRACTICES

The findings presented above raise a number of issues concerning model codes and standards, and the practices surrounding their adoption, application, and enforcement. The process for modifying current model codes is laid out clearly by the NFPA and the ICC. The major standards developing organizations (ANSI, ASCE, ASME, ASTM, ISO, NFPA and UL) also have set procedures for amending the standards they maintain. The decision to adopt one or more sections of a model code is made at the local or state level. The federal government has no direct role in code adoption, but individual representatives of federal agencies can propose modifications to the model standards and codes, and can share their expertise with the private sector technical committees responsible for particular building and fire standards or sections of the model codes. NIST, as authorized by the NCST Act, is obligated to recommend modifications that are warranted by the findings of its investigations. Some significant actions already have been taken by the state of Rhode Island and the NFPA that incorporate aspects of the recommendations that follow, and these actions are described in section 8.4.

8.3.1 Recommendations for all new and existing nightclubs

The first four recommendations should be applied in the model codes to all new and existing nightclubs regardless of size The application to all existing nightclubs is a recognition that (i) the environment within The Station became lethal in less than 1-1/2 minutes, and (ii) the control of building contents, finish materials, and occupancy limits has been demonstrated to be considerably less rigorous in nightclubs (see Appendix C for multiple examples) than in most other places of assembly.

Recommendation 1

The results of the investigation clearly demonstrated the value of an NFPA 13 compliant automatic fire sprinkler system in extending the time the nightclub remained tenable.

NIST recommends that model codes require sprinkler systems for all new and existing nightclubs regardless of size, and that state and local authorities adopt this provision.

Recommendation 2

The reaction to fire of building finish materials and contents is mentioned throughout the building and fire codes. The investigation identified portions of the national model codes and standards that were inadequate in this area.

In relation to the fire performance of finish materials and building contents, NIST recommends that model codes require, and that state and local authorities adopt the following provisions:

a) certain classes of materials (including non-fire retarded flexible polyurethane foam) that are known to easily ignite and rapidly propagate flames (i.e., they have an ignition temperature below some minimum, or a flame spread index and heat release rate greater than some maximum values) be clearly and specifically forbidden, with no exceptions, as finish materials from all new and existing nightclubs;

b) greater guidance be provided for when large-scale tests are required to demonstrate that materials do not pose an undue hazard for the use intended;

c) the pass/fail criteria for flame spread tests and large-scale tests (including ASTM E-84, NFPA 255, and NFPA 286) be established using best measurement and prediction practices; and

d) strengthen provisions in NFPA 1126 (Use of Pyrotechnics before a Proximate Audience) which apply to all new and existing nightclubs through the following actions: banning the use of pyrotechnic devices from buildings less than 10,000 ft^2; requiring that all materials (including structural, finish, and contents) in structures that pyrotechnic devices are to be permitted meet low flame spread and heat release rate criteria; and require a minimum clearance greater than twice the designed projection of the pyrotechnic device from the nearest fixed surface or moveable contents.

Recommendation 3

The rationale for changes in egress provisions include the realization that other fire safety systems may be non-functional; that the impact of smoke, heat, and gases on human behavior during evacuation is not known; that mobility challenged persons take longer to evacuate; and that threats other than fire can require rapid evacuation.

NIST recommends that the factor of safety on the time for occupants to egress from all new and existing nightclubs be increased in the model codes in the following manner, and that state and local authorities adopt these provisions:

- ***a) Compute the number of required exits and the permitted occupant loads assuming at least one exit (including the main entrance) will be inaccessible in an emergency evacuation.***
- ***b) Increase the capacity of the main entrance to accommodate, at a minimum, 2/3 of the maximum permitted occupant level during an emergency.***
- ***c) Eliminate trade-offs between sprinkler installation and factors that impact the time to evacuate buildings.***
- ***d) Require staff training and evacuation plans for buildings that cannot be evacuated in less than 1-1/2 minutes.***
- ***e) Provide improved means for occupants to locate emergency routes -- such as exit signs near the floor and floor lighting -- once standard exit signs become obscured by smoke.***
- ***f) Establish the threshold building area and occupant limits for egress provisions using best practices for estimating tenability and evacuation time.***
- ***g) Require explicit evacuation directions be provided to occupants prior to the start of any public event inside a structure used for public assembly.***

Recommendation 4

A current practice that could have influenced the outcome of The Station fire was the use of the grandfather clause to exclude safety upgrades to existing buildings.

NIST recommends that model building and fire codes require, and that state and local authorities adopt, the application of new life-safety provisions to existing as well as new nightclubs, and that the practice of grandfathering of older structures be eliminated. Exemptions from the new provisions should be on a case-by-case basis and justified by a comprehensive fire safety analysis using best practices.

8.3.2 Recommendations for Improving General Building and Code Practices

The general public expects, and has a right to expect, that the model codes upon which their community depends will protect them from severe hazards in public buildings that can be anticipated. Invariably, the source of a building failure that leads to significant loss of life can be traced to a breakdown in one or more of the following key assumptions upon which the model codes are based: 1) the building designer, constructor, owner, operator, staff and patrons adhere to all applicable code provisions; 2) the historical record is a reliable predictor of worst case events; and 3) the authorities having jurisdiction (AHJ) properly interpret and enforce the code provisions. Building officials and the profession should strive for model codes that are robust and sensibly redundant to minimize the chances of loss of life caused by the failure of a building that is out compliance, or is operating out of compliance, with one or more code provisions. The next two recommendations, along with recommendation 4, are intended to move model codes and the building and fire safety professions in that direction.

Recommendation 5

NIST recommends that model codes and standards require redundancy in the passive and active fire protection systems to ensure adequate performance of the structure when one or more of the protective systems is compromised by uncertain behaviors of the building owner or occupants such as the following:

- ***a) installing building decorations or temporary features that greatly exceed flame spread or fire load provisions;***
- ***b) exposing the building to strong ignition sources;***
- ***c) exceeding the posted occupancy limits;***
- ***d) temporarily blocking an exit; and***
- ***e) disabling sprinklers or other life safety systems for maintenance.***

Recommendation 6

Appendix C recounts dozens of other tragedies in nightclubs and places of assembly where adherence to the model building and fire codes would have prevented the failure of the building. Of most relevance to the current incident are the Happy Land Social Club fire[17], the Gothenburg Dance Hall fire [18], the Café de Hemel fire [19], and the E2 Nightclub [20]. Each of these events killed between 14 and 87 people, with the root causes related to limitations on exits, overcrowding, an unanticipated initiating event, and (except for E2) building contents and materials that were inconsistent with the model fire codes.

NIST recommends that when performing an analysis of proposed changes to model building and fire codes, proper account should be taken of the soundness of and safety factor provided by the existing provisions in light of the history of similar building failures.

Recommendation 7

Portable fire extinguishers, if readily available, can be effective early in a fire and delay fire spread in the event the sprinkler system is not functioning.

NIST recommends that the model codes increase the number of portable fire extinguishers required, with their number and placement based upon a minimum time for access and application in a fully occupied building, and that staff be properly trained in their use.

8.3.3 Recommendations for fire prevention and emergency response

Even though the first fire engine arrived expeditiously, the speed at which the fire engulfed The Station rendered it impossible for the fire department to save the structure or the lives of many victims. However, the importance of the role of fire prevention activities in avoiding a future tragedy was highlighted by this incident. As in all mass causality events, especially those where the window of opportunity for rescue is extremely limited, effective and efficient communications within and among the various responding agencies is imperative. Developing effective interoperable communications requires addressing numerous critical success factors, including frequent use of interoperable communications equipment and procedures, formal governance and collaboration, formal standard operating procedures, appropriate technology, and multiagency training and exercises. Tools and best practice models addressing many of these success factors, including a statewide communications interoperability planning methodology are available though the Department of Homeland Security's SAFECOM Program.

Recommendation 8

An effective fire prevention and inspection program can greatly enhance the ability of emergency service providers to protect their community.

NIST recommends that the model codes provide specific guidance on how to implement an effective fire inspection program, including the training necessary to implement it, and that state and local authorities adopt such guidance in practice. Items to consider include the following:

- ***a) documentation of building permits and alterations;***
- ***b) means of egress inspection and record keeping;***
- ***c) frequency and rigor of fire inspections, including follow-up and auditing procedures;***
- ***d) education and training of inspectors, owners and operators; and***
- ***e) guidelines on recourse available to the inspector for identified deviations from code provisions.***

Recommendation 9

An effective response to a structure fire/mass casualty incident is critically dependent upon sufficient staffing of the responding units and communications capabilities the IC will utilize to direct appropriate operations and tactics.

NIST recommends that

- ***a) career and volunteer fire departments comply with the minimum apparatus staffing such as suggested in NFPA Standards 1710 [5] and 1720 [13], respectively, and 1500 [14] as appropriate;***
- ***b) public safety agencies at all levels give greater attention to the difficulty of communications systems interoperability, and that fire service and emergency medical services organizations make every effort to assure they develop and maintain sufficiently robust, interoperable communications capabilities to support major incident operations, including those requiring substantial mutual aid augmentations, such as those suggested in NFPA Standard 1221; and***
- ***c) major incident/mass casualty operations be conducted utilizing appropriate Incident Command/ Unified Command structures, policies and practices such as suggested in NFPA Standard 1561 [16].***

8.4 ACTIONS ALREADY TAKEN

The magnitude of the incident at West Warwick invoked a swift response by code developing organizations as well as by the State of Rhode Island. A number of the most critical recommendations from NIST presented above already have been enacted, either on a temporary emergency basis or as a permanent change to the codes. Some NIST recommendations have been addressed only partially, while aspects of others have been proposed and rejected by code bodies. Table 8-5 provides a cross-walk between the recommendations from NIST and the actions already taken that are discussed below.

(i) National Fire Protection Association

The Standards Council of NFPA held hearings to consider Technical Interim Amendments (TIAs) to address certain life safety issues raised by The Station fire. The TIAs dealt with sprinklers, occupancy levels, crowd management, and means of egress. The following TIAs, and the NFPA Code section to which they apply, were approved in July 2003:

- Sprinkler existing nightclub type facilities and festival seating venues with occupant loads greater than 100 (TIA #739R, 101: 13.3.5.1 [7])
- Sprinkler new nightclub type facilities and festival seating venues (TIA #741R, 101:12.3.5.1 [7], and TIA #743R, 5000: 16.3.5.1.1 [3])
- Require trained crowed managers for existing and new assembly occupancies (TIA #738, 101:12.7.5 [7] and 101:13.7.5 [7])
- Restrict festival seating in new and existing facilities if occupant load is greater than 250 unless life-safety evaluation conducted (TIA #737R, 101:12.2.5.4.1 [7] and 101:13.2.5.4.1 [7]; and TIA #740R, 5000:16.2.5.4.1 [3]).
- Require of owner means of egress inspection and record keeping (TIA #742R, 101:12.7.1 [7] and 101:13.7.1 [7]).

(ii) International Code Council

A number of proposals for code changes related to The Station fire incident were submitted to the ICC at its September 2003 public hearing. One proposal, to require foam plastics covered with a textile or vinyl facing to pass a flame spread test (proposal FS108-03/04) [4], was approved.

Several proposals were aimed at increasing the capacity of the main entrance and the area requirement per occupant:

- Proposal E101-03/04 to eliminate 300 occupant minimum before requiring 50% capacity for main entrance, and increasing capacity requirement to 67%
- Proposals E102-03/04 and E103-03/04 to increase capacity of main entrance to 75% and 67%, respectively.
- Proposal E11-03/04 to increase area required per occupant from 0.47 m^2 (5 ft^2) to 0.65 m^2 (7 ft^2)
- Proposal E13-03/04 to eliminate sprinkler trade-offs with egress width requirement

These proposals were disapproved, primarily due to lack of technical justification to substantiate the change. The recommendations for research presented later in this chapter were made to address this issue.

Table 8-5. Actions taken by model code bodies and State of Rhode Island

NIST Recommendation	Related Action Taken	Comments
1. Strengthen requirement for sprinklers	NFPA TIA #739R NFPA TIA #743R	NIST recommendation based upon max egress time (1-1/2 minutes), NFPA mod based upon occupant load (100)
	RI strengthened regulation requiring sprinklers	based upon occupant load (150), some exemptions
2. Strengthen restrictions on foam plastic finish materials and use of pyrotechnics	ICC FS108-03/04	ICC action deals with one aspect of foam plastic finish materials; NIST recommendation is broader, needs formal proposal
	RI strengthened restrictions on pyrotechnics	same objectives as NIST recommendation, needs formal proposal
3. Increase factor of safety on egress	NFPA TIA #737R NFPA TIA #738	NIST recommendation is broader, based upon egress time rather than occupant load; some research required before formal proposal is submitted
4. Eliminate practice of grandfathering	adopted by RI	grandfathering not required by code; local and state jurisdictions can eliminate practice if so desired
5. Require redundancy in active and passive fire protection systems	none	formal proposal required
6. Include high consequence-low probability events on cost/benefit analyses	none	some research may be required before formal proposal can be submitted

NIST Recommendation	Related Action Taken	Comments
7. Increase number of fire extinguishers	RI increased number required in stage areas	formal proposal required
8. Enhance guidance for fire inspection programs	NFPA TIA #742R	NFPA action encompassed within broader NIST recommendation, needs formal proposal
	RI strengthened fire marshal's enforcement power	critical aspect of NIST recommendation
9. Adopt and practice communication, response, and command structures already established	no code modifications needed	more local and state jurisdictions should consider adopting and practicing guidance already in model codes and standards
10. Conduct research to understand human behavior better in emergency situations	none	multi-agency effort needed
11. Conduct research to understand fire spread and suppression better	none	work ongoing at NIST and elsewhere
12. Conduct research to refine computer-aided decision tools	none	work ongoing at NIST and elsewhere

(iii) State of Rhode Island

The State of Rhode Island acted quickly to examine its own building and fire codes. A special legislative commission was formed, held hearings, and delivered its report to the governor on June 5, 2003 [21]. Quoting from the letter of transmittal, five actions were identified to improve building standards, codes, and practices:

- "Require the use across the board of up-to-date fire safety codes -- this will require the elimination of the "grandfather clause"-- and the coordinated administration of fire safety building codes.
- Prohibit the use of pyrotechnics in places of assembly such as nightclubs and strictly regulate their use in large venues…that can accommodate them safely.
- Mandate sprinklers in nightclubs with an occupancy of 150 or greater and in all Class A and B places of assembly, except places of worship and state and municipal buildings used for government purposes and place other requirements on nightclubs as high risk places of assembly.
- Provide greater enforcement powers to fire marshals to assure their ability: a) to make inspections, b) to require immediate abatement of conditions that pose an imminent threat to public safety or property and when necessary to order a premises vacated, and c) to inspect of nightclubs and other places of assembly during their actual hours of operation.
- Establish comprehensive planning requirements to identify in the future the weaknesses in Rhode Island's approach to fire safety and to recommend actions needed to improve fire safety."

The Fire Safety Code of the State of Rhode Island was amended significantly by The Comprehensive Fire Safety Act of 2003 [22] to address these five items and other issues discussed in the June 5 Report. Among the most significant changes was the adoption by Rhode Island of the Uniform Fire Code (NFPA 1) [5] and the Life Safety Code (NFPA 101) [7], which now includes the provisions of TIAs #737R, 738R, 739R, 740R, 741R, 742R, and 743R. All new and existing places of assembly in Rhode Island with a capacity greater than 300 will be required to be completely protected by an approved automatic sprinkler as of July 1, 2005. For new and existing buildings similar to The Station nightclub with occupancy less than 301 but greater than 150, the deadline for installing sprinklers is July 1, 2006. Additional provisions in The Comprehensive Fire Safety Act of 2003 include the requirement for two 20 pound fire extinguishers in stage areas and the strengthening of inspection authority for the Fire Marshal.

8.5 RESEARCH RECOMMENDATIONS AND OTHER APPROPRIATE ACTIONS

This investigation focused on The Station nightclub. Several recommendations in this report relate directly to nightclub structures, and other recommendations apply more broadly. Model building code organizations as well as state and local regulatory authorities should review the results of this investigation and consider the findings regarding sprinklers, egress, and materials flammability as they make revisions to their codes.

The acceptance by the model code and standards organizations of the recommendations being made by NIST and the adoption of modified provisions of the national model codes into the local code depend upon the strength of the technical evidence when weighed against the economic impact of implementing the change. There are a number of areas where the benefits may be obvious and the costs of implementation to the property owner and community can be computed easily. In those areas, to apply a particular provision of the code or not becomes a local policy decision that is not necessarily hindered by a lack of information available to the decision-maker.

There are other areas in which the basis for making the change is unsupported by data or technical rigor. Research is often needed in order to gain new knowledge and collect the data necessary to ensure that such changes are adopted if justified, or rejected if not. Research results also serve as the basis for setting thresholds or pass/fail criteria.

8.5.1 Recommendations for Research

NIST is required, under the NCST Act, to identify areas of research needed to support improvements to model building codes, standards and practices. Based upon the findings of this investigation and the resultant recommendations presented in section 8.3, additional research is recommended in three general areas:

- human behavior and people movement,
- material behavior and fire spread, and
- decision aids.

Recommendation 10

A basic tenet of our model codes is that public buildings should be designed and operated in a manner that assures there is enough time for occupants to evacuate safely for an anticipated worst case fire. In addition, we need to determine the desired behavior of occupants when faced with an unanticipated extreme event. Crowd-crush as observed in The Station fire also occurred in the E-2 [18] nightclub in Chicago the week prior to The Station incident, killing 21 people even though there was no fire, or even a real threat to the occupants. There is a need to understand better the behavior of people and crowds in emergency situations to pinpoint the factors that lead to crowd crush. This would enable sensible changes in building design to minimize the possibility of crowd crush, and improved ways to communicate to the crowd in emergency situations that go beyond the code.

NIST recommends that research be conducted to better understand human behavior in emergency situations, and to predict the impact of building design on safe egress in fires and other emergencies (real or perceived), including the following:

a) ***the impact of fire products (gases, heat, and obscuration) on occupant decisions and egress speeds;***

b) ***exit number, placement, size and signage;***

c) ***conditions leading to and mitigating crowd-crush;***

d) ***the role of crowd managers and group interactions;***

e) ***theoretical models of group behavior suitable for coupling to fire and smoke movement simulations; and***

f) ***the level of safety that model codes afford occupants of buildings.***

Recommendation 11

The behavior of people in a fire emergency and the time they have to escape depend upon the speed at which the fire spreads. Significant progress has been made in our ability to model the dynamics of a fire moving through a building, as evidenced by the simulations of The Station fire presented in this report. However, the state of the technology is insufficient to *accurately* model, in general, the spread of fire over common composite structures such as foam insulation on plywood, fabric covered foam furnishings, or gypsum covered wood frames. The detailed mechanisms for the formation of toxic products and smoke are extremely complex and are not amenable for inclusion in predictive fire models. Instead, it is necessary to rely on scientific experiments and real-scale fire testing of products and room geometries that are similar to what existed in the actual event to develop the empirical data required as input to computer fire models. This can be an impossible task for a fire that has occurred in a very large space, or when the fire totally destroys the structure along with the key evidence necessary for a reasonable recreation.

The time available for safe egress is influenced by the building geometry and ventilation system, the materials of construction and furnishings, and actions to suppress the fire. Predicting sprinkler activation and suppression and the influence of fire fighting activities on the spread of the fire is another aspect of the problem that cannot be done today to any but the grossest level of precision.

NIST recommends that research be conducted to understand fire spread and suppression better in order to provide the tools needed by the design profession to address recommendations 1 through 10, above. The following specific capabilities require research:

- ***a) prediction of flame spread over actual wall, ceiling and floor lining materials, and room furnishings;***
- ***b) quantification of smoke and toxic gas production in realistic room fires; and***
- ***c) development of generalized models for fire suppression with fixed sprinklers and for firefighter hose streams.***

Recommendation 12

New knowledge, data, and predictive methods generated in the above research will lead to new technologies and improved fire standards. The selection among alternative fire safety technologies or building design options, and the setting of threshold values in the model codes, can have significant economic ramifications. New tools are needed that can be tailored to the individual stakeholder that rigorously account for cost in a manner transparent to competing interests.

NIST recommends that research be conducted to:

- ***a) refine computer-aided decision tools for determining the costs and benefits of alternative code changes and fire safety technologies, and***
- ***b) develop computer models to assist communities in allocating resources (money and staff) to ensure that their response to an emergency with a large number of casualties is effective.***

8.5.2 Impact of Research

Completing the research recommended will put a sound technical foundation under the changes to codes, standards and practices that have already been made or are suggested. Specifically, a comprehensive research program would lead to an ability to:

- evaluate the impact of changing egress capacity and occupant load factors on the minimum time available for safe evacuation;
- quantify the value of increasing the size of the main entrance to handle a greater fraction of the occupant load;
- determine the relationship between flame spread rating on finish materials and fire spread in actual buildings;
- predict the smoke and toxic gas levels to a much greater level of precision, and the ramification of these fire products on occupant movement;
- quantify the value of sprinklers in places of assembly with different occupant loads, and compare the performance of alternative designs;
- investigate different strategies for managing crowds under various threat types and levels;
- supplement training for firefighters, fire marshals, other emergency responders, code officials, and crowd managers; and
- educate building owners, their employees and the general public on approaches to remain safe in places of assembly.

8.6 REFERENCES FOR CHAPTER 8

[1] *NFPA 13, Standard for the Installation of Sprinkler Systems,* National Fire Protection Association, Quincy, MA, 2002.

[2] *Providence Journal*, “In the Fire,” p. B4, February 20, 2004.

[3] *NFPA 5000, Building Construction and Safety Code,* National Fire Protection Association, Quincy, MA, 2002

[4] *2003 International Building Code,* International Code Council, Inc., Country Club Hills, IL, 2002.

[5] *NFPA 1710, Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*, National Fire Protection Association, Quincy, MA, 2001.

[6] *NFPA 1, Uniform Fire Code,* National Fire Protection Association, Quincy, MA, 2003.

[7] *NFPA 101, Life Safety Code*, National Fire Protection Association, Quincy, MA, 2003.

[8] *NFPA 10, Standard for Portable Fire Extinguishers*, National Fire Protection Association, Quincy, MA, 2002

[9] *ASTM E84-00a, Standard Test Method for Surface Burning Characteristics of Building Materials,* American Society for Testing & Materials, West Conshohocken, PA, 2001.

[10] *NFPA 286, Standard Methods of fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth,* National Fire Protection Association, Quincy, MA, 2002.

[11] *NFPA 255, Standard Method of Test of Surface Burning Characteristics of Building Materials,* National Fire Protection Association, Quincy, MA, 2002.

[12] *NFPA 1126, Use of Pyrotechnics before a Proximate Audience,* National Fire Protection Association, Quincy, MA, 2002

[13] *NFPA 1720, Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Volunteer Fire Departments,* National Fire Protection Association, Quincy, MA, 2001.

[14] *NFPA 1500, Standard on Fire Department Occupational Safety and Health Program,* National Fire Protection Association, Quincy, MA, 2002.

[15] *NFPA 1221, Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems,* National Fire Protection Association, Quincy, MA, 2002.

[16] *NFPA 1561, Standard on Emergency Services Incident Management Systems,* National Fire Protection Association, Quincy, MA, 2002.

[17] *NFPA Alert Bulletin*, “Social Club Fire Bronx, New York”. Number 90-2, May 1990.

[18] *NFPA Fire Investigation Report, Dance Hall Fire, Gothenburg, Sweden*, National Fire Protection Association, Quincy, MA, 1998.

[19] Lostetter, S.M.O., and Reijman, P.B., "Reconstruction of the Fire in 'de Hemel' in Volendam, New Years Eve 2000/2001," Interflam 2004.

[20] Johnson, Mark, *Chicago Club had been told to Close*, Milwaukee Journal Sentinel, 18 Feb. 2003.

[21] "Making Rhode Island the Safest State," Report to the Rhode Island General Assembly, June 5 2003.

[22] Comprehensive Fire Safety Act of 2003, Chapter 23-28, Amendment to the General Laws, Health and Safety, SECTION 2. Title 23.

APPENDIX A. LARGE FORMAT EVACUATION TIMELINE STILLS

A.1 LARGE FORMAT EVACUATION TIMELINE STILLS

This Appendix, compiled by Arup [1] presents the still frame pictures taken from the WPRI-TV video of the incident at the Station nightclub on February 20, 2003 [2]. The events comprising the incident timeline (see Chapter 2) were identified through these still frames.

Each video frame includes a time bar representing the incident duration considered here with an indication of where the given event occurred in this time span. The analysis focused upon the time period beginning when the lights in the club were turned down in preparation for the show until the camera operator, in the parking lot, places the camera on the ground and significant flames are seen emanating from the front of the building. Beyond this time, the building is heavily engulfed by the fire and no additional events specifically significant to this analysis are shown on the video.

The time bar provided above each still frame corresponds to the comprehensive timeline given in the main report. Note that “Video Time” refers to the absolute videotape co unter time associated with the events as captured on the television crew video, while “Fire Time” refers to the time of events relative to the start of the fire.

Each frame also includes a location key showing where the camera was located (yellow dot) and in which direction it was pointing (green arrow) when the frame was recorded. The faces of occupants have been blurred to preserve anonymity.

Figure A.1 Timeline Event 1

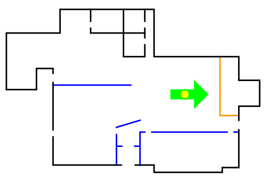
Video Time: 0:05:49

Fire Time: -0:00:33

Description:

Stage lights turned down for beginning of show.

Location Key:



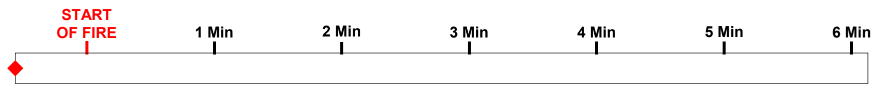


Figure A.2 Timeline Event 2

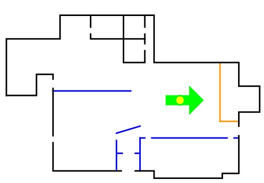
Video Time: 0:06:08

Fire Time: -0:00:14

Description:

Band first shown on stage.

Location Key:



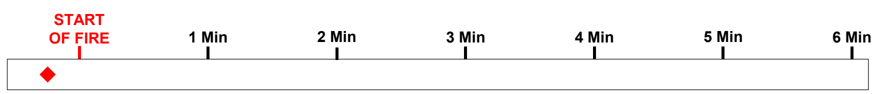


Figure A.3 Timeline Event 3

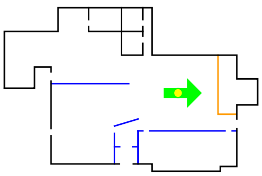
Video Time: 0:06:14

Fire Time: -0:00:08

Description:

Pyrotechnic display initiated.

Location Key:



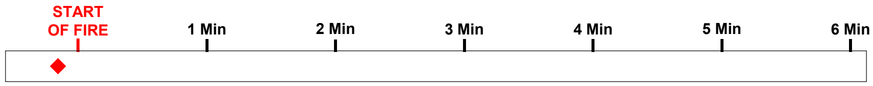


Figure A.4 Timeline Event 4

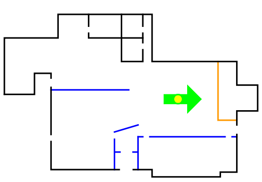
Video Time: 0:06:22

Fire Time: 0:00:00

Description:

First flames on upper wall, left of stage.

Location Key:



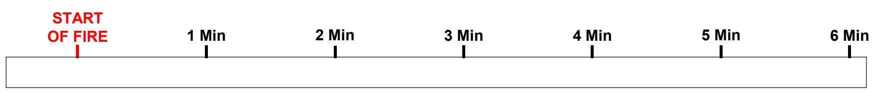


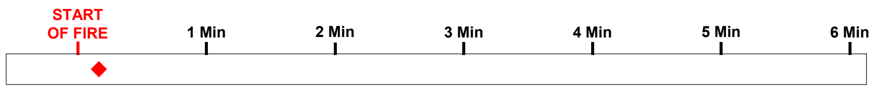
Figure A.5 Timeline Event 5

Video Time: 0:06:31

Fire Time: 0:00:09

Description:

Flames on upper wall, right of stage. Pyrotechnic display turned off.



Location Key:

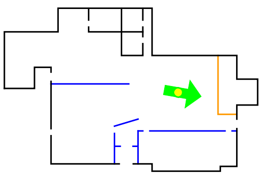


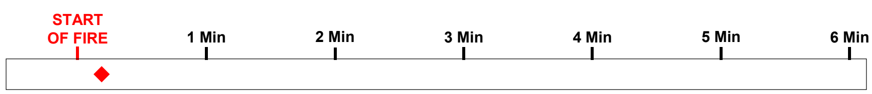
Figure A.6 Timeline Event 6

Video Time: 0:06:33

Fire Time: 0:00:11

Description:

Band members first notice flames.



Location Key:

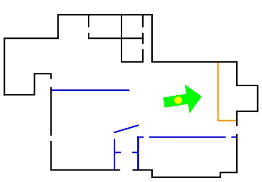


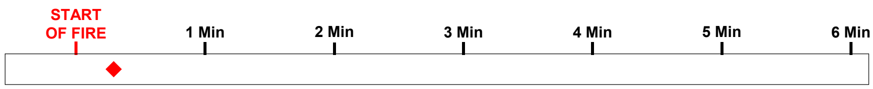
Figure A.7 Timeline Event 7

Video Time: 0:06:38

Fire Time: 0:00:16

Description:

Flames reach ceiling to right of stage.



Location Key:

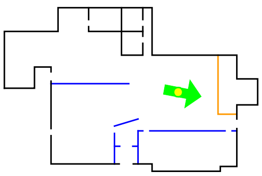


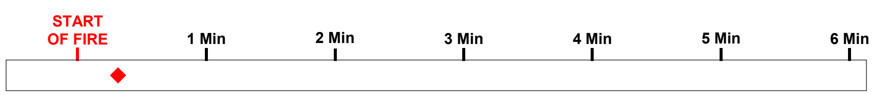
Figure A.8 Timeline Event 8

Video Time: 0:06:40

Fire Time: 0:00:18

Description:

Camera operator begins to evacuate.



Location Key:

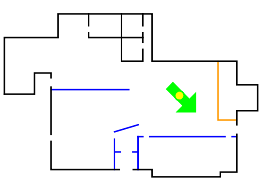


Figure A.9 Timeline Event 9

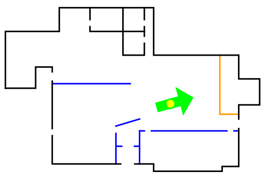
Video Time: 0:06:47

Fire Time: 0:00:25

Description:

Flames touching ceiling on both sides of stage.

Location Key:



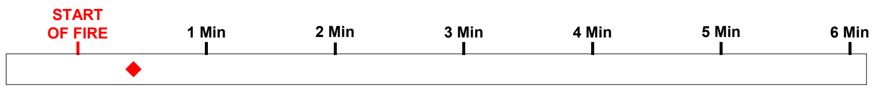


Figure A.10 Timeline Event 10

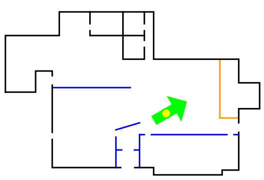
Video Time: 0:06:52

Fire Time: 0:00:30

Description:

Band members begin to evacuate stage.

Location Key:



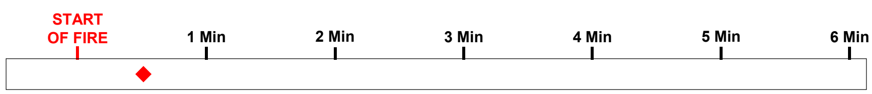


Figure A.11 Timeline Event 11

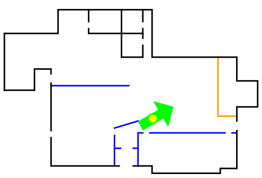
Video Time: 0:06:54

Fire Time: 0:00:32

Description:

Flames extend fully across ceiling above stage.

Location Key:



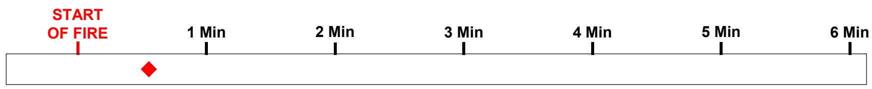


Figure A.12 Timeline Event 12

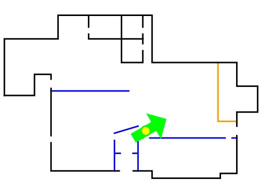
Video Time: 0:07:07

Fire Time: 0:00:41

Description:

Fire alarm strobes begin to flash. Fire alarm can be heard.

Location Key:



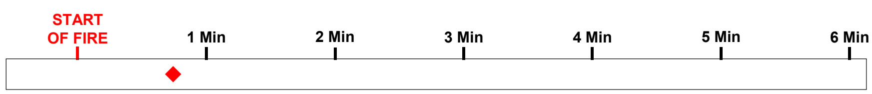


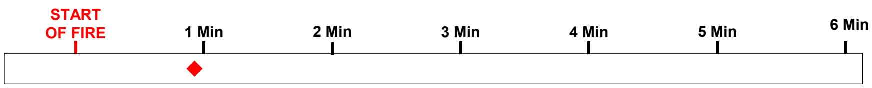
Figure A.13 Timeline Event 13

Video Time: 0:07:16

Fire Time: 0:00:54

Description:

Camera operator reaches exit lobby.



Location Key:

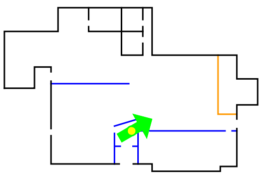


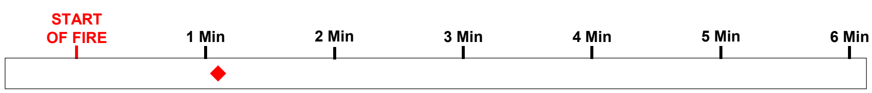
Figure A.14 Timeline Event 14

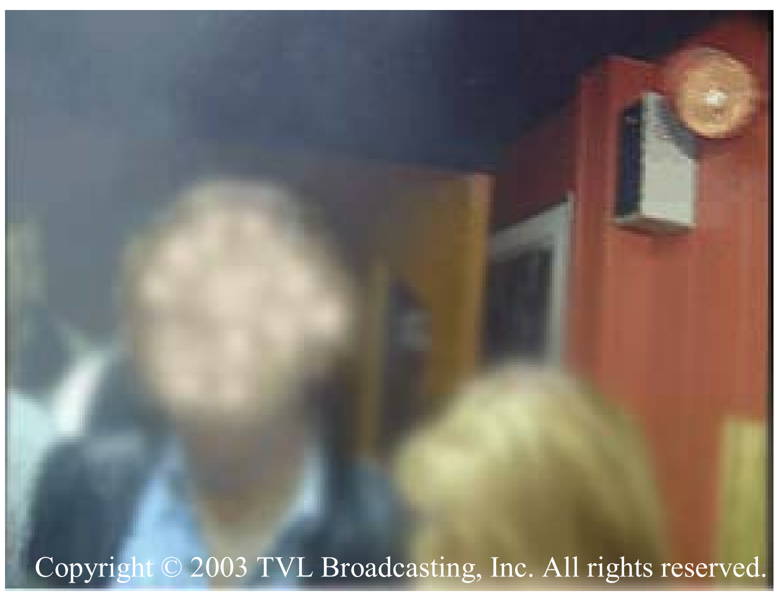
Video Time: 0:07:28

Fire Time: 0:01:06

Description:

Smoke in outer exit lobby.





Location Key:

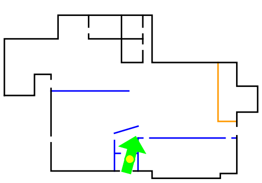


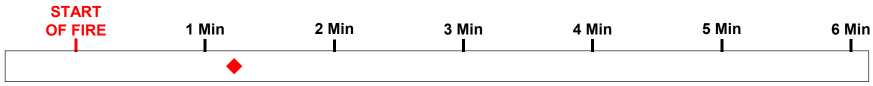
Figure A.15 Timeline Event 15

Video Time: 0:07:33

Fire Time: 0:01:11

Description:

Camera operator exits building.



Location Key:

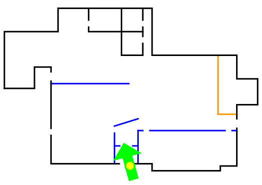


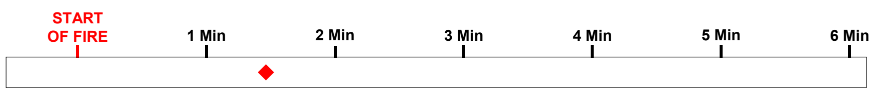
Figure A.16 Timeline Event 16

Video Time: 0:07:48

Fire Time: 0:01:26

Description:

Smoke coming out of stage exit. Flames visible inside at this location.



Location Key:

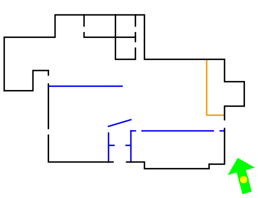


Figure A.17 Timeline Event 17

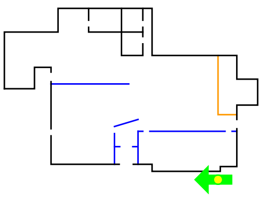
Video Time: 0:07:52

Fire Time: 0:01:30

Description:

Thick black smoke from pool room windows. Smoke appears to be at floor level inside. Occupants egressing through windows.

Location Key:



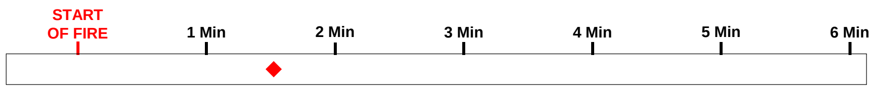


Figure A.18 Timeline Event 18

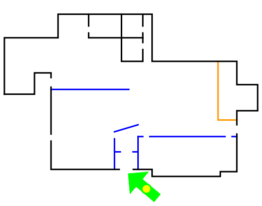
Video Time: 0:08:04

Fire Time: 0:01:42

Description:

Camera operator returns to main exit. People piled up in doorway. Smoke pouring out above people.

Location Key:



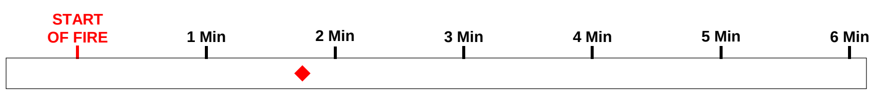


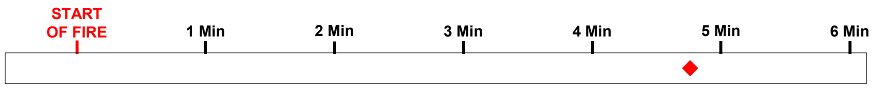
Figure A.19 Timeline Event 19

Video Time: 0:11:00

Fire Time: 0:04:38

Description:

Camera operator returns to stage exit. Smoke ~1 ft above floor inside. Flames near door.



Location Key:

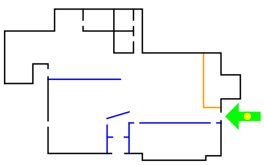


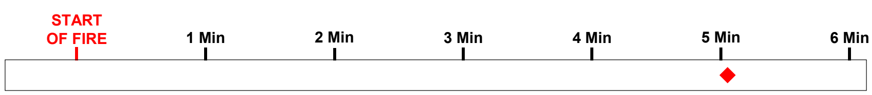
Figure A.20 Timeline Event 20

Video Time: 0:11:18

Fire Time: 0:04:56

Description:

Flames outside building at roof level in rear.



Location Key:

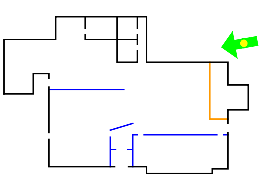


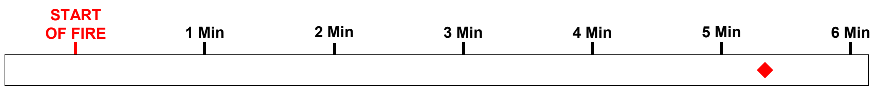
Figure A.21 Timeline Event 21

Video Time: 0:11:34

Fire Time: 0:05:12

Description:

Flames first recorded out front of building.



Location Key:

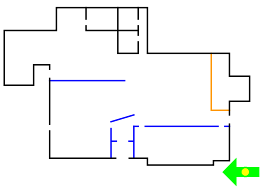


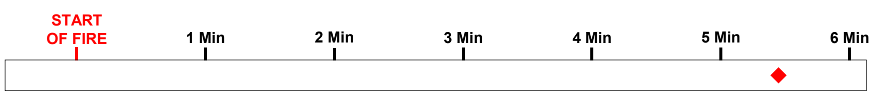
Figure A.22 Timeline Event 22

Video Time: 0:11:43

Fire Time: 0:05:21

Description:

Fire department confirmed on scene.



Location Key:

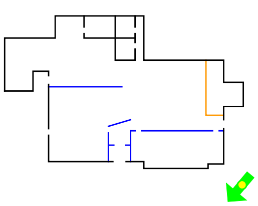


Figure A.23 Timeline Event 23

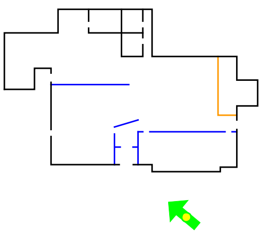
Video Time: 0:11:56

Fire Time: 0:05:34

Description:

Fire department commences running first hose line. Flames extending from main exit ~8-10 ft.

Location Key:



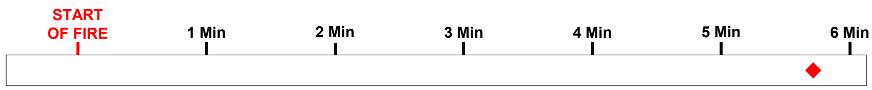


Figure A.24 Timeline Event 24

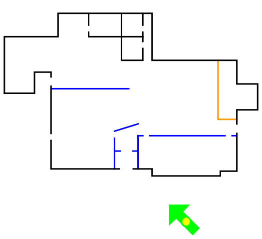
Video Time: 0:12:05

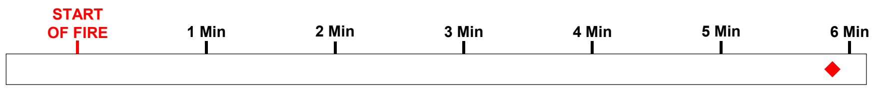
Fire Time: 0:05:43

Description:

Flames extend from front windows.

Location Key:





A.2 REFERENCES FOR APPENDIX A

[1] "Evaluation of Limitations to Egress through Doorways in Emergency Situations," vol. 1, Ove Arup & Partners Massachusetts Inc., Job number 32979, Westborough MA, February 18, 2004.

[2] Butler, Brian, Video by WPRI-TV, Channel 12, February 20, 2003.

Appendix B.
LARGE FORMAT DEVICE STILLS

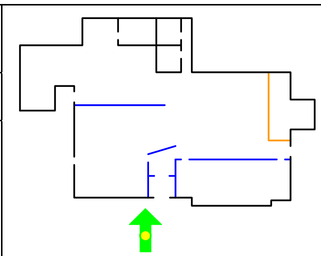
B.1 INTRODUCTION

This Appendix, compiled by Arup[1], provides large-format versions of the photographs and video still frames [2] used in the review of life safety features (see Chapter 6) in the Station nightclub prior to the fire on February 20, 2003. The photos and still frames are primarily organized based upon the type of life safety feature shown (i.e. exit doors, exit signs, emergency lighting, suppression, and fire alarm and detection). On a secondary level, the pictures are organized based upon their source (i.e. photographic or video evidence). Each picture includes a location key showing where the camera was located (yellow dot) and in which direction it was pointing (green arrow) when the photograph was taken or the video frame was recorded. The ID number provided with each picture can be used to locate the represented life safety feature on the map provided in Figure 6-10 of the main report. The faces of occupants have been blurred to preserve anonymity.

B.2 EXIT DOORS

B.2.1 Photograph Evidence: Exit Doors

Figure B.1 Life Safety Feature 1 [3]

Life Safety Feature ID:	LSF 1	
Type:	Exit door / exterior stairs and ramp	
Description:	Main double doors with ramp and stairs	

courtesy of Anthony Baldino, III

Figure B.2 Life Safety Feature 2

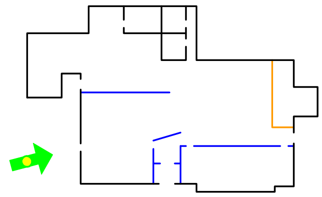
Life Safety Feature ID:	LSF 2	
Type:	Exit door / exterior stairs	
Description:	Exterior stairs from Left-side front bar exit	

Figure B.3 Life Safety Feature 3

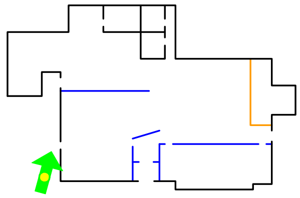
Life Safety Feature ID:	LSF 3	
Type:	Exit door / exterior stairs	
Description:	Exterior stairs from kitchen	

Figure B.4 Life Safety Feature 4

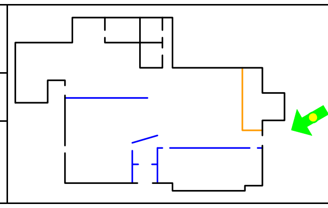
Life Safety Feature ID:	LSF 4	
Type:	Exit door / exterior stairs	
Description:	Exterior stairs from stage area	

Figure B.5 Life Safety Feature 5

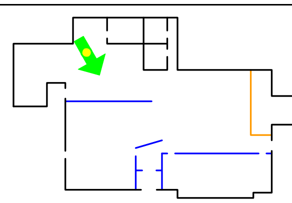
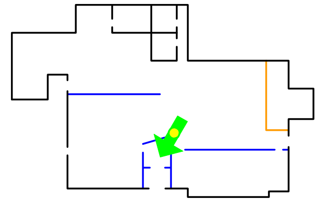
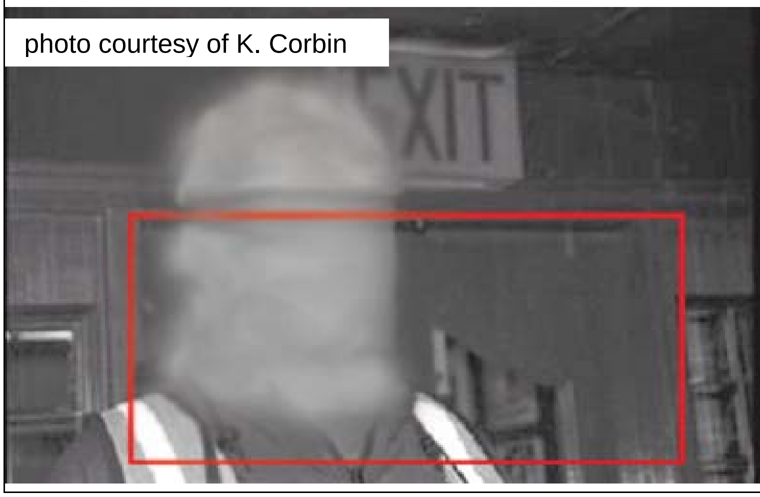
Life Safety Feature ID:	LSF 5	
Type:	Exit Sign	
Description:	Exit sign above door out to front vestibule	

Figure B.6 Life Safety Feature 6 [4]

Life Safety Feature ID:	LSF 6	
Type:	Interior Door	
Description:	Door leading from the interior ticket area towards the outer vestibule	



B.2.2 Video Evidence: Exit Doors

Figure B.7 Life Safety Feature 7 [2]

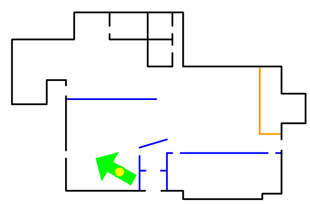
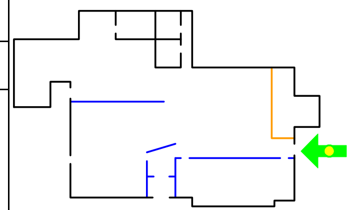
Life Safety Feature ID:	LSF 7	
Device Type:	Exit door with panic hardware	
Description:	Exit door from left side of main bar to exterior concrete stairs. Panic hardware was provided on this door.	

Figure B.8 Life Safety Feature 8 [2]

Life Safety Feature ID:	LSF 8
Device Type:	Exit door with panic hardware
Description:	Exit door adjacent to stage to exterior concrete stairs. Panic hardware was provided on this door. Note that it appears there was foam attached to this door and that there was an additional interior door that swung against the egress direction.



B.3 EXIT SIGNS

B.3.1 Photograph Evidence: Exit Signs

Figure B.9 Life Safety Feature 9 [4]

Life Safety Feature ID:	LSF 9
Device Type:	Exit Sign
Description:	Located near the rear bar. The exit sign is pointing toward the kitchen exit door.

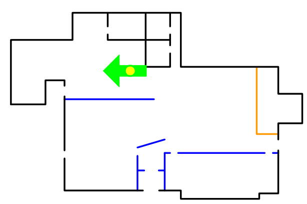


photo courtesy of K. Corbin

Figure B.10 Life Safety Feature 10 [4]

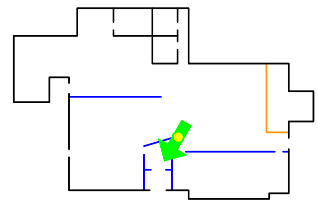
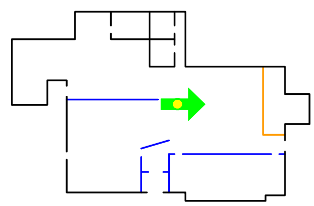
Life Safety Feature ID:	LSF 10	
Device Type:	Exit Sign	
Description:	Exit sign above door from ticket area to front vestibule	

Figure B.11 Life Safety Feature 11 [4]

Life Safety Feature ID:	LSF 11	
Device Type:	Exit Sign	
Description:	Exit sign above door to the right of the stage. Note that sign is clearly illuminated.	

B.3.2 Video Evidence: Exit Signs

Figure B.12 Life Safety Feature 12 [2]

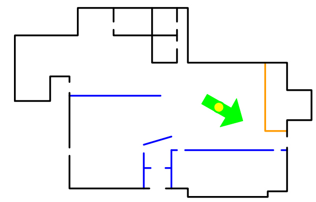
Life Safety Feature ID:	LSF 12	
Device Type:	Exit Sign	
Description:	Exit sign above door to the right of the stage. Note that sign does not appear to be illuminated.	

Figure B.13 Life Safety Feature 13 [2]

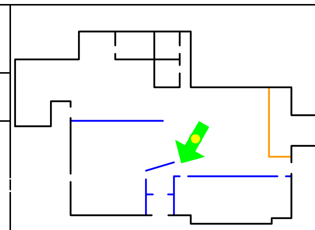
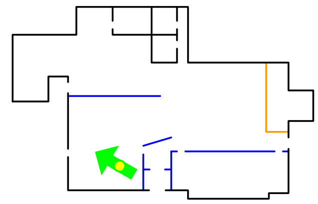
Life Safety Feature ID:	LSF 13	
Device Type:	Exit Signs	
Description:	Two visible. One located in the main floor area with an arrow towards the ticket area. One above the ticket area doors leading to the front vestibule.	

Figure B.14 Life Safety Feature 14 [2]

Life Safety Feature ID:	LSF 14
Device Type:	Exit Sign
Description:	Exit sign over left side main bar area door.



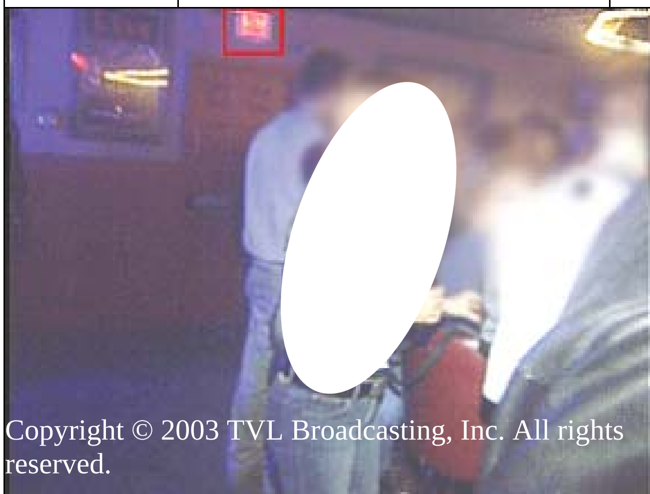
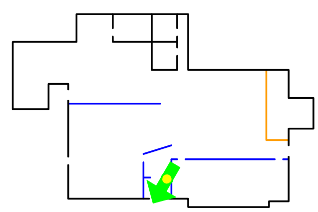


Figure B.15 Life Safety Feature 15 [2]

Life Safety Feature ID:	LSF 15
Device Type:	Exit Sign
Description:	Located in front vestibule above main double exit doors. This location is based upon similar wall and ceiling features observed in the WPRI video.



B.4 EMERGENCY LIGHTING

B.4.1 Photograph Evidence: Emergency Lighting

Figure B.16 Life Safety Feature 16 [4]

Life Safety Feature ID:	LSF 16
Device Type:	Emergency Light
Description:	Located near the rear bar adjacent to exit sign.

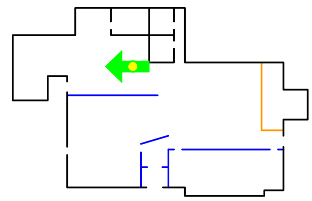


photo courtesy of K. Corbin

B.4.2 Video Evidence: Emergency Lighting

Figure B.17 Life Safety Feature 17 [2]

Life Safety Feature ID:	LSF 17
Device Type:	Emergency Light
Description:	Emergency light above and to the right of the stage exit door.

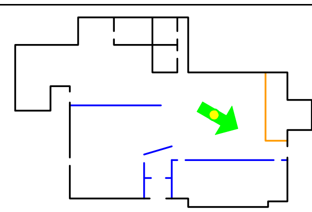


Figure B.18 Life Safety Feature 18 [2]

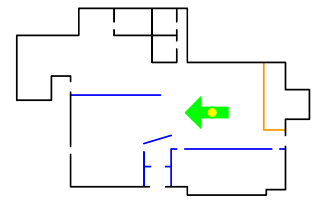
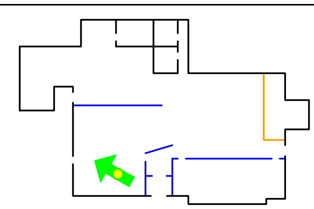
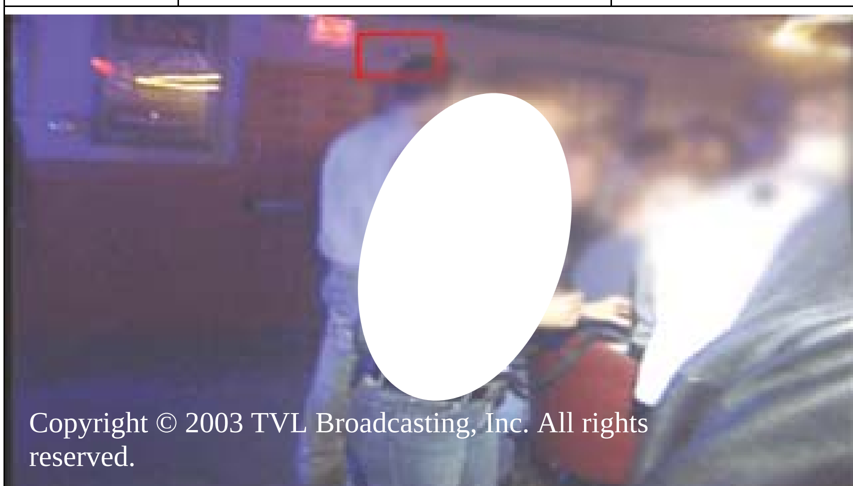
Life Safety Feature ID:	LSF 18	
Device Type:	Emergency Light	
Description:	Location on the wall adjacent to the kitchen by the main bar.	

Figure B.19 Life Safety Feature 19 [2]

Life Safety Feature ID:	LSF 19	
Device Type:	Emergency Light	
Description:	Emergency light above and to the right of the left side exit door in the main bar area.	

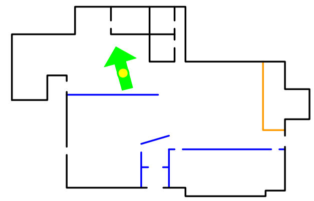


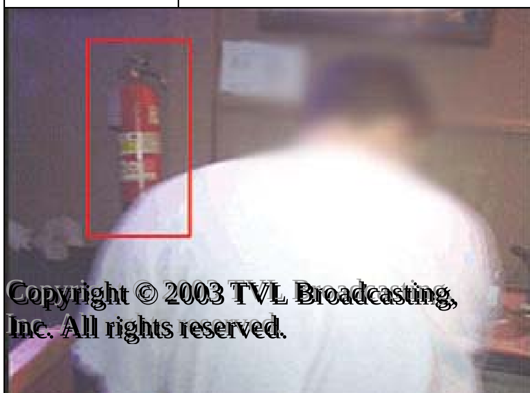
B.5 SUPPRESSION

B.5.1 Video Evidence: Suppression

Figure B.20 Life Safety Feature 20 [2]

Life Safety Feature ID:	LSF 20
Device Type:	Fire Extinguisher
Description:	Located by the small bar.



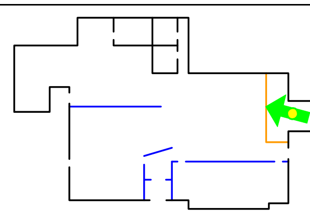


B.6 FIRE ALARM AND DETECTION

B.6.1 Video Evidence: Fire Alarm and Detection

Figure B.21 Life Safety Feature 21 [2]

Life Safety Feature ID:	LSF 21
Device Type:	Detector
Description:	Located above lighting grid in the vicinity of the stage.



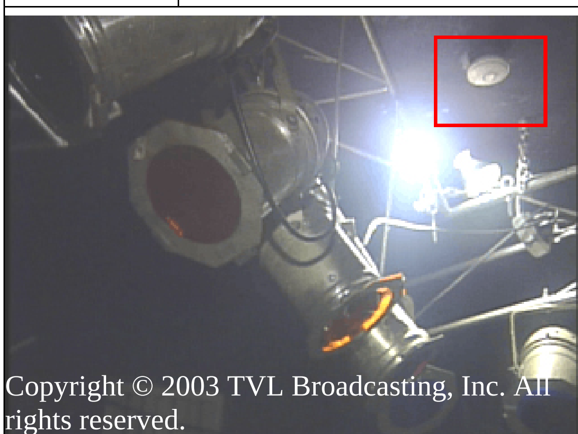


Figure B.22 Life Safety Feature 22 [2]

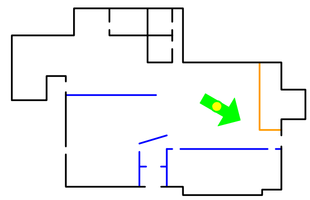
Life Safety Feature ID:	LSF 22	
Device Type:	Fire Alarm Strobe	
Description:	Adjacent to exit sign at stage exit door.	

Figure B.23 Life Safety Feature 23 [2]

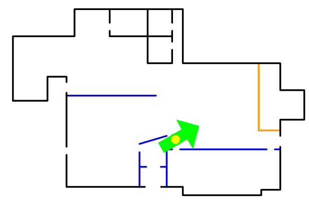
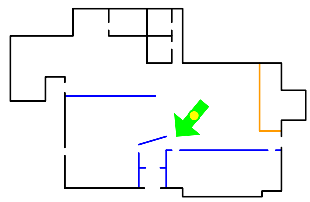
Life Safety Feature ID:	LSF 23	
Device Type:	Fire Alarm Strobe	
Description:	On ceiling to the left and in front of the stage	

Figure B.24 Life Safety Feature 24 [2]

Life Safety Feature ID:	LSF 24	
Device Type:	Fire Alarm Strobe	
Description:	Located adjacent to exit sign in the main floor area.	

B.7 APPENDIX B REFERENCES

[1] "Evaluation of Limitations to Egress through Doorways in Emergency Situations," vol. 1, Ove Arup & Partners Massachusetts Inc., Job number 32979, Westborough MA, February 18, 2004.

[2] Butler, Brian, Video by WPRI, Channel 12, February 20, 2003.

[3] photograph by Anthony Baldino III (undated)

[4] courtesy of K. Corbin

Appendix C.
PREVIOUS EGRESS INCIDENT ACCOUNTS

C.1 INTRODUCTION

In order to identify the different factors that contribute to lives lost during emergency evacuations and how these events may have contributed to historical regulatory changes, a review was conducted of previous fires with significant loss of life that have occurred in the United States and abroad. This review was conducted under a contract to Arup Fire [45] on behalf of the NCST. In addition, past events in which evacuation efforts were successful and lives were not lost were documented.

C.2 SUMMARY OF PAST EVACUATIONS

The following steps were taken in this review:

- A literature search was conducted to identify significant fires or other incidents, with particular emphasis upon incidents in which exit geometry may have played a significant role. The search included the following sources: standard internet searches, *fire doc* searches, review of significant conference proceedings, review of journal articles and review of various handbooks.
- From the literature search, significant details of incidents were coordinated with specific NFPA 101 and model code requirements.
- Code changes from each cycle of NFPA 101: *Life Safety Code®*, the Board for the Coordination of Model Codes (BCMC), the Uniform Building Code (UBC), the BOCA Basic National Building Code (BOCA), or the Standard Building Code (SBC) were reviewed and specific changes were noted. The monographs were reviewed for each change to determine the reasons for submitting or accepting these code changes. Arup personnel visited NFPA, ICC Alabama, ICC Chicago, and ICC Los Angeles libraries to review historic codes and monographs.
- Code change dates were matched to significant fire dates, and where possible, code changes precipitated by large life loss fires were identified.

C.2.1 Unsuccessful Evacuation

Table C-1 provides a summary of the unsuccessful incidents. The contributing factors listed in the table were identified as possible links to code changes that followed the incident. Contributing factors flagged were the following: delayed notification, combustible interior finishes, some exits blocked or not obvious, incorrect exit door swings, locked exit doors, inadequate exit capacity, barred or boarded windows, and crowd crush at exits.

Delayed notification was considered a contributing factor if the incident reports specifically stated this fact. Combustible interior finishes were considered a contributing factor if it was mentioned in the sources that combustible finishes were located on the walls, ceilings, or structure. Combustible finishes were not considered a contributing factor if a large amount of combustibles were present, but finishes were noncombustible. Blocked or concealed exits were considered a contributing factor if it was found in the literature that the exits were blocked by fire, blocked by building contents, or if they were concealed or hidden by building contents, furnishings, or layout.

If the literature stated that the building had incorrect exit door swings, this was considered a contributing factor. Locked exits were considered a factor if it was stated in the reports that doors were locked or were difficult to open to unfamiliar occupants. If the incident reports stated that there was inadequate exit capacity, or this could be inferred by the situation then this was considered a contributing factor. If a building was overcrowded and could otherwise accommodate the number of occupants specified by the building code, inadequate exit capacity was still considered a factor. If the reports stated that the windows were barred or boarded and the windows could otherwise be considered a means of escape, this was considered a contributing factor. If the incident accounts included descriptions of occupants piling-up at the exit doors, and thus hindering evacuation, crowd crush at the exits was considered a contributing factor.

Table C-2 provides additional details regarding these incidents, as well as an overview of any regulatory changes brought about as a result and any efforts to analytically model each incident. Note that the regulatory changes listed in Table C-2 are not necessarily directly related to the specific incident, but rather, the changes listed indicate modifications to the subsequent revision of the particular regulation.

C.2.2 Successful Evacuations

Table C-3 is set up similarly to Table C-1, except that it lists factors that may have contributed to a successful evacuation.

C.3 DETAILS OF UNSUCCESSFUL INCIDENTS

C.3.1 Conway's Theater Fire, Brooklyn, NY, 1876

On December 5, 1876, during the final act of the play *The Two Orphans*, a fire erupted in Conway's Theater [1]. The theater seated 1700, but held 800 at the time of the fire. The rising velvet curtain created a draft that caught a gas jet flame. The flame ignited a flimsy drape and spread quickly. The audience saw the fire spreading out from around the stage before the actors on stage knew what was happening. A member of the company in the wings alerted the actors. Three actors stood at the front of the stage and told the audience to stay calm. Some people even sat back in their seats when they heard this.

The theater construction included a cheap wooden bench gallery; this gallery collapsed, throwing 150 audience members into the fire below. This also led to further fire spread into the theater. Stagehands were trying to put out the fire with canvas, since there was no fire fighting equipment available. The stagehands stopped attempts to extinguish the fire after the collapse of the gallery.

The stage manager ordered everyone on stage to save themselves; some actors escaped through the stage door to an adjoining alley or through the cellars under the stage, which opened through horizontal grates to the street. All of the people in the theater company escaped except for the three actors that stood at the front of the stage to calm the audience during the beginning stages of the fire. Many of the audience members were crushed to death in the obstructed, narrow, winding stairs of the main exit. In addition, many perished in the cellar. However, since the fire department had no way of knowing the occupant load of the theater at the time of the fire, and since a significant number people made it out of the building safely, the firefighters thought that all had been saved and started trying to prevent the fire from spreading to other buildings. In all, 315 lives were lost in the Conway's Theater fire.

DRAFT

Table C-1. Historical Review of Incidents: Data and Contributing Factors

Facility Name	INCIDENT DATA									CONTRIBUTING FACTORS							
	Year	Type of Occupancy	Type of Incident	Fatalities	Occupants at Time of Fire	Occupants Allowed by Code	Fire Origin	Sprinkler System Present	Alarm System Present	Delayed Notification	Combustible Interior Finishes	Some Exits Blocked or not Obvious	Incorrect Exit Door Swings	Locked Exit Doors	Inadequate Exit Capacity	Barred or Boarded Windows	Crush at Exits
Conway's Theater [1]	1876	Assembly	Fire	315	800	1700	Gas Jet Flame				✓	✓			✓		✓
Iroquois Theater [2, 3]	1903	Assembly	Fire	602	~2400		Hot Light			✓	✓	✓		✓	✓		✓
Lakeview Elementary School [4]	1908	Educational	Fire	174	~400		Overheated Steam Pipe		✓		✓	✓					✓
Triangle Shirtwaist [5]	1911	Factory	Fire	147	~500		Rag Bin			✓			✓	✓	✓		✓
Italian Hall [5, 6]	1913	Assembly	False Alarm / Prank	72			No Fire						✓		✓		✓
Clinic [7, 8]	1929	Hospital	Fire	123	~250		X-Ray Film Ignited			✓							✓
Rhythm Club [9]	1940	Assembly	Fire	207	700+		Food Grill				✓	✓	✓		✓	✓	✓
Cocoanut Grove [5, 10]	1942	Assembly	Fire	492	~1000	600	Unknown				✓	✓	✓	✓	✓		✓
Winecoff Hotel [11, 12, 13]	1946	Hotel	Fire	119	280		Accident (suspicious)			✓		✓			✓		
Our Lady of Angels [5]	1958	Education	Fire	93			Unknown		✓	✓	✓	✓			✓		
Upstairs Lounge [14]	1973	Assembly	Fire	32	65	110	Arson				✓	✓		✓	✓	✓	
Gulliver's Disco [15]	1974	Assembly /Mixed	Fire	24	~500		Arson			✓		✓			✓		
Beverly Hills Supper Club [3, 5, 16]	1977	Assembly	Fire	164	2400-2800	1511	Electrical			✓	✓	✓		✓	✓		✓

Facility Name	INCIDENT DATA									CONTRIBUTING FACTORS							
	Year	Type of Occupancy	Type of Incident	Fatalities	Occupants at Time of Fire	Occupants Allowed by Code	Fire Origin	Sprinkler System Present	Alarm System Present	Delayed Notification	Combustible Interior Finishes	Some Exits Blocked or not Obvious	Incorrect Exit Door Swings	Locked Exit Doors	Inadequate Exit Capacity	Barred or Boarded Windows	Crush at Exits
The Who Concert [3, 17]	1979	Assembly	Crowd Ingress	11	~8000		No Fire							✓	✓		✓
Haunted Castle [18]	1984	Amuse-ment park	Fire	8	~30		Accident				✓	✓					
Happy Land Social Club [20, 21]	1990	Assembly	Fire	87			Arson	✓*			✓	✓		✓	✓		
Private Club [22]	1992	Assembly/ Hotel	Fire	3			Accident		✓		✓						
E2 Nightclub [23, 24, 25]	2003	Assembly	Crowd Egress	21	~500	240-300	No Fire					✓		✓	✓		✓
Summerland [26]	1973	Assembly	Fire	51	~3000		Accident			✓	✓			✓	✓		✓
Stardust Cabaret [27]	1981	Assembly	Fire	48	846		Arson				✓						
Gothenburg Dance Hall [28]	1998	Assembly	Fire	63	~400	150	Arson				✓	✓			✓		✓
de Hemel [45]	2000	Assembly	Fire	14			Accident				✓	✓					

*Sprinkler or alarm covered only a portion of the building, or system was not operational (see Table C-2 for details).

Table C-2. Historical Review of Incidents: Additional Details, Regulatory Changes, and Modeling

Facility Name	Year	Deaths	Crowd Crush	Additional Details	Resulting Regulatory Changes	Modeling Information
Conway's Theater [1]	1876	315	✓	No basic fire fighting equip. in bldg. Wooden bench gallery collapse causing fire spread. Narrow, winding exit stairs. Firefighting efforts focused on surrounding exposures.		
Iroquois Theater [2, 3]	1903	602	✓	No fire hoses and extinguishers. Stage fire curtain failed to completely close. Occupants informed to remain seated. Exit doors covered by metal gates. Exits converged in a common stairway.		
Lakeview Element. School [4]	1908	174	✓	Fire under wooden exit prevented stair usage. Floor collapsed into fire below. Non-isolated stairways. Delayed response by fire department.		
Triangle Shirtwaist [5]	1911	147	✓	Combustible construction and interior finishes. High fuel loads of hanging, piled cloth. Exit doors were locked and swung in the opposite direction of travel. Fire escape collapsed.	***NFPA 101®:*** Creation of a Committee on Safety, a Factory Investigating Commission, New York Fire Prevention Bureau and the NFPA Building Exiting Code (Life Safety Code).	
Italian Hall [5, 6]	1913	72	✓	No fire, unknown mass evacuation. Single stair for egress. Inward swinging doors.		
Clinic [7, 8]	1929	123	✓	Some X-rays were stored outside of metal cabinets. Two explosions produced poisonous gasses that killed nearly all victims. Toxic gases were spread by the ventilation system and open fire door.		
Rhythm Club [9]	1940	207	✓	Dry moss suspended from ceiling. One available exit, windows were boarded up. No upper windows or skylights to vent heat, smoke.		

Facility Name	Year	Deaths	Crowd Crush	Additional Details	Resulting Regulatory Changes	Modeling Information
Cocoanut Grove [5, 10]	1942	492	✓	Highly overcrowded as compared to codes. Combustible decorations placed throughout. Exits hidden by decorations, many were locked. Narrow hallways and converging exits. Jammed revolving entrance door.	***NFPA 101®:*** Greater acceptance of Building Exits Code; clarification of exit requirements; limitation noted concerning use of combustible finishes.	CFAST, WPI/Fire used to model fire effects within bldg. FPETool was used to estimate available evacuation time, sprinkler activation if sprinklers had been present.
Winecoff Hotel [11,12,13]	1946	119		No fire escapes or sprinklers. Delayed notification to fire department. Open main central staircase allowed flame and smoke to spread. Fire doors were not used. Transoms were not all air sealed.		
Our Lady of Angels [5]	1958	93		2 of the 5 available stairways were enclosed. Combustible materials were located in the stair. Delayed notification due to teachers evacuating their own classes. Inadequate opening protection.	***NFPA 101®:*** Improved fire safety procedures; tests were conducted to explore multistory school building with open stairs; requirement of sprinklers in school bldgs of different type. ***BOCA:*** Changes were made to the classification of the interior finishes requirements.	
Upstairs Lounge [14]	1973	32		Rapid fire spread in only stair due to combustible interior finishes. Fire door at the top of the stairs was opened and lead to smoke spread. Hidden and obstructed rear exit door. Numerous windows were boarded up or equipped with steel bars.	***BOCA:*** Increases to egress capacity, travel distance; panic hardware was required for >100 occupants; widely requirement of sprinklers and standpipes	
Gulliver's Disco [15]	1974	24		Delayed discovery of the fire. Lack of fire-rated doors and wall separations. Exits were not separated Exits from dance floor were not remote and one stairway was blocked by smoke.	***NFPA 101®:*** Requirement for fire alarm/notification systems be installed with loads >300. ***BOCA:*** Increases to egress capacities of travel distances, doors and stairs; panic hardware for >100 occupants; sprinkler systems and standpipes were more widely required.	

Facility Name	Year	Deaths	Crowd Crush	Additional Details	Resulting Regulatory Changes	Modeling Information
Beverly Hills Supper Club [3, 5, 16]	1977	164	✓	Number of occupants greater than the applicable codes Overcrowded room with tables and additional seating which blocked egress movement Rapid fire spread due to combustible interior finishes Delayed movement time No alarm system was installed in the building	***NFPA 101®:*** Although not necessarily directly related to this incident, the 1981 Edition required fire alarm and automatic sprinkler systems in assemblies > 300 persons. ***BOCA:*** Doors were to be installed with panic hardware and swing in the direction of travel for loads of >50 occupants.	A resistor network diagram and mean flow volume equations showed that opening doors drew the fire into the escape routes.
The Who Concert [3, 17]	1979	11	✓	Poor crowd management plan Only one of two doors were open to allow the 8000 concert goers to enter the building	***NFPA 101®:*** Requirements regarding festival type seating were introduced. Crowd Management report that offered 108 safety recommendations was developed.	
Haunted Castle [18]	1984	8		No automatic detection or suppression system installed. Large amounts of combustible materials were present. Foam plastic mounted on walls. Occupants had difficulty escaping.	***NFPA 101®:*** Limits placed on use of types of interior finishes. ***BCMC:*** Size, location and illumination of exit signs. ***UBC:*** Interior finish requirements were changed	
Happy Land Social Club [20, 21]	1990	87		Building violated code regulations but still in operation. Building was only partially sprinklered. One of the two main exit doors was covered by a roll-down steel security door, swinging doors were locked. Four doors separated the patron areas from an entrance lobby. Exit stairs were not enclosed. Combustible interior finishes in lobby area.	***UBC:*** Although not necessarily a direct result of this incident, changes were made to the requirements of exit width and fire alarm/notification system for the subsequent edition.	
Private Club [22]	1992	3		Lack of approved sprinkler and unprotected penetrations in walls, ceiling assemblies contributed to spread. Concealed spaces increased hazard for firefighters. Wood paneling on walls, ceiling tiles left in concealed spaces contributed to fire extent	***BOCA:*** Sprinklers were being required in assembly occupancies of various sizes.	

Facility Name	Year	Deaths	Crowd Crush	Additional Details	Resulting Regulatory Changes	Modeling Information
E2 Nightclub [23, 24, 25]	2003	21	✓	Club should have been closed due to numerous building code violations. Pepper spray caused the crowd to rush the main exit. Alternate exits not easily accessible. The club was overcrowded.	Since this fire is so recent there have not been any regulatory changes.	
Summer-land [26]	1973	51	✓	Delayed notification to fire service. Combustible exterior and interior finishes aided in fire spread. Emergency doors were padlocked. Turnstiles could not handle numbers.	Isle of Man and the United Kingdom tightened fire regulations on public buildings.	
Stardust Cabaret [27]	1981	48		Adequate exit capacity. Fire spread quickly due of large amount of combustible materials.	Fire investigation lead to significant range of recommendations but unknown if that lead to changes in regs.	
Gothen-burg Dance Hall [28]	1998	63	✓	Fire growth and spread was high due to fuel loads. Hall was severely overcrowded. No automatic detection or sprinkler system was installed. Occupant that first discovered fire did not notify others. Numerous people jumped from windows. Crowds of people surrounding the building hampered the fire service.	Discussions concerning the use of multiple "normal" exits would be better than a fewer wider exits for public halls/auditoria were conducted.	BuildingEXODUS evacuation model used to analyze similar scenario (fire load used in model was main difference). [29]
de Hemel nightclub	2000	14		New Years eve, 2000/2001, Fire spread over Christmas tree boughs suspended from ceiling, ignited accidentally with a sparkler		Fire recreated at TNO laboratory

Table C-3.Table 5-1. Historical Review of Incidents: Successful Evacuations

Incident	Year	Fire Origin	Manual Alarm	Detection System	Sprinklers	Occupants	Fatalities	Occupant Injuries	Delayed Evacuation	Delayed FD Response	Fire Contained by Construction
School, California [30]	1992	Cooking equipment	✓	✓		1,000	0	0	✓		
Nightclub, Texas [31]	1992	Electrical			✓	100's	0	0			
School, Oregon [32]	1992	Arson	✓		✓[2]	450	0	0			✓
School, Mass. [33]	1992	Pyrotechnic device					0	0		✓	
School, Oregon [34]	1994	Electrical		✓			0	0			
Restaurant, Indiana [35]	1996	Cooking equipment			✓[3]		0	0			
Dinner Theater, Florida [36]	1996	Pyrotechnic device	✓	✓	✓	400	0	0			
Restaurant, Michigan [37]	1996	Equipment malfunction					0	0			
Community Cntr, Penn. [38]	1997	Electrical	✓	✓	✓[2]	100	0	4			
Restaurant, Massachusetts [39]	1997	Cooking equipment			✓[2,3]	25	0	0			
School, California [40]	1998	Electrical	✓[1]				0	0	✓	✓	
Casino, Nevada [41]	1998	Unknown		✓	✓		0	1			✓
Restaurant, New Jersey [41]	1998	Smoking materials		✓	✓[2]		0	2			
Restaurant, Michigan [41]	1998	Cooking equipment			✓[3]		0	0			
Theater, Nevada [42]	1999	Electrical			✓		0	5			
Fine Line Music Café, Minneapolis [43]	2003	Pyrotechnic device			✓	120	0	0			

[1] Manual alarm system out of service at time of fire.
[2] Sprinkler system covered only part of the building.
[3] Kitchen area protected by dry chemical extinguishment system.

The following details regarding this incident are of note:

- The theater did not have the basic fire fighting equipment, including a hose or any water buckets, because it was believed that a brick building would not burn;
- The wooden bench gallery collapsed, killing many audience members and spreading the fire beyond the stage;
- The main exit was at the bottom of narrow, winding stairs, which were eventually blocked by bodies that had fallen in the evacuation push;
- Fire fighters thought that everyone had made it safely out of the building and concentrated on saving the surrounding buildings.

Impact on regulations or practices

The NFPA Life Safety Code, the Board for the Coordination of Model Codes (BCMC), the Uniform Building Code (UBC), the BOCA Building Code (BOCA), and the Standard Building Code (SBC) had not yet been developed at the time of the fire.

C.3.2 Iroquois Theater Fire, Chicago, Illinois, 1903

Less than one month after its grand opening, the Iroquois Theater in Chicago, Illinois suffered a fast-moving fire during a performance [2,3]. At 3:15 PM, a hot light ignited highly combustible stage scenery items. The fire spread rapidly, and the efforts of the lone on-duty firefighter proved futile. Contrary to standard precautions in theaters at the time, the Iroquois Theater had no fire hoses or extinguishers and the standpipes on the stage were dry because the water supply system was not completed. Confident that the fire could be controlled, an actor urged the audience to remain seated. However, the fire rapidly escalated, and people eventually began moving. Numerous deaths occurred as people from the balcony level, the gallery level, and the main level converged in the exit stairway. Additionally, numerous people jumped from the upper levels as the stairway became blocked.

All 602 deaths occurred within 15 minutes of the start of the fire. Most of the fatalities were in the third floor or gallery area. A draft caused by the stage exit doors being opened caused flames to rush to open vents above the gallery rather than to the stage vents, which were missing counterweights and were nailed shut. Upon arrival, fire department personnel were able to extinguish the fire within 30 minutes. The building was largely undamaged, and reopened within one year.

The following details regarding this incident are of note:

- The theater lacked fire hoses and extinguishers, so the on-duty firefighter was not able to fight the fire above his head;
- The ushers and personnel received no instructions about what to do in the case of a fire;
- The curtain designed to separate the stage area from the audience got caught before it could reach its full down position, and thus was unable to prevent fire spread from the stage. Later testimony revealed that the curtain may have been improperly installed, and also may not have been fireproof;

- After the fire started, the audience was urged to stay in their seats and not to evacuate, and the orchestra continued playing;
- Some exit doors had been covered by metal gates. Some of these were locked, and others had latches that were likely unfamiliar to occupants;
- Exit paths from the balcony area and the main floor met in a single, common stairwell.

Impact on Regulation or Practices

The NFPA Life Safety Code, the Board for the Coordination of Model Codes (BCMC), the Uniform Building Code (UBC), the BOCA Building Code (BOCA), or the Standard Building Code (SBC) had not yet been developed at the time of the fire.

C.3.3 Lakeview Elementary School Fire, Collinwood, Ohio, 1908

The Lakeview Elementary School fire was the worst disaster in Cleveland history with a toll of 172 children and two teachers [4]. The three-story school had a brick exterior, but the interior was all constructed of wood. It was theorized at the time that the fire was caused by an overheated steam pipe that ignited wood joists under the front stairs. The fire was discovered by a child who had gone down to the girls' lavatory in the basement. The student told the janitor who then sounded the alarm and opened the front and rear doors. Students that attempted to escape using the front doors were pushed back by flames and smoke, so they ran to the back entrance. Someone fell at the back entrance and a blockage of people developed as many tried to force their way through. One of the exterior doors had blown shut and children became wedged in the narrow space. The pushing of the students trying to escape and the weakening of the structure by the fire below caused the floor to collapse, which plunged the crowd into the burning basement. Classes on upper floors fled using fire escapes and others jumped out of windows. The team of village horses used by the volunteer fire department was busy dragging a road scraper a mile away, so by the time they arrived little could be done.

The following details regarding this incident are of note:

- Wooden construction ignited under the front stairs, rendering them useless for evacuation;
- The floor at the rear exit collapsed, throwing many occupants into the fire;
- Stairways were not enclosed;
- Exterior rear door blew shut;
- The team of horses that normally pulled the fire engine were not readily available at the time of the fire and arrived late to the scene.

Impact on regulations or practices

The fire in Collinwood brought about laws requiring fire resistant construction, enclosed stairwells, and "panic bars" that trigger door latches when pushed from inside in schools. The NFPA 101 Life Safety Code, the Board for the Coordination of Model Codes (BCMC), the Uniform Building Code (UBC), the BOCA Building Code (BOCA), or the Standard Building Code (SBC) had not yet been developed at the time of the fire.

C.3.4 Triangle Shirtwaist Company Fire, New York, New York, 1911

The fire at the Triangle Shirtwaist Company in New York in 1911 had possibly the greatest impact on modern fire and life safety codes of any historical fire. The business was located on the three topmost floors of a ten-story wood-framed building. Fire initiated in a bin of rags on the lowest of the three floors, and quickly spread despite the efforts of employees to extinguish it using buckets of water [5]. Large amounts of fabric throughout the space contributed to rapid fire growth and spread.

Initial evacuation was hampered by a locked exit door, which, when eventually unlocked, swung against the direction of egress travel, thus causing a crush of evacuating occupants. Even after the door was opened, some occupants tripped on the exit stairway and caused a further delay in the egress.

Some occupants from the top floor escaped via the roof to an adjacent building. Occupants of the upper and lower floors never notified the middle floor occupants of the fire. Instead, occupants of this floor learned of the fire when flames extended through the windows. During the exiting of occupants from this floor, the fire escape collapsed. Some occupants tried to use the elevators, but they were already packed with occupants from other floors. As a last resort, some occupants jumped from the ninth-floor windows. A total of 147 people died in this incident.

The following details regarding this incident are of note:

- The building was of combustible wood construction with combustible interior finishes. The New York City building codes of the time allowed this for structures less than 11 stories high;
- Each of the two lower floors, where large numbers of employees worked, included vast amounts of cloth either piled on the floors, in bins or on tables, or hanging from lines. This contributed to rapid fire growth and spread on the floor of origin;
- Numerous exit doors were locked in an effort to monitor employees and prevent theft;
- The exit doors swung opposite the direction of egress travel;
- The building had only two staircases. This violated New York City building codes of the time, which required three staircases per floor where the floor area of each floor exceeded 10,000 ft^2;
- Elevators placed priority on the topmost floor, and thus were full when they stopped at the lower floors, where the danger was more imminent;
- A lack of communication between the eighth and tenth floors and the ninth floor led to late notification of the occupants of the ninth floor;
- The fire escape, when heated by the fire extending from the windows, could not support the large number of evacuating occupants and collapsed;
- The New York City fire department did not have equipment that could fight fires higher then seven stories up in a given building.

Impact on regulation or practices

According to information in the Life Safety Code® Handbook:

- Immediately after the incident, New York City residents formed the Committee on Safety, which worked to pass laws requiring greater safety in factory buildings;

- The Governor of New York, in response to this incident, created a Factory Investigating Commission within the state;
- Later in the same year, a law was passed creating the New York City Fire Prevention Bureau (the first such bureau in the US).

NFPA 101®: Life Safety Code®

Again, according to the Life Safety Code Handbook, due to the severity of this incident, NFPA began to broaden its scope to include elements of life safety. The first such publication dealt with exit drills in factories, schools, department stores, and theaters. Two years later, an NFPA committee on Safety to Life, which was to study the current situation regarding life safety in buildings, was formed. This was the beginning of the NFPA Life Safety Code. In 1927, this work also resulted in the NFPA Building Exiting Code.

Board for the Coordination of Model Codes (BCMC)
The earliest BCMC reports obtained were from 1977; therefore, information on changes prior to 1977 was not available.
Uniform Building Code (UBC)
The first edition of the UBC was not published until 1927.
BOCA Building Code (BOCA)
The first edition of the BOCA code was not published until 1950.
Standard Building Code (SBC)
The first edition of the SBC was not published until 1945. Details of proposed changes and committee reports were not available prior to 1977.

C.3.5 Italian Hall Disaster, Calumet, Michigan, 1913

On Christmas Eve of 1913, a party was being held in an upstairs function room in the Italian Hall in Calumet, Michigan. The majority of the attendees were children. At some point during the party, something caused the occupants to initiate a mass evacuation. Reports of the cause of this vary, but no fire was found [5,6]. The evacuating occupants rushed down the main stairway and clogged in the exit doorway. The resulting crush of people in the stairwell led to the deaths of 72 people; all of these were either crushed or suffocated.

Some reports indicate that intoxicated, disgruntled workers may have yelled ‘fire.’ It is unclear if this did occur.

The following details regarding this incident are of note:

- The function room was served by a single main exit stairway;
- The exit doors at the bottom of the main stairwell opened inward; this resulted in a blockage as people rushed down the stairway before the first evacuating occupants could open the doors.

Impact on regulation or practices
NFPA 101®: Building Exits Code®

NFPA 101 was not yet published; the incident occurred in 1913 while the first edition of the *Building Exits Code* was released in 1927.

Board for the Coordination of Model Codes (BCMC)

The earliest BCMC reports obtained were from 1977; therefore, information on changes prior to 1977 was not available.

Uniform Building Code (UBC)

The first edition of the UBC was not published until 1927.

BOCA Building Code (BOCA)

The first edition of the BOCA code was not published until 1950.

Standard Building Code (SBC)

The first edition of the SBC was not published until 1945. Details of proposed changes and committee reports were not available prior to 1977.

C.3.6 Clinic Fire, Cleveland, Ohio, 1929

On May 15th, 1929 a fire started at 11:25 AM in a basement room where 70,000 X-rays were stored [7,8]. The burning films released poisonous gases that traveled through the building's ventilation system that was also located in the basement. A fire door was left open aiding in the movement of the poison gas. At 11:31 AM, an explosion rocked the building, spreading more poisonous gas and starting fires throughout the building. When the fire department arrived, the building was already shrouded in smoke. Soon after, another explosion shook the building. Patients ran for the exits, and many succumbed to the toxic gases while trapped in stairways and near the elevator. Many of the nurses and doctors died helping the patients. Some patients found their way out, but eyewitness accounts state that many of these perished as a result of their injuries or inhalation of smoke. The fires were extinguished, and the victims were removed from the building within two hours. The incident claimed 123 lives; 43 of these were doctors and nurses. Nearly all of the victims died of inhalation of poison gas.

The following details regarding this incident are of note:

- Contrary to American Hospital Association guidelines, the X-rays were stored in paper folders and some had been left outside the steel cabinets where they were supposed to be kept;
- A fire door was open and allowed the gas to spread throughout the clinic;
- The building was not equipped with a sprinkler system.

Impact on regulation or practices

The fire resulted in the development of new standards for the storage of hazardous materials, particularly X-ray film. Also, poisonous gases were recognized as a hazard and fire insurance companies began to develop and strictly enforce safety regulations.

The impacts that this incident had on various regulations are discussed below.

NFPA 101®: Building Exits Code

While there do not appear to be any changes to NFPA 101 directly associated with this incident, the 1929 edition brought the first introduction of the "Assembly Occupancies" chapter. The 1934 edition expanded upon occupant loading, exit capacities, required number of exits, and travel distances.

Board for the Coordination of Model Codes (BCMC)

The earliest BCMC reports obtained were from 1977; therefore, information on changes prior to 1977 was not available.

Uniform Building Code (UBC)
There do not appear to be any changes to the UBC directly related to this incident.

BOCA Building Code (BOCA)
The first edition of the BOCA code was not published until 1950.

Standard Building Code (SBC)

The first edition of the SBC was not published until 1945. Details of proposed changes and committee reports were not available prior to 1977.

C.3.7 Rhythm Club Fire, Natchez, Mississippi, 1940

The Rhythm Club was a single-story dance hall in Natchez, Mississippi. It was a wood framed building with corrugated steel walls and roof. Several years before the fire, the ceiling joists of the building had been concealed by adding a layer of Spanish moss on top of a netting system. On the night of the fire, the moss was extremely dry; it is suspected that the heat from a grill located near the front of the building caused the moss to ignite. The fire spread rapidly across the dry moss [9].

The building was equipped with only one exit, which was located at the front of the building. When the fire began to grow, several occupants were able to exit through this door. However, the location of the ignition near the front of the building caused most of the occupants to move to the back into the building, where there were no additional exits. The main exit doors opened against the direction of egress travel, but since only a few people were able to reach this exit, it was not expected that this detail significantly contributed to the loss of life, and no fatalities occurred near these doors. The sides of the building were lined with numerous small windows, but all of these in the main open portion of the building had shutters, some of which were latched, but most of which were nailed closed. All of the shutters opened inward. As a last resort, occupants attempted to break through the corrugated steel walls of the building to reach the outside, but were unsuccessful. The majority of the 207 fatalities occurred at the very back of the building, at the opposite end from the only available exit.

The following details regarding this incident are of note:

- The tinder-dry Spanish moss layered below the ceiling joists led to extremely fast fire spread along the length of the building, and contributed to further fire spread by falling and igniting combustible items below;
- The building was equipped with only one available exit door. The location of the fire in the front portion of the building prevented most occupants from accessing this exit;
- None of the windows along the sides of the main portion of the building could be used as a means of escape, since they were very small and most were boarded up. One plain glass window was included in a subdivided portion at the front of the building, but occupants were not able to reach this area due to the location of the fire, and even if they had, the door to this room was locked;
- At the time of the fire, more than 700 people were packed into the 120 ft by 38 ft structure;

- There were no skylights or other windows to vent the heat or smoke, so the metal walls held the heat in like an oven.

Impact on Regulation or Practices

NFPA 101®: Building Exits Code®
There do not appear to be any changes to NFPA 101 directly associated with this incident.

Board for the Coordination of Model Codes (BCMC)
The earliest BCMC reports obtained were from 1977; therefore, information on changes prior to 1977 was not available.

Uniform Building Code (UBC)
There do not appear to be any changes to the UBC directly related to this incident.

BOCA Building Code (BOCA)
The first edition of the BOCA code was not published until 1950.

Standard Building Code (SBC)

The first edition of the SBC was not published until 1945. Details of proposed changes and committee reports were not available prior to 1977.

C.3.8 Cocoanut Grove Nightclub Fire, Boston, Massachusetts, 1942

The Cocoanut Grove Nightclub was a single-story building with a finished basement. The basement contained an additional lounge and a kitchen. Technically, the capacity of the club was 600 occupants. On the night of November 28, 1942, when a fire broke out in some combustible decorations in the basement lounge, there were over 1000 occupants in the club [5,10]. From the portion of the building where the fire broke out, there was only one obvious exit, and this was up a set of stairs leading through an approved exit door to a hallway, and eventually to the main exit, which included a revolving door. This hallway also had a door exiting to the street, but this was locked at the time of the fire. Other means of egress existed, but were concealed behind decorations and false walls; some were locked.

The fire spread rapidly across the underside of the false ceiling in the compartment of origin, and eventually went up the exit stairs and into the exit hallway and spread into the main dining room. The patrons in the main dining area knew of only one exit, the main exit with the revolving door. Other exits were not obvious or were hidden with decorations similar to the basement lounge. Some of the patrons stumbled upon these exits and escaped; however, some of the exits on the first floor were also locked trapping occupants.

There was a second lounge area on the first floor down a narrow hallway from the dining area. The smoke spread into this area and people rushed for the only exit door, which opened inward. The push of the crowd jammed the door closed and many of the occupants within this area died.

It is reported that the fire lasted less than an hour from ignition to extinguishment; 492 people died. Many of these deaths resulted from a bottleneck of evacuating occupants in the narrow exit hallway leading from the downstairs lounge. Many more people died when they got trapped behind the revolving door that served as the main exit from the lobby area.

The following details regarding this incident are of note:

- The night of the fire, the club was highly overcrowded (compared to its capacity according to the applicable codes);
- The fire spread rapidly across combustible decorations throughout the club;
- While numerous exits from the lower-floor lounge existed, only one was obvious and unlocked the night of the fire. Others were hidden by decorations or false walls, and many of these were locked. Only employees, and the few people the employees were able to assist, used these exits;
- The main exit from the lower lounge required that occupants traverse a narrow hallway and enter the main lobby, where they would converge with occupants evacuating from other parts of the building. An additional exit door located in the narrow hall was locked;
- Many of the patrons in the dining area only knew of the main exit, since many of the other exits were concealed or unmarked;
- Some of the exits were locked;
- The only exit in the smaller lounge off from the dining area opened inward and trapped patrons in the lounge;
- A large number of people were trapped behind the revolving main entrance door, which became jammed with people early in the evacuation.

Impact on Regulation or Practices

NFPA 101®: Building Exits Code®

According to information in the Life Safety Code® Handbook:

- Subsequent to this incident, the NFPA Building Exits Code began to be accepted by more jurisdictions throughout the country;
- At the 1945 NFPA Annual Meeting, the Committee on Safety to Life recommended changes to the prescribed method of egress capacity measurement, clarification of stairway enclosure requirements, changes to requirements regarding moveable chairs in nightclubs, and changes in exit lighting and signage requirements, as a result of this fire;
- A caution was added to the Building Exits Code warning that, where combustible interior finishes exceeding the limitations of the Code were used, the provisions of the Code may not be sufficient to ensure life safety.

Board for the Coordination of Model Codes (BCMC)

The earliest BCMC reports obtained were from 1977; therefore, information on changes prior to 1977 was not available.

Uniform Building Code

The 1943 edition of the UBC did not contain any significant changes from the previous edition; however, a number of changes were made between the 1943 and the 1946 editions. Though it is unclear if this incident had any direct impact, the following were changes incorporated into the 1946 edition of the UBC:

- Required egress width requirements changed to provide one foot of width for every 50 occupants. The previous requirement provide for a varying number of inches of exit width per person based upon the total occupant load;
- A main entrance/exit provision was added such that the main entrance/exit was now required to have a capacity not less than 50% of the design occupant load;
- The number of required exits was changed such that 2 exits were required from 10-499 occupants; 3 exits for 500-999 occupants; and 4 exits for more than 1,000 occupants;
- Panic hardware was now required for doors serving more than 50 occupants in assembly occupancies.

BOCA Building Code (BOCA)
The first edition of the BOCA code was not published until 1950.

Standard Building Code (SBC)
The first edition of the SBC was not published until 1945.

Modeling Efforts

In one study, the Cocoanut grove fire was the subject of a number of modeling efforts. Both CFAST and WPI/Fire were used to model fire effects within the building. FPETool was also used to estimate the evacuation time from the building and to estimate sprinkler activation time (had sprinklers been present).

C.3.9 Winecoff Hotel Fire, Atlanta, Georgia, 1946

In the early morning hours of December 7, 1946 a fire occurred at the fifteen-story Winecoff Hotel in downtown Atlanta [11,12,13]. At the time the hotel had 280 guests in its 194 rooms and 119 of these guests died in the fire. The hotel was advertised as fireproof because of a brick exterior and concrete and steel construction. It was built in 1913 and did not have fire escapes or a sprinkler system because it was not required by code when it was built. The authorities believed that the fire began on the fourth or fifth floor. The fire was reported to the night auditor and as soon as he verified that there was a fire he sounded the alarm around 3:20am. However, the fire department records indicate that the first alarm came in by telephone at 3:42am. The night auditor then contacted as many rooms as possible before the switchboard stopped working telling the guests to keep their doors closed and to stay calm. However, only the rooms on the third through the sixth floors had heavy wooden doors and tightly sealed transoms. Above the sixth floor, the rooms did not have the thick doors and many of the transoms had been permanently opened allowing for smoke and flame to spread into these rooms. Also, the fire spread quickly because it was aided by the open narrow staircase that acted as a flue. The fire was ruled as an accident, caused by a burning cigarette on a mattress. However, there are some investigations that have pointed toward arson.

The following details regarding this incident are of note:

- There were no fire escapes or sprinklers in the hotel;
- There was a twenty minute delay in reporting the fire to the fire department;
- The main central staircase was open and allowed flame and smoke to spread floor to floor;
- Fire rated doors were not used;

- The transoms were not fire rated or sealed.

Impact on Regulation or Practices

The Winecoff fire led to a number of new fire regulations for Atlanta. The major change was to require the enclosing of stairwells with additional requirements for alarm systems and smoke detectors.

The impacts that this incident had on various regulations are discussed below.

NFPA 101®: Building Exits Code®
There do not appear to be any changes to NFPA 101 directly associated with this incident.

Board for the Coordination of Model Codes (BCMC)
The earliest BCMC reports obtained were from 1977; therefore, information on changes prior to 1977 was not available.

Uniform Building Code (UBC)
There do not appear to be any changes to the UBC directly related to this incident.

BOCA Building Code (BOCA)
The first edition of the BOCA code was not published until 1950.

Standard Building Code (SBC)
The first edition of the SBC was not published until 1945. Details of proposed changes and committee reports were not available prior to 1977.

C.3.10 Our Lady of Angels School Fire, Chicago, Illinois, 1958

Inadequate exit components were blamed for the loss of 93 occupants in a fire that spread rapidly through the Our Lady of Angels School in Chicago in 1958 [5]. The school consisted of a pair of two-story brick buildings connected together. However, per the applicable code, the building was considered one fire area, since the masonry wall separating the two annexes did not have protected openings, and the majority of the stairways within the buildings were not enclosed. The actual origin of the fire is not known, but it was located in a rear unenclosed stairway. Combustible materials here, as well as in adjoining corridors, contributed to rapid spread from the stairway to other areas of the building. Additionally, combustible ceiling tiles in the classrooms likely added to fire growth and spread.

After the fire was discovered and efforts were made to locate the school principal, the few teachers aware of the fire evacuated their own classes to another building. Only after returning did they activate the school's fire alarm and initiate general evacuation. Because the fire had moved up the open stairway in which it initiated and was largely burning in the second floor corridor, the first floor occupants were able to evacuate through the five available exit stairs. Some of the upper level occupants were able to escape because someone closed the dividing door between the two annexes, thus largely confining the products of the fire to the North wing. However, occupants of the North wing could not use the corridor to escape because of smoke and heat, and thus were forced to jump from the second-story windows or to be rescued by fire fighters using ladders. The majority of the fatalities occurred in this area.

The following details regarding this incident are of note:

- Only two of the five available stairways were enclosed, and these had inadequate opening protection at their landings. At the time of the fire, the doors to these stairwells were propped open;
- Combustible materials in the stairwell where the fire started, combustible wood trim in the main second-floor corridor, and combustible ceiling tiles in the classrooms all contributed to rapid and widespread fire impact on the second floor of the North annex;
- Notification was delayed because teachers evacuated their own classes before sounding a general alarm. By the time a general evacuation was initiated, dense smoke and heat had reached the upper corridor through the open stairwell. This prevented occupants of the upper floor of the North annex from reaching the enclosed exit stairway at the North end of the corridor;
- The opening protection between the two annexes was substandard, and the door in the upper corridor was propped open leading up to the fire. An occupant closed it during the fire, thus isolating the occupants of the second story portion of the South annex from the heat and smoke of the fire.

Impact on Regulation or Practices

Spurred by the Our Lady of Angels fire, the Los Angeles Fire Department conducted a series of tests designed to explore methods of protecting multistory school buildings containing open stairways. One of the major conclusions of these tests was that automatic sprinkler systems provided the best chance of occupant safety and egress.

Generally speaking, the Our Lady of Angels fire awakened much of the US to hazards present in the country's schools, and efforts were undertaken to improve conditions. One year after the fire, the NFPA polled fire departments regarding fire safety in schools, and it was found that the majority of communities had implemented better fire drill procedures, improved waste control measures, refined inspection requirements, and more appropriate storage of combustible goods;

NFPA 101®: Building Exits Code®

In response to the Our Lady of Angels fire and the Los Angeles fire tests, the NFPA reorganized its provisions for educational occupancies, which included requirements for sprinklers in school buildings of different types.

Board for the Coordination of Model Codes (BCMC)

The earliest BCMC reports obtained were from 1977; therefore, information on changes prior to 1977 was not available.

Uniform Building Code (UBC)

There do not appear to be any changes to the UBC directly related to this incident.

BOCA Building Code (BOCA)

The 1960 edition of BOCA contained changes in the Interior Finish requirements which modifying how material combustibility was classified. It is uncertain if any changes occurred in the requirements for the types of materials allowed in various occupancies.

Standard Building Code (SBC)

The first edition of the SBC was not published until 1945. Details of proposed changes and committee reports were not available prior to 1977.

C.3.11 Upstairs Lounge Fire, New Orleans, Louisiana, 1973

On June 24, 1973, an arson fire killed 32 patrons of the Upstairs Lounge in New Orleans, Louisiana [14]. The fire was started in the only staircase serving the upper floors of the three-story building. The second floor was the lounge, and the third floor included unoccupied apartments. At the time of the fire, there were 65 people in the lounge, which had a capacity of 110. Once established, the fire spread rapidly up the stairwell, fueled by combustible wood paneling and carpeting. The stairway was separated from the lounge on the second floor by a wood-framed partition with plaster-on-lath covering the studs. An approved fire door assembly was installed in this partition. However, on the night of the fire, a patron responding to repeated rings of the doorbell opened this door, and fire rushed into the lounge.

The location of the fire in the exit staircase prevented occupants from evacuating down the main exit stairs. An alternate escape path, opening onto an adjacent building's roof, was located in the back of the lounge, but was not marked as an exit. Also, the path to this door was obstructed by equipment on a stage, and the door had an improvised latch. The bartender attempted to lead people to this door, and was successful in evacuating several people in this fashion. However, on his second attempt to move people to the back door, he received no response, and evacuated, latching the fire door behind him. The final exit option was through the windows of the club. The building was equipped with a single fire escape, accessed through one of the windows. Many windows in the lounge were boarded up; other windows in the bar area were equipped with metal bars to prevent patrons from falling through. This proved to hamper escape efforts. Some occupants were able to squeeze through the bars and reach the outside, where they jumped, slid down drainpipes and other building features, or utilized the fire escape. Many of the fatalities occurred in the bar area in the vicinity of the exterior windows.

The following details regarding this incident are of note:

- The fire spread rapidly up the only stairway in the building due to the combustible interior finishes within the stairwell;
- The fire door at the top of the stairwell, which initially blocked the heat and smoke from the fire, was opened by a patron and, presumably, remained open for the duration of the fire. Smoke and flames entered the lounge immediately after this door was opened, and patrons had little time to react;
- A rear door, which turned out to be the only safe exit, was not properly marked as an exit, and the path to it was hidden and obstructed by a stage and associated equipment. Also, it had an improvised latch, which may have been difficult to operate by those unfamiliar with it;
- Numerous windows were boarded up, and the rest were equipped with steel bars to prevent people falling through the large glass panels. Many of these also had wooden shutters over their lower sections.

Impact on Regulation or Practices

NFPA 101®: Life Safety Code®
There do not appear to be any changes to NFPA 101 directly associated with this incident.

Board for the Coordination of Model Codes (BCMC)

The earliest BCMC reports obtained were from 1977; therefore, information on changes prior to 1977 was not available.

Uniform Building Code (UBC)

There do not appear to be any changes to the UBC directly related to this incident.

BOCA Building Code (BOCA)

While it is unclear if changes were perpetuated by this incident, a number of changes appear in the 1975 BOCA code. Due to the fact that these changes tend to make the Code more lenient, it is doubtful that they were in response to this incident. These include:

- Increases in the egress capacities of doors and stairs as follows:
    - Unsprinklered - 75 people per unit width for stairs and 100 people per unit width for doors;
    - Sprinklered – 113 people per unit width for stairs and 150 people per unit width for doors;
- Before the 1975 edition, the egress capacities for unsprinklered buildings was 60 people per unit exit width for stairs and 90 people per unit exit width for doors;
- Travel distances were increased to 150 ft. for unsprinklered buildings and 200 ft for sprinklered buildings. Before the 1975 edition, the travel distance was 100 feet for all construction types;
- Panic hardware was now required for all assembly occupancies with an occupant load greater than 100 persons;
- Sprinkler systems were now more widely required for various assembly spaces;
- Standpipes were more widely required for assembly spaces with more than 300 occupants.

Standard Building Code (SBC)

The first edition of the SBC was published in 1945. Details of proposed changes and committee reports were not available prior to 1977.

C.3.12 Gulliver's Discotheque Fire, Port Chester, NY, 1973

On June 30, 1974 a fire killed twenty-four people in a nightclub called Gulliver's in Port Chester, New York [15]. Gulliver's was part of a small shopping center on the Connecticut-New York border that also housed a bowling alley, a men's clothing store, and a barbershop. It was a one-story building with a basement. The basement was used for storage, offices and a children's playroom that the bowling alley rented. The fire started in the basement in a children's playroom. The fire was deliberately set.

The dance floor itself was five feet lower than the dining room and had two adjacent sets of stairs leading to the basement and to the dining room. These were the only exits from the dance floor. At approximately 1:00 am people in the service bar area of the basement at the foot of the stairs to the dance floor noticed smoke. Someone called the fire department while someone else notified the bandleader who told people to leave the building. The evacuation was orderly, but within a minute heavy smoke started coming up the stairs from the basement to the dance floor. Smoke had traveled in the floor joist channels above the playroom into the service bar area below the dining area and then billowed up the stairs leading to the dance floor. Occupants were forced to leave by using the “up” stairs leading to the dining room adjacent to the basement stairs. Even though the stairs were 5 ½ feet wide there was not enough time for the crowd to evacuate and the twenty-four people that died did so of smoke inhalation.

Once the crowd was warned to evacuate there was not enough time to complete evacuation before smoke exposure became a problem. Some of the reasons for the lack of evacuation time were:

- Delayed discovery of the fire, since it originated in the unoccupied children’s play area in the basement;
- Lack of a fire-rated wall between the discotheque and the rest of the shopping center;
- Lack of a fire-rated door at the bottom of the stairs from the service bar to the dance floor;
- Lack of occupant load restrictions;
- Exits from the dance floor were not remote from each other.

Impact on Regulation or Practices

NFPA 101®: Life Safety Code®

There do not appear to be any changes to the 1976 edition of NFPA 101 directly associated with this incident. However, this incident is specifically mentioned in a proposal to change the fire alarm / notification system requirement for the 1981 edition of NFPA 101. The proposal as submitted was rejected, but the concepts were accepted toward creating a new requirement for fire alarm / notification systems in assembly spaces with an occupant load greater than 300 persons.

Board for the Coordination of Model Codes (BCMC)

The earliest BCMC reports obtained were from 1977; therefore, information on changes prior to 1977 was not available.

Uniform Building Code (UBC)

There do not appear to be any changes to the UBC directly related to this incident.

BOCA Building Code (BOCA)

While it is unclear if changes were perpetuated by this incident, a number of changes appear in the 1975 BOCA code. Due to the fact that these changes tend to make the Code more lenient, it is doubtful that they were in response to this incident. These include:

- Increases in the egress capacities of doors and stairs as follows:
  - Unsprinklered - 75 people per unit width for stairs and 100 people per unit width for doors;
  - Sprinklered – 113 people per unit width for stairs and 150 people per unit width for doors;
- Travel distances were increased to 150 ft for unsprinklered buildings and 200 ft for sprinklered buildings;

- Panic hardware was now required for all assembly occupancies with an occupant load greater than 100 persons;
- Sprinkler systems were now more widely required for various assembly spaces;
- Standpipes also more widely required for assembly spaces with more than 300 occupants.

Standard Building Code (SBC)
The first edition of the SBC was published in 1945. Details of proposed changes and committee reports were not available prior to 1977.

C.3.13 Beverly Hills Supper Club Fire, Southgate, Kentucky, 1977

Few assembly occupancy fires have been investigated and documented as thoroughly as the one that occurred at the Beverly Hills Supper Club in Southgate, Kentucky, in 1977. This sprawling nightclub had multiple event rooms of varying sizes. On the day of the fire, multiple events were scheduled, including a wedding reception earlier in the afternoon, and a show was in progress when the fire broke out. In total, 2400 to 2800 people were in the building at this time, and 1200 to 1300 of these were in a single event room (the Cabaret Room). The fire initiation, assumed to be electrical in nature, occurred in an unoccupied room where an event had taken place earlier in the day [5,6]. Employees noticed the flames, and attempted to extinguish them using fire extinguishers. The fire was seated in a concealed space within the wall, and the employees' extinguishment efforts were unsuccessful. Largely because of the unsuccessful efforts to extinguish the fire, approximately 15 minutes elapsed between the discovery of the fire and the general notification of the employees and occupants. Additionally, it is reported that some employees were not sure of evacuation procedures, and this may have further delayed notification.

According to witness accounts, the initial evacuation of patrons followed an interesting trend. Employees tended to notify only those patrons for which they were responsible during the normal operations. In other words, a given waitperson might only have notified the people seated at the tables that that person served. This led to delayed notification of some guests in remote parts of the building. Unfortunately, during the performance in the Cabaret Room, the wait staff was isolated from the patrons so as not to interrupt the performances, and thus employees did not instinctively notify occupants in the Cabaret Room. This led to delayed notification within the Cabaret Room; thus, almost all of the 164 fatalities occurred in the Cabaret Room.

Many survivors of this fire owe their lives to a calm and quick-thinking busboy, who took the stage in the crowded Cabaret Room, pointed out the available exits, and asked people to leave. Some followed his advice, but many did not perceive the danger until smoke and heat reached the area outside of the Cabaret Room. At this point, occupants began to rush to the exits. Some tripped or were knocked down, and the exits became blocked. According to the busboy, one of the three available exit doors was locked, and he was unable to break it open.

The following details regarding this incident are of note:

- While the applicable codes of the time limited the occupancy of the club to 1511 based on its construction, more than 2400 occupants were inside at the time of the fire;
- The Cabaret Room was vastly overcrowded, with tables pushed together and additional seating placed in the aisles, thus blocking egress movement. Based on the codes at the time the capacity of the Cabaret Room was just over 500, but there were over 1000 occupants in the room that evening [3];

- The exit capacity of the egress system was approximately 60% of the code-required capacity;
- The Cabaret Room should have had four separate exits, but it only had three, and at least one was locked at the time of the fire. Some of these exits were poorly marked or intentionally masked;
- There was no evacuation plan and personnel were not properly trained;
- Once established in the compartment of origin, fire spread rapidly across combustible interior finish within the room of origin and the main corridor of the building;
- Many occupants did not perceive the severity of the fire until it was too late, and few evacuated immediately upon being told to do so. No alarm system was installed within the building.

Impact on Regulation or Practices

NFPA 101®: Life Safety Code®

According to information in the Life Safety Code® Handbook:

- Previous to the Beverly Hills Supper Club fire, the NFPA 101 Life Safety Code required alarm systems in all occupancies except storage spaces and places of assembly. The reasoning for the latter was that it was felt that an alarm might cause panic. This fire showed the importance of rapid notification, and the next version of the Code, the 1981 edition, included a requirement for alarm systems in places of assembly. Additionally, a note was added requiring that notification of places of assembly be done through a voice alarm or a public address system. These requirements were implemented retroactively in existing buildings, as well;
- The Life Safety Code historically only required sprinkler systems in assembly occupancies when those spaces were used as exhibit halls. After the Beverly Hills Supper Club incident, provisions were added to the 1981 edition of the code requiring sprinkler systems in different assembly occupancies based on the types of construction used. Some of these requirements were also issued retroactively.

Board for the Coordination of Model Codes

There do not appear to be any recommended changes to the model building code from the BCMC as a result of this event.

Uniform Building Code (UBC)

There do not appear to be any changes to the UBC directly related to this incident.

BOCA Building Code (BOCA)

While unclear if changes were directly related to this incident, a few changes appear in the 1978 BOCA code. These include:

- Panic hardware in all assemblies with 50 or more occupants.
- Door swing in the direction of travel when serving 50 or more occupants.

Standard Building Code (SBC)

There do not appear to be any changes to the SBC directly related to this incident.

Modeling Efforts

In the early 1980s Emmons [44] attempted to estimate mathematically fire growing and fire gas spread rate in the Beverly Hills Summer Club fire. Using a resistor network diagram and mean flow volume equations this “educated guess” clearly showed that the act of opening doors to escape drew the fire into the escape routes.

C.3.14 “The Who” Concert, Cincinnati, Ohio, 1979

The Who concert was a sold out show and many ticket holders had arrived to the Coliseum early and were waiting to be let into the venue to claim the best seats. There were over 18,000 general admission tickets sold and as many as 8,000 ticket holders waiting outside competing for the preferred general admission seating [3]. Two banks of eight doors were finally opened, but according to many in the crowd, not all of the doors were opened. The guards would let in people until the lobby was full and then they would temporarily close the doors. This resulted in the crowd pushing forward. Within an area outside one of the banks of doors, several people fell. The people behind those that had fallen were pushed forward by the crowd. The surge toward the Coliseum resulted in eleven people being crushed to death and approximately two-dozen more becoming injured from he incident [17]. Concertgoers told of only one or two doors being open out of a possible sixteen to process the incoming crowd.

The following details regarding this incident are of note:

- Poor crowd safety was the major cause of this tragedy;
- Only a few doors out of a total of 16 were open to accommodate 8,000 people and when the lobby filled the guards closed the doors, which caused the crowd to become concerned about getting into the arena.

Impact on Regulations or Practices

This incident spurred the Cincinnati government to take action. By the end of the month the Mayor and City Council had passed legislation that banned festival seating and gave the police emergency on-the-scene authority at major public assembly venues. In addition, a full-scale investigation was conducted by an independent citizen’s task force called “The Task Force on Crowd Control and Safety”, which was established by the City Council. The Task Force released a report called Crowd Management in 1980 that offered 108 crowd safety recommendations. The report is now in its fourth printing and remains one of the important manuals on facility rock concert crowd management.

NFPA 101®: Life Safety Code®
A requirement regulating festival seating-type assembly areas was introduced into the code for the 1994 edition.
Board for the Coordination of Model Codes
There do not appear to be any recommended changes to the model building code from the BCMC as a result of this event.
Uniform Building Code (UBC)
There do not appear to be any changes to the UBC directly related to this incident.
BOCA Building Code (BOCA)
There do not appear to be any changes to the BOCA code directly related to this incident.
Standard Building Code (SBC)
There do not appear to be any changes to the SBC directly related to this incident.

C.3.15 Haunted Castle Amusement Facility Fire, Jackson Township, NJ, 1984

On May 11, 1984 a fire destroyed the “Haunted Castle” amusement at the Six Flags Great Adventure Park located in Jackson Township, New Jersey [18]. Eight young adults died as a result of smoke inhalation and carbon monoxide poisoning. The structure was composed of seventeen commercial trailers connected by plywood and wood framing. The interior of the amusement was constructed of plywood partitions creating a convoluted path 450 ft. long. Other materials used in the interior of the structure were synthetic foam, various fabrics and plastics, and tarpaper. The cause of the fire was the accidental ignition of a wall mounted, polyurethane foam pad by a cigarette lighter from a visitor trying to light their way through the dark path. The foam pad burned rapidly and fire spread down the corridor fueled by plywood construction of the ceiling, floor, and walls. The foam was not flame retardant and the plywood was untreated.

At approximately 6:30 PM an employee in the Haunted Castle smelled smoke and went to investigate. Coming upon heavy smoke he went to the main gate to instruct employees to discontinue entry of visitors and then went to the control room inside the facility to call the park fire brigade. Meanwhile, a visitor in the amusement discovered the fire and alerted an employee. There was approximately a five-minute delay between the employee detecting the fire and alerting the fire brigade.

There were a total of seven exits including the main entrance and fire protection features included emergency lighting and portable fire extinguishers. There were no automatic detection or sprinkler systems provided in the facility.

The following details regarding this incident are of note:

- The fire was not detected and suppressed in its incipient stage because of the lack of automatic detection and suppression systems;
- There was a large amount of combustible material present including interior finishes such as foam and plywood;
- The occupants had difficulty escaping due to fire conditions in the haunted house type of environment.

Impact on Regulation or Practices

NFPA 101®: Building Exits Code®

Though unclear if directly related to this incident, the interior finish requirements were changed for the 1985 edition of NFPA 101 so that rooms with an occupant load greater than 300 were limited to Class II interior finish materials. Class III materials were still allowed in rooms with less than 300 occupants.

Board for the Coordination of Model Codes (BCMC)

The BCMC report dated February 19, 1985 included recommendations for the size, location and illumination of exit signs. It is uncertain if these recommendations were directly related to this incident, but they certainly address the pertinent issue of the Haunted Castle fire.

Uniform Building Code (UBC)

Though unclear if directly related to this incident, the interior finish requirements were changed for the 1985 UBC so that rooms with an occupant load greater than 300 were limited to Class II interior finish materials. Class III materials were still allowed in rooms with less than 300 occupants.

BOCA Building Code (BOCA)

There do not appear to be any changes to BOCA directly related to this incident.

Standard Building Code (SBC)

While unclear if directly related to this event, the main exit provision was modified for the 1985 edition of the SBC. The new requirement called for 1/2 of the total egress capacity to be provided through the main exit and 2/3 of the total egress capacity to be provided by all other exits.

C.3.16 Happy Land Social Club Fire, New York, New York, 1990

Early on the morning of March 25, 1990, numerous patrons were in the Happy Land Social Club in the Bronx borough of New York City [20,21]. It is suspected that an arsonist used an accelerant to ignite a fast-growing fire in the building's main lobby, and that combustible interior finish contributed to the rapid growth of the fire. The ground floor of the building, which is where the lobby was located, had been left unsprinklered during a previous renovation, and thus the fire spread unimpeded. Coatroom employees discovered the fire, and alerted first floor occupants. Another employee went up to the second floor, where the majority of occupants were located, to alert patrons to the fire. Only two occupants from the second floor survived, although one of these sustained severe burns running through the lobby to the main exit; these individuals left the second floor immediately upon being informed of the fire. Fire damage was limited to the front portion of the building. A total of 87 people died in this fire, 18 on the first floor, and 69 on the second.

The following details regarding this incident are of note:

- At the time of the fire, the club was in violation of New York City building and fire code regulations, and had been ordered shut down, but was still in operation;
- At some point in its history, the building had been converted from one story (high ceiling) to two, and the original sprinkler system was not extended to the first floor. Also, part of the sprinkler system on the second floor was not functional. The fire initiated in an unsprinklered area;
- One of the two main exit doorways to the front exterior of the building was covered by an unlocked roll-down steel security door. The swinging doors here were locked, and the doorway was not marked from the inside as an exit. However, at some point during the evacuation, an employee unlocked this door, and it was used by several egressing occupants;
- Four additional doors separated patron areas from an entrance lobby. All of these doors swung in the direction of egress travel, but three of the four were locked at the time of the fire;
- The two available exit stairs were not enclosed. The stairway closer to the front exit was a steep "ships ladder" type stair. The primary stair access to the second floor, and the stairway labeled as the main exit, was at the back of the building. This stair had uneven risers, as well as a 90° bend and a width that varied down to 19 inches;

- Combustible interior finishes in the lobby area, where the fire was ignited, led to rapid fire growth, thus blocking the only available exits from the building.

Impact on Regulation or Practices

NFPA 101®: Life Safety Code®

There do not appear to be any changes to NFPA 101 directly associated with this incident.

Board for the Coordination of Model Codes

There do not appear to be any recommended changes to the model building code from the BCMC as a result of this event.

Uniform Building Code (UBC)

Though it is unsure if this incident had any direct impact, the following were changes incorporated into the 1991 edition of the UBC:

- Required egress width requirements changed to provide 0.3 inches of stair width and 0.2 inches of door width for each occupant. The 1946 through 1988 editions of the UBC specified required exit width as the number of occupants divided by 50. However, in the 1943 version of the UBC required 0.24 inches per person for occupancies with 1 to 1000 occupants, which is greater than the width required in 1991;
- A fire alarm / notification system was now required for assembly spaces with and occupant load greater than 300.

BOCA Building Code (BOCA)

The 1993 edition of the BOCA code incorporated changes in the requirements for sprinkler and standpipe system, but it is unclear if there changes were related to this incident.

Standard Building Code (SBC)

There do not appear to be any changes to the SBC directly related to this incident.

C.3.17 Indianapolis Athletic Club Fire, Indianapolis, Indiana, 1992

On February 5, 1992 a fire occurred at the Indianapolis Athletic Club that killed two fire fighters and one patron [22]. At 12:06am the Indianapolis Fire Department received a phone call reporting the fire. Upon their arrival, they could find no external evidence of fire in the high-rise building, but once inside they found heavy smoke in the first floor lobby. Investigating further, they discovered a room on the third floor that was fully involved in fire. During suppression operations on the third floor, a flashover occurred in the room adjacent to the room of fire origin. The sudden increase in the magnitude of the fire caused it to spread to other areas and resulted in the death of two fire fighters. Several other fire fighters were injured. A search of the building revealed that one patron died in the fire between the sixth and seventh floors.

The fire department determined that the fire was accidental and caused by an electrical fault involving a refrigerator caused the ignition of wood paneling in a third-story bar. It was further determined that the release of combustion gases which were trapped in a concealed space contributed to the flashover that killed and injured the fire fighters. After the flashover, the fire spread to other areas of the third floor and it also spread to the fourth floor via an open stairway. The HVAC systems also continued operation until electrical power was lost and contributed to the spread of smoke throughout the building.

The following details regarding this incident are of note:

- The lack of an approved automatic sprinkler contributed to the spread of the fire;
- Unprotected penetrations in the wall and ceiling assemblies aided the fire spread;
- Concealed spaces increased the hazard for fire suppression personnel;
- Combustible interior finish which included wood paneling on walls and ceiling tiles left in concealed spaces after a building renovation also contributed to the magnitude of the fire.

Impact on Regulation and Practices

NFPA 101®: Building Exits Code®

There do not appear to be any changes to NFPA 101 directly related to this incident.

Board for the Coordination of Model Codes (BCMC)

There do not be any recommended changes from the BCMC directly relating to this event.

Uniform Building Code (UBC)

There do not appear to be any changes to the UBC directly related to this incident.

BOCA Building Code (BOCA)

Changes to the automatic sprinkler requirements appeared in the 1993 BOCA code. Sprinkler system were now required as follows:

- In A-1 (theaters), A-3 (amusement / entertainment spaces), and A-4 (churches / schools) where the fire area exceeds 12,000 ft^2;
- In A-2 (dance halls / clubs) where the fire area exceeds 5,000 ft^2 or is located above or below the level of exit discharge.

It is uncertain if these changes are directly related to this incident.

Standard Building Code (SBC)

There do not appear to be any changes to the SBC directly related to this incident.

C.3.18 E2 Nightclub, Chicago, Illinois, 2003

In the early morning hours of February 17th, 2003 21 people were killed and 57 people were injured when a stampede occurred at the E2 nightclub in Chicago [23]. A fight had broken out on the dance floor between two women and escalated to include a larger group. Security guards sprayed pepper spray into the crowd triggering a stampede toward the front exit. The nightclub is located on the second floor of the building, so the front exit was a set of stairs leading down to the main exit door. The surge toward the main exit stairway resulted in the deaths of 12 women and 9 men. Most of the deaths occurred at the top of the stairs.

The nightclub was on the second floor of a building. There was a restaurant on the first floor of the building that housed the nightclub that was not open at the time of the incident. The club had been ordered closed due to fire and structural building code violations months before the incident. However, the Chicago Fire Department estimated that 500 people were in the building that night.

The following details regarding the incident are of note:

- The club should have been closed due to numerous building code violations;
- Alternate exits were not easily assessable to the patrons [24];
- A consultant hired by the lawyers representing some of the victims and their families found 20 code violations including that the two rear exit signs were not lighted and based on the width of the exit doors the second floor of the building could safely handle 240 to 300 people, which would mean that the club was overcrowded since the FD estimated there to be 500 occupants at the time [25];
- Although the violations involving the back exit doors did not contribute to the deaths, one of the back doors was locked and another was partially blocked by laundry bags.

Impact on Regulation or Practices

It is too early to determine how or if the building codes will be impacted by the E2 incident.

C.3.19 Summerland Fire, Isle of Man, United Kingdom, 1973

On August 2, 1973 a fire broke out in a kiosk outside the Summerland entertainment complex on the Isle of Man and killed 51 people [26]. It is believed that adolescents smoking in the kiosk started the fire. The burning kiosk fell against the adjacent building and ignited the outside of the building. The building was clad with combustible transparent acrylic sheeting called Oroglaso. When ignited, the material became molten and dripped on the people trying to escape. In addition to the combustible exterior, there was a flammable material used to line the inner walls for soundproofing purposes. These materials caused the fire to spread rapidly.

Upon hearing of the fire, people began to leave, but an employees told the crowd that it was just a chip-pan fire and that there was no need to worry. Some of the people returned to their seats. It took the staff twenty-five minutes to contact the fire brigade. Later the fire burst into the building and the evacuation of the building became pandemonium. Emergency doors had been padlocked and there were turnstiles that could not handle the amount of people evacuating.

The following details regarding this incident are of note:

- It took twenty-five minutes for the staff to notify the fire brigade;
- Combustible exterior sheeting as well as combustible interior finishes aided fire spread;
- Emergency doors had been padlocked;
- There were turnstiles that could not handle the size of the crowd.

Impact on Regulation or Practices

The aftermath of Summerland fire led to the tightening of fire regulations on public buildings across the Isle of Man and the United Kingdom.

C.3.20 Stardust Cabaret, Dublin, Ireland, 1981

In the early morning hours of February 14th, 1981, a fire spread through the Stardust Cabaret in Dublin, killing 48 young people and seriously injuring 128 [27]. It was originally intended that the building be used for cabarets and concerts, but it was subsequently used as a disco. The space consisted of a dancing area, a small stage, and two seating areas. The fire started in the back row of one of the seating areas. The fire spread rapidly from seat to seat in the area of origin and ultimately through the entire area due to the presence of a tier of seats containing quantities of combustible material abutting a wall lined with combustible carpet tiles, the presence of a low ceiling, and the presence of a large area of combustible seating. Although there were eight exits from the ballroom, five of these being principal emergency exits, forty-eight young people died because of the rapid fire spread. The investigation concluded that the fire was set deliberately and that the arsonist aided the fire spread by slashing the seats and igniting them or by lighting newspapers under a seat.

There was adequate exit capacity in the Stardust, but the fire spread rapidly, resulting in the large death toll. Combustible seating and interior finishes aided the fire spread.

Impact on Regulations or Practices

The Irish Government established a Tribunal to carry out a full investigation of the fire. The Tribunal made a significant range of recommendations that were examined by the Irish authorities. However, it was not confirmed whether the Stardust fire led to changes in regulation.

C.3.21 Dance Hall Fire, Gothenburg, Sweden, 1998

During a Halloween party in 1998 at a second-floor dance hall in Gothenburg, Sweden, an arsonist initiated a fire in one of the two available exit stairways [28]. The fire spread through the stairwell, fuelled by combustible furniture and wall coverings within the stairwell. At the time of the fire, approximately 400 people were in the hall. Based on the size of the hall and the available exit door width, US codes of the time would have limited the occupant load to 312 people. The local fire brigade has indicated that, based on the exit door width, they would have limited the occupant load to 150.

The dance hall was equipped with two separate exit doors at opposite ends of the space. Each exit door swung in the direction of egress travel. The main entrance/exit door was noncombustible, and was equipped with an automatic closer. The other door was constructed of combustible material, but had a 30-minute rating, and was equipped with an automatic closer. Because the fire was located in this second stairway, it was not used in the evacuation. It is not clear if this door remained open after the discovery of the fire. Both doors had an opening width of 31.2 in.

The large number of people in the yard surrounding the building hampered fire department access to the incident. Once inside the main entrance of the two-story building, firefighters discovered numerous victims on the stairway leading to the second floor. These victims were removed, and firefighters continued to the second floor, where the discovered a stack of additional victims in the exit doorway from the main hall. Victims, some alive and others unconscious were apparently stacked right up to the top doorjamb. As firefighters pulled the occupants out, others from inside the hall took their places on the pile. Eventually, the doorway was cleared, and the fire was quickly extinguished. Additional victims were later discovered in a small office where they had attempted to seek refuge when the discovered that the exit was blocked. Smoke had breached this room through failed glass panels near the ceiling.

An occupant-use fire hose was available in the main entrance stairwell, but was not used. Its condition prior to the fire was not known. The building was not equipped with an alarm system or sprinklers.

In total, 63 people died in this incident. None were older that 20 years. 43 of the victims were found piled up at the exit doorway. Another 20 victims were found in a small office. An additional 180 people were injured in the incident.

The following details regarding this incident are of note:

- Fire growth and spread was somewhat rapid due to the fuel loads within the stairwell where the fire was initiated and in the dance hall itself;
- The hall was severely overcrowded, and even though two remote exits were provided, the sheer number of evacuating occupants caused a bottleneck in the one available exit door. It has been theorized that the exit capacity would have been sufficient had the occupant load restrictions been enforced;
- The building was not equipped with a fire alarm or an automatic sprinkler system;
- The occupant (the disc jockey) who first discovered the fire apparently immediately jumped out of a window, and did not notify the other occupants of the fire. It is unclear how much of a delay occurred between initial discovery of the fire and the commencement of a general evacuation;
- Numerous people jumped from the high windows, 20 ft above the ground level. These windows were over 7 ft above the floor level in the dance hall, and were not viable exits;
- Fire brigade arrival at the scene and access to the building were hampered by the crowds of people in the yard surrounding the building. Additionally, there were reports of assaults on firefighters, both in and out of the building, as they attempted to rescue occupants.

Impact on Regulation or Practices

There was some discussion after the investigation of the fire in relation to code requirements for public halls and auditoria. For example, it was questioned whether multiple "normal" exit door widths (0.8 m.) might be better than fewer wider exits (≥1.2 m.) and whether the requirements for the floor surface hazard properties should be made more strict.

Note that these discussions were related to public halls and auditoria. The "dance hall" in Gothenburg was not designed for this purpose and would hence not technically have been affected by such changes.

C.3.22 De Hemel Fire, Volendam, The Netherlands, 2000/2001

A fire occurred during a New Year's eve celebration in a 125 m^2 (1346 ft^2) café on the top floor of a three story building in The Netherlands [46]. Of the approximately 300 people present, fourteen died, primarily from smoke inhalation, and 200 were injured when the fire spread very rapidly through fir branches attached as holiday decorations to the ceiling of the café. Ignition of the branches occurred immediately when a sparkler held above the head of one of the patrons accidentally came in contact with the decorations. The fire quickly overpowered any attempts to extinguish it. There were two exits available from the café, but they were not obviously marked, and in any case, because the fire spread so rapidly, the exit doorways became blocked by those trying to escape.

Two recommendations were made by TNO [46] as a result of their investigation into the fire:

- to provide an organization that can learn from the mistakes already made (nationally and internationally)
- to increase awareness of the dangers of using flammable materials and the need for sufficient escape routes

C.4 DETAILS OF SUCCESSFUL INCIDENTS

C.4.1 School Fire, California, 1992

A grease fire ignited on a stove in the home economics classroom of a single story 4,800 square-foot school building of unprotected ordinary construction [30]. There was a delay in the activation of the alarm system because of a nonfunctioning smoke detector and failure of school personnel to use manual alarms. The students and staff were able to safely evacuate but the fire impinged on the room's ceiling. Personnel saw smoke coming from the classroom and investigated but failed to initiate the alarm system. Building personnel attempted to extinguish the fire with portable extinguishers but the fire re-ignited.

The fire department arrived and the building was still occupied by approximately 1,000 students and staff. The fire department ordered the evacuation by the manual fire alarm system and extinguished the fire. The damage to the building was estimated to be $2,500 and there were no injuries because there were a limited number of students in the involved section.

The following details regarding this incident are of note: the smoke detection failed and there was a delayed evacuation of the building, but there were no injuries because of the limited number of occupants in the area of the fire.

C.4.2 Nightclub Fire, Texas, 1992

At about 12:30 am on a weekend evening, a short circuit occurred in suspended sound equipment on the second floor of a crowded two-story nightclub occupied by hundreds of patrons [31]. The building was 10,000 square foot building of unprotected, noncombustible construction that was located in a mall and housed a two-story nightclub. The automatic sprinkler system operated immediately and quickly extinguished the fire, but smoke and water forced an evacuation of the building.

The fire department arrived and found that four sprinklers had operated and extinguished the fire. Damage was limited to the electrical equipment and was estimated to be $150,000. Several of the occupants were treated for minor smoke inhalation but none were transported to a hospital.

The following details regarding this incident are of note: four sprinklers quickly extinguished the fire and allowed for occupants to safely escape.

C.4.3 School Fire, Oregon, 1992

An 11-year-old child set a fire in a closet of an unoccupied classroom. The fire quickly spread to the attic space of the building [32]. There were 450 students present when the fire occurred. It was discovered by a passerby and a teacher almost simultaneously. The teacher activated the manual evacuation alarm that alerted students and staff to evacuate the building.

The building was constructed in several stages during the 1940's with a total of 37,500 square feet and consisted primarily of wood-frame components. The building was designed so that it circled an interior courtyard on three sides. In 1975, a partial sprinkler system was installed that covered common hallways and areas above classroom doors but there were no other suppression systems installed in the building.

Damage to the building was limited to the attic area and to classrooms below sections where the roof and ceiling collapsed. There were no injuries to students and staff during the evacuation.

The following details regarding this incident are of note: the fire was started in a closet and quickly burned into the attic; the ceiling assembly provided protection to occupants as they escaped.

C.4.4 School Fire, Massachusetts, 1992

Fireworks ignited a fire on the roof of a regional high school after an outside assembly for graduating students had begun [33]. A school official climbed to the roof and discovered an intense fire that involved the roof covering. An attempt was made using portable extinguishers before the fire department was notified, which delayed the response.

The fire department limited and prevented the fire from spreading to the interior, which was confined to the tar and rubber covering of the built-up roof of brick, block, concrete and steel building. There were no injuries that resulted from the incident or the evacuation of the occupied school.

The following details regarding this incident are of note: an exterior fire on the roof required the evacuation of the school; the building materials prevented the fire from spreading to the interior of the building.

C.4.5 School Fire, Oregon, 1994

A fire occurred in a two-story middle school that was constructed of unprotected wood framing and a brick veneer on the exterior [34]. The school's automatic smoke detection system alerted students and faculty of an electrical fire that started in the ceiling and roof voids. The building was not equipped with a sprinkler system but the detection system was connected to an automatic dialer, which notified the fire department.

The fire department found the blaze in concealed wall voids and in the attic where it was spreading laterally over the classrooms. Firefighters made a trench cut, which helped stop the spread of fire. The fire was confined to one wing of the building and limited damage to classrooms, offices, lockers, and a bathroom. An investigation determined that an electrical conduit in the wall void that was placed directly against wood shiplap siding had heated the siding over a period of time. It eventually ignited at a spot level within the ceiling. There were no injuries.

The following details regarding this incident are of note: fire occurred in a concealed space but a smoke detection system notified the occupants of the hidden danger.

C.4.6 Restaurant Fire, Indiana, 1996

A grill fire damaged a restaurant when the flames spread to the ductwork and then to the concealed attic space [35]. The fire occurred in a single story 3,200 square foot facility that was constructed of unprotected, wood-frame construction. The building did contain a localized dry chemical system that was installed in the hood over the grill.

The cook dropped a plastic container filled with an oil-based marinade on to the hot grill. The plastic container melted and the marinade ignited, which caused flames to flare up toward the hood and ductwork. The fire spread to the concealed attic space before the suppression system could be activated. An employee immediately called the fire department, which arrived to find flames extending from the roof ducts. Firefighters surrounded the building and prevented spread to two adjacent buildings. There were no injuries during the fire.

The following details regarding this incident are of note: an accidental fire occurred on the grill and spread to the attic space in an unprotected building that did not injure any occupants.

C.4.7 Dinner Theater Fire, Florida, 1996

A fire occurred in a two-story, 20,000 square-foot building that was constructed of concrete walls and floors with unprotected steel roof with metal deck and built up roof covering [36]. The building contained a wet-pipe sprinkler system throughout, which was monitored by a central station alarm company.

During a performance, someone fired a pyrotechnic device that ignited a burlap net attached to a curtain. The net ignited and smoke began to fill the auditorium that contained 400 children and teachers. Four sprinkler heads were activated that extinguished the fire. Almost simultaneously, an occupant and the alarm company notified the fire department that arrived to find the safe evacuation of the children and teachers.

A majority of the loss of the contents was due to water damage to electronic equipment. There were no injuries to the occupants of the facility.

The following details regarding this incident are of note: a pyrotechnic device ignited materials on the stage that was controlled by sprinklers. The 400 children and teachers were able to safely evacuate the auditorium without injury.

C.4.8 Restaurant Fire, Michigan, 1996

A fire occurred in a single story 3,000 square-foot, single-story restaurant that was constructed of wood framed walls and a wood truss roof deck [37]. The building had no detection system or sprinklers but there were portable extinguishers installed in the building.

An employee in the storage/break room area was waiting for her shift to start and noticed flames coming from the top of a cooler/freezer. She alerted other staff members, notified the fire department and evacuated patrons. An unsuccessful attempt was made by another employee to extinguish the fire using a portable extinguisher.

The fire department arrived to find heavy smoke coming from the restaurant. The fire had spread to the concealed ceiling spaces and the wood trusses. Investigators believe the controls located at the top of the cooler/freezer malfunctioned, starting the fire. The restaurant was destroyed, but there were no injuries during the blaze.

The following details regarding this incident are of note: a malfunctioning cooler/freezer sparked a fire that destroyed the restaurant that was discovered by an employee. There were no injuries during the evacuation, but the building was destroyed.

C.4.9 Community Center Fire, Pennsylvania, 1997

An fire of electrical origin broke out between the fourth and fifth floors of a religious community center [38]. The building was five-stories tall and had a footprint of 10,000 square feet that contained a religious community center, a school and a synagogue. The building was constructed with heavy timber with exterior brick walls and a wooden roof deck that contained a built-up roof covering. There were smoke detectors and manual pull stations located throughout the building along with a partial sprinkler system in a second floor day care center.

There were nearly 100 staff members and students present when an occupant discovered a fire who activated a manual pull station. A central station notified the fire department while the occupants began to evacuate. The fire was confined to the fourth and fifth floors of the auditorium.

An investigation determined that the fire started in a fault in the wiring of a HVAC unit that ignited the structural framing in the concealed void between the fourth floor ceiling and the gymnasium roof. Two firefighters and two civilians were injured.

The following details regarding this incident are of note: an electrical fault in a community center lead to the injuries of two civilians and two firefighters along with extensive damage to two floors of the structure.

C.4.10 Restaurant Fire, Massachusetts, 1997

A fire occurred in a 7,200 square-foot restaurant that was located in a one-and-a-half-story shopping mall located in Massachusetts that was constructed of unprotected noncombustible construction [39]. There were 25 occupants present when a fire in a portable chicken broiler, which was installed after the fire department inspection and was not protected by the chemical suppression system that protected all of the cooking surfaces ignited. All of the occupants safely evacuated the building.

The burners ignited a grease buildup in the bottom of the broiler cabinet. The central station that monitors the wet-pipe sprinkler system received an alarm and notified the fire department. On arrival of the fire department they found a sprinkler located above the cabinet had extinguished the blaze.

The following details regarding this incident are of note: sprinklers extinguished the fire before arrival of the fire department and occupants were assisted with their evacuation.

C.4.11 School Fire, California, 1998

A fire occurred in an unoccupied classroom of an 8,800 square foot, eight-classroom school in California [40]. The fire spread in the attic and concealed spaces between the ceiling and roof of this single story elementary school that consisted of unprotected wood framing with a stucco exterior. The building did not have a fire detection system or sprinklers and the manual fire alarm was out of service when the fire occurred.

The fire is believed to have been started by a short circuit or a circuit overload in fixed wiring in the attic. Teachers had reported several electrical malfunctions in the past prior to the fire. The discovery of the fire by a student lead to the notification of the fire department who arrived to find flames coming from the building’s roof and that two of the classrooms were fully involved. The fire spread horizontally because of the lack of fire stops and then burned through the ceiling to the classrooms below igniting the heavy fuel load. There were no injuries to the occupant during the fire.

The following details regarding this incident are of note: a lack of a detection system and the unoccupied classroom allowed for the fire to grow within the attic space, but the ceiling assembly protected the occupants.

C.4.12 Casino Fire, Nevada, 1998

A fire started from unknown causes on the roof behind the casino’s façade and then spread through the roof and down through the structure of a three-story casino and hotel [41]. The building was constructed with noncombustible construction and had a ground floor area of 30,000 square feet. The building had a complete-coverage heat and smoke detection system but there were no devices located in the area of origin of the fire. Additionally, there was a complete-coverage wet pipe sprinkler system but was not effective because it did not extend to the area of origin of the fire.

The fire spread was too rapid to allow for extinguishment by handheld extinguishers but was limited to the casino by a firewall and doors that connected the hotel and casino. One civilian was injured.

The following details regarding this incident are of note:

- A fire occurred in the façade and roof area that burned for a significant time in a concealed area before notification of the fire department.
- The area of origin did not contain any suppression or detection devices.

C.4.13 Restaurant Fire, New Jersey, 1998

A three-story restaurant sustained substantial damage as a result of a fire caused by carelessly discarded smoking materials [41]. The restaurant was built partially over a pier and the fire broke out under the pier. The fire spread up the side of the restaurant to a breezeway, and then moved into the kitchen above a drop ceiling. The restaurant was constructed of protected, wood-frame construction.

A full-coverage smoke detection system activated and prompted evacuation. A partial wet-pipe sprinkler system also activated, but it could not control the fire. There was also a partial-preaction system under the pier that activated and prevented the fire from spreading along the underside of the pier. At the time of the fire the restaurant was in full operation and was hosting several parties. There were no injuries to occupants, but two fire fighters were injured.

The following details regarding this incident are of note:

- The smoke detection system activated and initiated evacuation of the building, so that no occupants were injured.
- The partial sprinkler system could not control the fire and the fire spread above the sprinklers.

C.4.14 Restaurant Fire, Michigan, 1998

A fire initiated in a broiler exhaust hood and then spread to concealed spaces during the operation of the restaurant [41]. The fire occurred in a two-story, unprotected wood-frame structure that had no fire or smoke detection or suppression system. There was a dry chemical extinguishing system that protected the exhaust hood system.

An employee smelled smoke in the kitchen and found a fire in the baffle filters over the operating broiler. After the discovery of the fire the patrons were evacuated and the fire department was notified. Initially, two employees were able to control the fire using portable extinguishers but on the arrival of the fire department there was heavy smoke showing from the vents over the kitchen. The fire spread to the roof/ceiling space and could not be extinguished by the fire department.

An investigation found that the fire originated in a broiler exhaust stack. The fire caused the supports to fail, which allowed the connections in the ductwork to fail and the fire to spread to the void and roof. There were no injuries to the occupants.

The following details regarding this incident are of note:

- The fire occurred in a concealed space that protected the occupants but lead to the discovery of a significant fire that was not easily extinguishable.
- There was a delay of the activation of the dry chemical system protecting the exhaust hood system because the blower was drawing heat and flames away from the fusible links in the hood.

C.4.15 Theater Fire, Nevada, 1999

A fire broke out in the showroom/theater of a large 17-story hotel and casino [41]. The building was equipped with an automatic sprinkler system and smoke exhaust system. Staff noticed flames spreading up the drapes near the stage. Two employees attempted to pull the drapes to the floor while other staff activated the safety evacuation plan.

Firefighters arrived within five minutes to find the evacuation of the theater and the fire that was extinguished by the sprinklers. The smoke exhaust system was used which limited smoke damage. The fire department evaluated five employees for minor smoke inhalation.

An investigation of the fire determined that the fire began near a television monitor that was plugged into an electrical receptacle outlet. The components did not show any signs of fault but a similar monitor located on the other side of the stage had decorative drapes, which had a gold metal base that conducted electricity. The plug was not completely inserted into the receptacle and energized the hanging fabric.

The following details regarding this incident are of note: sprinklers extinguished the fire while employees activated the safety evacuation plan, which led to the successful evacuation of the theater.

C.4.16 Fine Line Music Café, Minneapolis, Minnesota, February 13, 2003

On February 17, 2003 the warm-up band was playing its encore when it set off a pyrotechnic display [43]. This started a fire in the ceiling of the club about 7:15 pm with an estimated crowd of 120 present in the building. The employees had just reviewed safety procedures the previous day and were quick and effective during the evacuation process. All of the occupants escaped and the fire was extinguished by the building's sprinklers within 15 minutes.

The Fine Line Music Café has a capacity of 720 people and occupies a 100-year-old Consortium Building located at 318 1st Avenue North in the warehouse District of Minneapolis, MN. No one was injured in the incident.

The following details regarding this incident are of note:

- The club had a sprinkler system and staff had reviewed the safety procedures the day before the event.
- All of the occupants were outside of the building when the fire department arrived.

C.5 REFERENCES FOR APPENDIX C

[1] Heary, Monica, *Theatre of Death*, The Daily Telegraph, Sydney, Australia, 26 June 2001.

[2] Chicago Public Library, "1903, December 30: Iroquois Theater Fire".

[3] Chertkoff, Jerome M. and Kushigian, Russell H., *Don't Panic: The Psychology of Emergency Egress and Ingress*, Praeger Publishers, Westport, CT.

[4] McGunagle, Fred, *Horror in Collinwood; 172 Students Die in City's Worst Disaster*, Plain Dealer, Cleveland, Ohio, 29 March 1998.

[5] Coté, Ron. *Life Safety Code Handbook*, *Eighth Edition*, Supplement 1 (Paul E. Teague, M.A.). National Fire Protection Association, Quincy, MA, 2000.

[6] Daily Mining Gazette, "Italian Hall Confession", March 16, 1982.

[7] Callahan, Kevin. "Survivor Remembers Clinic Fire," *Plain Dealer*, Cleveland, Ohio, May 13, 1994.

[8] McGunagle, Fred. "123 Die in Clinic Disaster; Poison Gas Seeps into System; Explosion Rocks Building," *Plain Dealer*, Cleveland, Ohio, 23 August 1998.

[9] NFPA Fire Investigation Report, *Dance Hall Fire (Rhythm Club), Natchez, MI*, April 23, 1940. As published in: "The Natchez Dance Hall Holocaust." *NFPA Quarterly*, 34 #:70-75. 1940.

[10] Second International Conference on Fire Research and Engineering. Gaithersburg, Maryland, USA. 3-8 August 1997.

[11] Brownlee, Ken. *A Date 'Living in Infamy' Fire Years Later; The Winecoff Hotel Fire, Atlanta, Dec. 7, 1946* Claims Magazine, December 2002.

[12] Morehouse, Macon. "Focus on Winecoff Fire," *The Atlanta Journal and Constitution*, Atlanta, Georgia, December 6, 1996.

[13] Soto, Lucy. "Memories of Fear and Destruction," *The Atlanta Journal and Constitution*, 6 December 1993.

[14] NFPA Fire Investigation Report, Night Club Fire (The Upstairs Lounge), New Orleans, LA, June 24, 1973. As published in: "Upstairs Lounge Fire," A. Elwood Willey, *NFPA Journal*, 68 #1: 16-20. 1974.

[15] Lathrop, James K., *Discotheque Fire Twenty-Four Dead*, National Fire Protection Association, Quincy, MA, 1974.

[16] NFPA Fire Investigation Report, Beverly Hills Supper Club Fire, Southgate, KY, May 28, 1977. Includes: "Tragedy in Kentucky," Robert L. Best, *Fire Journal*. (1978) 72#1:21, 36-40; "Comparing the Club with the Code." *Fire Journal*. (1978) 72#1:21, 36-40; "Human Behavior in the Beverly Hills Fire," Joseph A. Swartz, *Fire Journal*, (1979) 73#3:73-74, 108.

[17] Wertheimer, Paul L., *"The Who" Rock Concert Tragedy: When Rock Concert Crowd Management Came of Age*, Engineering for Crowd Safety, 1993.

[18] Bouchard, John, NFPA Investigation Report, National Fire Protection Association, Quincy, MA, 1984.

[19] International Conference on Fire Research and Engineering. Orlando, Florida, USA. September 10-15, 1995.

[20] *NFPA Alert Bulletin*, "Social Club Fire Bronx, New York". Number 90-2, May 1990.

[21] "Arson Suspected as 87 Die in New York Disco Blaze". *The Independent* (London). March 26, 1990.

[22] Isner, Michael, *Fire Investigation Report: Private Club Fire*, National Fire Protection Association, Quincy, MA, 1992.

[23] Johnson, Mark, *Chicago Club had been told to Close*, Milwaukee Journal Sentinel, 18 February 2003.

[24] Reed Business Information US Staff, *Disasters Offer Lessons for Future*, Consulting-Specifying Engineer, 1 March 2003.

[25] Ciokajlo, Mickey and Deardorff, Julie, *Expert Finds E2 Violations*, Chicago Tribune, 20 February 2003.

[26] Carter, Helen. "Isle of Man's Forgotten Holiday Horror." *The Guardian*, London, August 2, 2003.

[27] Pigott, Pierce T. "The Fire at the Stardust, Dublin: The Public Inquiry and its Findings," *Fire Safety Journal*, #7, 1984.

[28] *NFPA Fire Investigation Report, Dance Hall Fire, Gothenburg, Sweden*, National Fire Protection Association, Quincy, MA, 1998.

[29] Jiang, H. et. al. "The Use of Evacuation Simulation, Fire Simulation and Experimental Fire Data in Forensic Fire Analysis." Pedestrian and Evacuation Dynamics 2003: Proceedings of the 2nd International Conference. Greenwich, Uk. Ed. Galea, E. R.

[30] "Firewatch: Students, Staff Evacuate Safely Despite Delay in Alarm." *NFPA Journal*. November/December 1992.

[31] "Firewatch: Sprinklers Extinguish Fire in Crowded Nightclub." *NFPA Journal*. November/December 1992.

[32] "Firewatch: 11-Year-Old Ignites $1 Million Fire." *NFPA Journal*. March/April 1992.

[33] "Firewatch: Student Prank with Pyrotechnic Device Ignites School Roof." *NFPA Journal*. July/August 1992.

[34] "Firewatch: Detectors Alert Occupants to Fire in School." *NFPA Journal*. September/October 1994.

[35] "Firewatch: Grill Fire Damages Restaurant." *NFPA Journal*. September/October 1996.

[36] "Firewatch: Sprinklers Extinguish Fire in Occupied Dinner Theater." *NFPA Journal*. March/April 1996.

[37] "Firewatch: Fire Destroys Restaurant, Patrons Evacuate Safely." *NFPA Journal*. May/June 1996.

[38] "Firewatch: Electrical Fire Damages Community Center." *NFPA Journal*. September/October 1997.

[39] "Firewatch: Sprinkler Controls Grease Fire." *NFPA Journal*. July/August 1997.

[40] "Firewatch: Fire in Concealed Space Damages Occupied School." *NFPA Journal*. January/February 1998.

[41] "1998 Large Loss Fires and Explosions." *NFPA Journal*. November/December 1999.

[42] "Firewatch: Drapes Ignite in Theater." *NFPA Journal*. May/June 1999.

[43] Chanen, David. Warm-up act sets Fine Line afire; No one hurt; club has heavy water damage. Star Tribune. Minneapolis,

[44] Emmons, Howard. 'Analysis Of A Tragedy'. Harvard University, Cambridge, Ma. *Fire Technology*, *Vol 19*, No. 2, 115-124, May 1983.

[45] "Evaluation of Limitations to Egress through Doorways in Emergency Situations," vol. 1, Ove Arup & Partners Massachusetts Inc., Job number 32979, Westborough MA, February 18, 2004.

[46] Lostetter, S.M.O., and Reijman, P.B., "Reconstruction of the Fire in 'de Hemel' in Volendam, New Years Eve 2000/2001," Interflam 20

APPENDIX D. SMALL SCALE LABORATORY TESTS

D.1 INTRODUCTION

Computational fire models incorporate specific material properties in order to calculate fire development and growth for a given fire incident. These material properties, such as thermal conductivity, heat capacity, density, flame spread, and heat of combustion, are utilized by the model to predict if and when a component will ignite and how much energy or heat will be released as the component burns. The ignition and subsequent release of energy causes the fire to grow and spread throughout a structure.

The type and composition of the materials that were identified as being present inside the nightclub were characterized generically as polyurethane foam, ceiling tiles, wood paneling, carpet, and an industrial pyrotechnic device. This materials testing conducted by NIST and described in this appendix did not include any materials actually recovered from the nightclub.

The contribution of assorted fuels to fire spread and total heat release rate can be very different. For example, a polyurethane foam is low density and quick to ignite, but the mass of the foam is consumed in a relatively short period of time. The foam may contribute to quick initial fire growth, but typically would not have sufficient mass to carry the fire past the initial stages. Wood and carpet flooring have greater mass and are a larger source of energy than the foam, but the wood and carpet require longer times to ignite. Once ignited, both the wood and carpet could provide most of the energy released during a fire.

The contribution of a specific fuel is dependent on the relative amounts of the fuel and how quickly the fuel becomes involved in the fire. Wood is often found in flooring, wall paneling, and structural members such as studs, joists and rafters. Carpeting is typically used only as a floor covering. In a wood frame structure, the wood component of the fuel load may provide the bulk of the energy released. The location of the fuel can also impact when a how rapidly a specific fuel becomes a contributor to the heat release rate. For instance, wood paneling near the ceiling might become involved more quickly than wood flooring.

Five test series were conducted in this investigation: small scale heat release measurements using a cone calorimeter; ignition temperature determination by Southwest Research Institute; real-scale heat release and flame spread measurements of foam covered wall panels; heat flux and temperature measurements of pyrotechnic devices impinging on surfaces; and fire growth measurements in real-scale mockups of the raised platform (or stage), main floor, and alcove. This appendix describes the cone calorimeter and ignition temperature tests. The other test series are described in subsequent appendices: foam covered wall panels (Appendix E), pyrotechnic devices (Appendix F), and real-scale mockup (Appendix G).

D.2 CONE CALORIMETER TEST SERIES

Cone calorimeter experiments were conducted on five different materials at five different levels of external heat flux. The tests conducted on the polyether- and polyester-polyurethane foams and the external fluxes that were imposed on the samples are tabulated in Table D-1. Similar information for the wood, carpet, and ceiling tiles is located in Table D-2.

The data from the cone calorimeter is summarized in tables and is also plotted graphically for each of the 38 cone tests. The test protocol detailed in ASTM E 1354 [1] was used for these experiments. The E-

Table D-1. Cone Calorimeter Tests for Polyurethane Foams

Material	Thermal Flux kW/m^2	Test ID	Manufacturer
Polyurethane Foam (Ester) Convoluted / Egg Crate Non-Fire Retardant Gray Color	35	PUF-NFR-A-1	A*
	35	PUF-NFR-A-2	
	35	PUF-NFR-A-3	
Polyurethane Foam (Ether) Convoluted / Egg Crate Non-Fire Retardant Gray Color	20	PUF-NFR-B-13	
	20	PUF-NFR-B-14	
	20	PUF-NFR-B-15	
	35	PUF-NFR-B-1	B*
	35	PUF-NFR-B-2	
	35	PUF-NFR-B-3	
	35	PUF-NFR-B-4	
	35	PUF-NFR-B-5	
	35	PUF-NFR-B-6	
	40	PUF-NFR-B-16	
	40	PUF-NFR-B-17	
	40	PUF-NFR-B-18	
	60	PUF-NFR-B-19	
	60	PUF-NFR-B-20	
	60	PUF-NFR-B-21	
	70	PUF-NFR-B-7	
	70	PUF-NFR-B-8	
	70	PUF-NFR-B-9	
	70	PUF-NFR-B-10	
	70	PUF-NFR-B-11	
Polyurethane Foam (Ether) Convoluted / Egg Crate Fire Retardant Gray Color	35	PUF-FR-1	C*
	35	PUF-FR-2	
	35	PUF-FR-3	

* Distributor purchases foam from a number of different sources based on price and availability. When foam arrives at warehouse, new stock is intermingled with old stock. Labeling on single pieces of foam identifies type of foam, such as polyurethane (ester), but does not provide information on manufacturer. Distributor unable to identify specific manufacturer of purchased foam. Fire retardant foam was purchased in single lot. Non-fire retardant foam purchased in two lots. Cannot rule out possibility that individual foam within the same purchase came from different sources.

1354 test method utilizes a cone calorimeter (Figure D-1) to collect data on heat release rate, mass loss rate, optical density of smoke, and gas concentrations in combustion products. The cone calorimeter exposes relatively small samples (10 cm x 10 cm) to a uniform thermal flux. These samples were stored

Table D-2. Cone Calorimeter Tests for Wood, Carpet, and Ceiling Tile.

Material	Thermal Flux kW/m^2	Test ID
Wood Paneling 5 mm thick Plywood Substrate	35	WP-01
	35	WP-02
	35	WP-03
	70	WP-04
	70	WP-05
	70	WP-06
Carpet Flooring 100% Filament Olefin Ave. Tufted Face Weight 39 oz. Polyester short nap 0.25" thick Beige color	35	CF-01
	35	CF-02
	35	CF-03
	70	CF-04
	70	CF-05
	70	CF-06
Ceiling Tile – 942 B Textured 610 mm x 1219 mm x 16 mm (24 in x 48 in x 0.6250 in)	35	CT-01
	35	CT-02
	35	CT-03
	70	CT-04
	70	CT-05
	70	CT-06

in a controlled humidity (50 % relative humidity) and temperature (23 ^{o}C) room for at least two weeks prior to testing. Each sample was wrapped in an aluminum foil, except for the exposed side, and positioned in a stainless steel specimen holder (Figure D-2). The thermal flux which is generated via a cone shaped electrical resistance heater was set to the desired test value of 20 kW/m^2, 35 kW/m^2 , 40 kW/m^2, 60 kW/m^2, or 70 kW/m^2, and verified using a heat flux meter. The sample in the specimen holder was then positioned horizontally on the load cell and exposed to the thermal flux. An electric spark was used to ignite the combustible gases near the surface of the sample. A sample of polyurethane foam that was ignited under the cone is shown in Figure D-3. The smoke and combustion products were drawn through the center of the cone heater and into the instrumented exhaust duct. The load cell tracked mass loss rate throughout each burn. The small amount of residue left in the aluminum tray afterthe cone tests of three polyurethane foam samples is shown in Figure D-4. Additional instruments allowed the optical density of the smoke and gas concentrations to be monitored continuously. The distance between the top surface of the sample and the cone housing was 25 mm. The energy release per mass of oxygen depleted was assumed to be a constant 13.1 MJ/kg. While the cone calorimeter can provide heat release rate as a function of thermal flux, the impact of ventilation, corner geometries, and composite assemblies are difficult to characterize.

A test plus two replicates of each sample (total of three tests) were conducted with the cone calorimeter providing an external heat flux of 20 kW/m^2, 35 kW/m^2, 40 kW/m^2, 60 kW/m^2, or 70 kW/m^2. The lower thermal fluxes represent a radiation exposure the materials might experience early in the fire

Figure D-1. Cone Calorimeter – Test Chamber (right side), computer display (center), and gas analyzers (left side).

Figure D-2. Sample of Polyurethane Foam Placed in Aluminum Foil Tray on Top of Horizontal Sample Holder.

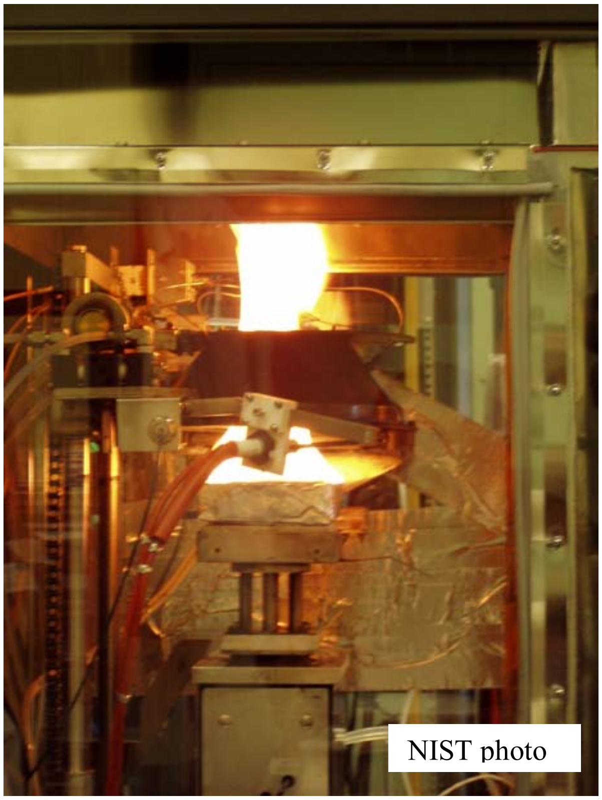


Figure D-3. Test Specimen – Exposed to thermal flux from cone shaped heater, combustion products drawn through center of cone, sample positioned on load cell.

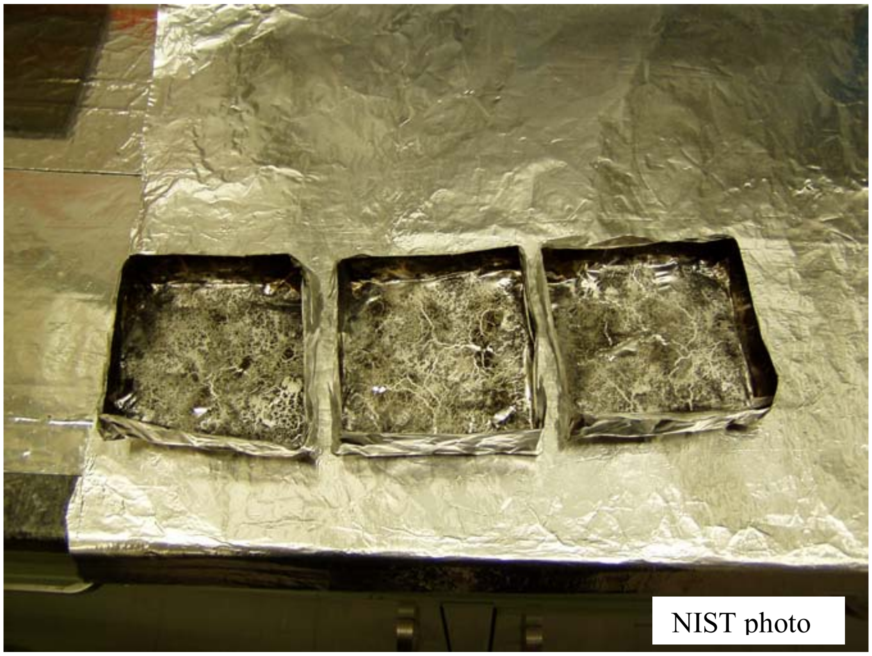


Figure D-4. Burn Residue of Polyurethane Foam after Cone Calorimeter Test.

development. The higher thermal fluxes simulate conditions that the material might encounter near the peak heat release rate in the fire.

The data that were collected during the cone calorimeter tests are summarized in tables in Section D.2.8 of this appendix. The data tables provide the time to sustained ignition, peak heat release rate, time to peak heat release rate, total heat release, 60 s average heat release rate, total mass loss, average mass loss rate, average effective heat of combustion, average smoke yield, average carbon dioxide yield, average carbon monoxide yield, time to ignition, time to flameout, and a number of specimen properties.

D.2.1 Polyurethane Plastics and Flammability Ratings

Polyurethane refers to a large category of materials including surface coatings, elastomers, and foams, rigid or flexible, and thermoplastic or thermosetting. While large quantities of polyurethanes are used to manufacture adhesives and protective coatings, the foam type of polyurethane is widely used in the production of upholstered furniture, bedding, sponges, toys, wearing apparel, and medical dressings. Rigid urethane foams are used for insulation in building constructions. Flexible polyurethane foams are used in packaging materials and acoustical insulation panels. The urethane linkage, which all polyurethanes have in common, involves the reaction of an isocyanate group with a hydroxyl-containing group. A more detailed description of urethane formation chemistry is in Appendix H.

Fire retardant additives or compounds can be incorporated into polyurethane foam during the manufacturing procedure or can be applied to the foam in a post-production process. The molecular structure of polyurethane foam can also be adjusted to provide improved fire resistant properties. The polyurethane foam material itself is still a hydrocarbon compound, a long chain carbon based material that can act as a fuel source.

Fire performance tests, such as Flammability of Plastic Materials for Parts in Devices and Appliances (Underwriters Laboratories UL 94) have been developed to measure flammability characteristics of plastic materials. However, UL 94 specifically is not intended for foam plastics used in building construction or finish materials. Three of the UL 94 flame classifications relate to low density foam materials: HF-1, HF-2, and HBF. In each test, a small sample is positioned horizontally and exposed to a flame for 60 seconds. After the 60 second flame exposure, the flame is removed and the time required for the flaming to cease (after-flame) and the flaming and glowing to cease (after-glow) are monitored. The distance the flame travels across the sample is also recorded. Foams rated as HBF can sustain a limited flame spread; foams rated as HF-2 must self-extinguish in less than 30 s, but their drips are sufficient to ignite cotton fabric; an HF-1 rating is similar to HF-2, except that any dripping materials do not ignite a cotton fabric placed underneath the foam sample. The fire retardant foam from supplier C was identified by the supplier as being rated HF-1; the polyurethane foams from Lots A and B were not rated, and are thus considered non-fire retardant.

Fire retardant polyurethane foams may not ignite as quickly as non-fire retardant foams, and they also may have lower peak heat release rates than non-fire retardant foams. The classification of a foam as "fire retardant," however, does not prevent it from igniting and contributing to the fuel load and fire spread once the material is exposed to the high temperatures and high thermal flux conditions of a room fire. Both fire retardant foam and non-fire retardant foam were included in the cone calorimeter tests to help characterize time to ignition and heat release rate for each.

D.2.2 Test Results -- Non-fire Retardant Polyurethane Foam

Both polyether and polyester formulations of polyurethane can be used as packaging materials. The polyurethane foam which is offered for packaging typically does not include any fire retardant additives or incorporate any fire retardant compounds into the urethane structure. As a packaging material, the polyurethane foam (ether and ester) is commercially available in a range of sizes including 1.22 m (4 ft) x 2.44 m (8 ft) sheets. The gray colored foam can be obtained in several geometries including solid blocks, uniform thickness sheets, and convoluted or "egg-crate" sheets. In The Station nightclub, polyurethane foam had been installed on the rear wall, raised platform (stage) wall, and in the alcove as a sound attenuation material (see Figure 4-1). Photographs of the nightclub interior do not clearly demonstrate whether staples, nails, organic adhesive or some combination of all three were used to mount the foam on the wall. The polyurethane foam appeared to have been mounted over the top of the previous wall material, which, depending on the location may have been either wood paneling, gypsum board, or rigid polystyrene foam between vertical wood studs. The foam was installed in either full 1.22 m x 2.44 m sheets or was trimmed to fit the raised platform (stage), alcove, or rear wall geometry.

Each 1.22 m x 2.44 m sheet was supplied in a compressed roll, approximately 0.30 m (12 in) in diameter and 0.41 m (16 in) wide. After removing the wrapping, each compressed roll expanded to a 1.22 m x 2.44 m sheet. While the rear surface of each sheet was flat, the front side was convoluted. These convolutions were a series of peaks and depressions that resembled the surface of a continuous egg crate. There were approximately 36 peaks and 36 depressions per 0.09 m^2 (1 ft^2). Peak to peak spacing was approximate 0.05 m (2 in) for all the foam (Figure D-5 and D-6). The thickest dimension of the foam was measured from the tip of a peak to the back surface. The thinnest dimension of the foam was measured from the bottom of a depression to the back surface. There were noticeable differences in thickest and thinnest dimensions between the foam purchased from supplier A and supplier B. Foam from supplier A was measured at 0.04 m (1.5 in) and 0.009 m (0.35 in) at its thickest and thinnest dimensions, respectively (Figure D-5). Foam obtained from supplier B was measured at 0.03 m (1.2 in) and 0.015 m (0.6 in) at its thickest and thinnest dimensions, respectively (Figure D-6).

Twenty-three test samples were exposed to thermal fluxes ranging from 20 kW/m^2 to 70 kW/m^2. The heat release rate for each sample is plotted versus time in Figures D-7 through D-13.

The non-fire retardant polyurethane foam samples exposed to an external heat flux of 20 kW/m^2 reached peak heat release rates from 440 kW/m^2 to 460 kW/m^2 in approximately 50 seconds. The average time to sustained ignition was 14 seconds (Table D-3). When exposed to 35 kW/m^2 of external heat flux, the non-fire retardant polyurethane foam reached its peak heat release rate in approximately 30 seconds. Peak heat release rates for all nine foam samples ranged from 520 kW/m^2 to 680 kW/m^2 with an average of about 590 kW/m^2. There did not appear to be a significant difference in the range of peak heat release rates between the two suppliers. The average time to sustained ignition was 6 seconds and average time to peak heat release rate was 30 seconds.

Samples of the non-fire retardant foam, PUF-NFR-B, were exposed to external heat fluxes of 40 kW/m^2 and 60 kW/m^2, reaching peak heat release rates in approximately 29 seconds and 24 seconds, respectively. Peak heat release rates for the three 40 kW/m^2 foam samples ranged from 700 kW/m^2 to 880 kW/m^2 with an average of about 820 kW/m^2. The three 60 kW/m^2 exposures produced peak heat release rates ranging from 1000 kW/m^2 to 1300 kW/m^2 with an average of about 1150 kW/m^2. The average time to sustained ignition was 4 seconds and 3 seconds for the 40 kW/m^2 and 60 kW/m^2 exposures, respectively.

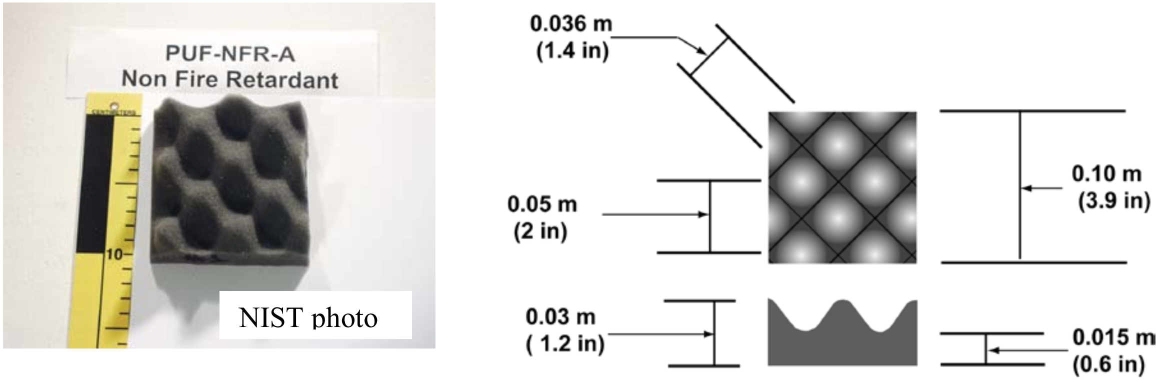


Figure D-5. Photograph and Dimensioned Diagram of Non Fire Retardant Foam Lot A (PUF-NFR-A).

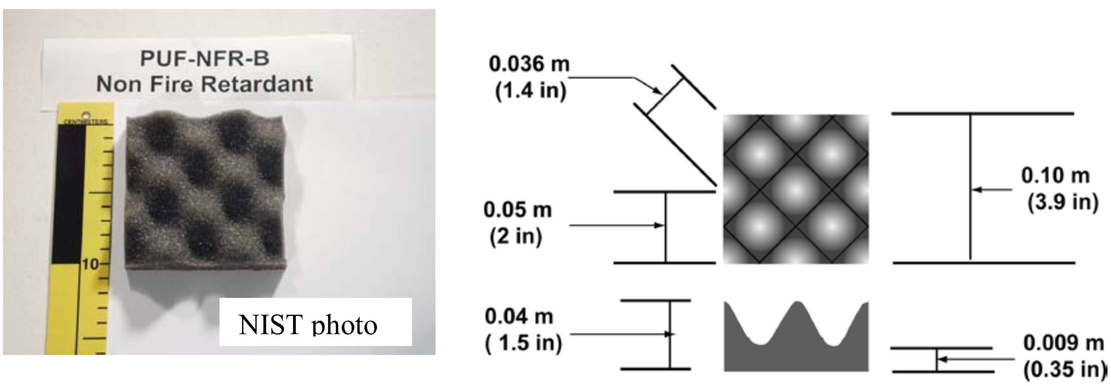


Figure D-6. Photograph and Dimensioned Diagram of Non Fire Retardant Foam Lot B (PUF-NFR-B).

When exposed to70 kW/m^2 of external heat flux, the non-fire retardant polyurethane foam reached its peak heat release rate in approximately 20 seconds. Peak heat release rates for all five foam samples ranged from 810 kW/m^2 to 1094 kW/m^2 with an average of 970 kW/m^2. At the higher flux it required an average 3 seconds to reach sustained ignition and an average of 21 seconds to reach the peak heat release rate.

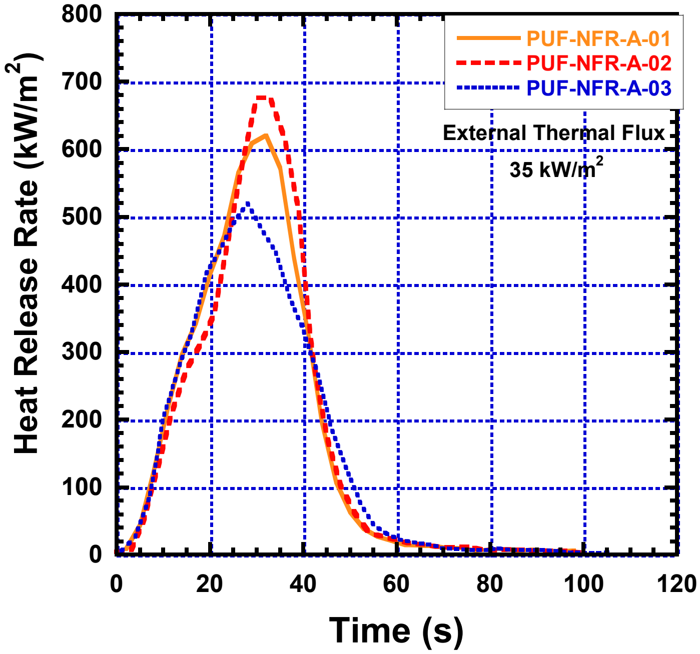


Figure D-7. Heat Release Rate versus Time for Polyurethane Foam Exposed to 35 kW/m^2 of External Heat Flux. Samples PUF-NFR-A-01, PUF-NFR-A-02, and PUF-NFR-A-03.

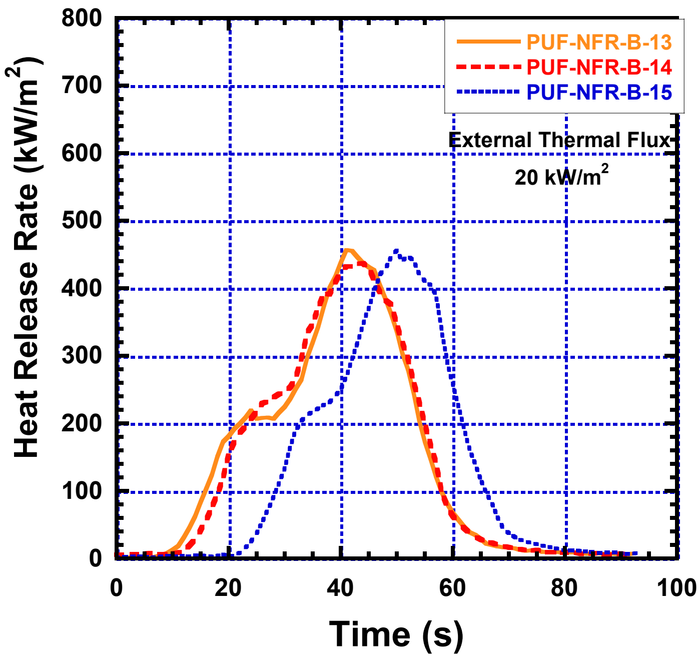


Figure D-8. Heat Release Rate versus Time for Polyurethane Foam Exposed to 20 kW/m^2 of External Heat Flux (PUF-NFR-B). Samples PUF-NFR-B-13, PUF-NFR-B-14, and PUF-NFR-B-15.

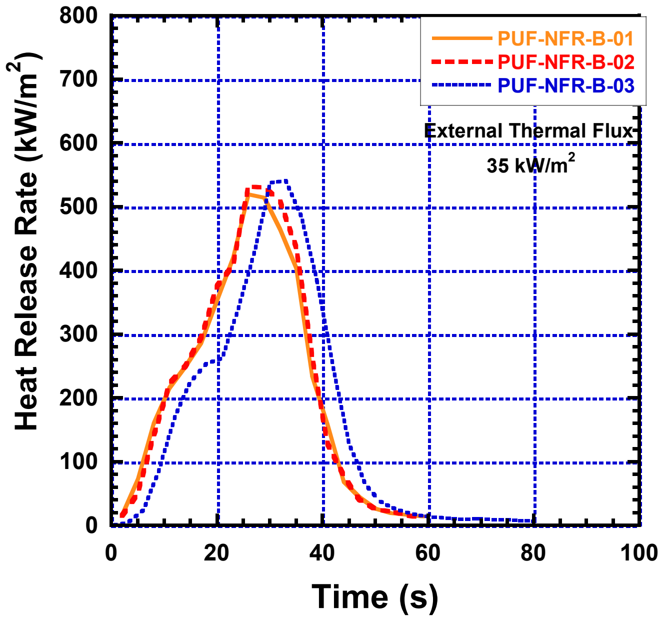


Figure D-9. Heat Release Rate versus Time for Polyurethane Foam Exposed to 35 kW/m^2 of External Heat Flux (PUF-NFR-B). Samples PUF-NFR-B-01, PUF-NFR-B-02, and PUF-NFR-B-03.

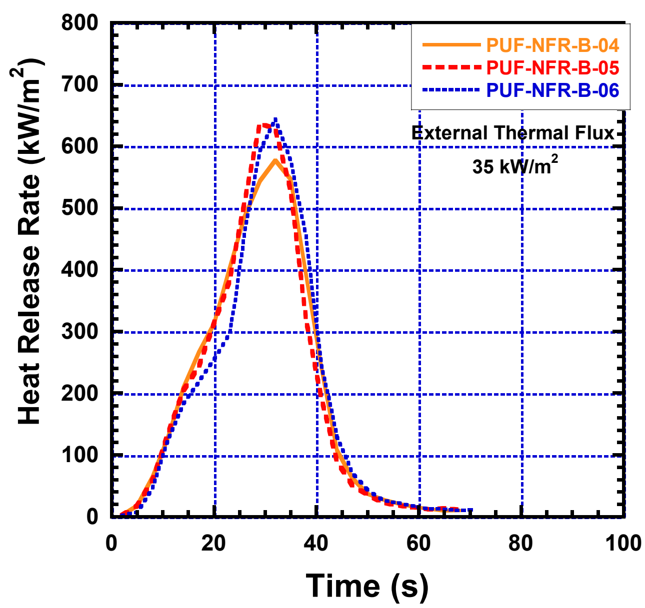


Figure D-10. Heat Release Rate versus Time for Polyurethane Foam Exposed to 35 kW/m^2 of External Heat Flux (PUF-NFR-B). Samples PUF-NFR-B-04, PUF-NFR-B-05, and PUF-NFR-B-06.

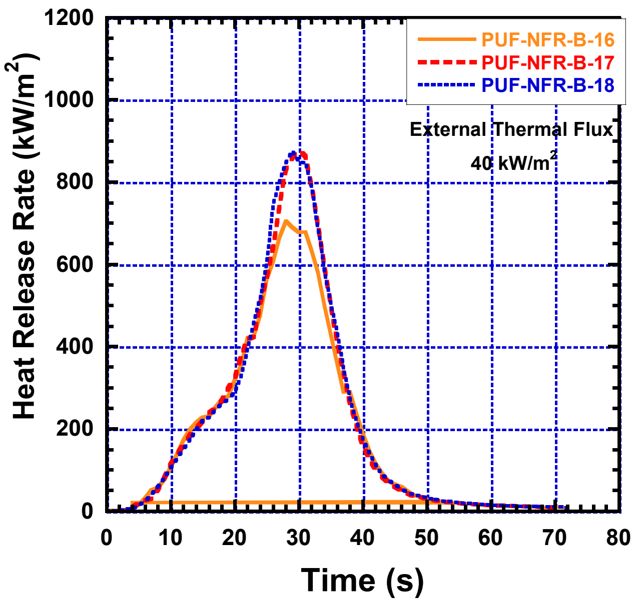


Figure D-11. Heat Release Rate versus Time for Polyurethane Foam Exposed to 40 kW/m^2 of External Heat Flux (PUF-NFR-B). Samples PUF-NFR-B-16, PUF-NFR-B-17, and PUF-NFR-B-18.

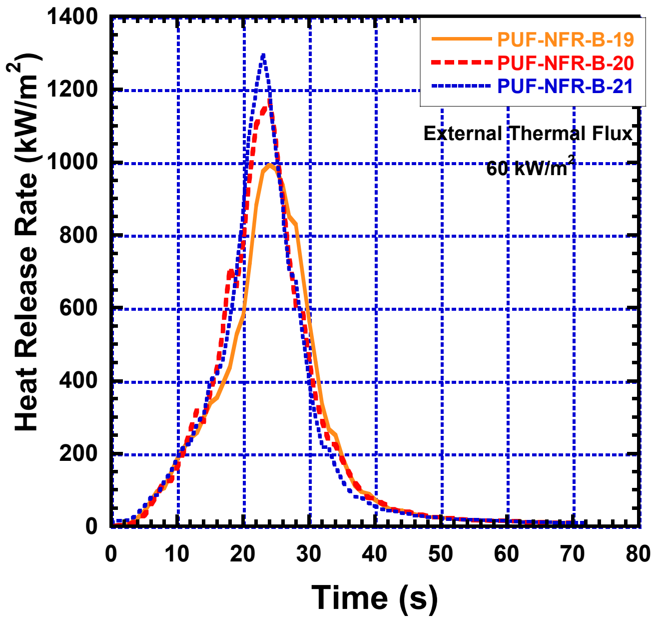


Figure D-12. Heat Release Rate versus Time for Polyurethane Foam Exposed to 60 kW/m^2 of External Heat Flux (PUF-NFR-B). Samples PUF-NFR-B-19, PUF-NFR-B-20, and PUF-NFR-B-21.

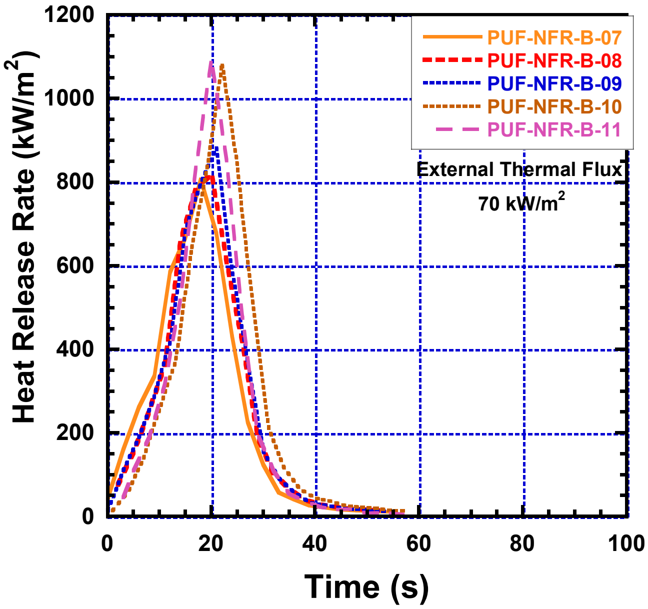


Figure D-13. Heat Release Rate versus Time for Polyurethane Foam Exposed to 70 kW/m^2 of External Heat Flux (PUF-NFR-B). Samples PUF-NFR-B-07, PUF-NFR-B-08, PUF-NFR-B-09, PUF-NFR-B-10, and PUF-NFR-B-11.

D.2.3 Test Results -- Fire Retardant Polyurethane Foam

Polyether polyurethane foam which is intended for packaging applications typically does not have additional fire retardant qualities, either through additives included in the manufacturing process or post-production treatments. It is still useful to characterize the performance of fire retardant foam in order to understand how the fire growth and spread differ from the non-fire retardant foam.

NIST purchased a number of 1.22 m (4 ft) x 2.44 m (8 ft) sheets of fire retardant polyester polyurethane foam from a commercial supplier. Unfortunately, the distributor was not able to identify the manufacturer of the foam.

As with the non-fire retardant foam, the fire retardant foam was supplied in compressed rolls, which were allowed to expand to a 1.22 m x 2.44 m sheet. Both the non-fire retardant and fire retardant foams were similar in the size, distribution, and number of peaks and depressions. There were approximately 36 peaks and 36 depressions per 0.09 m^2 (1 ft ^{2}). The thickest dimension of the foam was measured from the tip of a peak to the back surface. The thinnest dimension of the foam was measured from the bottom of a depression to the back surface. The fire retardant foam more closely resembled the non fire retardant foam obtained in the first lot (B). Fire retardant foam was measured at 0.03 m (1.5 in) and 0.010 m (0.4 in) at its thickest and thinnest dimensions, respectively (Figure D-14).

The heat release rate for each sample is plotted versus time in Figure D-15. When exposed to 35 kW/m^2 of external heat flux, the fire retardant polyurethane foam reached its peak heat release rate in approximately 36 seconds. Peak heat release rates for all three foam samples ranged from 430 kW/m^2 to 480 kW/m^2 with an average of 453 kW/m^2. Each of the three fire retardant samples exhibited lower peak heat release rates than for the non-fire retardant foam samples. It required about twice as long for the fire retardant foam, 13 seconds, to reach sustained ignition as required by the non-fire retardant foam (Table D-3). The time to peak heat release was longer for the fire retardant foam, increasing by about 20 %.

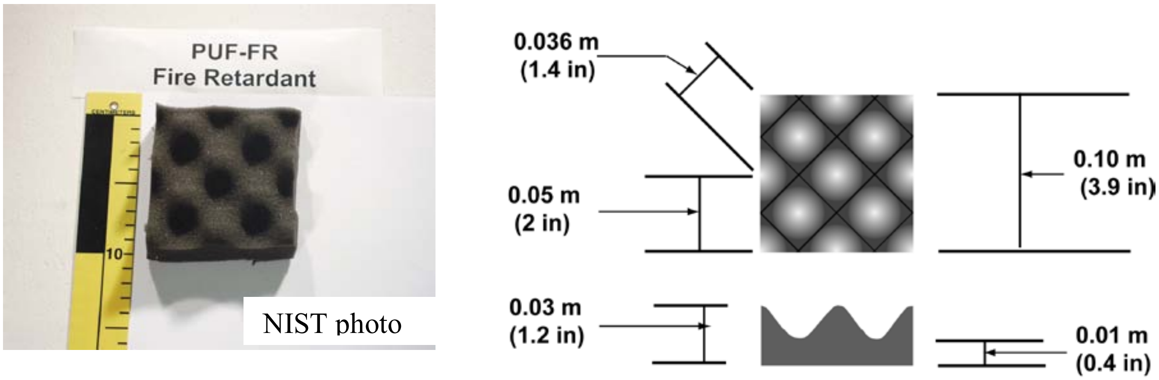


Figure D-14. Photograph and Dimensioned Diagram of Fire Retardant Foam (PUF-FR).

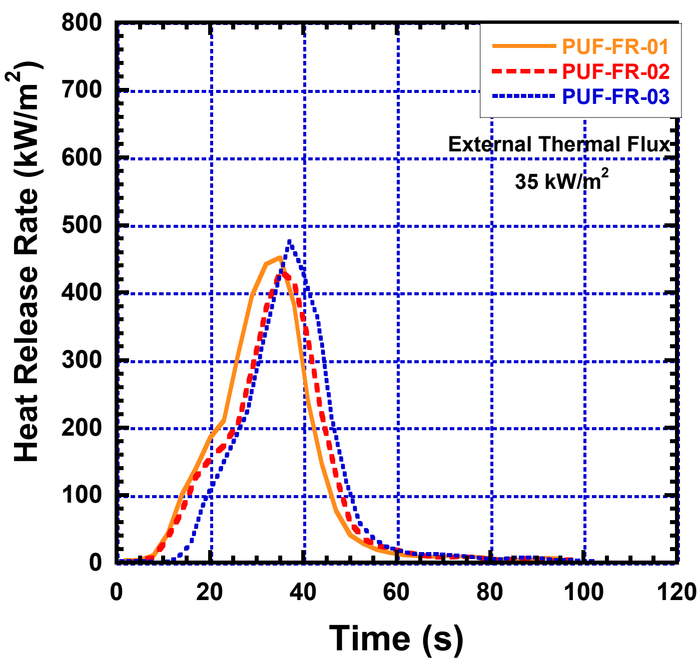


Figure D-15. Heat Release Rate versus Time for Fire Retarded Polyurethane Foam Exposed to 35 kW/m^2 of External Heat Flux. Samples PUF-FR-01, PUF-FR-02, and PUF-FR-03.

Table D-3 Time to Sustained Ignition, Time to Peak HRR, and Peak HRR for Polyurethane Foam Tested at National Institute of Standards and Technology.

ID	External Thermal Flux kW/m^2	Time to Sustained Ignition, Seconds	Time to Peak Heat Release, Seconds	Peak Heat Release Rate kW/m^2
PUF-FR-1	35	11	35	452
PUF-FR-2	35	11	35	432
PUF-FR-3	35	16	37	476
	Average	**13**	**36**	**453**
PUF-NFR-A-1	35	9	32	620
PUF-NFR-A-2	35	7	30	676
PUF-NFR-A-3	35	6	28	520
	Average	**7**	**30**	**605**
PUF-NFR-B-13	20	8	41	457
PUF-NFR-B-14	20	12	44	437
PUF-NFR-B-15	20	22	50	456
	Average	**14**	**45**	**450**
PUF-NFR-B-1	35	4	26	519
PUF-NFR-B-2	35	5	26	532
PUF-NFR-B-3	35	9	33	541
PUF-NFR-B-4	35	5	32	577
PUF-NFR-B-5	35	5	29	637
PUF-NFR-B-6	35	5	32	644
	Average	**6**	**30**	**586**
PUF-NFR-B-16	40	4	28	706
PUF-NFR-B-17	40	3	30	878
PUF-NFR-B-18	40	4	29	877
	Average	**4**	**29**	**820**
PUF-NFR-B-19	60	4	24	993
PUF-NFR-B-20	60	3	24	1170
PUF-NFR-B-21	60	3	23	1299
	Average	**3**	**24**	**1154**
PUF-NFR-B-7	70	4	18	806
PUF-NFR-B-8	70	3	20	820
PUF-NFR-B-9	70	3	21	881
PUF-NFR-B-10	70	3	22	1083
PUF-NFR-B-11	70	3	20	1094
	Average	**3**	**21**	**970**

D.2.4 ATF Test Results -- Polyether Polyurethane Foam from the Nightclub

A roll of gray convoluted foam was recovered from the basement of the burnt out nightclub one day after the fire and turned over to the West Warwick Police Department as evidence. The foam did not appear to have been painted or to have been mounted on any surface. Samples from this recovered foam were tested by the Bureau of Alcohol, Tobacco, and Firearms (ATF) in a cone calorimeter at the ATF Fire Laboratory in Maryland.

The time to sustained ignition, time to peak heat release rate, and the peak heat release rate for thermal flux exposures of 20 kW/m^2, 40 kW/m^2, and 60 kW/m^2 reported by ATF [2] are shown in Table D-4. For the 20 kW/m^2 flux exposure the ATF polyether foam required 9 seconds for sustained ignition which is less than the 22 seconds the NIST polyether foam required at 20 kW/m^2. The time to peak heat release rate was also longer for the NIST foam, 50 seconds, than for the ATF foam, 37 seconds. For the ATF foam, the average peak heat release rate at 20 kW/m^2, 260 kW/m^2, was about half of the peak release rate for the NIST foam.

The 40 kW/m^2 heat flux exposure for the ATF foam resulted in a peak heat release rate of 297 kW/m^2, less than half that observed for the NIST polyether foam. The time to peak heat release rate was 31 seconds and 29 seconds for the ATF and NIST foams, respectively. The time to sustained ignition was 3 seconds for the ATF tests and 4 seconds for the NIST samples. For the highest rate of external thermal flux tested by ATF, 60 kW/m^2, the peak heat release rate, 415 kW/m^2, was about a third of the value of 1154 kW/m^2 that was reported during the NIST cone calorimeter testing at 60 kW/m^2. The time to sustained ignition was 1 second for the ATF polyether samples as compared to 3 seconds for the NIST tests, and the time to peak heat release was 26 seconds and 23 seconds for the ATF and NIST samples, respectively.

Table D-4 Time to Sustained Ignition, Time to Peak HRR, and Peak HRR for Polyurethane Foam Tested at ATF [13].

Sample ID	External Thermal Flux kW/m^2	Time to Sustained Ignition, Seconds	Time to Peak Heat Release Rate, Seconds	Peak Heat Release Rate kW/m^2
03F0011-01	20	9	35	257
03F0011-02	20	8	39	267
03F0011-03	20	11	37	257
	Average	**9**	**37**	**260**
03F0011-04	40	2	29	301
03F0011-05	40	3	31	291
03F0011-06	40	3	32	298
	Average	**3**	**31**	**297**
03F0011-07	60	1	25	453
03F0011-08	60	2	29	415
03F0011-09	60	1	25	377
	Average	**1**	**26**	**415**

D.2.5 Test Results -- Acoustical Ceiling Tiles

A suspended or dropped ceiling had been installed in the nightclub except for in the sunroom, the raised platform (stage) area, and the dance floor areas (refer to Fig. 4-3). Each 0.61 m (2 ft) x 1.22 m (4 ft) x .016 m (0.625 in) panel had been installed or dropped into a metal grid support system. Photographs of the nightclub interior clearly demonstrate that the ceiling tiles had been painted black. It was not clear from the photographs whether the paint had been applied by brush, roller, or spray can. The surface of the tiles had a glittery appearance that may have been a result of the wet paint being dusted with glitter or sparkle dust. Some of the glitter would have become partially embedded in the wet paint and would have

Figure D-16. Photograph of Acoustical Tile Showing Factory Painted Surface.

provided a more glittery or sparkling appearance that was observed in some of the video of the nightclub interior.

Labeling found on a surviving acoustical tile indicated that that the surviving tile was a mineral fiber type of material, a 942 (residential coding) or 755 (commercial coding). Samples of 942B acoustical tiles were purchased from a local supplier for these cone calorimeter tests. The front side of each panel (Figure D-16) exhibited a factory-applied coat of white vinyl-latex paint while the rear side of each panel was unpainted. Samples that measured 0.1 m x 0.1 m were cut from the larger panels. These samples were then stored in a controlled humidity (50 % relative humidity) and temperature (23 ^{o}C) room for at least two weeks. Each sample was wrapped in an aluminum foil, except for the exposed side, and positioned in the cone calorimeter. In all tests, the painted side was exposed to the thermal flux.

Three test samples were exposed to thermal flux at 35 kW/m^2. Each test was terminated after 3 min of exposure when none of the three samples ignited (Table D-5). An additional three test samples were exposed to thermal flux at 70 kW/m^2. The heat release rate for each sample is plotted versus time in Figure D-17. The heat release curves show an initial peak, a period of decline, and then a second peak.

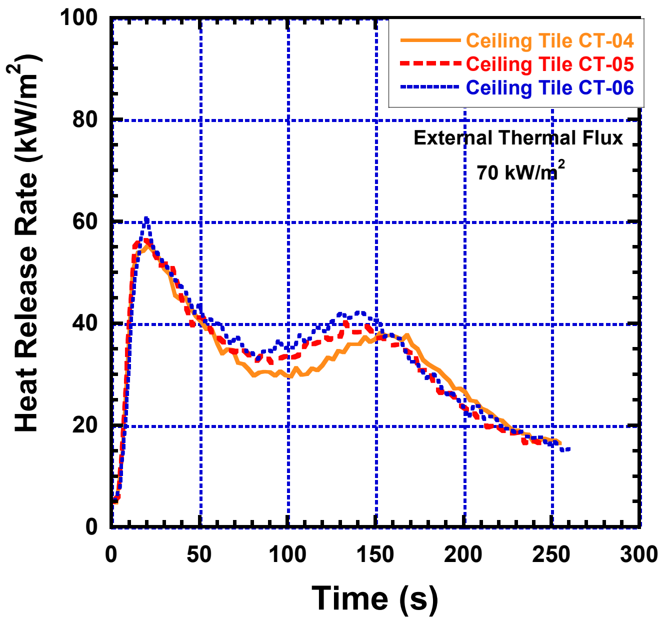


Figure D-17. Heat Release Rate versus Time for Ceiling Tile Exposed to 70 kW/m^2 of External Heat Flux (PUF-CT). Samples are CT-04, CT-05, and CT06.

The second peak was observed because as the material initially burns, some of the energy released by the combustion process is lost or conducted away into the unburned portion of the sample. As the test continued, the temperature of the unburned sample gradually increased with the continual heating from either the external flux or the combustion of the fuel itself. Eventually, the temperature of the material increased to the point where much less energy is lost through conduction. At this point, the energy, which was previously being conducted away, became available to increase the pyrolysis and subsequent burning of the fuel. This increase in the pyrolysis and burning resulted in a second peak in the heat release rate. Sometimes, if a sample contained some components that would ignite at a substantially lower temperature, these components would burn first and other components that had a higher ignition temperature would remain. As the sample temperature continued to increase and eventually reached the ignition temperature of the remaining components, even the higher ignition temperature fuel would begin to burn. This additional burning would have caused an increase in the heat release rate at some time after the initial peak due to the burning of the low temperature components.

When exposed to 35 kW/m^2 of external heat flux, the ceiling tiles did not ignite. As the thermal flux was increased to70 kW/m^2, ignition did occur and the samples reached their peak heat release rate in approximately 20 seconds. Peak heat release rates for all three ceiling tile samples ranged from 55 kW/m^2 to 61 kW/m^2 with an average of 57 kW/m^2.

D.2.6 Wood Paneling

Wood paneling had been installed in the nightclub around the raised platform area, around the sunroom, back bar area, and entry way (Figure 4-4). It is not clear whether or not there were any areas where polyurethane foam had been installed over wood paneling. Interior photographs of the nightclub did not provide sufficient information to identify the specific brand or type of paneling.

A veneer type paneling, which utilizes a plywood substrate, was selected as being most representative of the fuel load contributed by the paneling. The wood paneling was purchased from a local retailer in 1.22m (4 ft) x 2.44 m (8 ft) sheets. The 0.0005 m (0.0125 in) birch veneer was laminated to a 0.005 m (0.25 in) thick three-ply Luan mahogany backer layer. The front side of each panel (Figure D-18) had a glossy coat of finish while the rear side of each panel was unfinished plywood. Samples that measured 0.1 m x 0.1 m were cut from the larger panels. These samples were then stored in a controlled humidity (50 % relative humidity) and temperature (23 ^{o}C) room for at least two weeks. Then, each sample was wrapped in an aluminum foil, except for the exposed side, and positioned in the cone calorimeter. In all tests, veneer side was exposed to the thermal flux.

When exposed to 35 kW/m^2 of external heat flux, the wood paneling reached its average peak heat release rate, 440 kW/m^2 in approximately 130 s (Figure D-19). Peak heat release rates for all three wood samples ranged from 413 kW/m^2 to 460 kW/m^2. At the lower thermal flux, each sample required about 40 seconds to achieve sustained ignition. At the higher flux rate of 70 kW/m^2, the wood panel samples required much less time, on average 15 seconds, to sustain ignition (Figure D-20). The higher external flux resulted in a higher average peak heat release rate of 530 kW/m^2, but required substantially less time, 85 seconds, to achieve the peak value.

The heat release curves exhibited a two-peak shape, with the second peak much greater than the first peak. Each wood panel sample charred significantly as it burned and the char represented a greater fraction of the total available fuel than that which was burned early in the test. In the higher thermal flux exposure, the additional flux caused more of the fuel to be burned early in the test, so the two peaks were closer in value.

Figure D-18. Photograph of Wood Panel Sample Showing Veneer Surface.

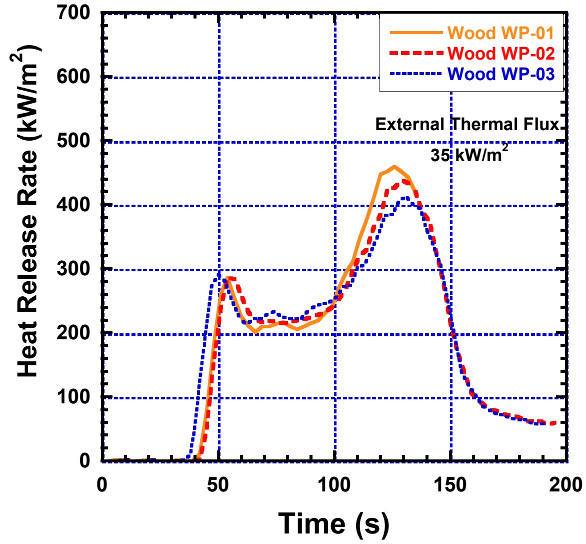


Figure D-19. Heat Release Rate versus Time for Wood Paneling Exposed to 35 kW/m^2 of External Heat Flux (WP). Samples are WP-01, WP-02, and WP-03.

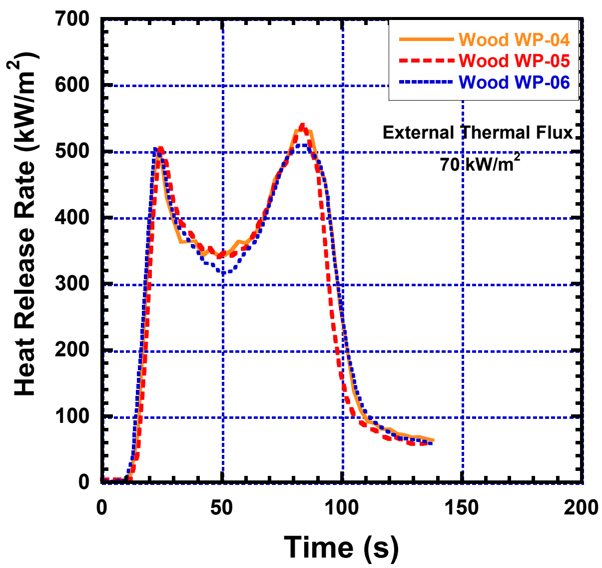


Figure D-20. Heat Release Rate versus Time for Wood Paneling Exposed to 70 kW/m^2 of External Heat Flux (WP). Samples are WP-04, WP-05, and WP-06.

Table D-5 Cone Calorimeter Results for Ceiling Tile, Wood Panels, & Carpet

Sample ID	External Thermal Flux, kW/m^2	Time to Sustained Ignition, seconds	Time to Peak Heat Release Rate, seconds	Peak Heat Release Rate kW/m^2
CT-01	30	Did not ignite		
CT-02	30	Did not ignite		
CT-03	30	Did not ignite		
CT-04	70	9	21	55
CT-05	70	7	19	56
CT-06	70	8	20	61
	Average	**8**	**20**	**57**
WP-01	35	43	126	460
WP-02	35	43	129	439
WP-03	35	37	131	413
	Average	**41**	**129**	**437**
WP-04	70	14	84	531
WP-05	70	16	84	543
WP-06	70	14	85	509
	Average	**15**	**85**	**526**
CF-01	35	38	221	474
CF-02	35	68	178	718
CF-03	35	40	206	536
	Average	**54**	**192**	**627**
CF-04	70	20	79	1378
CF-05	70	19	79	1289
CF-06	70	20	76	1447
	Average	**20**	**78**	**1371**

D.2.7 Test Results -- Carpet Flooring

Carpet flooring had been installed in the nightclub on the elevated section along the rear wall and around the raised platform area. (Figure 4-5). Interior photographs of the nightclub did not provide sufficient information to identify the specific brand or type of carpeting.

A closed-loop olefin carpet with a binding layer was selected as representing the fuel load contributed by the carpeting. The carpet was purchased from a local supplier in a 3.2 m (12 ft) wide x 15.7 m (50 ft) long continuous roll. The 0.006 m (0.25 in) nylon pile was embedded in a 0.002 m (0.1 in) thick binding layer. Samples that measured 0.1 m x 0.1 m were cut from the roll (Figure D-21). These samples were then stored in a controlled humidity (50 % relative humidity) and temperature (23 ^{o}C) room for at least

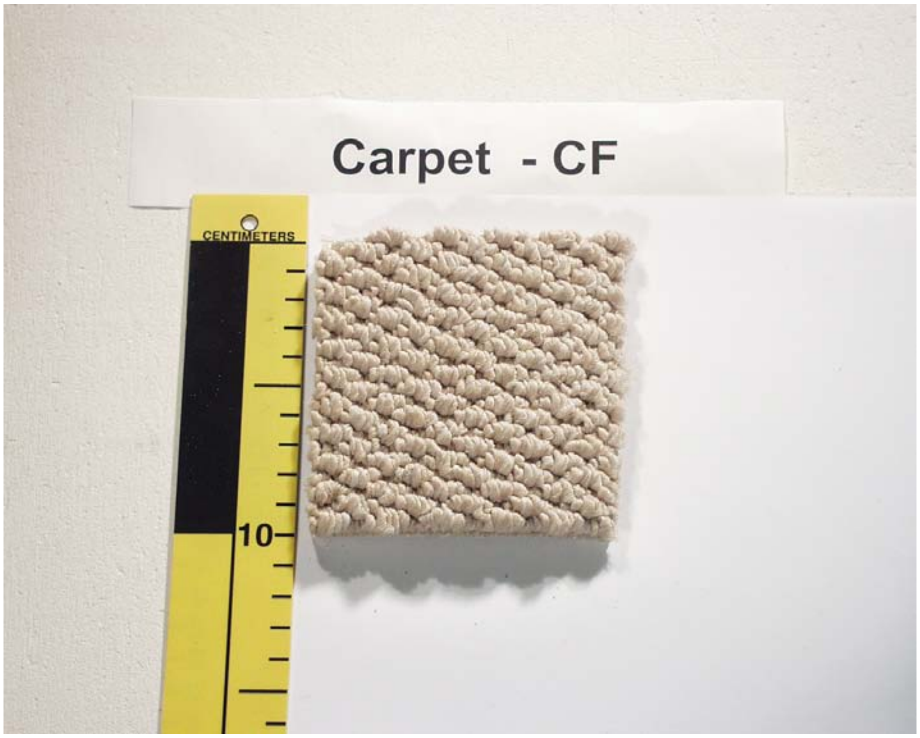


Figure D-21. Photograph of Carpet Sample Showing Olefin Pile.

two weeks. Then each sample was wrapped in an aluminum foil, except for the exposed side, and positioned in the cone calorimeter. In all tests, the olefin pile side was exposed to the thermal flux.

When exposed to 35 kW/m^2 of external heat flux (Figure D-22), the peak heat release rates for the three carpet samples ranged from 474 kW/m^2 to 718 kW/m^2. The carpet required about 54 seconds, on average, to achieve sustained ignition, and approximately 190 seconds to reach its peak heat release rate (Figure D-22). Three additional test samples were exposed to thermal flux at 70 kW/m^2 (Figure D-23) when exposed to the higher external heat flux, the carpeting reached its peak heat release rate in about half the time. Peak heat release rates for all three-carpet samples ranged from 1290 kW/m^2 to 1450 kW/m^2, with an average of 1370 kW/m^2.

For the lower flux exposure, the heat release curve exhibited a relatively brief step at around 200 kW/m^2 and then increased gradually to a single broad peak. As the carpet initially began to burn, some of the energy released was conducted into the olefin pile, but instead of producing a char, the polymer melted and formed a more uniform density fuel. As the burning continued, it increased at a relatively steady rate, reached its peak and decreased at a more rapid rate. At the higher flux exposure, the additional energy from the internal heating caused the melting to occur more rapidly, so the initial step seen at the lower flux was not observed.

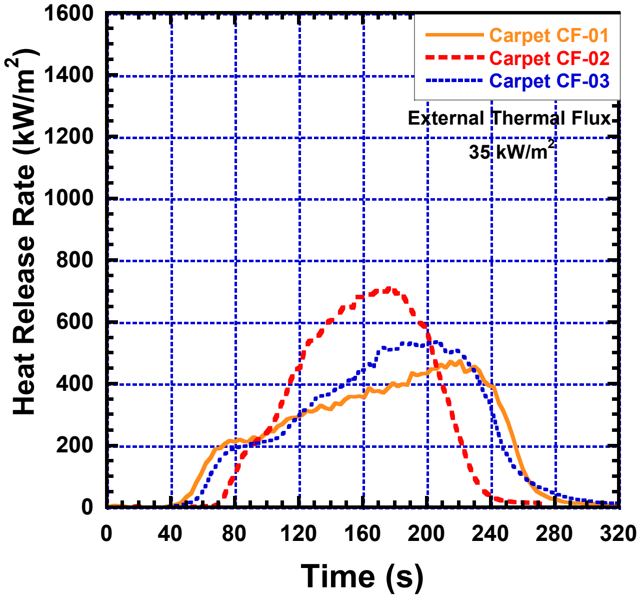


Figure D-22. Heat Release Rate versus Time for Carpet Sample Exposed to 35 kW/m^2 of External Heat Flux (CF). Samples are CF-01, CF-02, and CF-03.

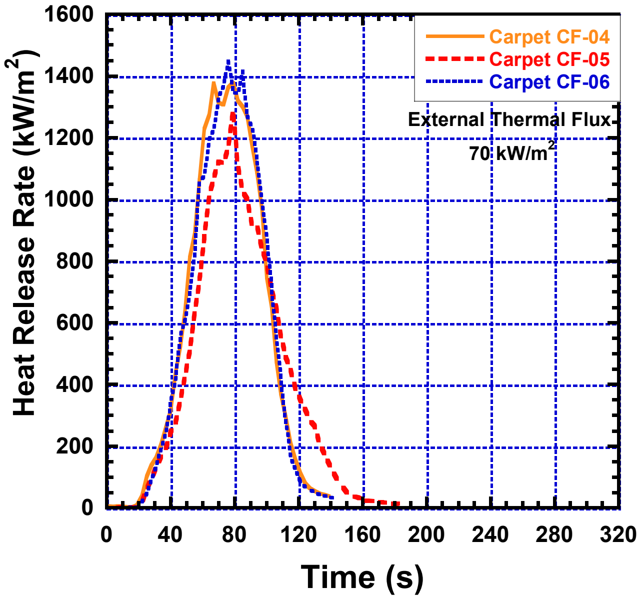


Figure D-23. Heat Release Rate versus Time for Carpet Sample Exposed to 70 kW/m^2 of External Heat Flux (CF). Samples are CF-04, CF-05, and CF-06.

D.2.8 Summary Tables

The materials that were tested and the sample identifiers that were used throughout the cone calorimeter test series are listed in Table D-6. The data that wer collected is summarized in Tables D-7 through D-19. The data tables provide the time to sustained ignition, peak heart release rate, time to peak heat release rate, total heat release, 60 s average heat release rate, total mass loss, average mass loss rate, average effective heat of combustion, average smoke yield, average carbon dioxide yield, average carbon monoxide yield, time to ignition, time to flameout, and a number of specimen properties. Each table groups a specific material that was exposed to a specific external heat flux.

Table D-6. Material Identification for Cone Calorimeter Experiments

Sample ID	Material	Fire Retardant/Non-Retardant	Description
PUF-FR	Polyurethane Foam (Ester)	Fire Retardant	Convoluted / Egg Crate Gray Color
PUF-NFR-A	Polyurethane Foam (Ether)	Non-Fire Retardant	Convoluted / Egg Crate Gray Color- Lot A
PUF-NFR-B	Polyurethane Foam (Ether)	Non-Fire Retardant	Convoluted / Egg Crate Gray Color- Lot B
CT-FR	Ceiling Tile	Fire Retardant	942 B (Commercial Equivalent 755) Textured
WP	Wood Paneling	Non-Fire Retardant	5 mm thick Plywood Substrate Antique Birch Finish
CF	Carpet	Non-Fire Retardant	100% Filament Olefin Color: Pottery (Beige)

Table D-7. Cone Calorimeter Data for Polyurethane Foam at 35 kW/m^2 (PUF-NFR-A).

Polyurethane Foam	**PUF-NFR-A-01**	**PUF-NFR-A-2**	**PUF-NFR-A-3**	**Average**
External Heat Flux 35 kW/m^2				
Test Results:				
Time to Sustained Ignition (s):	9.00	7	6	**7.3**
Peak Heat Release Rate (kW/m^2):	620	676	520	**605**
Time to Peak Heat Release Rate (s):	32.0	30	28	**30.0**
Total Heat Release (MJ/m^2):	15.6	16.3	15.4	**15.8**
60 s Average Heat Release Rate (kW/m^2):	262	268	248	**259**
Total Mass Loss (g):	6.25	6.2	5.94	**6.13**
Average Mass Loss Rate (g/s):	0.174	0.148	0.117	**0.146**
Average Effective Heat of Combustion (MJ/kg):	24.9	26.4	25.9	**25.7**
Average Smoke Extinction Area (m^2/kg):	206	285	235	**242**
Average CO_2 yield (g/g):	1.56	1.88	2.03	**1.8**
Average CO yield (g/g):	0.0136	0.0112	0.0129	**0.0126**
Specimen:				
Initial mass (g):	9.3	9.2	9.8	**9.4**
Thickness (mm):	25	25	25	**25.0**
Surface area (cm^2):	100	100	100	**100.0**
Test start time (s):	123	89	79	**97.0**
Time to ignition (s):	9	7	6	**7.3**
Time to flameout (s):	46	48	55	**49.7**

Table D-8. Cone Calorimeter Data for Fire Retardant Polyurethane Foam at 20 kW/m^2 (PUF-NFR-B).

Polyurethane Foam	PUF-NFR-B-13	PUF-NFR-B-14	PUF-NFR-B-15	Average
External Heat Flux 20 kW/m^2				
Test Results:				
Time to Sustained Ignition (s):	8	12	22	**14.0**
Peak Heat Release Rate (kW/m^2):	457	437	456	**450**
Time to Peak Heat Release Rate (s):	41	44	50	**45.0**
Total Heat Release (MJ/m^2):	9.87	10.33	10.0	**10.1**
60 s Average Heat Release Rate (kW/m^2):	206	205	192	**201**
Total Mass Loss (g):	4.55	4.48	4.05	**4.4**
Average Mass Loss Rate (g/s):	0.114	0.118	0.11	**0.114**
Average Effective Heat of Combustion (MJ/kg):	21.7	23.0	24.8	**23.2**
Average Smoke Extinction Area (m^2/kg):	323	343	385	**350**
Average CO_2 yield (g/g):	0	0	0	**0**
Average CO yield (g/g):	0.0103	0.012	0.0135	**0.0119**
Specimen:				
Initial mass (g):	6.7	6.7	6.7	**6.7**
Thickness (mm):	25	25	25	**25.0**
Surface area (cm^2):	100	100	100	**100**
Test start time (s):	82	92	83	**85.7**
Time to ignition (s):	8	12	22	**14.0**

Table D-9a. Cone Calorimeter Data for Polyurethane Foam at 35 kW/m^2 (PUF-NFR-B). Data and Averages are continued in Table D-9b.

Polyurethane Foam	PUF-NFR-B-01	PUF-NFR-B-02	PUF-NFR-B-03	PUF-NFR-B-04
External Heat Flux 36 kW/m^2				
Test Results:				
Time to Sustained Ignition (s):	4	5	9	5
Peak Heat Release Rate (kW/m^2):	519	532	541	577
Time to Peak Heat Release Rate (s):	26	26	33	32
Total Heat Release (MJ/m^2):	11.0	11.2	11.9	10.7
60 s Average Heat Release Rate (kW/m^2):	213	228	203	213
Total Mass Loss (g):	4.47	4.43	4.31	4.27
Average Mass Loss Rate (g/s):	0.135	0.148	0.13	0.142
Average Effective Heat of Combustion (MJ/kg):	24.7	25.4	27.5	25.0
Average Smoke Extinction Area (m^2/kg):	354	345	331	379
Average CO_2 yield (g/g):	0.86	0.87	1.3	0.91
Average CO yield (g/g):	0.0064	0.0071	0.0094	0.0111
Specimen:				
Initial mass (g):	9.1	9.3	9.5	9.2
Thickness (mm):	30	30	30	25
Surface area (cm^2):	100	100	100	100
Test start time (s):	87	75	74	84
Time to ignition (s):	4	5	9	5
Time to flameout (s):	37	37	44	36

Table D-9b. Cone Calorimeter Data for Polyurethane Foam at 35 kW/m^2 (PUF-NFR-B). Data and Averages are continued from Table D-9a.

Polyurethane Foam	**PUF-NFR-B-05**	**PUF-NFR-B-06**	**Average (for PUF-NFR-B -01 through -06)**
External Heat Flux 36 kW/m^2			
Test Results:			
Time to Sustained Ignition (s):	5	5	**5.5**
Peak Heat Release Rate (kW/m^2):	637	644	**575**
Time to Peak Heat Release Rate (s):	29	32	**29.7**
Total Heat Release (MJ/m^2):	11.0	10.2	**11.0**
60 s Average Heat Release Rate (kW/m^2):	211	211	**213**
Total Mass Loss (g):	4.43	4.51	**4.4**
Average Mass Loss Rate (g/s):	0.148	0.15	**0.142**
Average Effective Heat of Combustion (MJ/kg):	24.8	22.7	**25.0**
Average Smoke Extinction Area (m^2/kg):	489	326	**371**
Average CO_2 yield (g/g):	0.89	0.69	**0.92**
Average CO yield (g/g):	0.0103	0.0073	**0.0086**
Specimen:			
Initial mass (g):	9	9.2	**9.2**
Thickness (mm):	25	25	**27.5**
Surface area (cm^2):	100	100	**100**
Test start time (s):	81	78	**79.8**
Time to ignition (s):	5	5	**5.5**
Time to flameout (s):	35	36	**37.5**

Table D-10. Cone Calorimeter Data for Fire Retardant Polyurethane Foam at 40 kW/m^2 (PUF-NFR-B).

Polyurethane Foam	**PUF-NFR-B-16**	**PUF-NFR-B-17**	**PUF-NFR-B-18**	**Average**
External Heat Flux 40 kW/m^2				
Test Results:				
Time to Sustained Ignition (s):	4	3	4	**3.7**
Peak Heat Release Rate (kW/m^2):	706	878	877	**820**
Time to Peak Heat Release Rate (s):	28	30	29	**29**
Total Heat Release (MJ/m^2):	10.6	8.87	9.78	**9.8**
60 s Average Heat Release Rate (kW/m^2):	219	239	242	**233**
Total Mass Loss (g):	4.67	4.64	4.48	**4.6**
Average Mass Loss Rate (g/s):	0.156	0.172	0.166	**0.165**
Average Effective Heat of Combustion (MJ/kg):	22.8	19.1	21.8	**21.2**
Average Smoke Extinction Area (m^2/kg):	264	372	320	**319**
Average CO_2 yield (g/g):	0.04	0	0	**0.01**
Average CO yield (g/g):	0.0108	0.007	0.0081	**0.0086**
Specimen:				
Initial mass (g):	0.7	6.8	6.7	**4.7**
Thickness (mm):	25	25	25	**25**
Surface area (cm^2):	100	100	100	**100**
Test start time (s):	81	84	81	**82**
Time to ignition (s):	4	3	4	**3.7**

Table D-11. Cone Calorimeter Data for Fire Retardant Polyurethane Foam at 60 kW/m^2 (PUF-NFR-B).

Polyurethane Foam	**PUF-NFR-B-19**	**PUF-NFR-B-20**	**PUF-NFR-B-21**	**Average**
External Heat Flux 60 kW/m^2				
Test Results:				
Time to Sustained Ignition (s):	4	3	3	**3.3**
Peak Heat Release Rate (kW/m^2):	993	1170	1299	**1154**
Time to Peak Heat Release Rate (s):	24	24	23	**24**
Total Heat Release (MJ/m^2):	11.5	14.5	7.49	**11.2**
60 s Average Heat Release Rate (kW/m^2):	252	268	264	**261**
Total Mass Loss (g):	4.54	4.43	4.28	**4.4**
Average Mass Loss Rate (g/s):	0.189	0.153	0.225	**0.189**
Average Effective Heat of Combustion (MJ/kg):	25.2	32.8	17.5	**25.2**
Average Smoke Extinction Area (m^2/kg):	330	342	319	**330**
Average CO_2 yield (g/g):	0	0.74	0	**0.25**
Average CO yield (g/g):	0.0118	0.0302	0.0043	**0.0154**
Specimen:				
Initial mass (g):	6.8	6.8	6.7	**6.8**
Thickness (mm):	25	25	25	**25**
Surface area (cm^2):	100	100	100	**100**
Test start time (s):	85	84	96	**88**
Time to ignition (s):	4	3	3	**3.3**

Table D-12a. Cone Calorimeter Data for Polyurethane Foam at 70 kW/m^2 (PUF-NFR-B). Data and Averages are continued in Table D-12b.

Polyurethane Foam	**PUF-NFR-B-07**	**PUF-NFR-B-08**	**PUF-NFR-B-09**
External Heat Flux 71 kW/m^2			
Test Results:			
Time to Sustained Ignition (s):	4	3	3
Peak Heat Release Rate (kW/m^2):	806	820	881
Time to Peak Heat Release Rate (s):	18	20	21
Total Heat Release (MJ/m^2):	11.8	11.1	13.0
60 s Average Heat Release Rate (kW/m^2):	248	257	0.84
Total Mass Loss (g):	3.8	4.39	4.35
Average Mass Loss Rate (g/s):	0.181	0.209	0.181
Average Effective Heat of Combustion (MJ/kg):	31.0	25.3	29.8
Average Smoke Extinction Area (m^2/kg):	429	318	395
Average CO_2 yield (g/g):	0.64	0.35	0.67
Average CO yield (g/g):	0.0085	0.003	0.0073
Specimen:			
Initial mass (g):	9.2	9.1	9.1
Thickness (mm):	30	30	30
Surface area (cm^2):	100	100	100
Test start time (s):	104	78	77
Time to ignition (s):	4	3	3
Time to flameout (s):	25	25	27

Table D-12b. Cone Calorimeter Data for Polyurethane Foam at 70 kW/m^2 (PUF-NFR-B). Data and Averages are continued in Table D-12a.

Polyurethane Foam	**PUF-NFR-B-10**	**PUF-NFR-B-11**	**Average (PUF-NFR-B -01 to -11)**
External Heat Flux 71 kW/m^2			
Test Results:			
Time to Sustained Ignition (s):	3	3	**3.2**
Peak Heat Release Rate (kW/m^2):	1083	1094	**937**
Time to Peak Heat Release Rate (s):	22	20	**20.2**
Total Heat Release (MJ/m^2):	12.6	11.8	**12.0**
60 s Average Heat Release Rate (kW/m^2):	264	243	**203**
Total Mass Loss (g):	4.66	4.49	**4.3**
Average Mass Loss Rate (g/s):	0.194	0.214	**0.196**
Average Effective Heat of Combustion (MJ/kg):	27.1	26.2	**27.9**
Average Smoke Extinction Area (m^2/kg):	410	366	**384**
Average CO_2 yield (g/g):	0.44	0.35	**0.49**
Average CO yield (g/g):	0.0076	0.0062	**0.0065**
Specimen:			
Initial mass (g):	9.1	9	**9.1**
Thickness (mm):	25	25	**28.0**
Surface area (cm^2):	100	100	**100**
Test start time (s):	91	87	**87.4**
Time to ignition (s):	3	3	**3.2**
Time to flameout (s):	26	23	**25.2**

Table D-13. Cone Calorimeter Data for Fire Retardant Polyurethane Foam at 35 kW/m^2 (PUF-FR).

Polyurethane Foam	**PUF-FR-01**	**PUF-FR-02**	**PUF-FR-03**	**Average**
External Heat Flux 35 kW/m^2				
Test Results:				
Time to Sustained Ignition (s):	11.00	11	16	**12.7**
Peak Heat Release Rate (kW/m^2):	452	432	476	**453**
Time to Peak Heat Release Rate (s):	35.0	35	37	**35.7**
Total Heat Release (MJ/m^2):	8.69	8.5	8.58	**8.6**
60 s Average Heat Release Rate (kW/m^2):	155	150	151	**152**
Total Mass Loss (g):	5.95	5.86	5.67	**5.83**
Average Mass Loss Rate (g/s):	0.198	0.178	0.189	**0.188**
Average Effective Heat of Combustion (MJ/kg):	14.6	14.5	15.13	**14.7**
Average Smoke Extinction Area (m^2/kg):	539	474	542	**518**
Average CO_2 yield (g/g):	0.61	0.65	0.66	**0.6**
Average CO yield (g/g):	0.0618	0.0625	0.0623	**0.0622**
Specimen:				
Initial mass (g):	8.9	8.7	8.7	**8.8**
Thickness (mm):	25	25	25	**25.0**
Surface area (cm^2):	100	100	100	**100**
Test start time (s):	78	75	76	**76.3**
Time to ignition (s):	11	11	16	**12.7**
Time to flameout (s):	42	46	46	**44.7**

Table D-14. Cone Calorimeter Data for Wood Paneling at 35 kW/m^2 (WP).

Wood Paneling External Heat Flux 35 kW/m^2	**WP-01**	**WP-02**	**WP-03**	**Average**
Test Results:				
Time to Sustained Ignition (s):	43.0	43	37	**41.0**
Peak Heat Release Rate (kW/m^2):	460	439	413	**437**
Time to Peak Heat Release Rate (s):	126	129	131	**129**
Total Heat Release (MJ/m^2):	31.2	30.8	30.9	**31.0**
60 s Average Heat Release Rate (kW/m^2):	207	0.52	206	**138.1**
Total Mass Loss (g):	20.7	21.2	21.6	**21.1**
Average Mass Loss Rate (g/s):	0.187	0.191	0.189	**0.189**
Average Effective Heat of Combustion (MJ/kg):	15.0	14.6	14.3	**14.7**
Average Smoke Extinction Area (m^2/kg):	94.1	11.27	111.68	**72.4**
Average CO_2 yield (g/g):	1.48	1.41	1.36	**1.42**
Average CO yield (g/g):	0.0054	0.0047	0.0043	**0.0048**
Specimen:				
Initial mass (g):	28.8	28.8	29.3	**29.0**
Thickness (mm):	6	6	6	**6.0**
Surface area (cm^2):	100	100	100	**100**
Test start time (s):	80	77	84	**80.3**
Time to ignition (s):	43	43	37	**41.0**
Time to flameout (s):	154	155	151	**153**

Table D-15. Cone Calorimeter Data for Wood Paneling at 70 kW/m^2 (WP).

Wood Paneling	**WP-04**	**WP-05**	**WP-06**	**Average**
External Heat Flux 70 kW/m^2				
Test Results:				
Time to Sustained Ignition (s):	14.00	16	14	**14.7**
Peak Heat Release Rate (kW/m^2):	531	542	509	**528**
Time to Peak Heat Release Rate (s):	84.0	84	85	**84.3**
Total Heat Release (MJ/m^2):	35.4	33.1	34.8	**34.4**
60 s Average Heat Release Rate (kW/m^2):	348	368	353	**356**
Total Mass Loss (g):	23.2	21.7	22.8	**22.6**
Average Mass Loss Rate (g/s):	0.249	0.259	0.254	**0.254**
Average Effective Heat of Combustion (MJ/kg):	15.3	15.2	15.2	**15.2**
Average Smoke Extinction Area (m^2/kg):	92.8	93.0	95.1	**93.6**
Average CO_2 yield (g/g):	1.47	1.43	1.43	**1.44**
Average CO yield (g/g):	0.0056	0.0055	0.0055	**0.0055**
Specimen:				
Initial mass (g):	30	28.6	29.5	**29.4**
Thickness (mm):	6	6	6	**6.0**
Surface area (cm^2):	100	100	100	**100**
Test start time (s):	86	83	79	**82.7**
Time to ignition (s):	14	16	14	**14.7**
Time to flameout (s):	105	99	104	**103**

Table D-16. Cone Calorimeter Data for Ceiling Tile at 35 kW/m^2 (CT).

Ceiling Tile	**CT-01**	**CF-02**	**CT-03**	**Average**
External Heat Flux 35 kW/m^2				
Test Results:				
Time to Sustained Ignition (s):	Did not ignite	Did not ignite	Did not ignite	
Peak Heat Release Rate (kW/m^2):	Did not ignite	Did not ignite	Did not ignite	
Time to Peak Heat Release Rate (s):	Did not ignite	Did not ignite	Did not ignite	
Total Heat Release (MJ/m^2):	Did not ignite	Did not ignite	Did not ignite	
60 s Average Heat Release Rate (kW/m^2):	Did not ignite	Did not ignite	Did not ignite	
Total Mass Loss (g):	Did not ignite	Did not ignite	Did not ignite	
Average Mass Loss Rate (g/s):	Did not ignite	Did not ignite	Did not ignite	
Average Effective Heat of Combustion (MJ/kg):	Did not ignite	Did not ignite	Did not ignite	
Average Smoke Extinction Area (m^2/kg):	Did not ignite	Did not ignite	Did not ignite	
Average CO_2 yield (g/g):	Did not ignite	Did not ignite	Did not ignite	
Average CO yield (g/g):	Did not ignite	Did not ignite	Did not ignite	
Specimen:				
Initial mass (g):	33.8	33.5	33.5	**33.6**
Thickness (mm):	15	15	15	**15.0**
Surface area (cm^2):	100	100	100	**100.0**
Test start time (s):	*83*	84	112	**93.0**
Time to ignition (s):	Did not ignite	Did not ignite	Did not ignite	
Time to flameout (s):	Did not ignite	Did not ignite	Did not ignite	

Table D-17. Cone Calorimeter Data for Ceiling Tile at 70 kW/m^2 (CT).

Ceiling Tile External Heat Flux 70 kW/m^2	**CT-04**	**CT-05**	**CT-06**	**Average**
Test Results:				
Time to Sustained Ignition (s):	9.00	7	8	**8.0**
Peak Heat Release Rate (kW/m^2):	55.4	56.4	61.0	**57.6**
Time to Peak Heat Release Rate (s):	21.0	19	20	**20.0**
Total Heat Release (MJ/m^2):	7.52	7.15	7.79	**7.5**
60 s Average Heat Release Rate (kW/m^2):	44.3	44.5	45.2	**44.7**
Total Mass Loss (g):	6.54	6.68	6.76	**6.66**
Average Mass Loss Rate (g/s):	0.031	0.036	0.033	**0.033**
Average Effective Heat of Combustion (MJ/kg):	11.5	10.7	11.5	**11.2**
Average Smoke Extinction Area (m^2/kg):	1.64	0	23.3	**8.3**
Average CO_2 yield (g/g):	0.00	0	0.0339	**0.0113**
Average CO yield (g/g):	0.0411	0.0252	0	**0.0221**
Specimen:				
Initial mass (g):	33.8	34.2	34.1	**34.0**
Thickness (mm):	15	15	15	**15.0**
Surface area (cm^2):	100	100	100	**100**
Test start time (s):	95	91	105	**97.0**
Time to ignition (s):	9	7	8	**8.0**
Time to flameout (s):	221	194	213	**209**

Table D-18. Cone Calorimeter Data for Carpet Flooring at 35 kW/m^2 (CF).

Carpet Flooring	**CF-01**	**CF-02**	**CF-03**	**Average**
External Heat Flux 35 kW/m^2				
Test Results:				
Time to Sustained Ignition (s):	38	68	40	**48.7**
Peak Heat Release Rate (kW/m^2):	474	718	536	**576**
Time to Peak Heat Release Rate (s):	221	178	206	**202**
Total Heat Release (MJ/m^2):	67.6	71.4	71.8	**70.3**
60 s Average Heat Release Rate (kW/m^2):	139	246	111	**166**
Total Mass Loss (g):	12.2	16.6	18.0	**15.6**
Average Mass Loss Rate (g/s):	0.052	0.102	0.068	**0.074**
Average Effective Heat of Combustion (MJ/kg):	55.3	43.1	40.0	**46.1**
Average Smoke Extinction Area (m^2/kg):	1118	792	816	**908**
Average CO_2 yield (g/g):	3.87	3.07	2.86	**3.27**
Average CO yield (g/g):	0.0584	0.0437	0.0424	**0.0482**
Specimen:				
Initial mass (g):	28.7	29.2	30.2	**29.4**
Thickness (mm):	11	11	11	**11.0**
Surface area (cm^2):	100	100	100	**100**
Test start time (s):	111	79	84	**91.3**
Time to ignition (s):	38	68	40	**48.7**
Time to flameout (s):	272	229	302	**267**

Table D-19. Cone Calorimeter Data for Carpet Flooring at 70 kW/m^2 (CF).

Carpet Flooring External Heat Flux 70 kW/m^2	CF-04	CF-05	CF-06	**Average**
Test Results:				
Time to Sustained Ignition (s):	20.0	19	20	**19.7**
Peak Heat Release Rate (kW/m^2):	1378	1288	1447	**1371**
Time to Peak Heat Release Rate (s):	79.0	79	76	**78.0**
Total Heat Release (MJ/m^2):	74.6	70.0	73.4	**72.6**
60 s Average Heat Release Rate (kW/m^2):	706	548	677	**644**
Total Mass Loss (g):	17.0	16.6	20.8	**18.2**
Average Mass Loss Rate (g/s):	0.172	0.132	0.224	**0.176**
Average Effective Heat of Combustion (MJ/kg):	43.84	41.94	35.28	**40.4**
Average Smoke Extinction Area (m^2/kg):	842.12	987.34	768.5	**866.0**
Average CO_2 yield (g/g):	3.36	3.13	2.6	**3.03**
Average CO yield (g/g):	0.0581	0.0531	0.0457	**0.0523**
Specimen:				
Initial mass (g):	28.9	29.7	29.4	**29.3**
Thickness (mm):	11	11	11	**11.0**
Surface area (cm^2):	100	100	100	**100**
Test start time (s):	91	91	85	**89.0**
Time to ignition (s):	20	19	20	**19.7**
Time to flameout (s):	120	147	112	**126**

D.3 IGNITION TEMPERATURE TESTS

Ignition temperatures for polyurethane plastics were required for simulation of the mockup experiments and then for the simulation of the full nightclub. ASTM D 1929 [3] provides a laboratory determination of the spontaneous ignition temperature (SIT) and flash ignition temperature (FIT) for plastics. Southwest Research Institute (SwRI) was contracted to conduct analyses on PUF-NFR-B samples to determine ignition temperatures. This is the same polyurethane foam that was installed in the full-scale mockup. The results of the SIT tests were used in the computer fire model simulation of the mockup tests.

The report from SwRI included in this appendix describes the test protocol as well as the test results for the foam samples.

(Note that the SwRI report refers to a PU<u>R</u> foam, not a PU<u>F</u> foam; this is a typographical error. Also note that NIST provided the density of 0.39 kg/m^3 to SwRI. This value, which was determined from the cone calorimeter experiments conducted at NIST, mistakenly included the mass of the aluminum pan. The correct value for density should have be reported as 0.22 kg/m^3. This error had no impact on the results of the SwRI ignition temperature tests.)

DRAFT

SOUTHWEST RESEARCH INSTITUTE®

6220 CULEBRA RD. 78238-5166 • P.O. DRAWER 28510 78228-0510 • SAN ANTONIO, TEXAS, USA • (210) 684-5111 • WWW.SWRI.ORG
CHEMISTRY AND CHEMICAL ENGINEERING DIVISION
DEPARTMENT OF FIRE TECHNOLOGY
WWW.FIRE.SWRI.ORG
FAX (210) 522-3377

NSF-ISR
QUALITY SYSTEM REGISTERED TO ISO 9001:2000

ASTM D 1929 – 96 (Reapproved 2001)

Standard Test Method for
Determining Ignition Temperature of Plastics

Material ID: ***PUR-NFR-B***

Final Report
SwRI® Project No.: 01.10934.01.602a
Consisting of 5 Pages

Test Date: October 14, 2004
Report Date: November 9, 2004

Prepared for:

National Institute of Standards and Technology
Building and Fire Research Laboratory
100 Bureau Drive, MS 8661
Gaithersburg, MD 20899-8661

Prepared by:

Karen C. Carpenter

ALG

Karen C. Carpenter
Engineer
Material Flammability Section

Approved by:

Marc L. Janssens, Ph.D.
Director
Department of Fire Technology

HOUSTON, TEXAS (713) 977-1377 • WASHINGTON, DC (301) 881-0226

Introduction

ASTM D 1929 covers a laboratory determination of the spontaneous ignition temperature (SIT) and flash ignition temperature (FIT) of plastics using a hot-air furnace. The hot-air ignition furnace consists primarily of an electrical heating unit and specimen holder. The furnace tube is a vertical tube with an inside diameter of 100 ± 5 mm and a length of 230 ± 20 mm, made of ceramic that will withstand at least 750°C. The inner ceramic tube, with an inside diameter of 75 ± 5 mm, a length of 230 ± 20 mm, and a thickness of approximately 3 mm, is placed inside the furnace tube and positioned 20 ± 2 mm above the furnace floor on spacer blocks. The pilot flame is located immediately above the opening. The test apparatus is shown in Fig. 1 below.

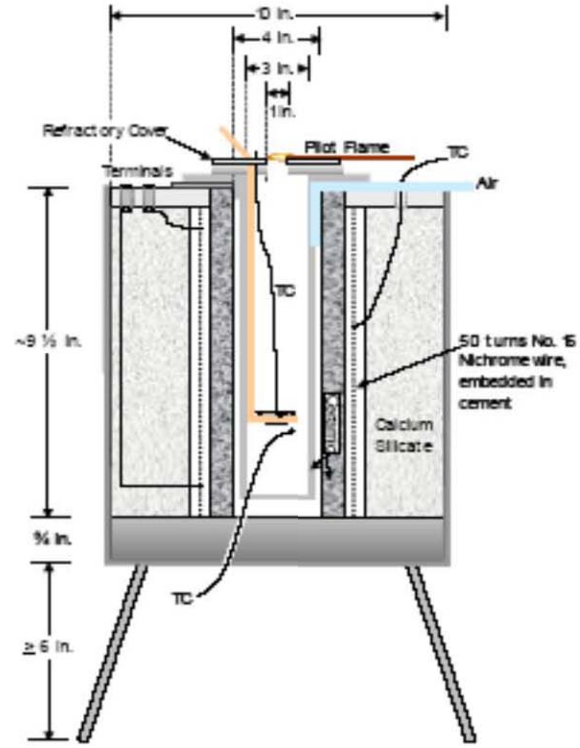


Figure 1. Schematic of SwRI's Hot-Air Furnace.

SIT is the minimum temperature at which the self-heating properties of the specimen lead to ignition or ignition occurs of itself, under specified test conditions, in the absence of any additional flame ignition source. The lowest air temperature at which the specimen burns during a 10-min period is recorded as the spontaneous ignition temperature.

FIT is the minimum temperature at which, under specified test conditions, sufficient flammable gases are emitted to ignite momentarily upon application of a small external pilot flame. The lowest air temperature at which a flash is observed during a 10-min period is recorded as the flash ignition temperature.

Sample Identification and Preparation

The National Institute of Standards and Testing (NIST), located in Gaithersburg, Maryland, provided a material identified as *PUR-NFR-B* for testing in accordance with ASTM D 1929. The material was described by the Client as "Polyurethane foam, convoluted, ether non-fire retardant" and was gray in color. Per NIST, the aerial density of the material was 0.39 kg/m^2. The material consisted of peaks and valleys with the peaks measuring 29 mm and the valleys measuring 10 mm. The material was received at SwRI on October 11, 2004. Upon receipt, samples were prepared for testing and conditioned in a controlled environment maintained at 23 ± 2°C (73 ± 5°F) and 50 ± 5% relative humidity for not less than 40 hours prior to testing. Tests were conducted October 14, 2004.

Sample preparation was in general accordance with ASTM D 1929. Because the density of the material was less than 100 kg/m^3, the test samples were prepared according to size instead of the normal 3-g weight. In accordance with ASTM D 1929, each test specimen was cut to 20 × 20 mm. Due to the uneven shape of the material (see Figure 1), the required height of 50 mm could not be achieved by stacking the samples and the 20 × 20-mm samples were left at the 10-29 mm height.

Results

Table 1 contains the results for the material provided by NIST. Test results are accurate to ± 5°C. A complete set of results and observations are presented at the end of this report. These test results relate only to the behavior of test specimens under the particular conditions of the test. They are not intended to be used, and shall not be used, to assess the potential fire hazards of a material in use.

Table 1. Ignition Temperature Data.

Material ID	SIT	FIT
PUR-NFR-B	410 °C	370 °C
	770 °F	698 °F

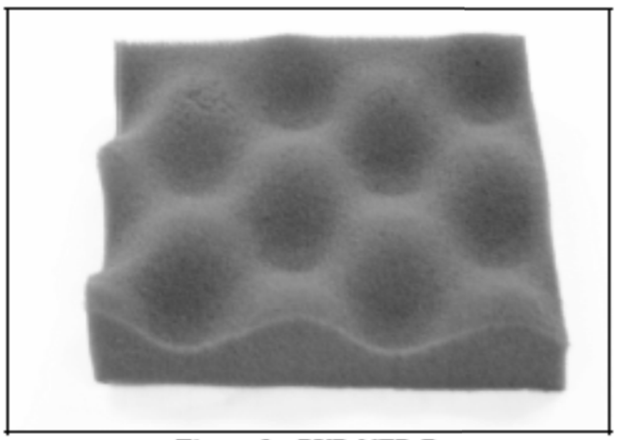


Figure 1. ***PUR-NFR-B.***

SOUTHWEST RESEARCH INSTITUTE

ASTM D 1929 TEST DATA SHEET - SPONTANEOUS IGNITION

Client:	National Institute of Standards and Technology	*Ignition Type:*	Spontaneous
Operator:	J. Anderson	*Receipt Date:*	October 11, 2004
Test Date(s):	October 14, 2004	*Date Prepared by SwRI:*	October 14, 2004
Material ID:*	PUF-NFR-B	*Color:*	Gray
Description:*	Polyurethane foam, convoluted, ether, non fire-retardant	*Original Thickness:*	10 mm -29 mm
		Average Sample Mass:	0.35 g

SPONTANEOUS IGNITION TEMPERATURE (°C) : 410

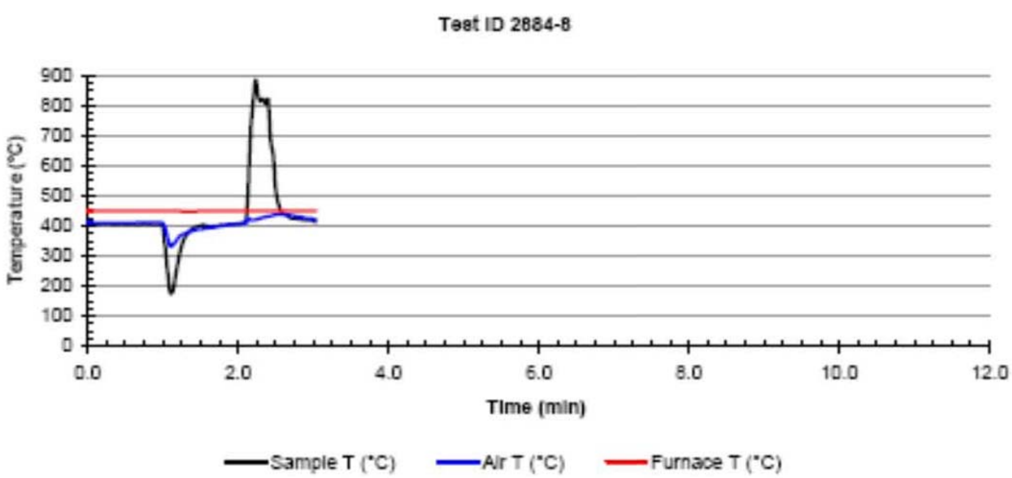
** Information/instructions provided by the Client*

RESULTS

Test ID	Initial Mass (g)	Final Mass (g)	Mass Loss (g)	Initial Temperature (°C) Sample	Air	Furnace	Final Temperature (°C) Sample	Air	Furnace	Ignition
2884-2	0.34	0.07	0.27	347	350	392	345	350	391	No
2884-3	0.35	0.04	0.31	398	400	448	395	402	440	No
2884-4	0.35	0.03	0.32	450	450	494	778	465	494	Yes
2884-5	0.36	0.02	0.34	438	440	483	921	455	483	Yes
2884-6	0.34	0.02	0.32	427	430	469	848	448	470	Yes
2884-7	0.35	0.03	0.32	417	420	461	839	437	462	Yes
2884-8	0.34	0.02	0.32	405	410	450	817	423	449	Yes

SPONTANEOUS IGNITION OBSERVATIONS

	Insertion Time (min:sec)	Combustion Time (min:sec)	Observed Soot (min:sec)	Observed Smoke (min:sec)	Observed Foam	Observed Melt	Observed Bubbling	Total Test Time (min:sec)
2884-2	1:20	None	None	1:30	None	None	None	11:20
2884-3	1:10	None	None	1:16	None	None	None	11:10
2884-4	1:11	Flaming at 1:49	1:49	1:13	None	None	None	1:49
2884-5	1:14	Flaming at 2:00	2:01	1:16	None	None	None	2:01
2884-6	1:15	Flaming at 1:59	1:17	1:18	None	None	None	1:59
2884-7	1:10	Flaming at 1:45	1:12	1:14	None	None	None	1:45
2884-8	1:08	Flaming at 2:09	2:12	1:14	None	None	None	3:00



SOUTHWEST RESEARCH INSTITUTE

ASTM D 1929 TEST DATA SHEET - FLASH IGNITION

Client:	National Institute of Standards and Technology	*Ignition Type:*	Flash
Operator:	J. Anderson	*Receipt Date:*	October 11, 2004
Test Date(s):	October 14, 2004	*Date Prepared by SwRI:*	October 14, 2004
Material ID:*	PUF-NFR-B	*Color:*	Gray
Description:*	Polyurethane foam, convoluted, ether, non fire-retardant	*Original Thickness:*	10 mm -29 mm
		Average Sample Mass:	0.35 g

* *Information/Instructions provided by the Client*

FLASH IGNITION TEMPERATURE (°C) : 370

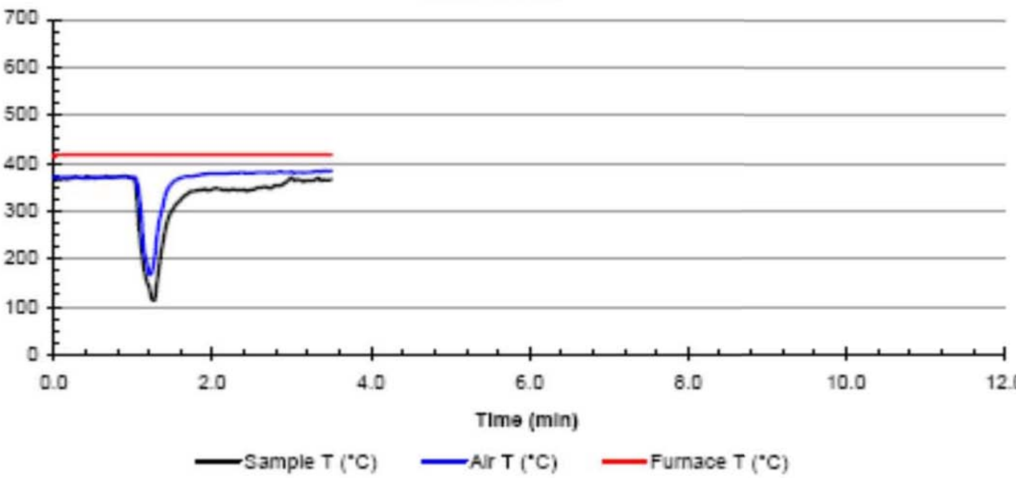
RESULTS

Test ID	Initial Mass (g)	Final Mass (g)	Mass Loss (g)	Initial Temperature (°C) Sample	Air	Furnace	Final Temperature (°C) Sample	Air	Furnace	Ignition
2884-9	0.35	0.06	0.29	349	350	390	356	353	392	No
2884-10	0.36	0.02	0.34	368	370	417	366	381	417	Yes
2884-11	0.34	0.03	0.31	356	360	398	360	362	399	No

FLASH IGNITION OBSERVATIONS

	Insertion Time (min:sec)	Combustion Type	Observed Soot (min:sec)	Observed Smoke (min:sec)	Observed Foam (min:sec)	Observed Melt (min:sec)	Observed Bubbling (min:sec)	Total Test Time (min:sec)
2884-9	1:12	None	None	None	None	None	None	11:12
2884-10	1:18	Flaming at 3:02	None	3:10	None	None	None	3:30
2884-11	1:16	None	None	None	None	None	None	11:16

Test ID 2884-10

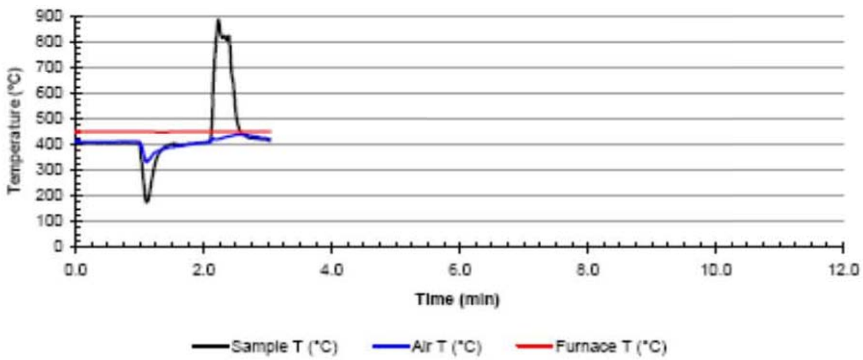


2884-6	0.34	0.02	0.32	427	430	469	848	448	470	Yes
2884-7	0.35	0.03	0.32	417	420	461	839	437	462	Yes
2884-8	0.34	0.02	0.32	405	**410**	450	817	423	449	Yes

SPONTANEOUS IGNITION OBSERVATIONS

	Insertion Time (min:sec)	Combustion Time (min:sec)	Observed Soot (min:sec)	Observed Smoke (min:sec)	Observed Foam	Observed Melt	Observed Bubbling	Total Test Time (min:sec)
2884-2	1:20	None	None	1:30	None	None	None	11:20
2884-3	1:10	None	None	1:16	None	None	None	11:10
2884-4	1:11	Flaming at 1:49	1:49	1:13	None	None	None	1:49
2884-5	1:14	Flaming at 2:00	2:01	1:16	None	None	None	2:01
2884-6	1:15	Flaming at 1:59	1:17	1:18	None	None	None	1:59
2884-7	1:10	Flaming at 1:45	1:12	1:14	None	None	None	1:45
2884-8	1:08	Flaming at 2:09	2:12	1:14	None	None	None	3:00

Test ID 2884-8



APPENDIX E. FOAM COVERED WALL PANEL TESTS

E.1 GEOMETRY

The video taken inside the nightclub demonstrated how quickly the foam ignited and how quickly the fire developed. The cellular structure of the polyurethane foam provides a very low density fuel layer that burns quickly. A series of wall burns were conducted to provide insight into how the geometry impacted the growth and spread of the fire. These data assisted in the design of the mockup experiments and provided guidance for the simulation of the entire nightclub.

Ignition of the foam on the wall of the nightclub by the gerbs occurred at the edge of an exterior corner of the drummers alcove, as described in Chapter 4. During the first 15 seconds of the fire, flames spread quickly upward and less quickly downward and laterally. To simulate this arrangement, two 0.064 m (0.25 in) thick plywood backer board panels, each 1.22 m (4 ft) x 2.44 m (8 ft), were mounted perpendicular to each other to form an external corner as shown in Figure E-1. The panels were supported on 2 x 4 studs and covered with a full sheet of non-fire retardant polyurethane foam (1.22 m x 2.44 m x 0.025 m) from lot A. The plywood was screwed to the studs and the foam was mounted to the plywood using staples and adhesive.

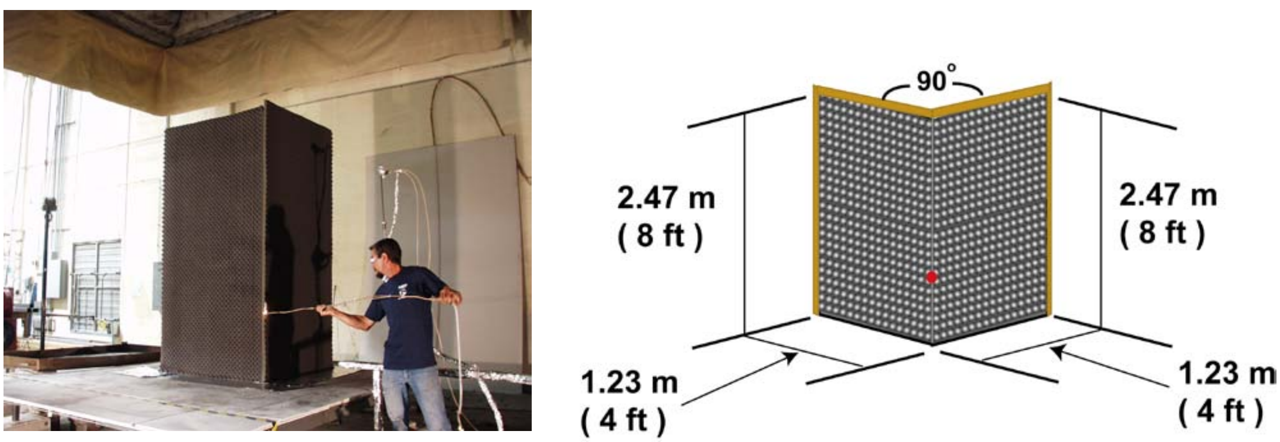


Figure E-1. Photograph and Dimensioned Diagram of External Corner

A second experiment used the identical 1.22 m (4 ft) x 2.44 m (8 ft) panels (0.025 m thick non-fire retarded lot A polyurethane foam on 0.064 m (0.25 in) thick plywood backer board, supported on 2 x 4 studs), but arranged to simulate an internal corner. (See Figure E-2.) An internal corner leads to faster flame spread than an external corner since in the former arrangement each surface is exposed to radiant heating from the adjacent wall. In both the mock-up and the actual nightclub fire, flame spread was enhanced further by the presence of the hot layer that built up at the ceiling. The corner arrangements examined here were open to the environment at the top (no ceiling); hence, the flame spread did not continue to accelerate.

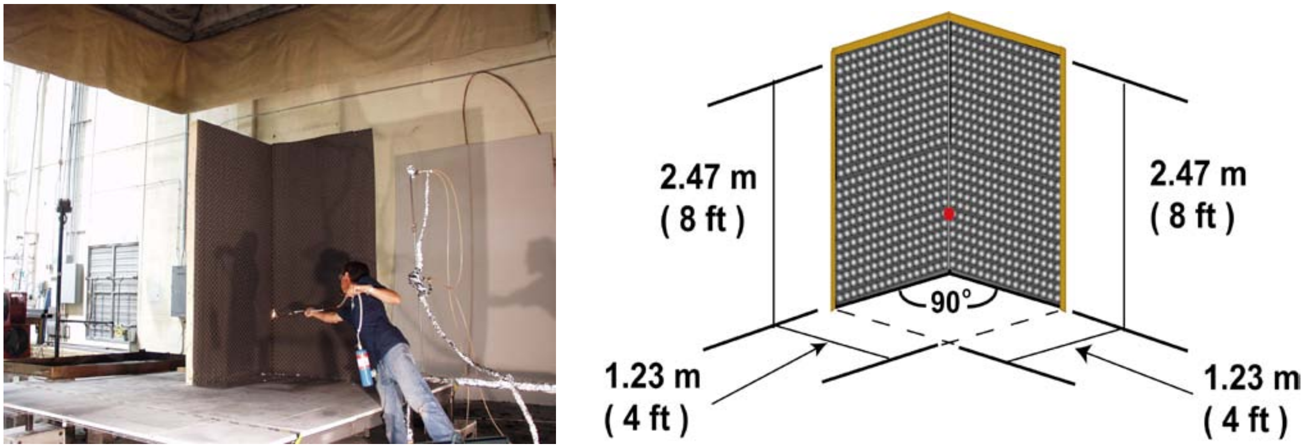


Figure E-2. Photograph and Dimensioned Diagram of Internal Corner

A propane torch was used to ignite the corner of the foam at 0.61 m (24 in) above the floor. While this was lower than the point of ignition in the nightclub, the purpose of these experiments was not to duplicate the fire growth, but to provide a controlled environment in which flame spread measurements (upward, downward, and lateral) could be accurately determined. The fire was videotaped from two directions, and the radiant heat flux and total heat release rate were measured. Figure E-3 includes a video of the external corner burn and internal corner burn, side by side, with a clock.

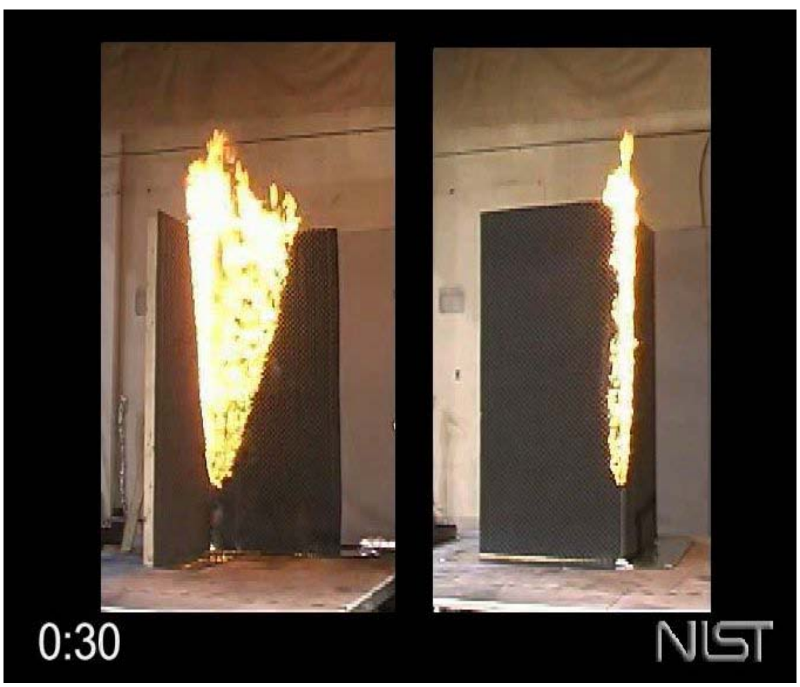


Figure E-3. Video of External and Internal Corner Burns

E.2 DESCRIPTION OF THE FIRES AND HEAT RELEASE RATES

E.2.1 External Corner Configuration

Figures E-3 (right video) and E-5 show the progression of fire in the external corner configuration for the first 610 seconds of the test. The flame spread can be broken into four distinct phases. In the first phase, the fire spreads upward rapidly, with flames reaching the top of the panel before they have had much chance to spread downward or laterally. Once the flames have reached the top of the panel, lateral spread occurs in the second phase, resulting in a vee-shaped flame with the vertex at the corner slightly below the point of ignition. The polyurethane melts and flows down the corner in the third phase, rapidly causing the flame to extend to the ground and to create a small pool fire. In the fourth phase, the flame extends from the floor to the upper edge of the panel, forming a line fire which spread laterally along the bottom and top edges. The flame on the upper horizontal edge reaches the vertical extent of the panel first, at which time the fire spreads downward until all of the foam is consumed. By the end of the test, the plywood backing can be seen to be burning near the initial point of ignition.

Since the wall panels were burned under an instrumented calorimetry hood, it was possible to utilize oxygen depletion measurements to calculate the heat release rate. The results for the external corner are plotted as the blue line in Fig. E-4. The heat release rate reached a peak value of 200 kW between 160 and 180 seconds after ignition. From the photos in Fig. E-3 taken 120 and 180 seconds into the burn, one can attribute this peak to the pool fire enhanced burning during the third phase of flame spread. The heat release rate included the energy released by all the fuel. Initially, the burning of the foam contributed most of the energy released by the fire while the wood contributed more energy as the foam was consumed. During phase 4, the heat release rate gradually reduces to about half its maximum value until

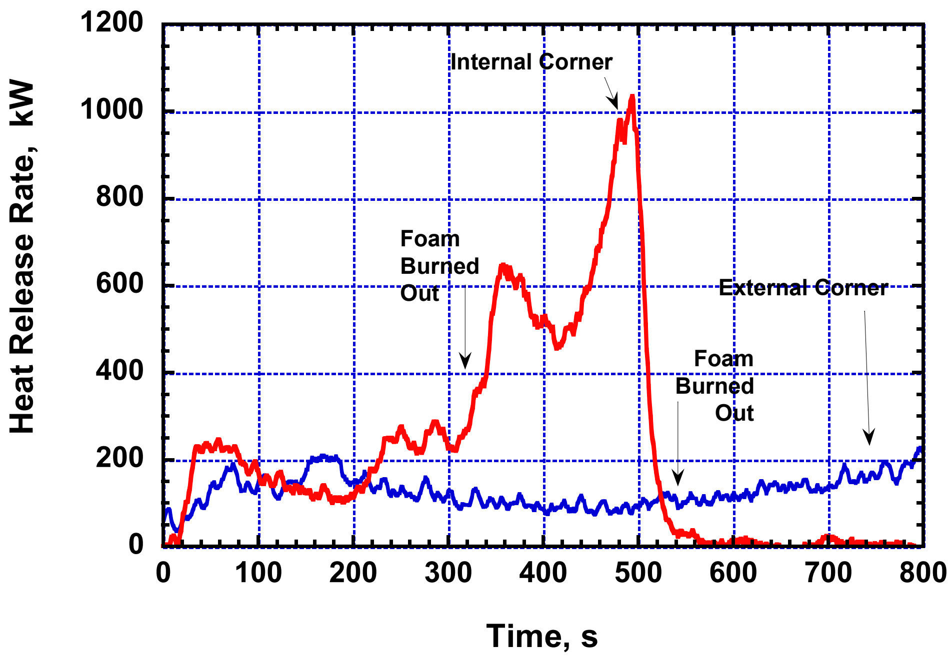


Figure E-4. Heat release rate versus time for external and internal corner configurations of foam covered wall panels.

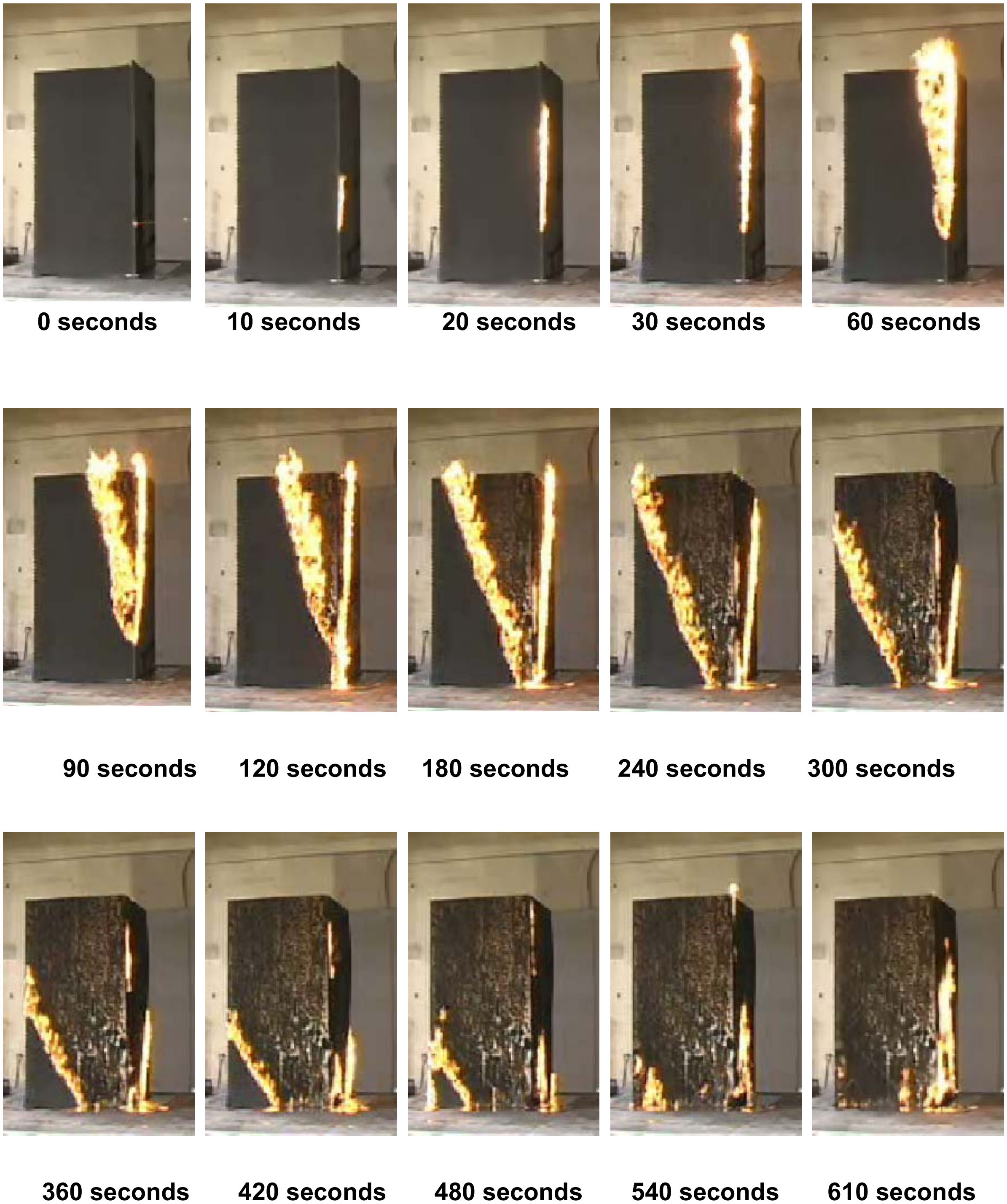


Figure E-5. Flame spread over polyurethane foam covered panels, external corner configuration.

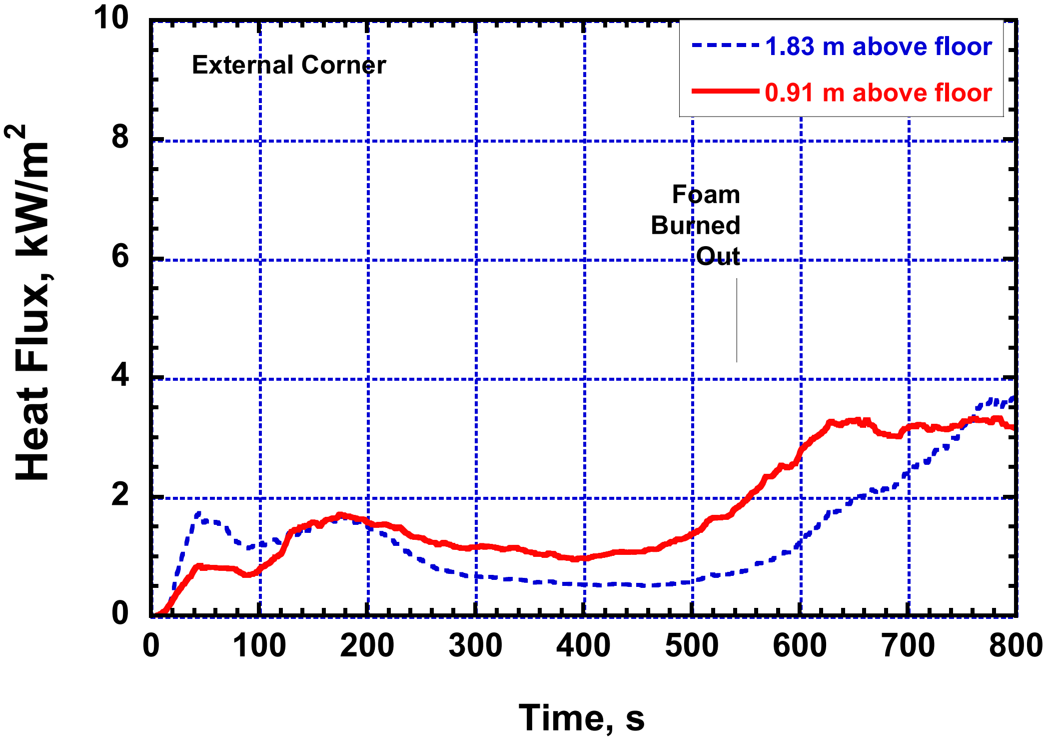


Figure E-6. Heat flux versus time for external corner burn.

almost all of the foam has been consumed at 540 seconds. The increase in heat release rate seen in Fig. E-4 after this point in time is due to the burning of the plywood panel. The irradiation perpendicular to and 2 m from the burning surface mirrors the heat release rate, as shown in Fig. E-6, attaining a value slightly above and below 1 kW/m^2 from measurements 0.91 m and 1.83 m, respectively, above the bottom of the panel.

The total energy contributed by the foam to the fire can be estimated from the area under the blue curve in Fig. E-4 to be 60 MJ to 70 MJ. This compares to any energy content of about 95 MJ for two 1.22 m x 2.44 m x 0.025 m thick panels of foam, using a heat release per unit area of 15.8 MJ/m^2 as measured in the cone calorimeter with an incident flux of 35 kW/m^2. The difference in total energy may be attributable to residual foam on the panel, liquid fuel that remained unburned on the floor, or less complete combustion of the panels as compared to the cone calorimeter sample irradiated at 35 kW/m^2.

E.2.2 Internal Corner Configuration

The internal corner test was conducted in the same manner as the test described above. Figure E-8 captures the fire during the first 400 seconds of the test. The same four phases of fire growth can be seen in Fig. E-5, however the rate of growth is considerably faster than occurred in the external corner configuration (compare left and right videos in Fig. E-3), as would be expected due to the enhanced feedback from the adjacent panel. The third phase, in which the melting foam forms a pool at the corner and rapidly drives the downward spread to the floor, occurs around 40 seconds into the internal corner test, as compared to some time around 120 seconds in the external corner test. The pool fire continues to burn and grow while the line fire associated with the fourth phase is established. By 400 seconds, the plywood backing is fully involved. A careful inspection of Fig. E-5 reveals what appears to be a continuously burning melt pool along the bottom edge of the panels as late as 400 seconds into the test.

The heat release rate from the internal corner test is plotted as the red line in Fig. E-4. The irradiation measured perpendicular to and 2 m away from the panel is plotted in Fig. E-7. The shapes of the first 200 seconds for both plots are similar to what was found during the first 500 seconds of the external corner test, although the magnitudes are larger for the internal corner fire; that is, a peak heat release rate in excess of 200 kW, corresponding to the phase 3 burning, occurs early, followed by a gradual decrease to about half the peak heat release rate, and the heat flux from the surface during this period is a bit over 1 kW/m^2 . The Beyond 200 seconds, the internal corner test undergoes a more complicated behavior, as the pool fire at the base of the panel grows. The vertical arrow at 310 seconds marks the time when no more foam was visible on the wall panels. The pool fire from the melted foam reached a maximum heat release rate of 650 kW about 360 seconds into the burn. The increase in the fire size after 420 seconds is caused by the burning plywood along the vertical corner. The fire was extinguished at 490 seconds. [Note that while the shape of the flame seen in Fig. E-8 at 400 seconds is reminiscent of the M-shaped pyrolysis region reported by Qian et al.[1], inspection of the panels following their extinguishment revealed that the dark region seen in the photo along the vertical corner was due to complete burnout of the thin plywood panel.]

The total energy released by the fire can be estimated by integrating the area under the red curve in Fig. E-4. There is a substantial uncertainty in how much of the power to attribute to the foam and how much to the wood for times longer than 300 seconds. If one assumes that that the measured heat release rate between 310 and 410 seconds is due primarily to the liquid fuel at the base of the wood panels, then the total energy released by the foam would be about 106 MJ, which is greater than the 95 MJ of energy

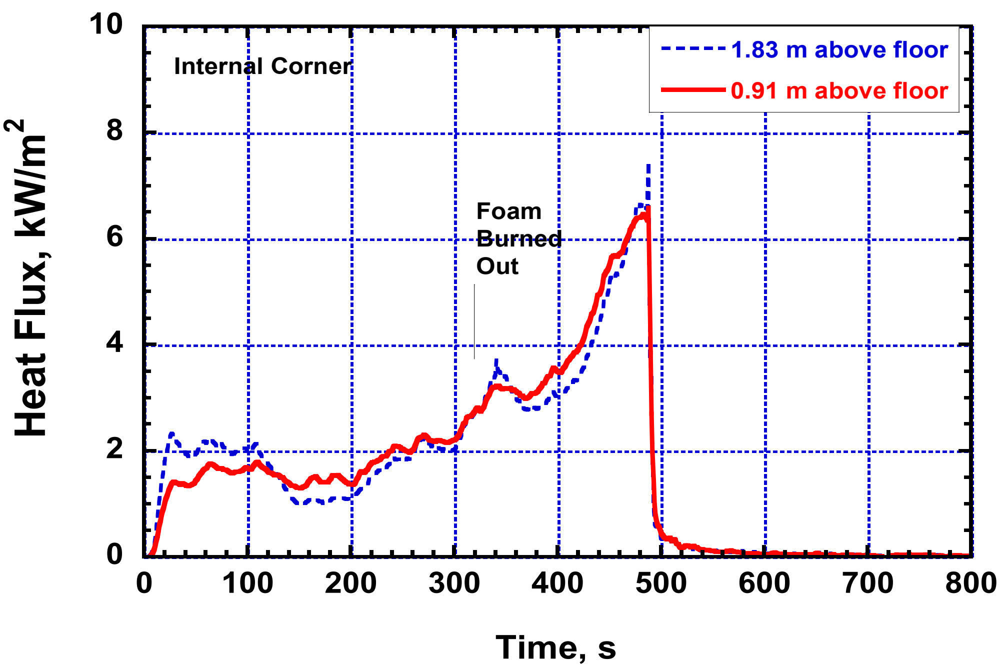


Figure E-7. Heat flux versus time for external corner burn.

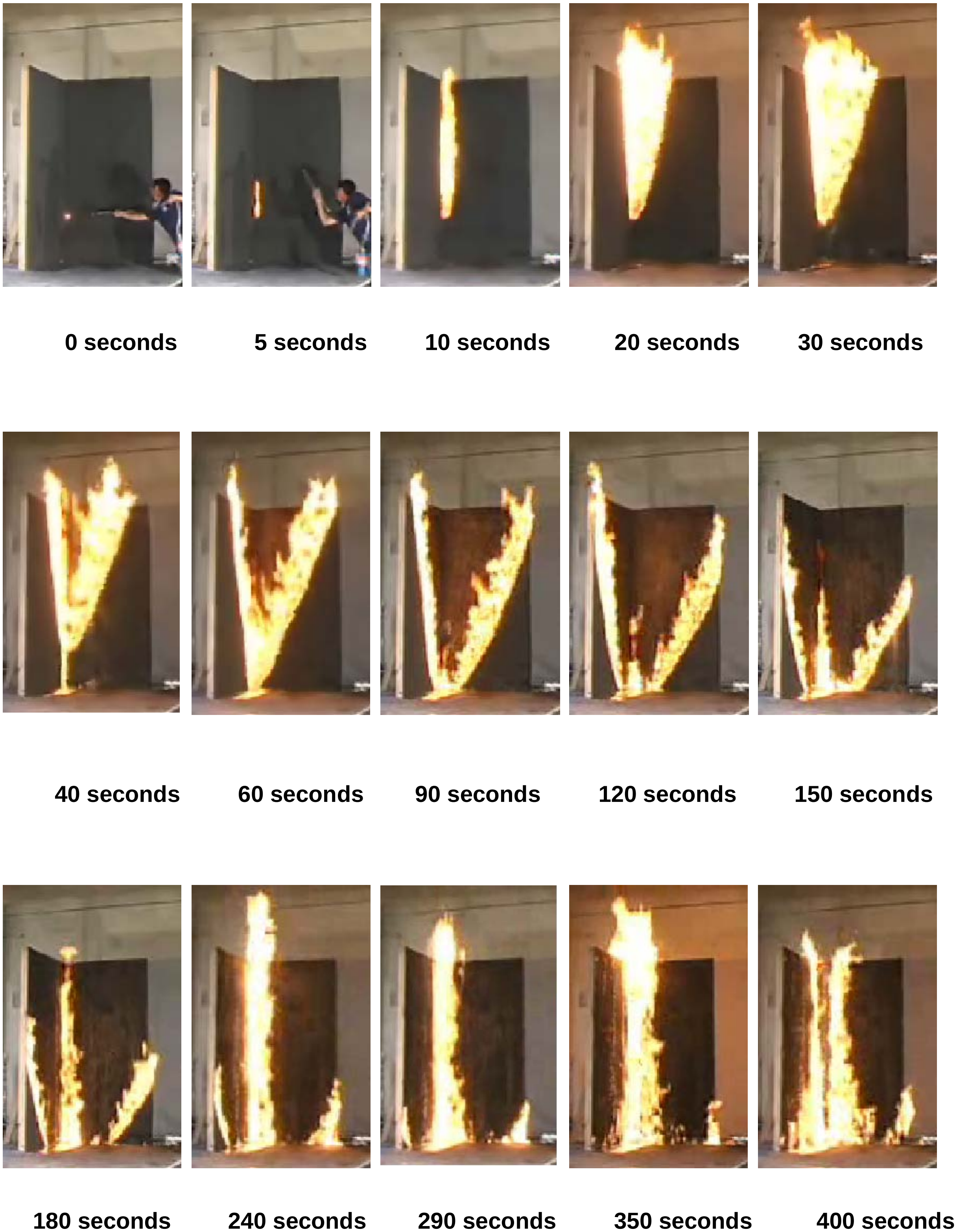


Figure E-8. Flame spread over polyurethane foam covered panels, internal corner configuration.

estimated to be in the two foam panels. The burning wood accounts for much of this discrepancy, although it is also likely that the internal corner would produce more complete combustion than the external corner due to the enhanced radiant interchange between the two adjacent panels.

E.3 FLAME SPREAD RATES

E3.1 External Corner Configuration

The speed at which the flames travel across the foam surface during each of the four phases of the fire can be estimated from the video record. While it is not possible to see through the flame to the pyrolysis zone during the first phase, when upward flame spread is dominant, the brightest portion of the flame can be used as a marker of the pyrolysis zone to roughly estimate the upward flame spread rate. The position of the leading edge of the flame in countercurrent regions provides a more accurate measure of the movement of the bulk of the pyrolysis zone as long as the time required to burn through the thickness of the foam is much less than the time for the flame to move across the surface. This is a reasonable assumption for a relatively thin sheet of low density, highly porous material like polyurethane foam, and is confirmed by inspection of the burned out regions behind the countercurrent flames.

Figure E-9 is a plot of the position of the flame along the boundaries of the panel as a function of time, showing the upward, downward (initially on the right of the panel, and later along the left edge), and lateral flame spread (along the top and bottom, respectively) as a function of time and position. The dotted lines in the figure are drawn to represent the approximately steady region of flame spread, and their

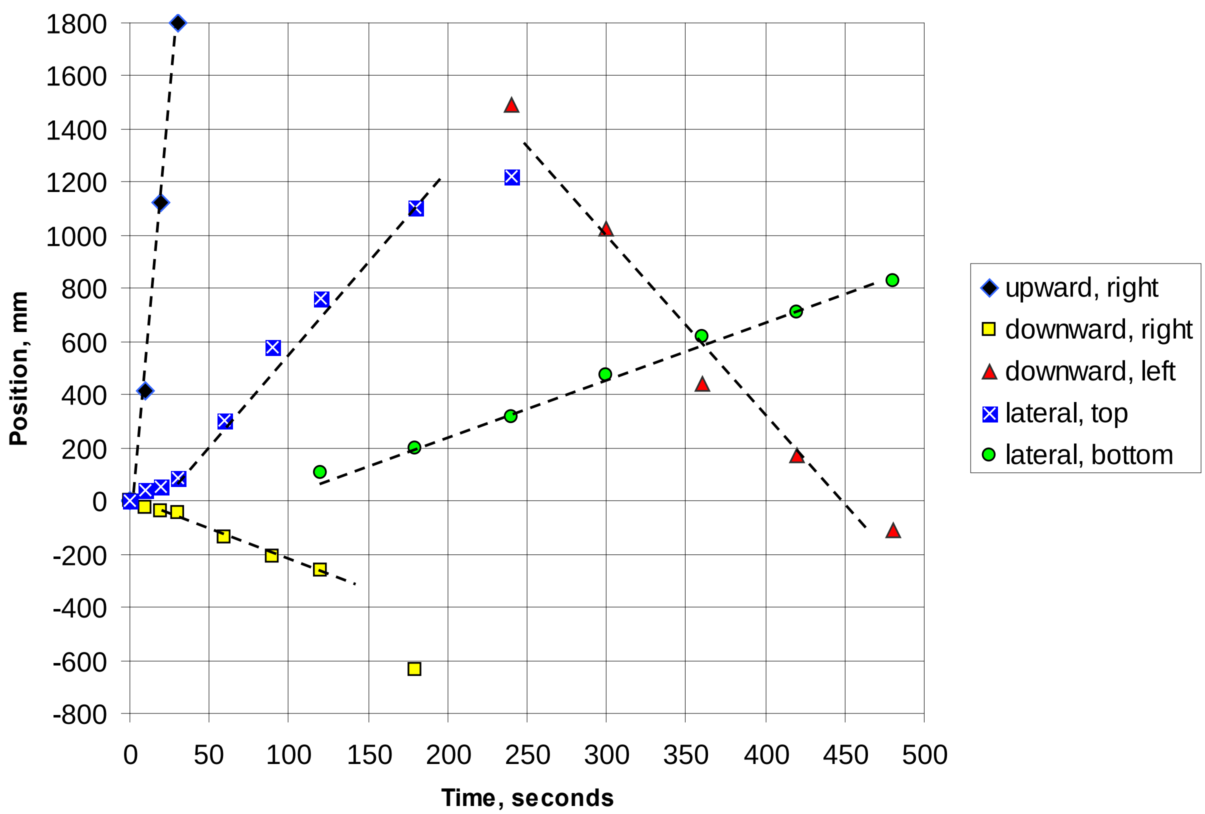


Figure E9. Flame position relative to ignition point on external corner configuration

Table E-1. Approximate flame spread rates over flexible polyurethane foam panels configured as vertical corners

Burning Phase	Direction of Spread	External Corner	Internal Corner
I	Upward (co-current)	63 mm/s	135 mm/s
II	Downward (counter-current)	2.3 mm/s	6.4 mm/s
II - IV	Lateral, top (counter-current)	6.8 mm/s	24 mm/s
IV	Lateral, bottom (counter-current)	2.2 mm/s	4.4 mm/s
IV	Downward (counter-current)	7.0 mm/s	14 mm/s
II, IV	Normal (counter-current)	7.2 - 7.3 mm/s	15 - 25 mm/s

slopes correspond to the respective spread rates. Table E-1 provides a summary of the estimated spread rates for the external corner configuration. The last row is the normal flame speed (the vector sum of the horizontal and vertical components) during the later phases of burning. The flame speed decreases from a maximum of 63 mm/s in the upward direction to just over 2 mm/s in the downward and lateral direction along the bottom edge of the panel. The normal flames speed during the steady burning period is 7.2 to 7.3 mm/s.

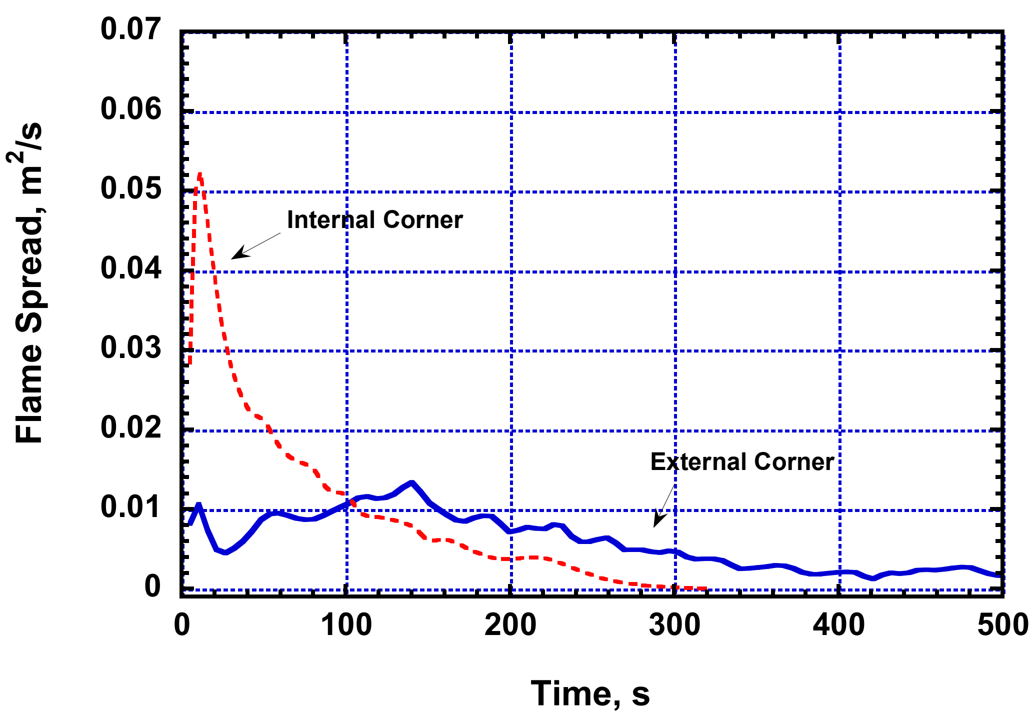


Figure E-10. Flame spread across foam covered wall panel (m^2/s).

The video images were processed to track the unburned portion of the panel not covered by flames to provide an estimate of the surface area burning rate. The result is shown as the blue line in Fig. E-10. Following a small spurt during the initial rapid upward flame spread, the area burning rate drops and then slowly increases in the second and third phases to reach a peak of 0.013 m^2/s about 140 seconds into the fire. The area burning rate gradually declines over the phase 4 period as the line of fire shortens about linearly with time. From the estimated downward and lateral flame speeds listed in Table E-1 and assuming the shape of the unburned foam remains approximately congruent to a triangle formed by the edges and diagonal of the panel, the area burning rate can be expressed as $(X_0 v_y + Y_0 v_x)/2 - v_x v_y (t - t_0)$, where X_0 and Y_0 are the lengths of the sides of the panel, v_x and v_y are the components of the normal flame velocity, and t_0 is the time when the flame begins moving downward along the outer edge of the panel. Using this formulation the area burning rate diminishes from 0.0070 m^2/s at 200 seconds to 0.0024 m^2/s at 500 seconds, consistent with the more accurate calculation represented by Fig. E-10.

E.3.2 Internal Corner

A similar analysis was conducted for the flame spreading over the polyurethane foam panels in the internal corner configuration. Figure E-11 shows the position of the flame, relative to the initial ignition point, as a function time. The same flame spread regions can be identified as with the external corner test. The time axis in Fig. E-11 has been expanded by a factor of two over Fig. E-9, indicative of the faster flame spread associated with the internal corner.

The last column in Table E-1 lists the flame spread rates, taken from the slopes of the curves in Fig. E-11, for different directions throughout the duration of the test. The table entries are two to three times faster than for the external corner, with the biggest difference being the lateral spread across the top of the panels (compare 24 mm/s to 6.8 mm/s). This is the region which is exposed to the largest flames and the highest view factor to enhance the surface irradiation.

The red line in Fig. E-10 is a plot of the area burning rate determine by processing the video images such as those seen in Fig. E-3 and E-8. The initial peak exceeds 0.05 m^2/s, which undoubtedly is an over estimate since the quickly growing flames conceal a portion of the foam panel that has not had time to be completely consumed. Applying the same formulation $[(X_0 v_y + Y_0 v_x)/2 - v_x v_y (t - t_0)]$ developed in section E.3.1 for the area burning rate, a lateral flame speed of 4.4 m/s, and a downward flame speed of 14 mm/s, the flame spread can be estimated to decrease from 0.014 m^2/s at 90 seconds to 0.001 m^2/s at 300 seconds, again consistent with Fig. E-10.

E.4 COMPARISON OF RESULTS TO MOCK-UP AND OTHER STUDIES

E.4.1 Fire Spread in Platform Area Mock-up Experiment

The geometry of the foam panels used in the full-scale mock-up of the drummer's alcove and the area around the platform was considerably more complex than the simple corners used in the flame spread experiments described above. The most significant complication comes from the ceiling, which produces horizontal edges and three-dimensional corners that affect the heat feedback and the flame spread mechanisms. The second significant effect of the ceiling is that it traps the combustion products and heat, leading to a vitiated environment and a rapidly increasing source of thermal radiation, either of which can greatly alter the flame spread rate.

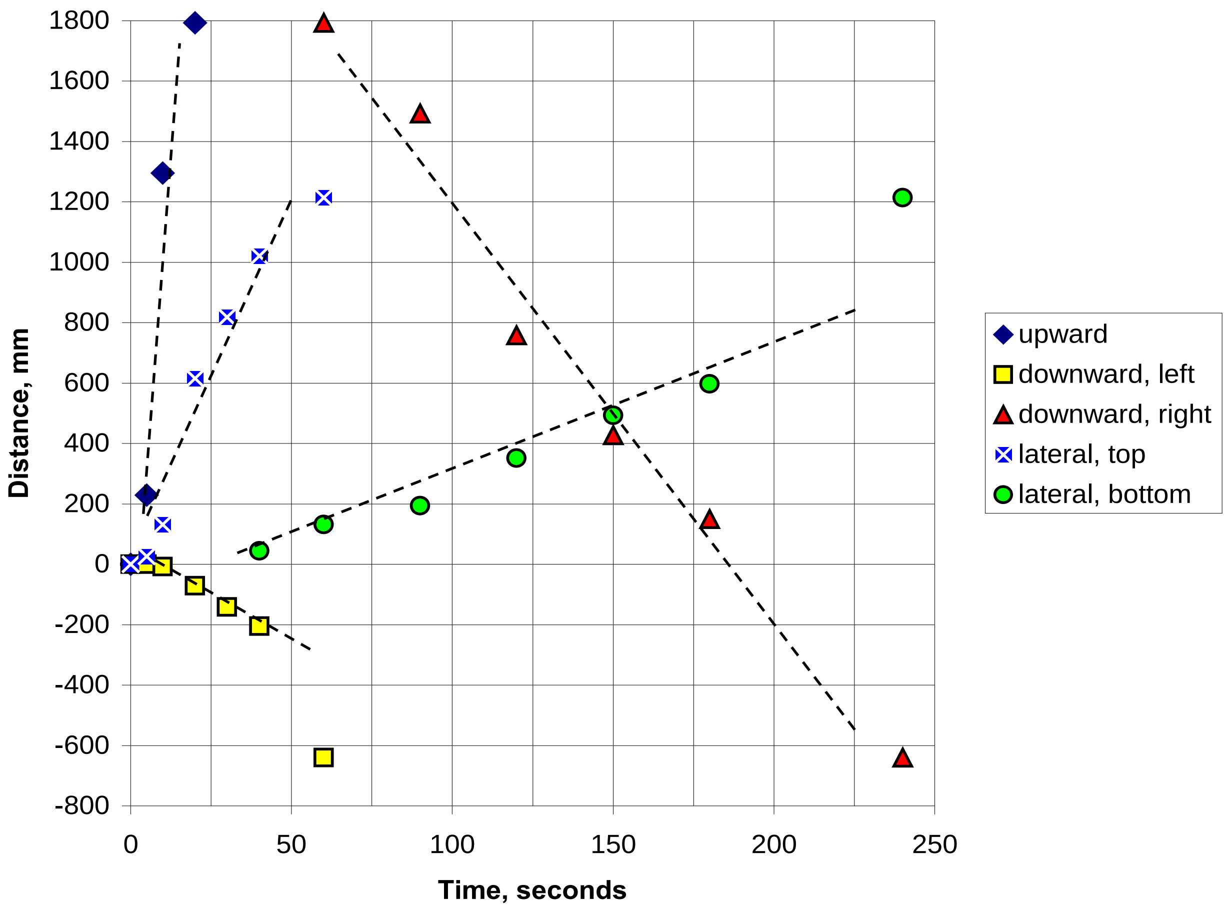


Figure E-11. Flame position relative to ignition point on internal corner configuration

If the video of the fire spread across the face of the east wall along the back of the platform is analyzed in the same manner as the fire spread across the corner panels, the following estimates of flame spread can be achieved:

- upward spread rate (0-10 seconds): 60 mm/s to 100 mm/s
- downward spread rate (0-20 seconds): 4 mm/s to 5 mm/s
- lateral spread rate (10 - 25 seconds): 11 mm/s to 26 mm/s

The lateral spread rate was computed from the increase in the full width of the fire plume, and then reduced by a factor of two to make it comparable to the flame spread in one direction from the corner panel experiments. The lateral flame speed was also determined by tracking the time it took for the thermal wave to reach thermocouples mounted in the foam 300 mm below the ceiling ,every 300 mm along the back wall. Fifteen seconds after ignition, the lateral flame spread rate was 11 mm/s; by 45 seconds after ignition the lateral spread rate had increased to 18 mm/s, in agreement with the video record.

One would expect the flame spread during the initial portion of the fire to be closer to the external corner panel experiments; however, the results for the mock-up in the upward, downward, and lateral flame spread rates lie between those measured in the internal and external corners. It should be noted that the non-fire retarded polyurethane foam used in the mock-up was from lot B, while the foam used in the corner panel experiments was from lot A. While the mass per unit area of the lot A foam was 50 % greater than the lot B foam, cone calorimeter measurements of the peak heat release rates and times to ignition with an irradiation of 35 kW/m^2 were within 5 % of each other.

Dripping of the melted foam along the external corners of the alcove occurred about 25 seconds after ignition. Because the initial point of ignition was much higher in the mock-up than in the corner panel experiments, phase II burning that became prevalent in the latter did not play a roll in the spreading the fire to the floor of the platform.

The lateral flame spread in the northerly direction along the east wall at the back of the platform stalled around 30 seconds after ignition. This appeared to be due to the high rate of air being entrained into the vigorously burning alcove, and the resulting high air velocity running counter to the flame along the back wall. Because the mass loading was less with the lot B foam, the stalled flame allowed the fuel to be consumed without spreading. Thus, the lateral spread mechanism observed in the panel tests did not contribute much to the fire development along the back wall of the platform in the mock-up for more than 30 seconds into the test.

Between 40 seconds and 60 seconds after ignition, most of the action occurred in the alcove, where the heat was transferred effectively to the foam due to intense radiation and high gas temperatures. The hot upper layer developed quickly between 60 seconds and 75 seconds, reaching close to 600 ^{o}C almost everywhere throughout the room. Radiant heat fluxes were measured in excess of 40 kW/m^2 during this period, much higher than imposed by the spreading flame in the corner panel experiments, and above the flux necessary for ignition within a few seconds.

E.4.2 Comparison to Previous Flame Spread Studies

Flame spread is a classic problem for fire science that has been investigated for decades, both theoretically and experimentally. The orientation of the fuel, the direction of the flame spread relative to the air flow, the geometry and properties of the fuel, and the temperature and composition of the environment all play a significant role. For the present discussion, we are interested primarily in counter-current flame spread over vertical walls, with fuels similar to polyurethane.

Quinterre and Harkleroad [2] focused on a method for measuring lateral flame spread over a wide variety of materials. They examined several foams, designated as (1) polyurethane S353M, (2) 25 mm flexible foam, and (3) 25 mm rigid foam. Lateral spread rates of the rigid foam, measured in the LIFT apparatus [4], increased from under 2 mm/s with irradiance levels below 10 kW/m^2 to over 10 mm/s with irradiance levels around 15 kW/m^2. The minimum heat flux necessary for unpiloted ignition was 20 kW/m^2. At this flux level the ignition delay time was around 5 seconds, dropping to about a second at 30 kW/m^2. The 25 mm flexible foam had a much greater lateral spread rate, exceeding a value of 25 mm/s for incident fluxes less than 10 kW/m^2. There is no indication in the report of chemical composition or either the rigid or flexible foams. The one material specifically identified as polyurethane (S353M) was not identified as either rigid or flexible, although it behaved more like the undesignated flexible foam.

Cleary and Quintiere [3] performed additional experiments on foam plastics using several different flammability test methods. For one non-fire retarded polyurethane foam tested in the LIFT apparatus, they measured a maximum flame spread rate of over 40 mm/s with an incident flux of about 10 kW/m^2, the highest flame spread rate at that flux level of all the materials evaluated.

In both of the above studies, the flame spread velocity (v_L) is assumed to be inversely proportional to the product of the effective thermal conductivity (k), density (ρ) and specific heat (c) of the foam according to the relationship [2]

$$v_L = \Phi\, h^2/(k\rho c)\, /(q''_{ig} - q''_{e})^2$$

where h is the heat transfer coefficient to the surface, q_{ig} is the heat flux necessary to ignite the material in a finite period of time, q''_e is the imposed heat flux, and Φ is a flame heating parameter.

An effective value is used for (kρc) because the properties change with temperature and the extent of pyrolysis. The ignition delay time measured in the cone calorimeter, t_{ig}, can be used to estimate (kρc) from the following relationship [2]:

$$k\rho c = 4/\pi\, [q''_e/(T_{ig} - T_s)]^2\, t_{ig}$$

where (T_{ig} - T_s) is the difference between the ignition temperature and the initial surface temperature of the material. For the PUF-NFR-B, at 35 kW/m^2 the time to sustained ignition was 6 seconds. Using an ignition temperature of 370 ^{o}C as measured by Southwest Research Institute for this foam, kρc is calculated to be 0.075 (kW/m^2-^{o}C)^2-s. This compares to 0.001 (kW/m^2-^{o}C)^2-s computed from the reference values in Table 4.1, and to 0.036 (kW/m^2-^{o}C)^2-s as tabulated by Cleary and Quintiere [3] for their non-fire retarded polyurethane foam. For this same foam they found Φ to be equal to 3.1 kW^2/m^3 and q''_{ig} to be 14.5 kW/m^2; for other polyurethanes Φ may be twice as high. With these values, and a natural convections coefficient taken as 0.015 kW/m^2-^{o}C, the lateral flame speed (mm/s) can be related to the irradiation (kW/m^2) by $v_L = 124/(14.5 - q''_e)^2$. To the extent this relationship approximately holds for the PUF-NFR-A material studied in the corner panel configuration, to achieve the lateral spread rate observed in the external corner test (6.8 mm/s) would require a radiant flux from the flame to the surface of about 10 kW/m^2. The internal corner test produced a lateral spread rate of 24 mm/s, corresponding to 33 kW/m^2. If a value for Φ were increased to 6 kW^2/m^3, the required heat flux from the flame to sustain a 24 mm/s lateral flame spread would decrease to 24 kW/m^2.

E.5 REFERENCES FOR APPENDIX E

[1] Qian, C., Ishida, H., and Saito, K., "Upward Flame Spread along PMMA Vertical Corner Walls Part II: Mechanism of "M" Shape Pyrolysis Front Formation," *Combustion and Flame 99:* 331-338 (1994).

[2] Quintiere, J., and Harkleroad, M., "New Concepts for Measuring Flame Spread Properties," NBSIR 84-2943, National Bureau of Standards, November 1984.

[3] Cleary, T., and Quintiere, J., "Flammability Characterization of Foam Plastics," NISTIR 4664, National Institute of Standards and Technology, October 1991.

[4] ASTM E 1321-97a, *Standard Test Method for Determining Material Ignition and Flame Spread Properties*, ASTM International, West Conshohocken, PA, 2004.

APPENDIX F. PYROTECHNIC DEVICE TEST SERIES

F.1 PYROTECHNIC GERBS

A series of full-scale experiments was conducted to document the thermal characteristics of a discharging pyrotechnic device like those that were ignited on stage in the nightclub on Feb. 20, 2003. At the beginning of the show, four separate pyrotechnic devices, or gerbs, were discharged on the platform in front of the alcove. Two gerbs, which had been positioned on the floor of the platform, discharged vertically along the centerline of the alcove opening. Two additional pyrotechnic gerbs, which were located near the other two gerbs on the platform floor, sprayed white "sparklers" at a 45 degree angle to both the left and right sides of the alcove. The WPRI-TV video of the nightclub interior showed that glowing particles or "sparklers" ignited the foam on both sides of the alcove in approximately 10 seconds.

The throw, or distance the hot particles traveled, the period of "sparkler" discharge, and the white appearance of hot particles, were consistent with a pyrotechnic device called a Silver 15 x 15 Stage Gerb. Forty silver 15 x 15 gerbs were purchased from a commercial manufacturer of stage pyrotechnics. Each gerb consisted of a cardboard tube approximately 0.022 m (0.88 in) in diameter and 015 m (6 in) long (Figure F-1)

The gerbs were constructed and ignited as described in the following manner. A non-combustible material was placed inside the tube filling up the upper 0.1 m (4 in) of the gerb. The non-combustible material formed a solid plug near the bottom center of the tube, but provided a hollowed-out cavity for the upper part of the gerb. The hollowed out portion of plug was filled with a mixture of energetic materials and metal compounds. When the energetic materials were ignited, the non-combustible material prevented the hot material from discharging out the bottom or through the walls of the gerb. The hot gases and metallic compounds were sprayed out the upper end of the gerb. The duration of the discharge was determined by the amount of the energetic material placed in the tube. The color of the sparklers was determined by the type of metal compound that was mixed in with the energetic materials. Titanium particles were added to provide a white- or silver-colored sparklers. The inclusion of ferro-titanium particles would produce yellow- or gold-colored sparklers.

Once the gerbs were positioned on the platform, an electrical match was inserted through the cap at the top end of the tube. An electric match consisted of a short section of resistance wire coated with a flammable chemical. When a current was passed through the wire, it heated up and ignited the coating, which in turn ignited the energetic materials in the gerb. The initial combustion generated enough gas pressure to pop the plastic cap off the end of the cardboard tube and to spray hot gases and sparklers to approximately 15 ft (4.5 m) for a period of approximately 15 seconds (hence the term 15 x 15)

For the NIST tests, each gerb or pair of gerbs was discharged either along or against a gypsum board wall. The wall had been painted black to enhance the contrast with the white sparklers. A grid of 0.3 m (1 ft) squares was painted on the wall. Gerbs were discharged in a plane parallel to the wall at an angle of either 45 degrees (Figure F-2) or 90 degrees (Figure F-3) from the horizon. Gerbs were also discharged against the wall in a plane perpendicular to the wall (Figure F-4). Heat flux gauges and thermocouples were embedded in the gypsum wall to monitor the heat flux and gas temperatures. In Figures F-5, F-6, and F-7, one can see how the instrumentation was positioned so that the sparkler discharge was centered

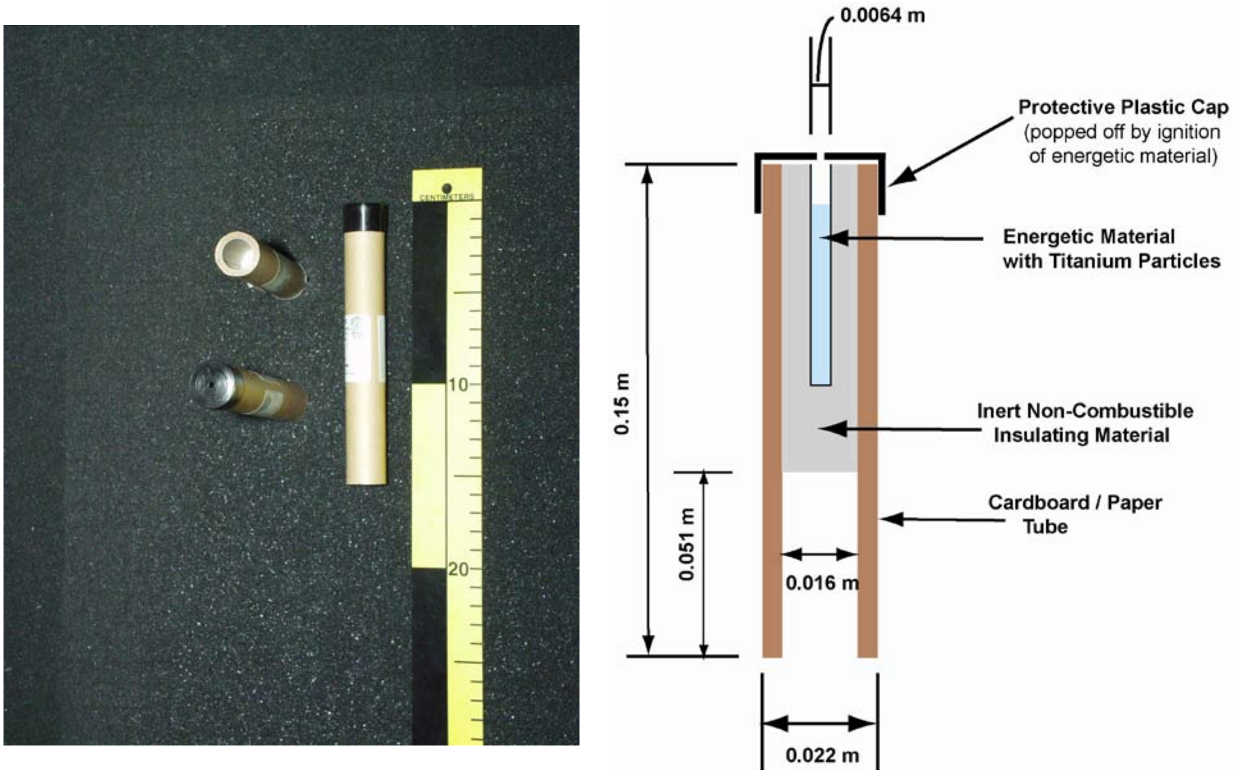


Figure F-1. Photograph of Silver 15 x 15 Stage Gerb and Cross-Sectional Schematic.

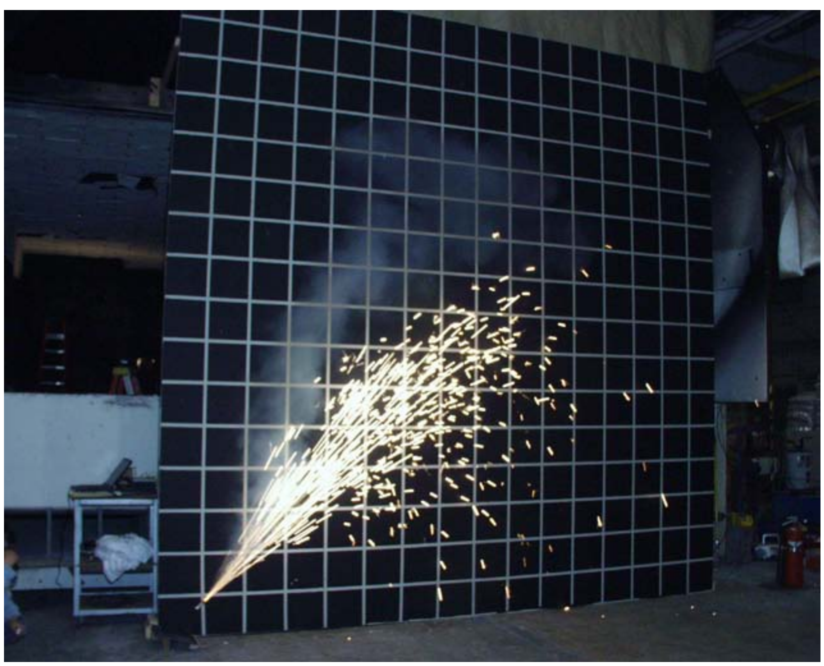


Figure F-2. Single Gerb at 45 Degrees and in Plane Parallel to Wall .

Figure F-3. Two Gerbs at 90 degrees and in Plane Parallel to Wall.

Figure F-4. Single Gerb at 45 degrees and in a Plane Perpendicular to Wall.

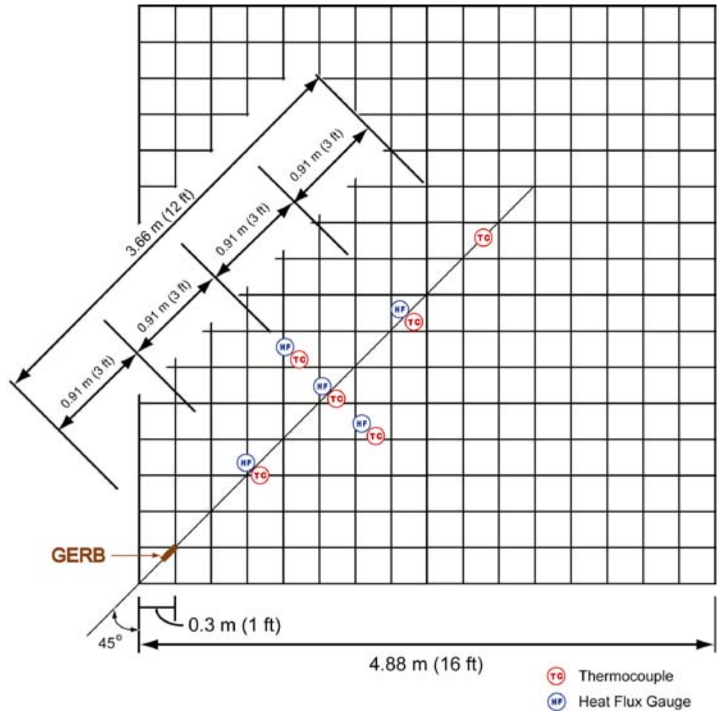


Figure F-5. Instrumentation Diagram for a Single Gerb at 45 Degrees and in Plane Parallel to Wall .

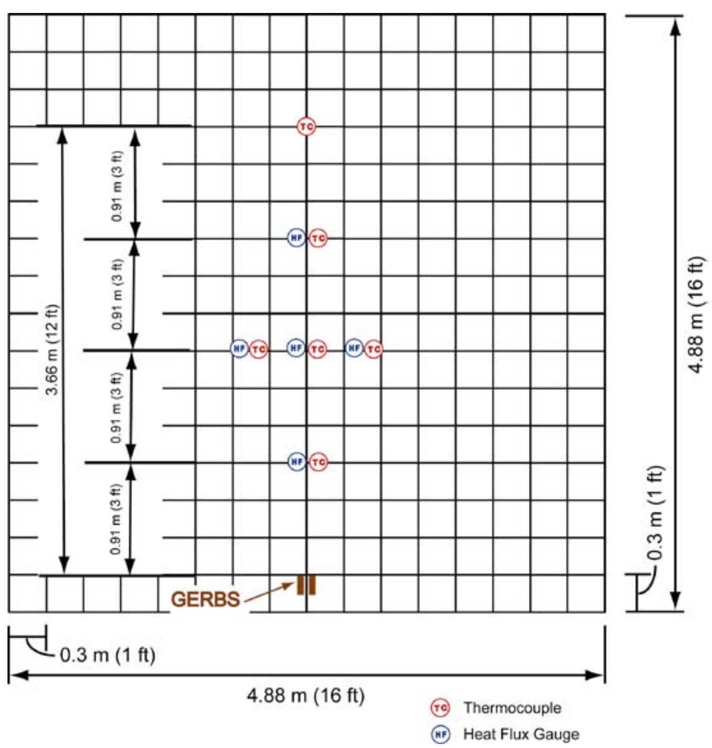


Figure F-6. Instrumentation Diagram for Two Gerbs at 90 degrees and in Plane Parallel to Wall.

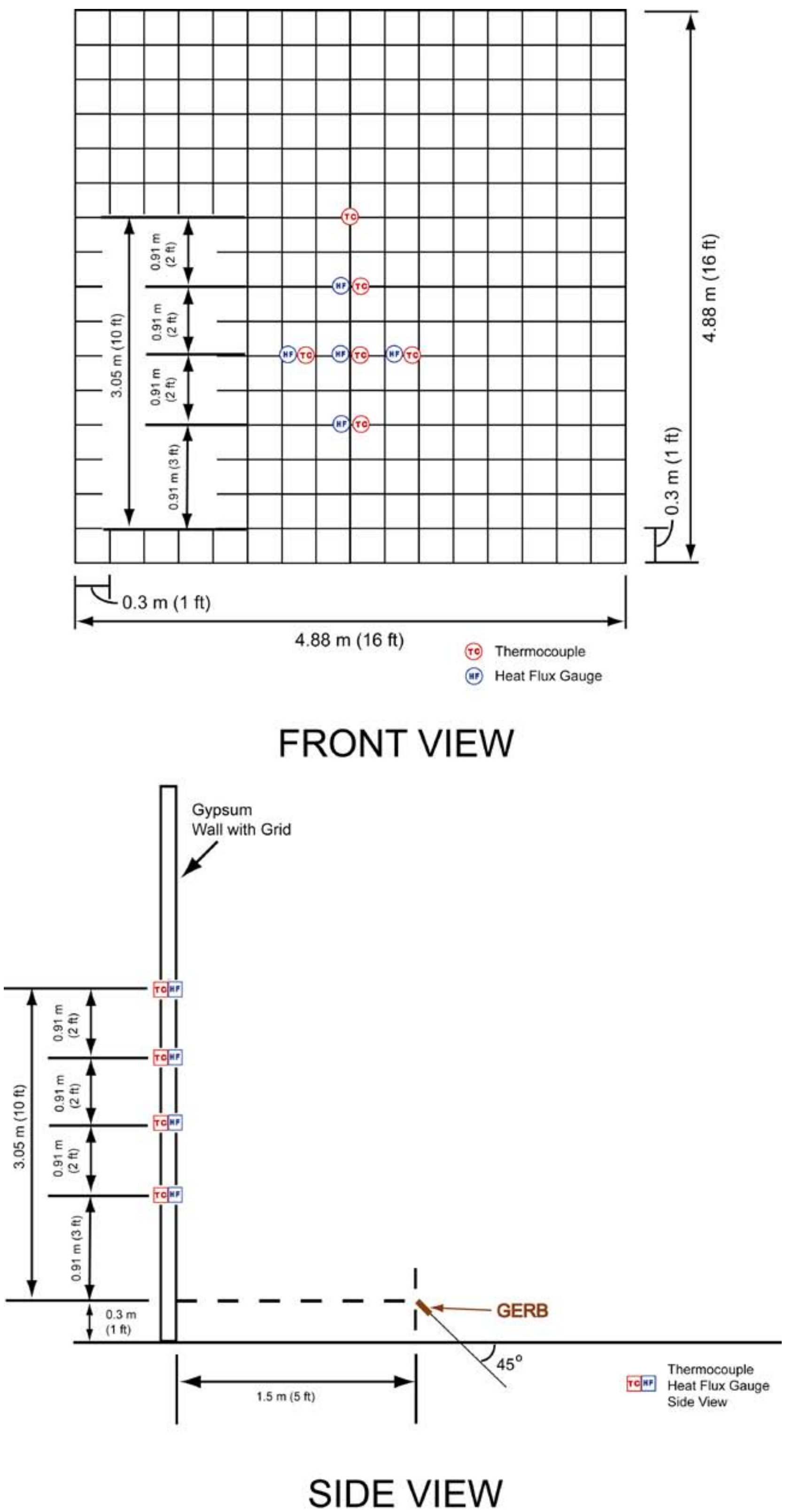


Figure F-7. Instrumentation Diagram for a Single Gerb at 45 degrees and in a Plane Perpendicular to Wall.

over the flux gauges and thermocouples. Electric matches were used to ignite the gerbs. Each discharge was video taped using a standard mini-DV digital video camera and an infrared camera. The infrared camera utilized a barium-strontium-titanate solid-state detector with a spectral response of 8 μm to 14 μm. The IR camera was included in these experiments to provide a qualitative image of the hot gas plume as well as the spray of the white sparklers.

F.2 45 DEGREE DISCHARGE TESTS

As seen in Figs. F-2 and F-4, tests were conducted with gerbs discharged at an angle of 45 degrees to the horizon, either parallel to or perpendicular to the wall Each discharge was recorded using a standard video camera and an infrared camera. For a 45 degree discharge in a plane parallel to the wall, pairs of visible and infrared images are shown for 0s, 2 seconds, 5 seconds, 14 seconds, 15 seconds, and 16 seconds in Figures F-8 to F-13.

The visible images show that each gerb discharged a spray of white sparklers for at least 14.5 seconds, but no more than 16 s. While most of the sparklers were thrown less than 2.74 m (9 ft), a limited number of sparklers traveled in excess of 4.6 m (15 ft) from the tip of the gerb. The infrared images show a central core of hot gases, a plume of warm gases that does not travel as far as the hot metallic particles. The buoyant hot gases developed a vertical trajectory within 1.2 m (4 ft) of the gerb tip. Temperatures and heat fluxes in the plume are plotted in Figs. F-14 and F-15.

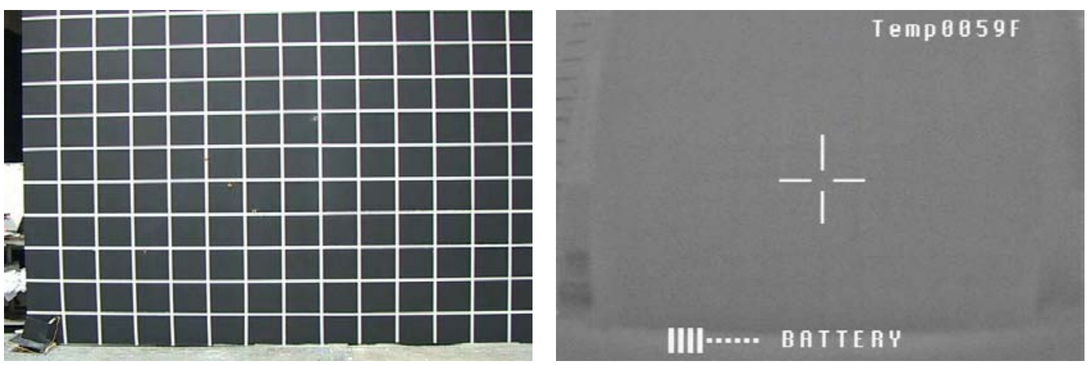


Figure F-8. Standard Video and Infrared Video Images of Gerb Discharge at 0 s.

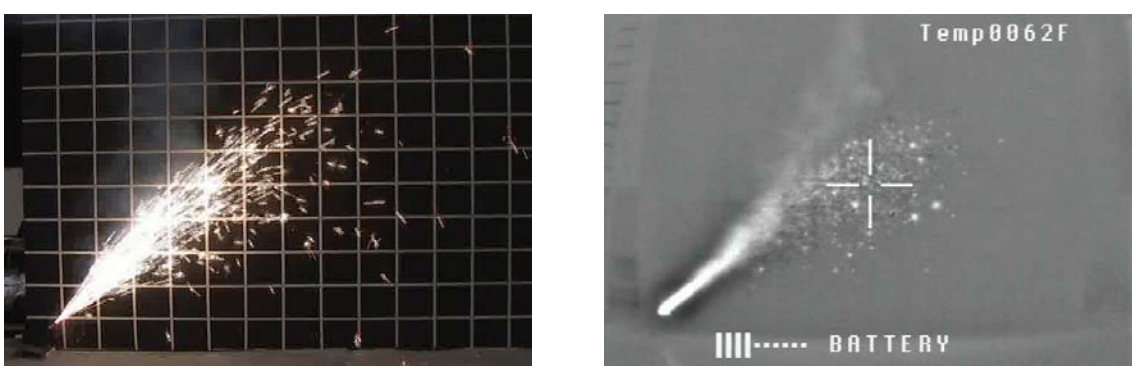


Figure F-9. Standard Video and Infrared Video Images of Gerb Discharge at 2 s.

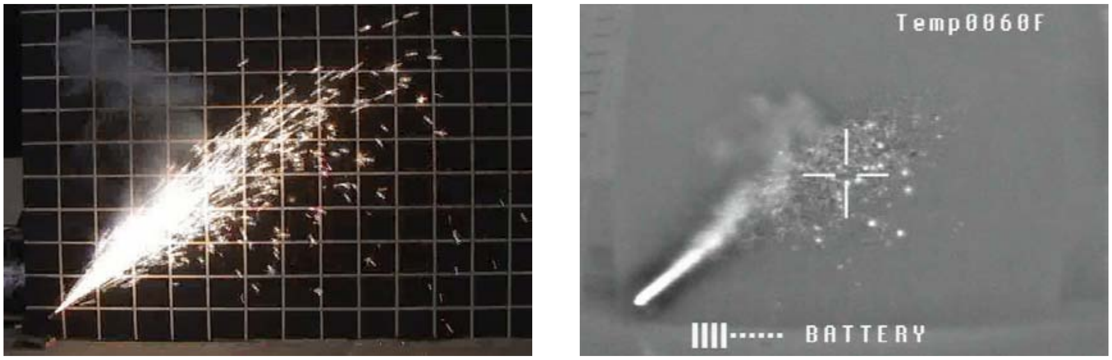


Figure F-10. Standard Video and Infrared Video Images of Gerb Discharge at 5 s.

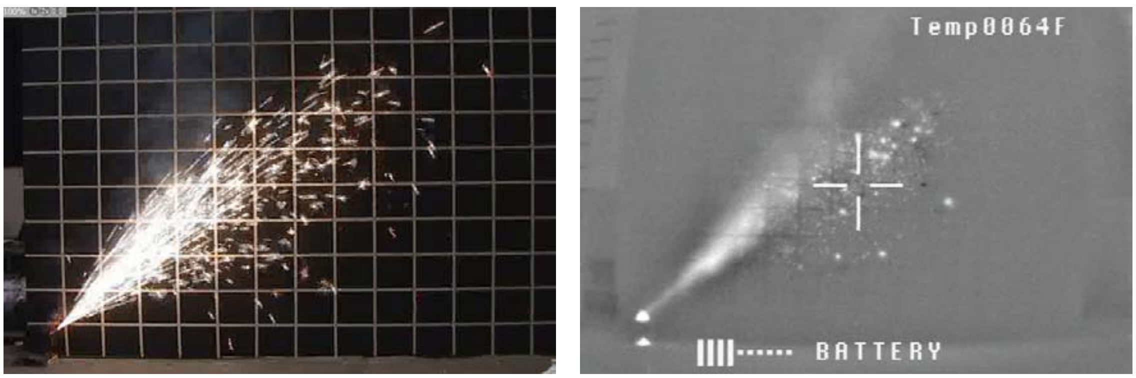


Figure F-11. Standard Video and Infrared Video Images of Gerb Discharge at 14 s.

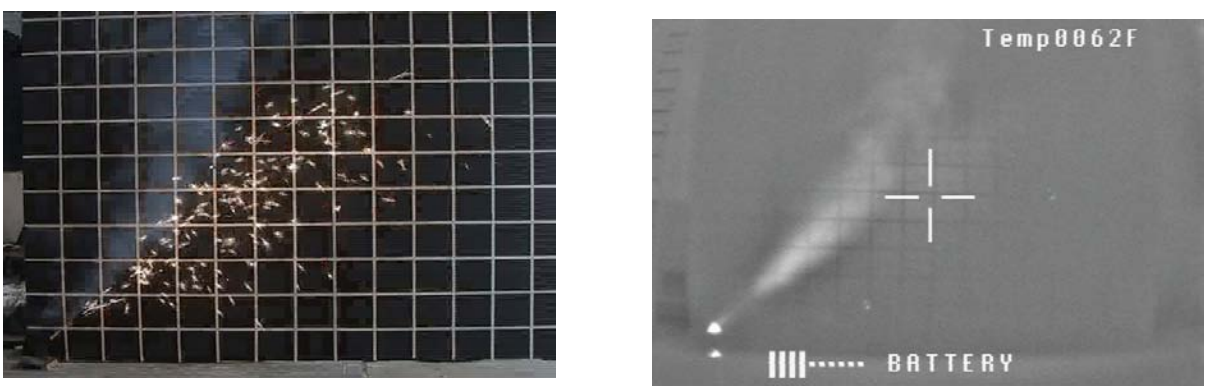


Figure F-12. Standard Video and Infrared Video Images of Gerb Discharge at 15 s.

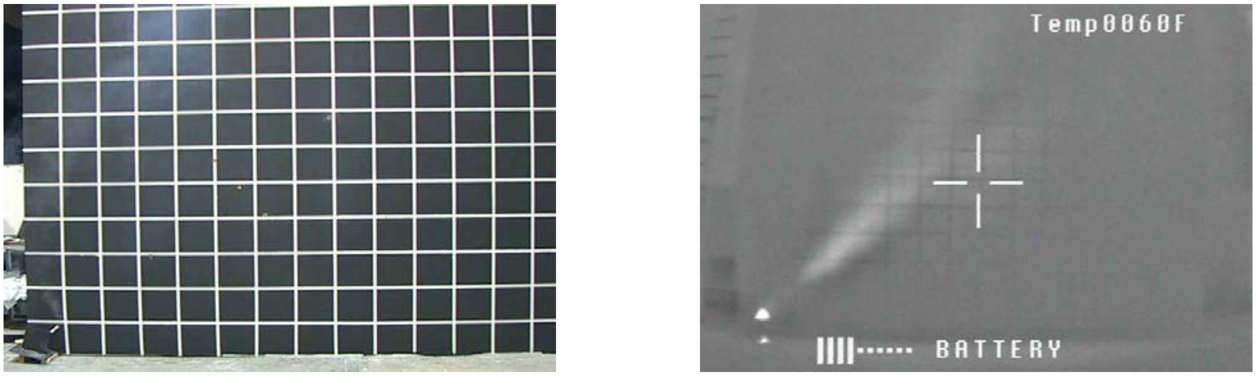


Figure F-13. Standard Video and Infrared Video Images of Gerb Discharge. Time is 16 seconds after ignition.

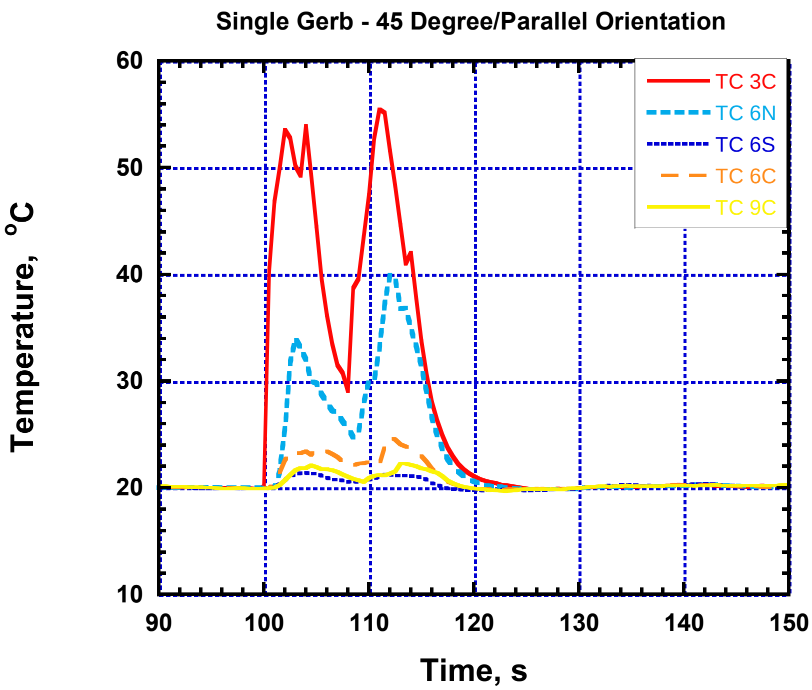


Figure F-14. Temperatures versus Time for Single Gerb Discharged at 45 Degrees in Plane Parallel to Wall.

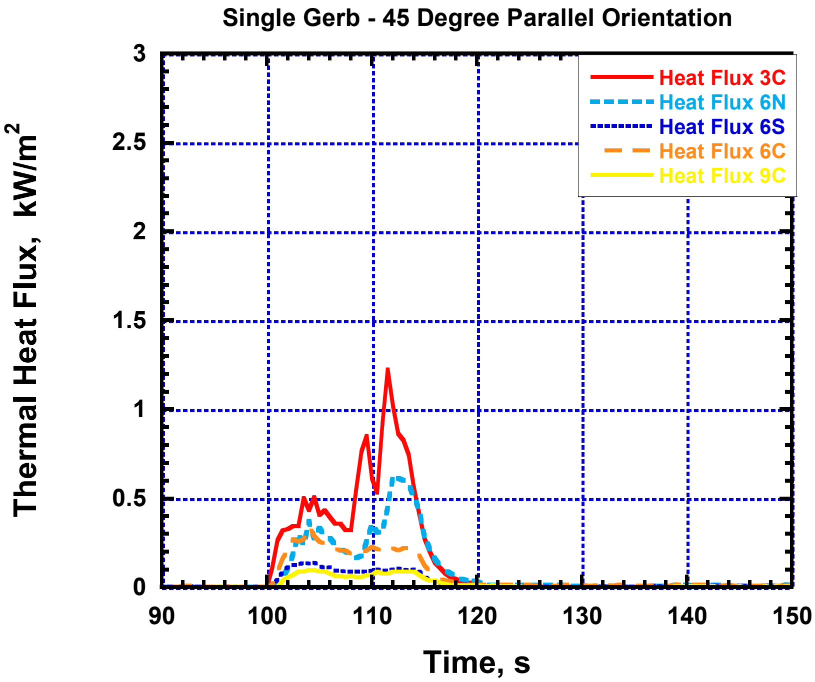


Figure F-15. Temperatures versus Time for Single Gerb Discharged at 45 Degrees in Plane Parallel to Wall.

Testing also was done with a gerb discharging at a 45 degree angle from the horizon and in a plane perpendicular to the wall. The wall was either gypsum board, plywood, non-fire retarded polyurethane covered plywood, or fire retarded polyurethane covered plywood. The results of these tests are presented in Chapter 4, section 4.5. The temperatures measured in the plume for the one case that led to burning of the wall, the non-fire retarded polyurethane foam, are plotted in Fig. F-16a and F-16b. The high temperatures reached 20 seconds into the test (120 seconds on the figure since ignition of the gerb occurred at 100 seconds) are clearly indicative of flaming combustion. Fig. F-16b shows the temperature scale greatly expanded, with the centerline temperature peaking 7 seconds after ignition, followed by a rapid increase in temperature elsewhere in the plume even as the centerline cools due to the end of the discharge from the gerb.

Since the alcove in the nightclub was 3.0 m (10 ft) wide and the gerbs were positioned at the center of the alcove opening, white sparklers would have easily reached both side of the alcove. The plume of hot gases would probably not have directly impinged on the side walls of the alcove. The hot gases would instead have traveled diagonally across the alcove opening and as the plume approached the side walls, the plume would have moved vertically to impinge on the wall above the alcove opening.

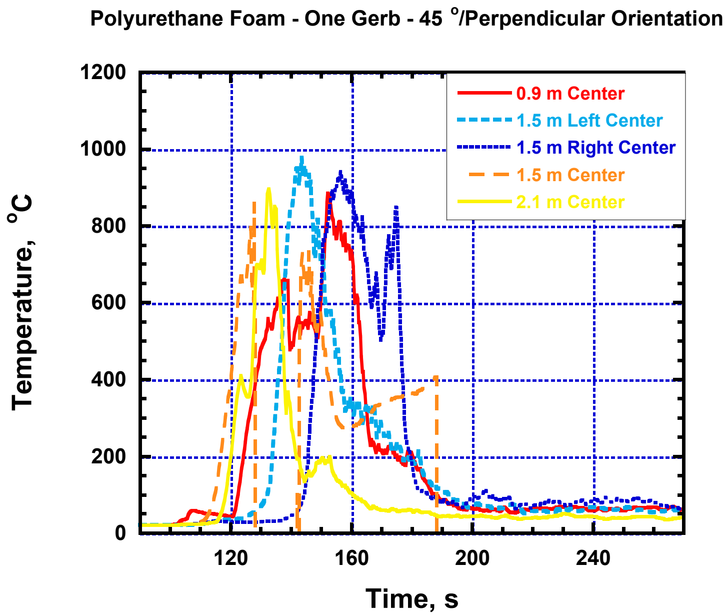


Figure F-16a. Temperatures versus Time for Single Gerb Discharged at 45 Degrees in Plane Perpendicular to Wall.

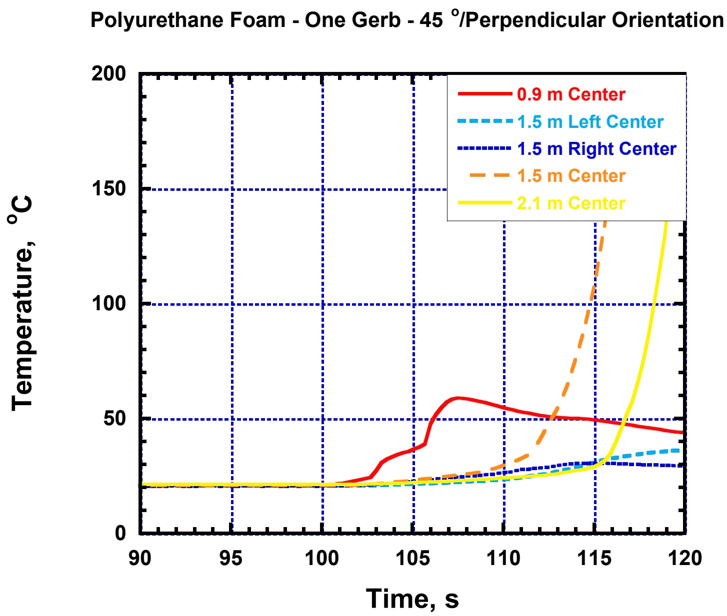


Figure F-16b. Temperatures versus Time for Single Gerb Discharged at 45 Degrees in Plane Perpendicular to Wall.

F.3 90 DEGREE DISCHARGE TESTS

A pair of gerbs was positioned to discharge in a direction 90 degrees from the horizon and parallel to the wall (see Fig. F-17). Visible and infrared images are shown 2 seconds, 5 seconds, 14 seconds, 15 seconds, and 16 seconds after ignition of the gerbs in Figure F-18 to F-22.

The visible images demonstrate that both gerbs discharged for at least 14.5 seconds, but no more than 16 s. The spray pattern of sparklers appeared similar to that of the gerbs, which had been positioned at 45 degrees. Most of the sparklers traveled less than 2.74 m (9 ft), but some hot sparklers were thrown in excess of 4.6 m (15 ft). The infrared images again demonstrate a central core of hot gases; in this vertical configuration, the plume of combustion gases is aligned with the trajectory of the hot sparklers. The temperatures and heat fluxes are plotted in Figures F-23 and F-24.

Since the alcove in the nightclub was 2.0 m (6.5 ft) tall and the gerbs were positioned at the center of the alcove opening, white sparklers would have easily reached the top of the alcove. The plume of hot gases would have directly impinged on the foam at the top of the alcove opening. (It is worth noting that the pair of gerbs directed vertically on the platform of the nightclub on Feb. 20, 2003, did not ignite the foam at the top of the alcove.)

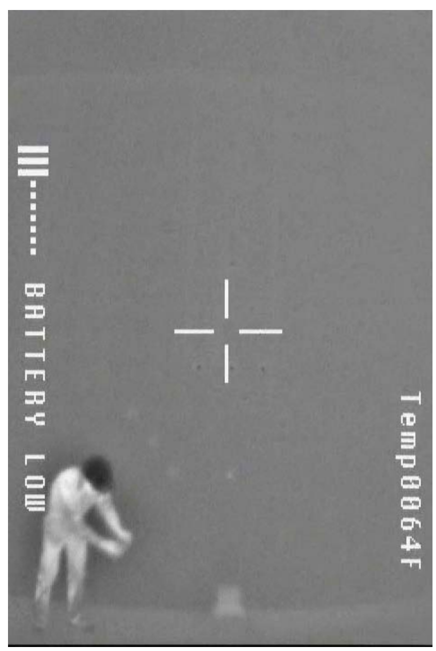


Figure F-17. Standard Video and Infrared Video Images of Gerb Discharge at 0 s.

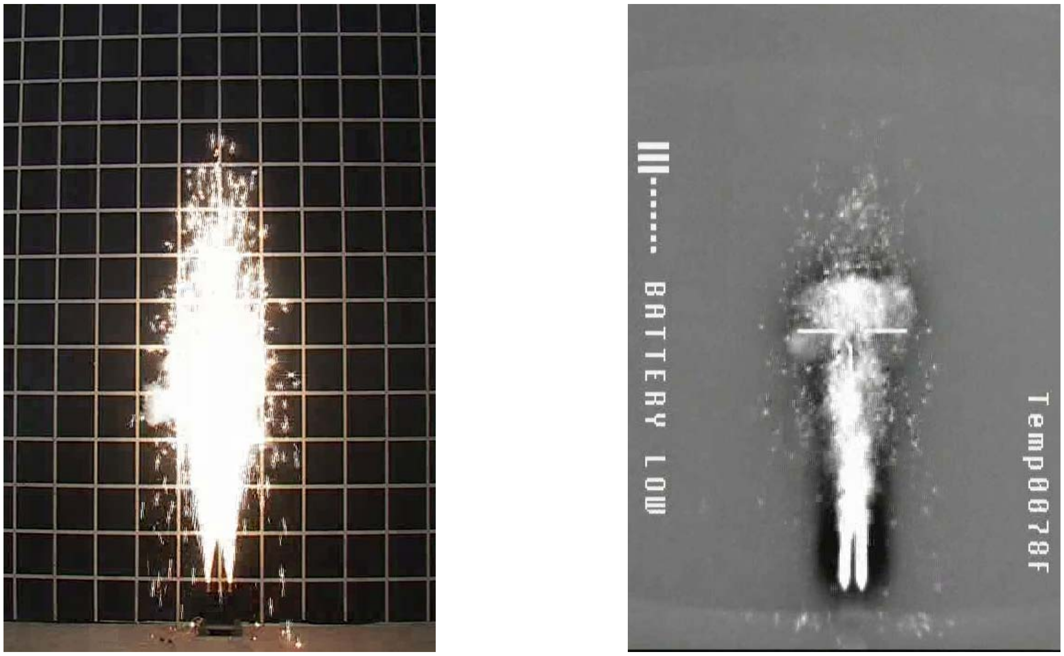


Figure F-18. Standard Video and Infrared Video Images of Gerb Discharge at 2 seconds.

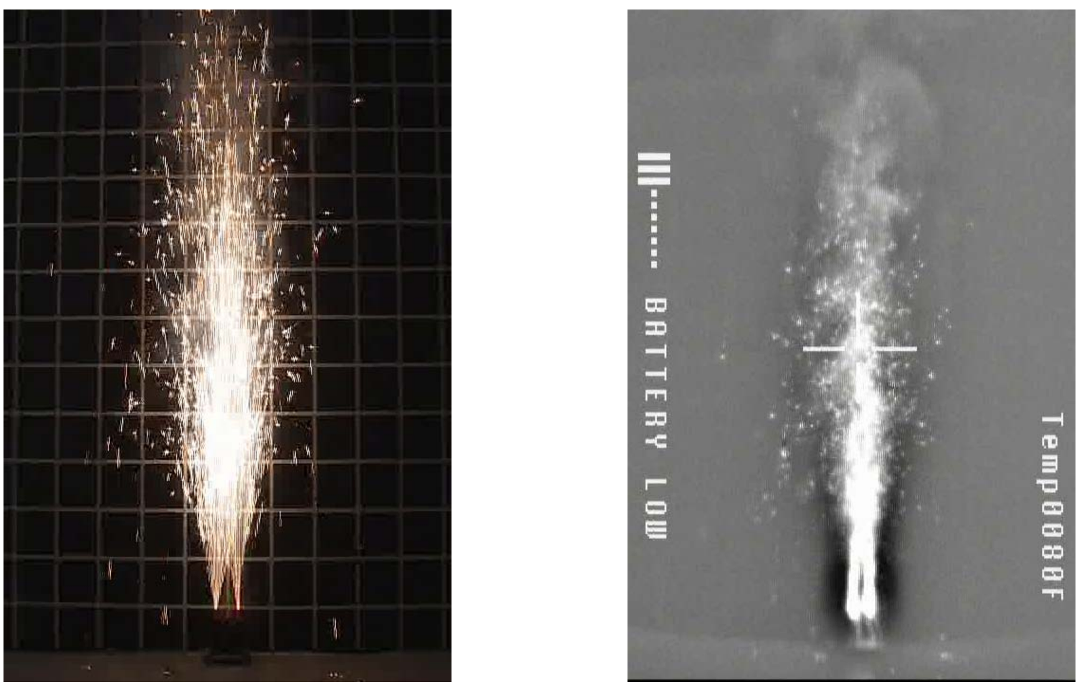


Figure F-19. Standard Video and Infrared Video Images of Gerb Discharge at 5 seconds.

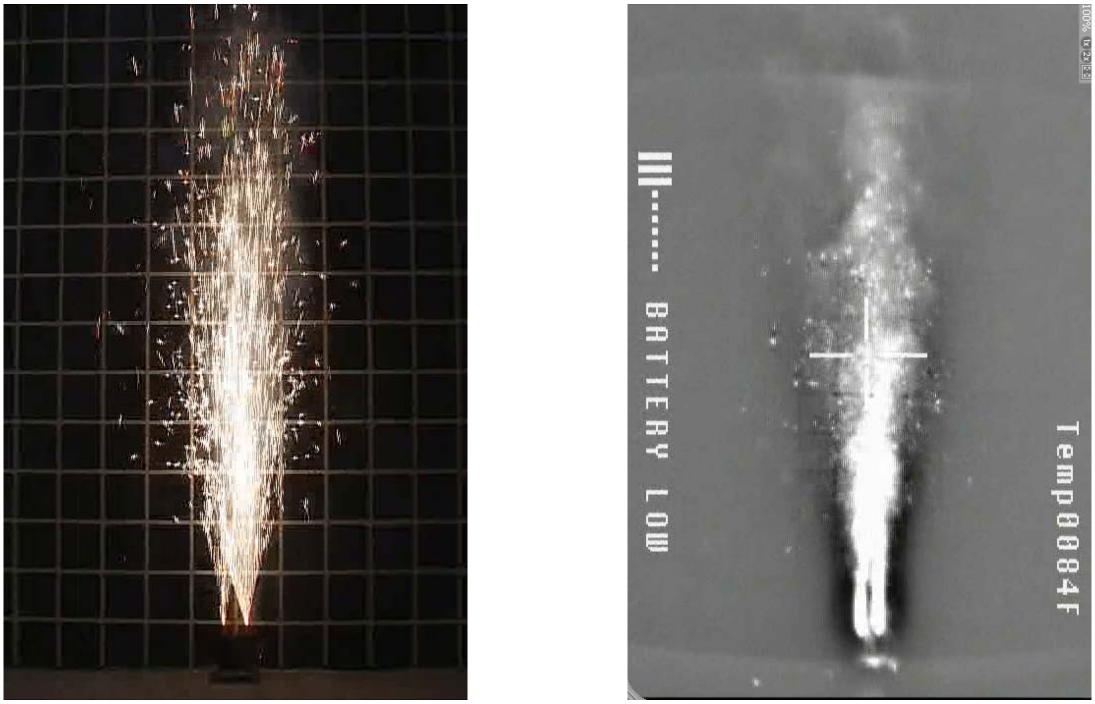


Figure F-20. Standard Video and Infrared Video Images of Gerb Discharge at 14 seconds.

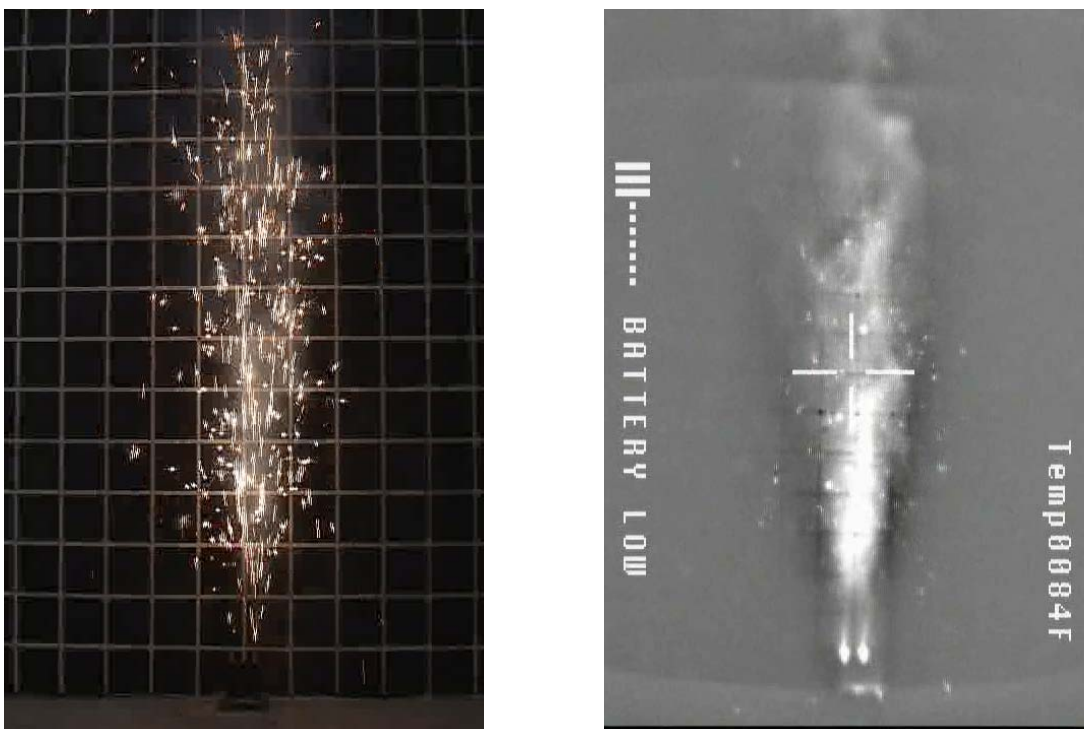


Figure F-21. Standard Video and Infrared Video Images of Gerb Discharge at 15 seconds.

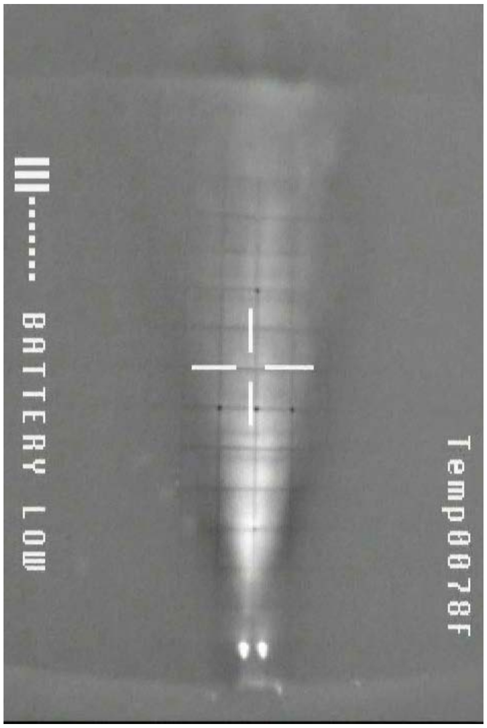


Figure F-22. Standard Video and Infrared Video Images of Gerb Discharge at 16 seconds.

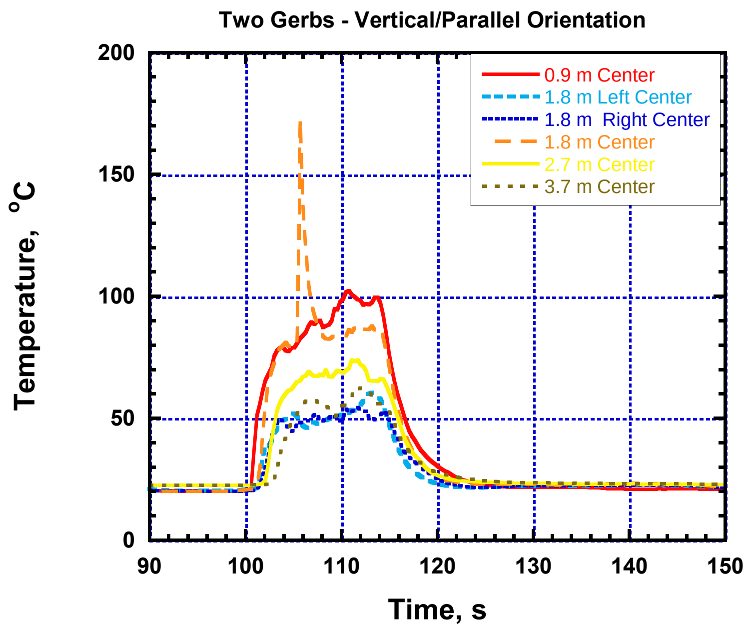


Figure F-23. Temperatures versus Time for Two Gerbs Discharged at 90 Degrees in Plane Parallel to Wall..

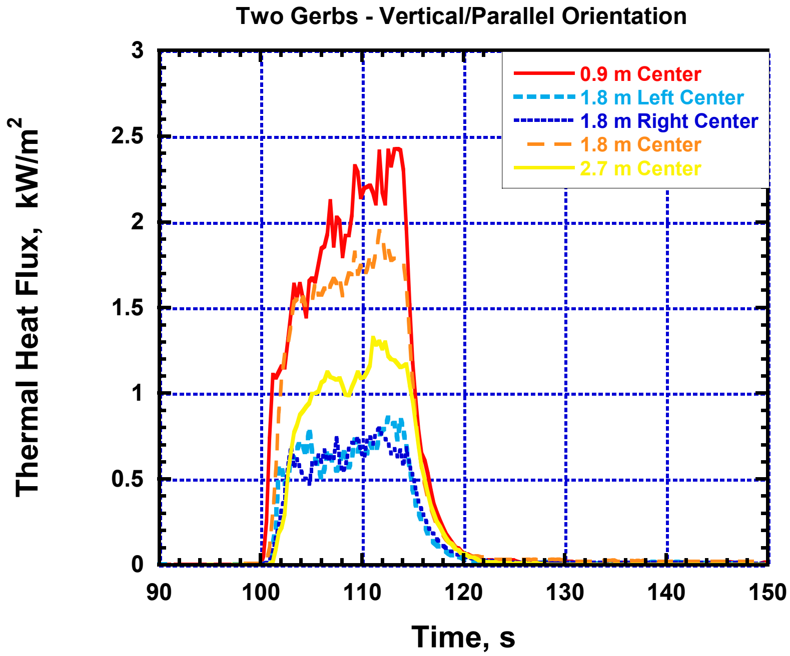


Figure F-24. Heat Fluxes versus Time for Two Gerbs Discharged at 90 Degrees in Plane Parallel to Wall.

APPENDIX G. REAL-SCALE PLATFORM AREA MOCK-UP EXPERIMENTS

This appendix contains additional data on the fire growth in the full-scale mock-up fire tests described in Chapter 4, and is compiled here for reference. Some material from Chapter 4 is repeated for the benefit of the reader.

G.1 INSTRUMENTATION AND EXPERIMENTAL PROCEDURE

The test room was equipped with thermocouples, video cameras, heat flux gauges, bi-directional probes, and gas extraction probes to measure carbon monoxide (CO), carbon dioxide (CO_2), oxygen (O_2), and hydrogen cyanide (HCN). In addition, fixed temperature and rate-of-rise heat detectors were installed, as were sprinklers. In one test, the sprinklers were not supplied with water but were monitored for time to activation. Figure G-1 is a schematic floor plan of the instrumentation positions.

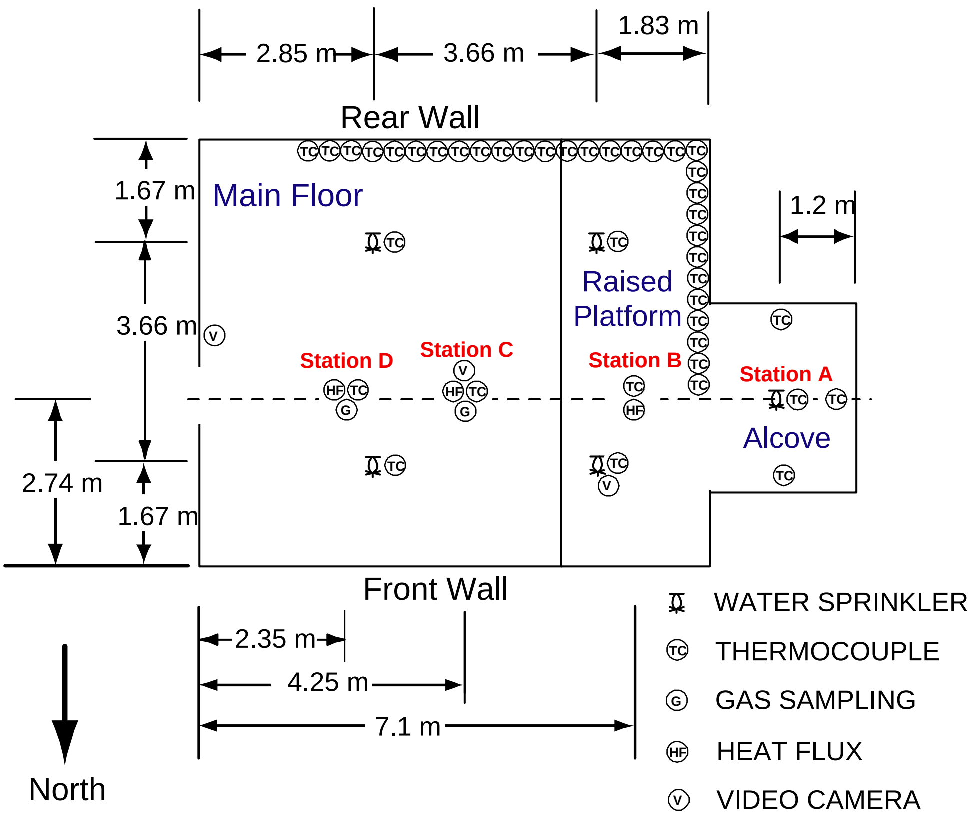


Figure G-1. Schematic floor plan with instrumentation positions.

Two full-scale experiments were conducted: one with and one without sprinklers. Prior to ignition, each of the analyzers was zeroed and calibrated and the data acquisition system and videos were started to collect background data. Data for 194 channels were recorded at one second intervals. Ignition of the foam was initiated with electric matches simultaneously at two locations on the outer corners of the alcove, 1.8 m above the raised floor area. The fire gases that emerged from the open door on the south end of the test room were captured in the hood of the oxygen depletion calorimeter. The data were reduced and plotted versus time for each of the channels.

G.2 TEMPERATURE MEASUREMENTS

The temperatures were measured with 0.51 mm nominal diameter bare bead, Type K thermocouples. The thermocouple array over the platform floor area had a thermocouple located at 0.025 m, 0.30 m, 0.61 m, 0.91 m, 1.22 m, 1.52 m, 1.83 m, 2.13 m, 2.44 m, 2.74 m, 3.05 m, 3.35 m, and 3.66 m below the ceiling.

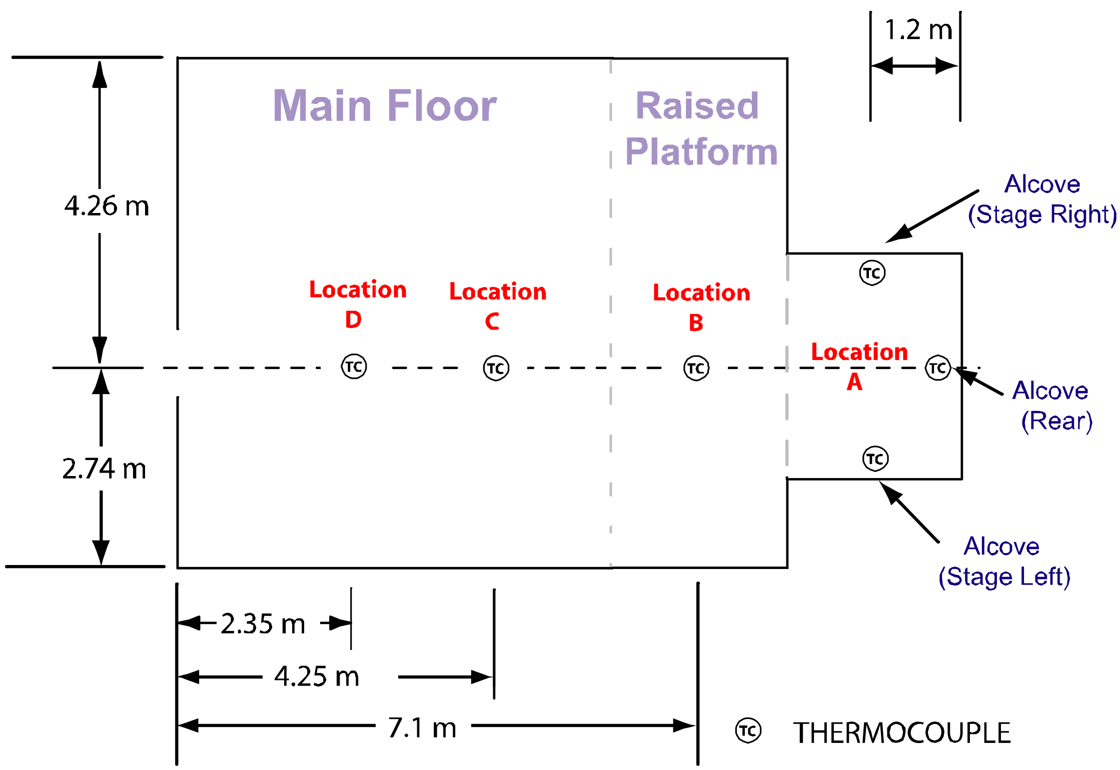


Figure G-2. Schematic floor plan with thermocouple positions.

For the platform floor thermocouple array, the thermocouple that was located 3.66 m below the ceiling, was positioned on the platform floor. The two-thermocouple arrays on the main floor also had a thermocouple located at 3.66 m below the ceiling, but in each case, the thermocouple was positioned 0.15 m above the main floor. Vertical thermocouple arrays were installed in the center of each wall of the alcove. Each array had a thermocouple located at 0.30 m, 0.61 m, 0.91 m, 1.22 m, 1.52 m, and 1.83 m below the ceiling of the alcove. A horizontal thermocouple array was installed 0.30 m below the ceiling. The array began at the centerline of the alcove opening and continued north along the rear wall, and then followed the platform wall west for 6.1 m. The thermocouples were spaced approximately 0.30 m apart.

In addition, thermocouples were located adjacent to the sprinklers. Temperatures versus time are plotted in Figures 4-22 through 4-28.

Thermocouples were installed near the ignition points on both sides of the alcove opening, 1.8 m above the floor of the platform. As shown in Figure G-3, in the unsprinklered compartment burn, the temperatures near the ignition point stage-left began to increase rapidly in less than 10 seconds and it then dropped to about 100 ^{o}C. After about 30 seconds, both stage-right and stage-left thermocouples began to increase to temperatures in excess of 600 ^{o}C. The initial peak and subsequent drop and then rapid increase were probably due to movement of the flame sheet or thermal plume. If the thin flame sheet was near the thermocouple bead, a high temperature would be recorded, but if the plume of hot gases moved and caused the bead to be in the fuel rich interior of the plume, lower temperatures could have been recorded.

Slightly different temperature behavior was recorded in the sprinklered test (Figure G-4). Initially both stage-left and stage-right temperatures increased rapidly as the stage-left thermocouple had in the unsprinklered test, but as sprinklered burn temperatures dropped back to about 100 ^{o}C, the sprinklers activated and caused the temperatures to decrease to near ambient temperatures.

Three thermocouple arrays were installed in the alcove, stage-right wall, stage-left wall, and rear wall of the alcove (Figures G-5, G-7, and G-9). The temperatures recorded by each of three thermocouple arrays were similar. In the unsprinklered test burns, the temperatures began to increase within 30 seconds after ignition. By 60 seconds to 70 seconds after ignition, temperatures exceeded 800 ^{o}C . In the sprinklered compartment burns (Figures G-6, G-8, and G-10), the temperatures also began to increase in approximately 30 seconds, but the temperatures had only increased to about 40 ^{o}C to 60 ^{o}C before the sprinklers activated and the temperature gradually decreased to ambient temperatures.

One thermocouple array was installed from ceiling to floor on the platform, Location B. For the unsprinklered case (Figure 4-22), the temperature at the ceiling began to increase within 10 seconds and continued to increase to over 800 ^{o}C in approximately 50 s. As the hot gases began to form an upper layer, the layer began to descend and in just over 110 seconds, the temperature at the floor of the platform had increased to over 600 ^{o}C . In less than 60 seconds, the temperature had exceeded 50 ^{o}C at the 1.4 m (4.5 ft) above the floor (2.4 m below the ceiling) elevation. For the sprinklered test burn (Figure 4-25), the ceiling thermocouple recorded temperatures in excess of 360 ^{o}C in less than 25 seconds, but had decreased to ambient in less than 40 seconds. The activation of the sprinklers caused the other thermocouples at lower elevations to record near ambient temperatures throughout the test burn.

The thermocouple array at Location C was installed 6.7 m from the foam covered platform wall. Location C thermocouples were an additional 3 m further away from the platform wall than the thermocouples at Location B. Since the thermocouples at Location C were further away from the fire source than the thermocouples at Location B, the temperatures might be expected to increase more slowly than at Location B. For the unsprinklered thermocouples (Figure 4-23), the temperatures did require slightly longer to begin to increase, about 15 seconds, and required approximately 70 seconds to reach peak temperatures of 800 ^{o}C. The temperatures at 3.6 m below the ceiling did not begin to increase until 60 seconds after ignition and then the temperatures reached peak values of approximately 100 ^{o}C in 90 s. The temperatures near the floor at Location C were significantly lower that the values recorded at the floor on the platform, Location B. In less than 70 seconds, the temperature had exceeded 50 ^{o}C at the 1.4 m (4.5 ft) above the floor (2.4 m below the ceiling) elevation. For the sprinklered test burn (Figure 4-26), the ceiling temperatures reached a peak temperature of 170 ^{o}C in about 20 seconds and declined to

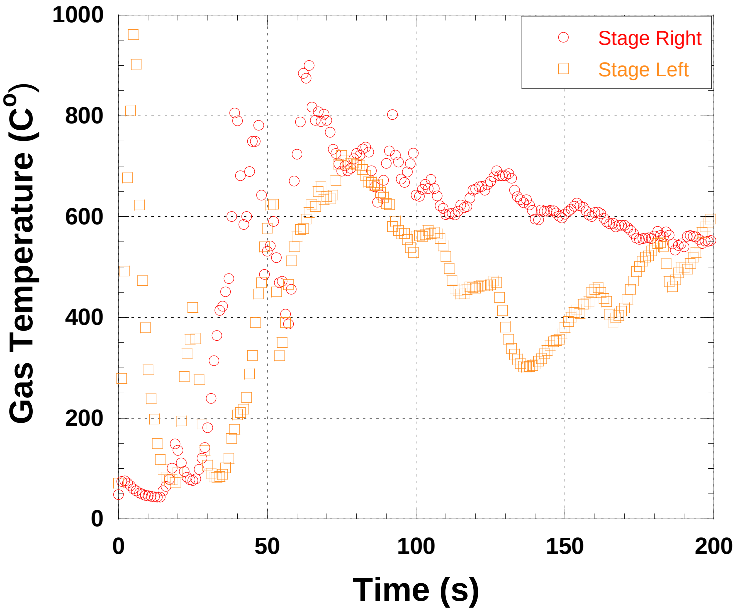


Figure G-3. Temperatures versus Time for Unsprinklered Mockup Test. Thermocouples positioned on right and left side of alcove opening 1.8 m (5.t ft) above platform floor at ignition points.

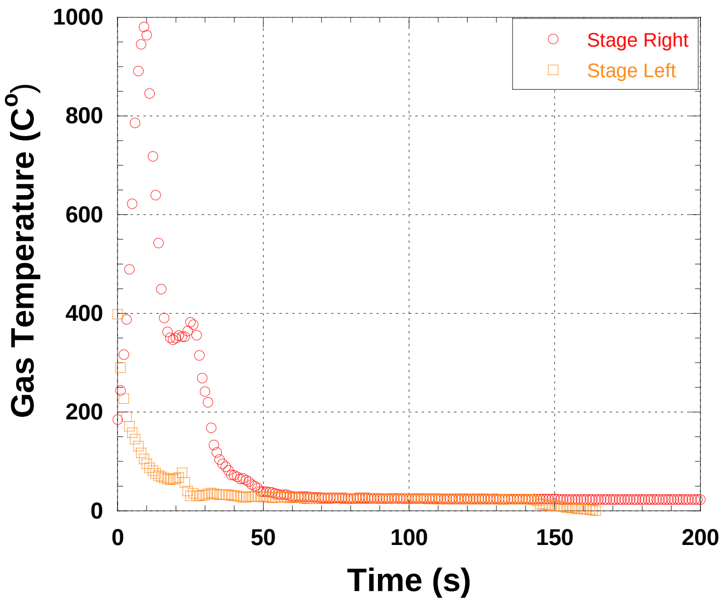


Figure G-4. Temperatures versus Time for Sprinklered Mockup Test. Thermocouples positioned on right and left side of alcove opening 1.8 m (5.5 ft) above platform floor at ignition points.

near ambient temperatures within 60 seconds. Thermocouples at lower elevations appeared to remain at near ambient temperatures throughout the test.

The thermocouple array at Location D was installed 8.5 m from the foam covered platform wall. Location D thermocouples were an additional 1.8 m further away from the platform wall than the thermocouples at Location C. Again, as the distance between the thermocouple array and the fire increased, the temperatures were expected to increase more slowly that the arrays that were located closer to the fire. For the unsprinklered thermocouples (Figure 4-24), the temperatures did require slightly longer to begin to increase, about 20 seconds, and required approximately 80 seconds to reach peak temperatures of 700 ^{o}C. The temperatures at 3.6 m below the ceiling did not begin to increase until 70 seconds after ignition and then the temperatures reached peak values of approximately 100 ^{o}C in 90 s. The temperatures near the floor at Location D were about the same as that the values recorded at the floor on the platform, Location C. In less than 70 seconds, the temperature had exceeded 50 ^{o}C at the 1.4 m (4.5 ft) above the floor (2.4 m below the ceiling) elevation. For the sprinklered test burn (Figure 4-27), the ceiling temperatures reached a peak temperature of 130 ^{o}C in about 20 seconds and declined to near ambient temperatures within 60 seconds. Thermocouples at lower elevations appeared to remain at near ambient temperatures throughout the test.

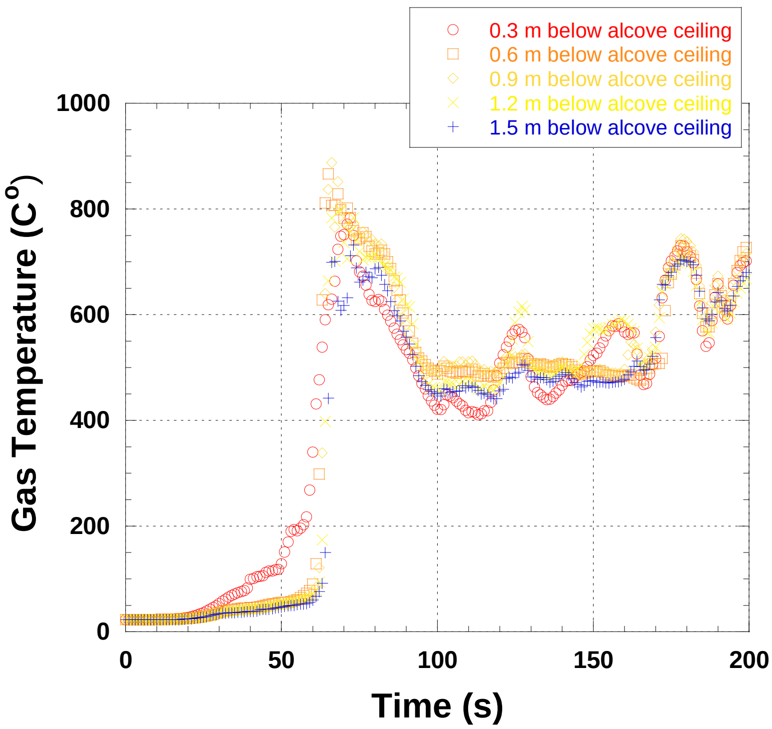


Figure G-5. Temperatures versus Time for Unsprinklered Mockup Test. Thermocouples positioned in Alcove (A-SR) on wall (stage-right).

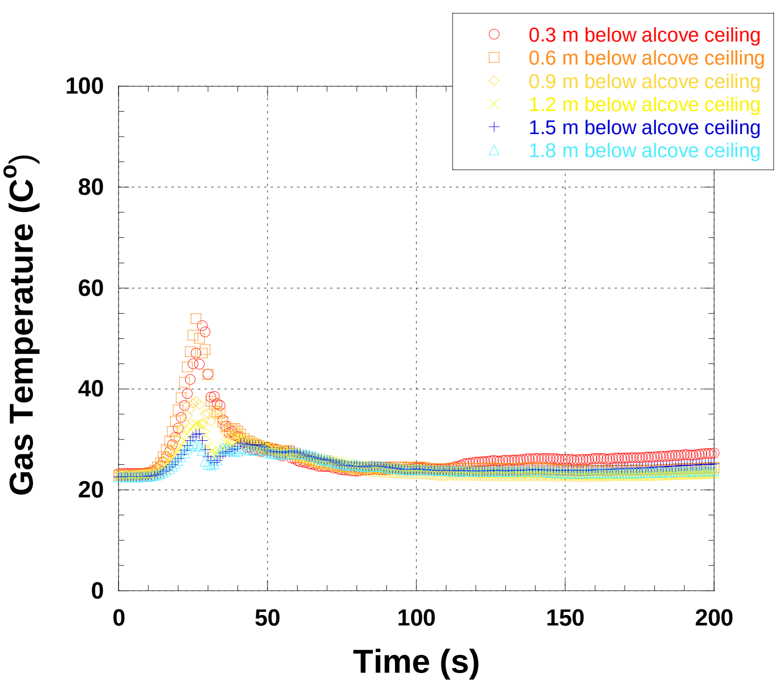


Figure G-6. Temperatures versus Time for Sprinklered Mockup Test. Thermocouples positioned in Alcove (A-SR) on wall (stage-right).

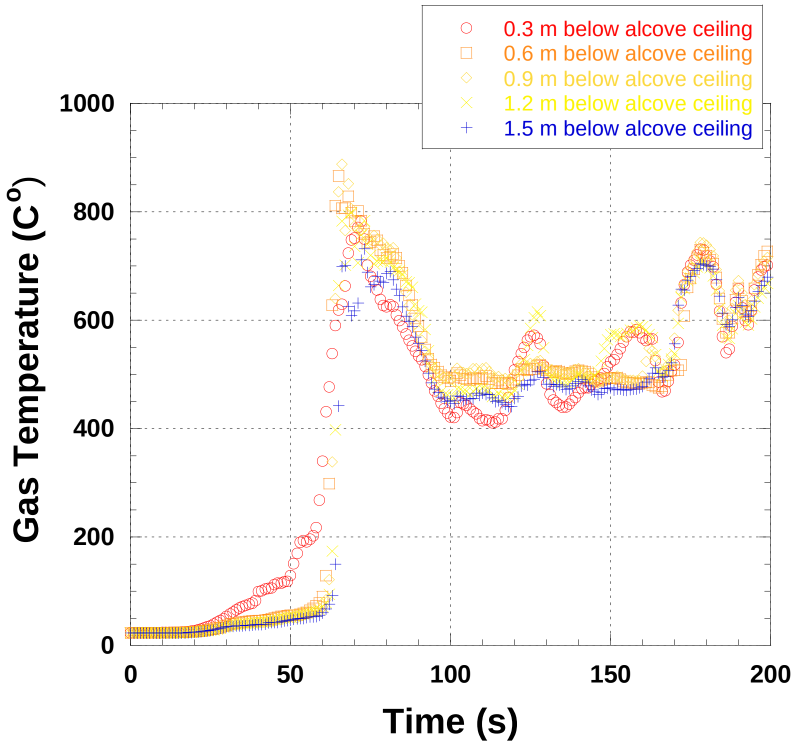


Figure G-7. Unsprinklered Mockup Test. Alcove (A-SB) on rear wall .

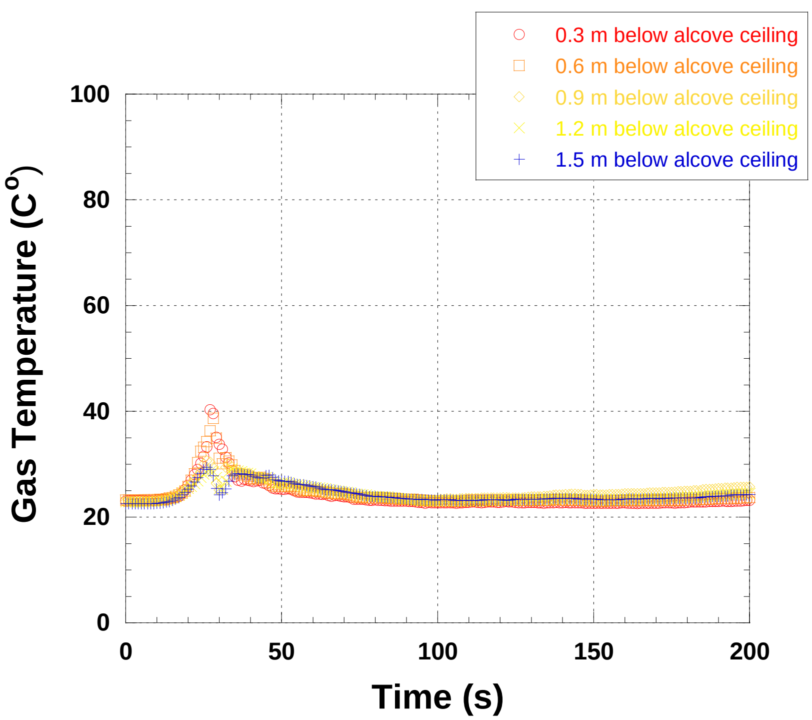


Figure G-8. Sprinklered Mockup Test. Alcove (A-SB) on rear wall.

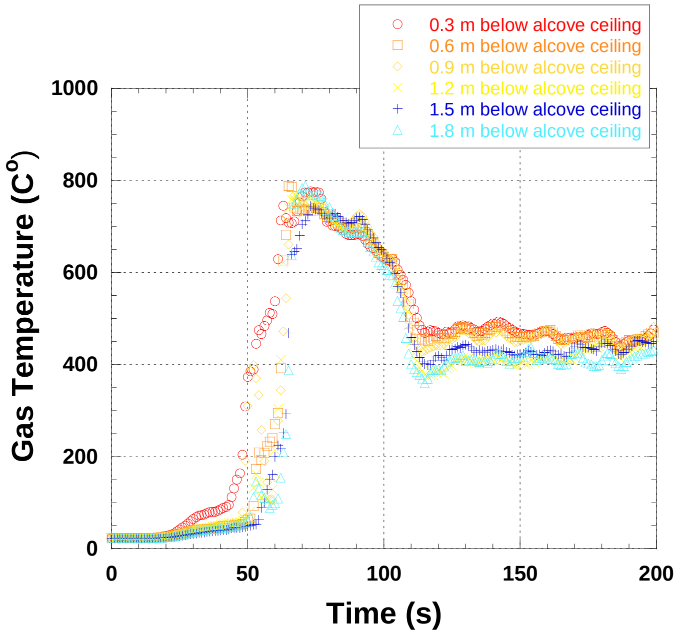


Figure G-9. Temperatures versus Time for Unsprinklered Mockup Test. Thermocouples positioned in Alcove (A-SL) on wall (stage-left).

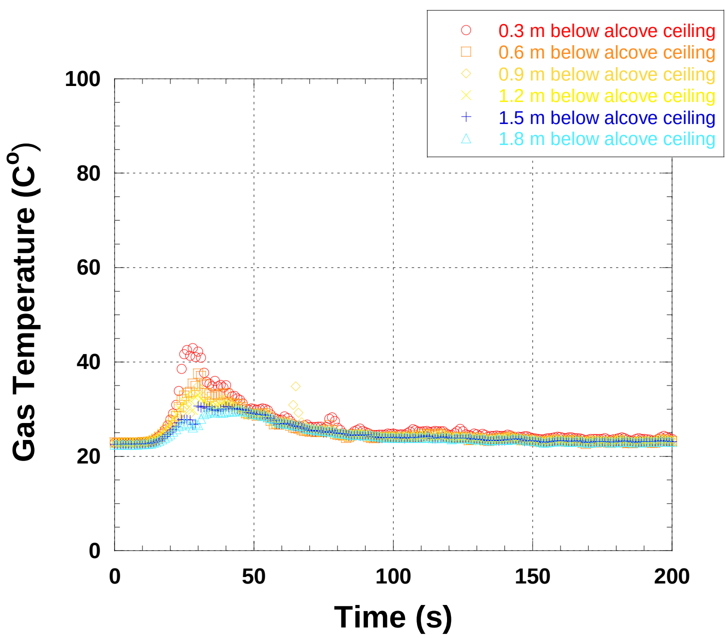


Figure G-10. Temperatures versus Time for Sprinklered Mockup Test. Thermocouples positioned in Alcove (A-SL) on wall (stage-left).

G.3 GAS MEASUREMENTS

The gas sampling ports were co-located with the heat flux sensors on the main floor area (Figure 4-63). The gases were pulled through 9.4 mm ID tubing to chemical analyzers after passing through moisture and particulate filters. Carbon monoxide and carbon dioxide concentrations were monitored using non-dispersive infrared gas analyzers while the oxygen concentrations were measured using paramagnetic analyzers. Hydrogen cyanide concentrations were monitored using impingers and real-time gas analyzers, which utilized an off-the-shelf cyanide combination electrode. Each impinger utilized 0.1 M KOH as the trapping solution and samples were analyzed according to NIOSH Method 7904 [1]

During the sampling process, the gas sample for the oxygen, carbon monoxide, and carbon dioxide analysis was drawn through a cold trap which removed the water vapor. The oxygen, carbon monoxide, and carbon dioxide concentrations were recorded by each analyser on a dry or Orsat basis. The hydrogen cyanide sample gas utilized a different sampling train and did not pass through a cold trap. Since the hydrogen cyanide samples were monitored on a wet basis, the oxygen, carbon monoxide, and carbon dioxide concentrations were corrected for the water removed by the cold trap. For complete combustion of low methane, two moles of water are generated for each mole of carbon dioxide produced. For larger hydrocarbon molecules, the ratio of moles of water produced for each mole of carbon dioxide decreases to a 1:1 ratio, assuming the carbon to hydrogen ratio approaches 1:2. It was assumed that for every mole of carbon dioxide or carbon monoxide generated that a mole of water was also generated. This assumption was used to correct the dry or Orsat basis analyzer data to a wet basis. By adding the water vapor back into the gas sample, the concentrations of oxygen, carbon monoxide, and carbon dioxide decreased. The relative uncertainty in the volume fraction measurement is estimated to be +/- 20 %.

Carbon dioxide gas concentrations versus time are plotted in Figures G-12 and G-13. For the unsprinklered tests, carbon dioxide concentrations at both Locations C and D began to increase 80 seconds after ignition and reached peak values of 12 % approximately 100 seconds after ignition. The fluctuations that were observed in the oxygen concentrations were also seen in the carbon dioxide concentrations. For the sprinklered compartment experiments, the carbon dioxide concentrations did not appear to increase above ambient concentrations.

G.4 HEAT FLUX MEASUREMENTS AND HEAT DETECTOR RESPONSE

Three elliptical radiometers were installed in the ceiling of the test cell viewing downward at Location B, C, and D (Figure G-14). In addition to the radiometer at Location B, a total heat flux gauge with an upward view was installed flush with the platform floor. At Locations C and D, two additional total heat flux gauges were installed 1.5 m above the floor. One total heat flux gauge was position to have an upward view, while the other gauge had a view of the alcove. The heat flux sensors were water-cooled Schmidt-Boelter type transducers. Heat flux versus time is plotted in Figure G-15 through Figure G-23. The uncertainty in the heat flux values reported is estimated to be +/- 20 %.

The three radiometers were plotted together in Figure G-15. As the distance between the radiometer and the fire source increased, the peak radiation flux decreased. For Locations B, C, and D, peak radiation levels were approximately 60 kW/m^2, 50 kW/m^2, and 20 kW/m^2, respectively.

Unsprinklered and sprinklered radiation and total heat fluxes are plotted in Figures G-16 through G-23. In each sprinklered test at Locations C and D, neither radiation nor total heat flux reached significantly higher fluxes than background. Only at Location B, was there a slight increase in radiation or total heat flux at about 20 s.

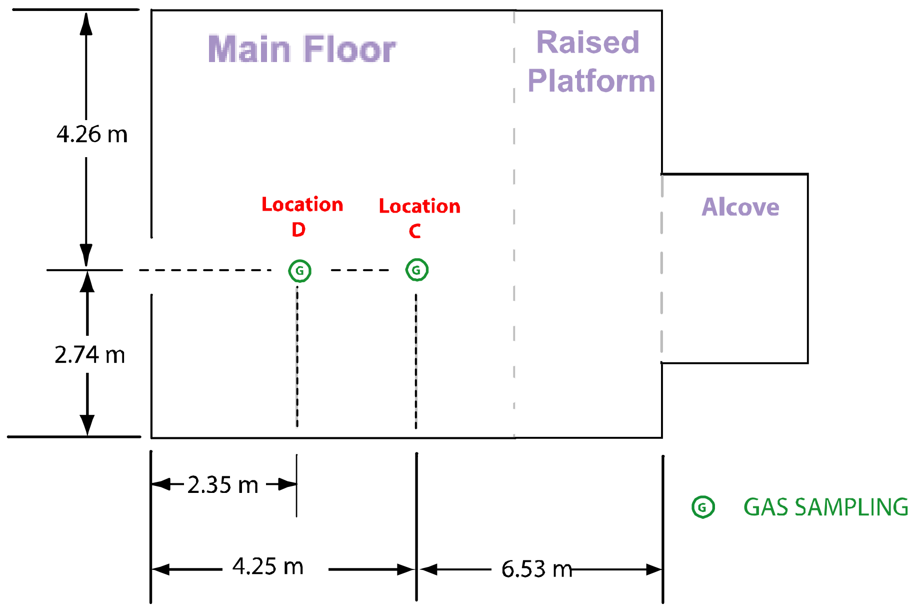


Figure G-11. Schematic floor plan with gas sampling locations.

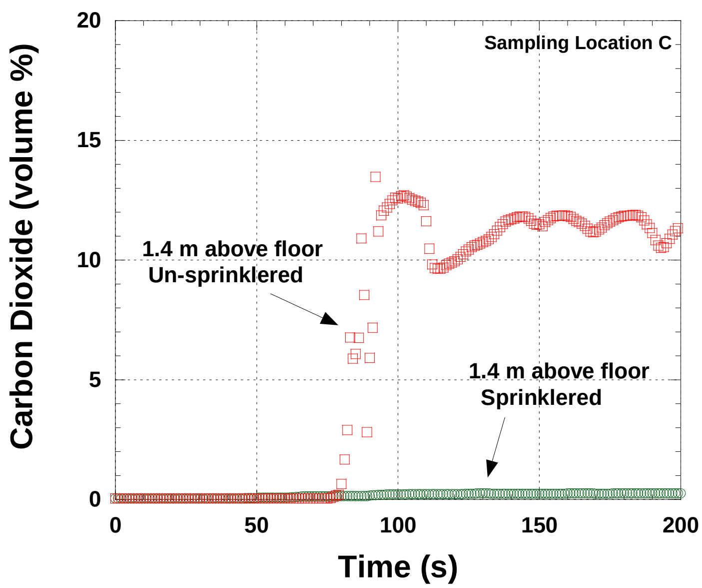


Figure G-12. Carbon dioxide volume fraction versus time for unsprinklered and sprinklered mockup test. Gas sampling probe positioned on main floor (Location C) at 1.4 m (4.5 ft) above floor.

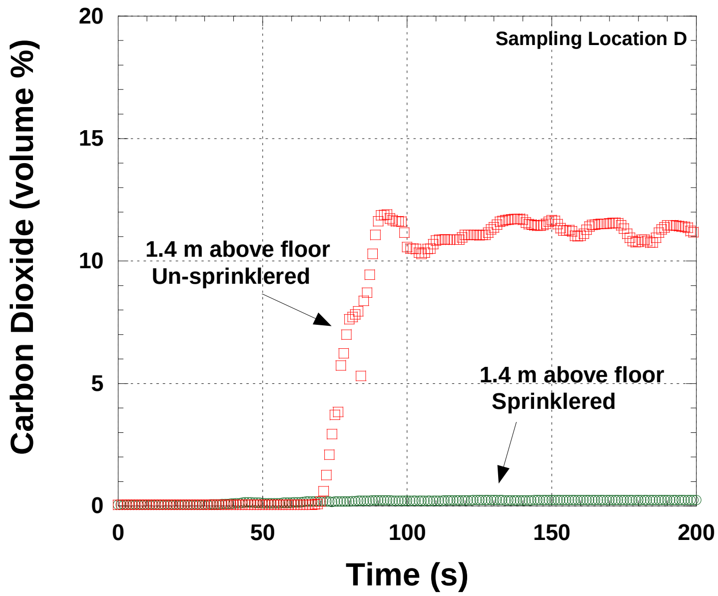


Figure G-13. Carbon dioxide volume fraction versus time for unsprinklered and sprinklered mockup test. Gas sampling probe positioned on main floor (Location D) at 1.4 m (4.5 ft) above floor.

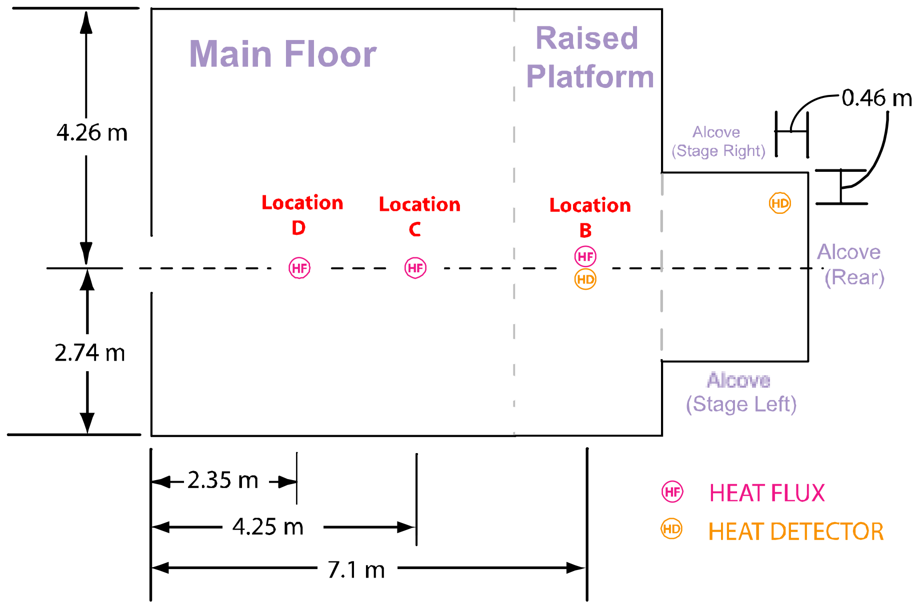


Figure G-14. Schematic floor plan with heat flux and heat detector locations.

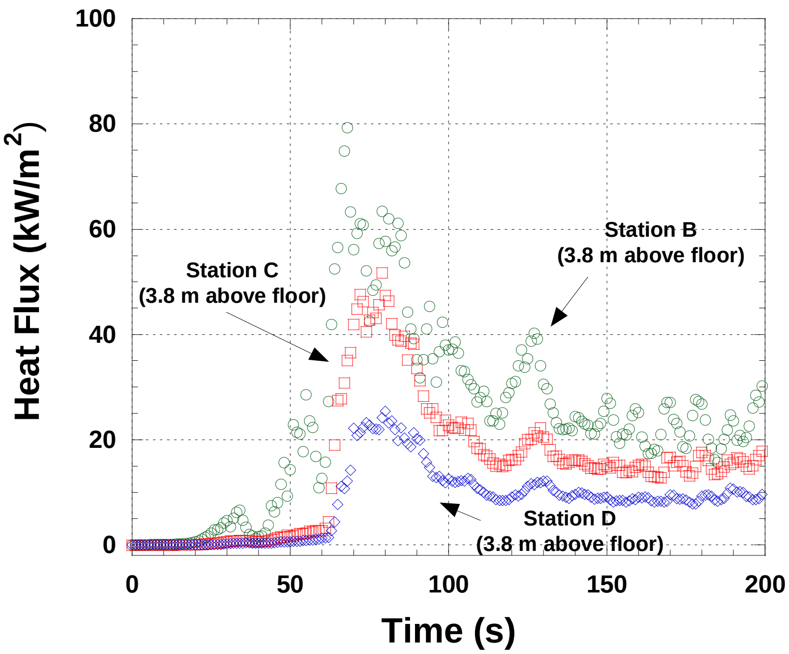


Figure G-15. Radiation fluxes versus time for unsprinklered mockup test. Gauges positioned flush with ceiling (3.8 m above floor) at locations B, C, and D.

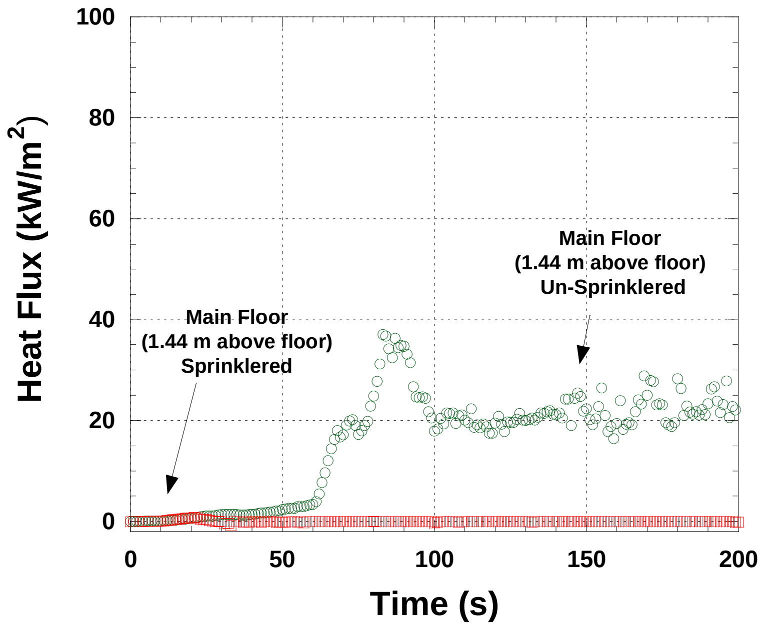


Figure G-16. Heat Fluxes versus Time for Unsprinklered and Sprinklered Mockup. Gauges positioned facing alcove (1.44 m above floor) at location C.

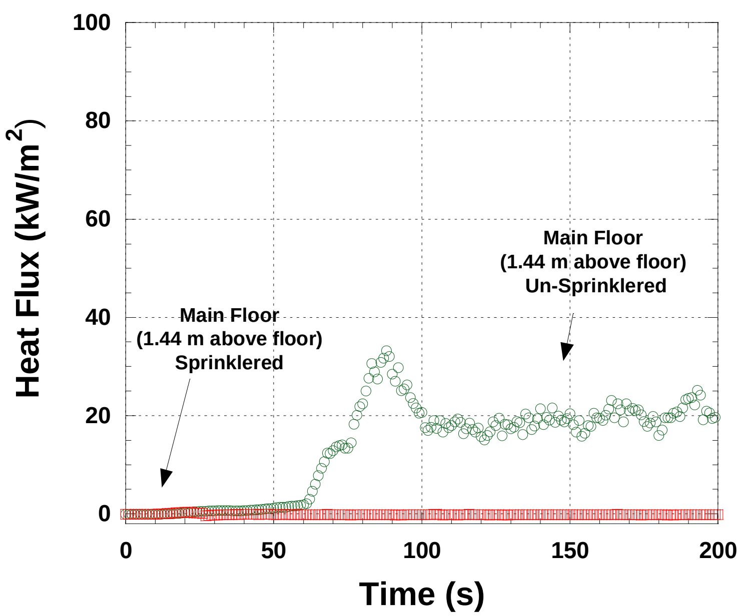


Figure G-17. Heat Fluxes versus Time for Unsprinklered and Sprinklered Mockup. Gauges positioned facing alcove (1.44 m above floor) at location D.

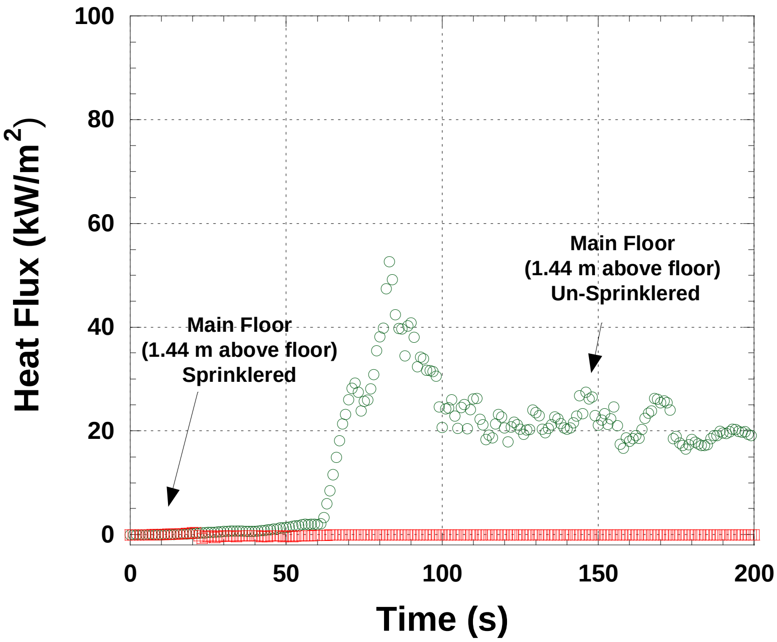


Figure G-18. Heat Fluxes versus Time for Unsprinklered and Sprinklered Mockup. Gauges positioned facing ceiling (1.44 m above floor) at location C.

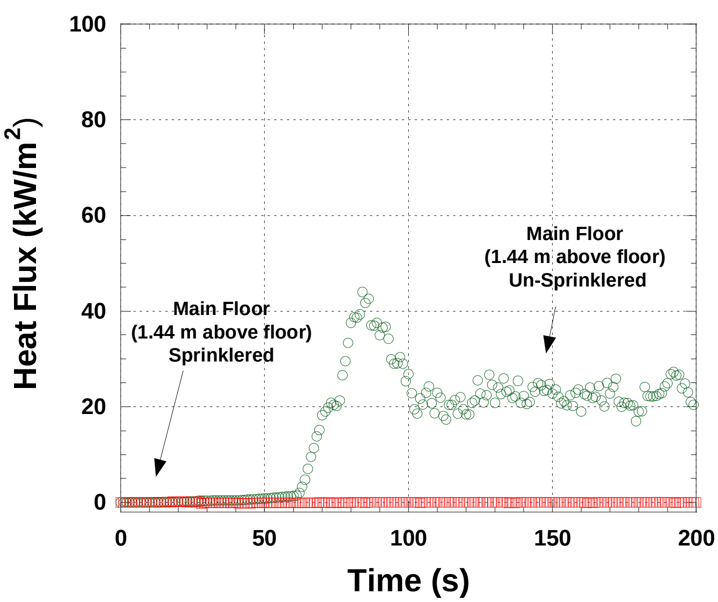


Figure G-19. Heat Fluxes versus Time for Unsprinklered and Sprinklered Mockup. Gauges positioned facing ceiling (1.44 m above floor) at location D.

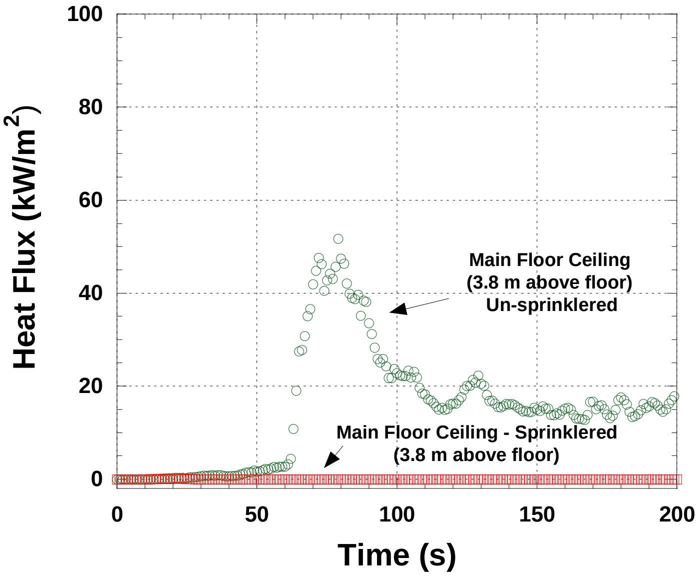


Figure G-20. Radiation Fluxes versus Time for Unsprinklered and Sprinklered Mockup. Gauges positioned flush with ceiling, facing down (3.8 m above floor) at location C.

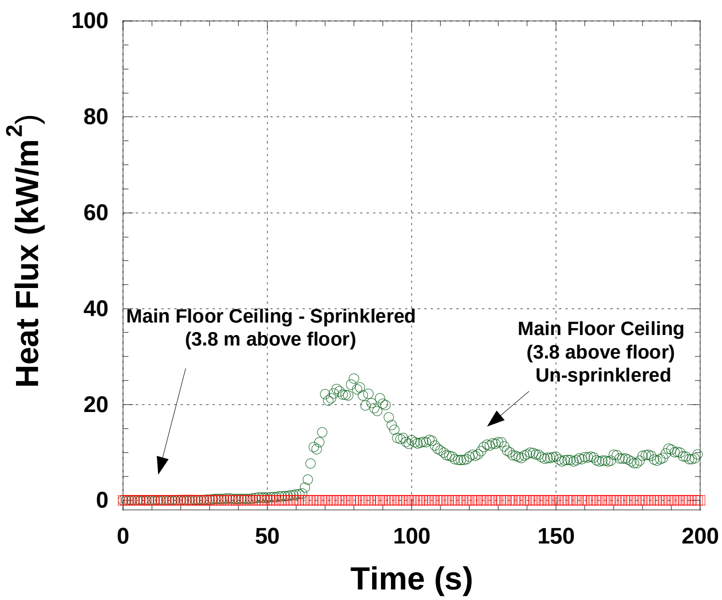


Figure G-21. Radiation Fluxes versus Time for Unsprinklered and Sprinklered Mockup. Gauges positioned flush with ceiling, facing down (3.8 m above floor) at location D.

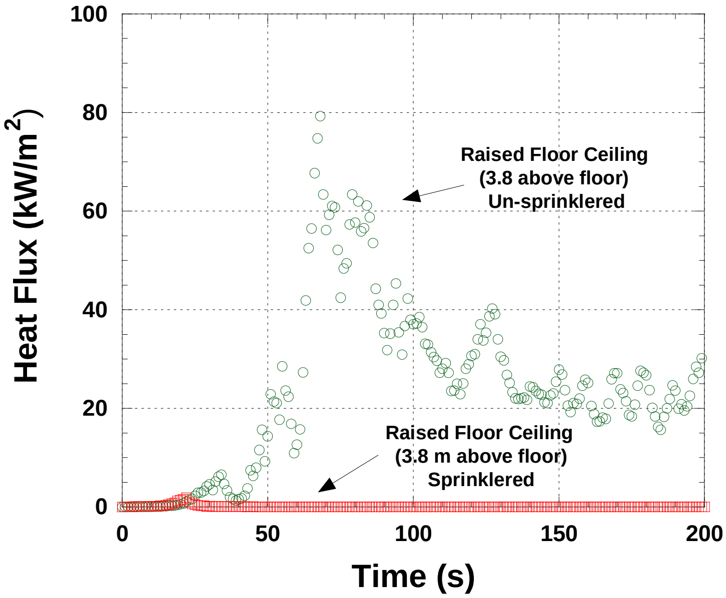


Figure G-22. Radiation Fluxes versus Time for Unsprinklered and Sprinklered Mockup. Gauges positioned flush with ceiling, facing down (3.8 m above floor) at location B.

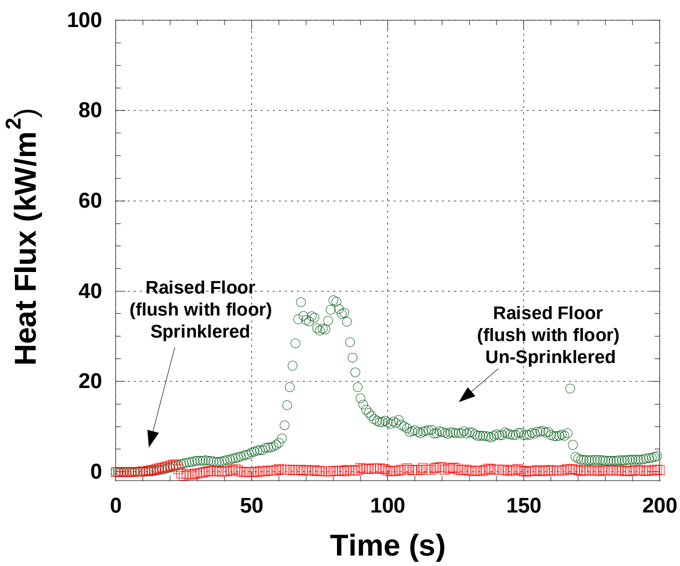


Figure G-23. Heat Fluxes versus Time for Unsprinklered and Sprinklered Mockup. Gauges positioned flush with raised floor of platform, facing up at location B.

G.4 REFERENCES FOR APPENDIX G

1. "Cyanides, Aerosol and Gas, Method 7904," *NIOSH Manual of Analytical Methods*, Fourth Edition, 8/15/94.

APPENDIX H. POLYURETHANE FOAM – CHEMISTRY

H.1 POLYURETHANE PLASTICS

Polyurethane refers to a large category of materials including surface coatings, elastomers, and foams, rigid or flexible, and thermoplastic or thermosetting [1,2]. While large quantities of polyurethanes are used to manufacture adhesives and protective coatings, the foam type of polyurethane is widely used in the production of upholstered furniture, bedding, sponges, toys, wearing apparel, and medical dressings. Rigid urethane foams are used for insulation in building constructions. Flexible polyurethane foams are used in packaging materials and acoustical insulation panels.

The urethane linkage, which all polyurethanes have in common, involves the reaction of an isocyanate group with a hydroxyl-containing group. Common hydroxyl-bearing groups include polyether alcohols, polyester alcohols, carboxylic acids, and amines. The chemical structure, such as the length and side branching, of the hydroxyl-bearing group plays an important role in the properties of the final foam product. In general, short chain length compounds with tri- and trifunctional-alcohols, are used to produce more rigid foams while longer chain length compounds with trifunctional-alcohols are used to generate more flexible foams [3]. However, additional hydroxyl-containing compounds including glycerol, castor oil, raw sugar, sorbitol, isocyanate, and phenols can be incorporated to produce plastics with increased flexibility, increased rigidity, and increased heat resistance. If a polyether alcohol was selected as the primary hydroxyl-containing group, the resulting foam may be referred to as polyether polyurethane foam. Choosing a polyester alcohol as the hydroxyl bearing reactant will generate polyester polyurethane foam.

Although the flammability of polyurethanes might be expected to be lower than those of many other polymers owing to their significant nitrogen content and the cross-linking usually present, in practice the fire performance of polyurethane-based materials is often poor due to the thin-walled structure and low density of the plastic foam [4]. The flame resistance properties of polyurethane foams can be improved by either incorporating additives into the foam or by careful selection of the hydroxyl-containing reactant.

Flame retardant additives may be inorganic, such as diammonium phosphate, or organic compounds containing chlorine, bromine or phosphorus. The fire-retardants typically work either by vaporizing when heated and displacing the oxygen or by releasing moisture that absorbs energy and delays ignition. These additives can be mixed in with the product as it is manufactured or applied to the surface after production. But, the low degree of permanency and the adverse impact on the physical properties of the foam, stimulated development of a second method of improving flame resistance. The second method involves choosing the hydroxyl-bearing reactant to contain flame resistant groups such as chlorine, bromine, or phosphorus, or to contain copolymers that contain heat resistant groups such as isocyanurates, cyclic imides, or other nitrogen heterocycles [5]. The second method incorporates the flame retardant groups into the polymer structure itself, insuring even distribution and more permanence of the flame retardant compounds.

H.2 POLYURETHANE CHEMISTRY

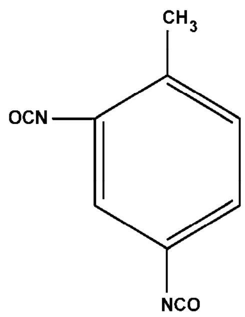
As a group of plastics, polyurethane encompasses a large number of materials including foams, elastomers, and surface coatings. The final properties of polyurethane, such as flexible, semi-flexible, or rigid, thermoplastic or thermosetting, and closed cell or open cell, is determined by the starting materials, how the polymer is processed or produced, extent of crosslinking, and additives.

Polyurethane is typically produced by reacting an isocyanate component with a polyol. Examples of three common isocyanate compounds, toluene-2,4-diisocyanate, toluene-2,6-diisocyanate, and diphenylmethane-4,4’-diisocyanate (Figure H-1). The isocyanate functional groups are also highlighted for each compound. A polyol is a hydrocarbon with a number of alcohol functional groups. Simple alcohols such as ethyl alcohol (Figure H-2) may have only one alcohol functional group, but longer chain alcohols may have multiple alcohol groups (Figure H-2). As the isocyanate functional group reacts with an alcohol group (Figure H-3), the urethane linkage is formed.

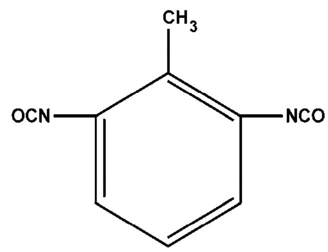
The chemical structure of the isocyanate and polyol components help determine the type and properties of the polyurethane. In addition to alcohol functional groups, polyols also incorporate other functional groups including ether and ester linkages. Examples of ether and ester functional groups are shown in Figure H-4.

If the polyol incorporates multiple ether groups, such as polyethylene oxide or polypropylene oxide, then the resulting polyurethane will have a number of ether linkages and is typically referred to as a polyether polyurethane. Short carbon chain polyether alcohols with tri- and multi-functional groups; result in more rigid polyurethane foam. Long chain hydrocarbons with trifunctional groups are used to create more flexible foams. If the polyol incorporates multiple ester groups, then the resulting polyurethane will have a number of ester linkages and is termed as polyester polyurethane foam.

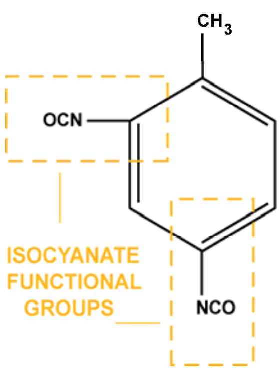
Other polyols, including glycerol, sorbitol, raw sugar, and modified castor oils can be incorporated in the polyurethane making process to effect the degree of crosslinking, length of chains, increase elasticity, and increase heat resistance. If additional isocyanate is added and allowed to react with other isocyanate functional groups, isocyanurate rings can be formed. These rings produce a more stable chemical structure that can increase rigidity, improve thermal stability, and decrease flammability. If additional isocyanate is added along with water or carboxylic acid, the resulting reaction will release carbon dioxide during the reaction. The gaseous carbon dioxide will act as a blowing agent and create the open-cell structure that is characteristic of foams.

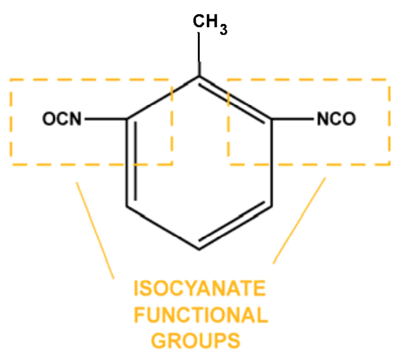


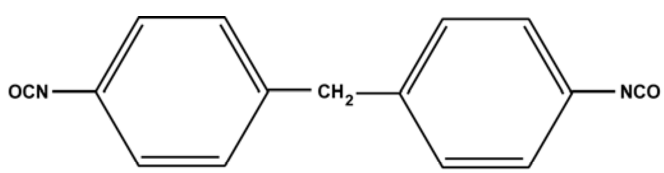
TOLUENE-2,4-DIISOCYANATE



TOLUENE-2,6-DIISOCYANATE







DIPHENYLMETHANE-4,4'-DIISOCYANATE

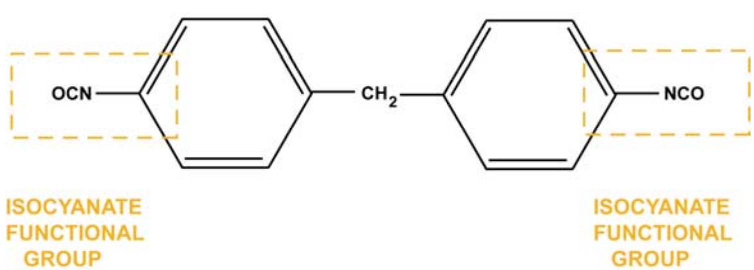
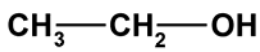
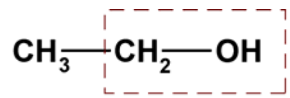


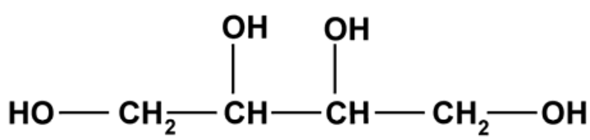
Figure H-1. Isocyanate Compounds used in Polyurethane Production.



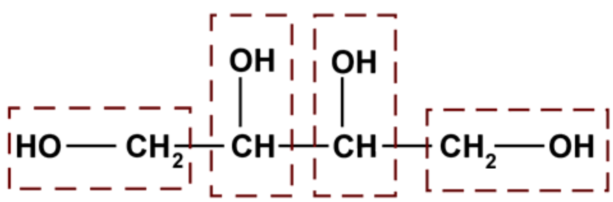
ETHYL ALCOHOL



ALCOHOL FUNCTIONAL GROUP



POLYOL



4 ALCOHOL GROUPS

Figure H-2. Example of Alcohol Functional Groups.

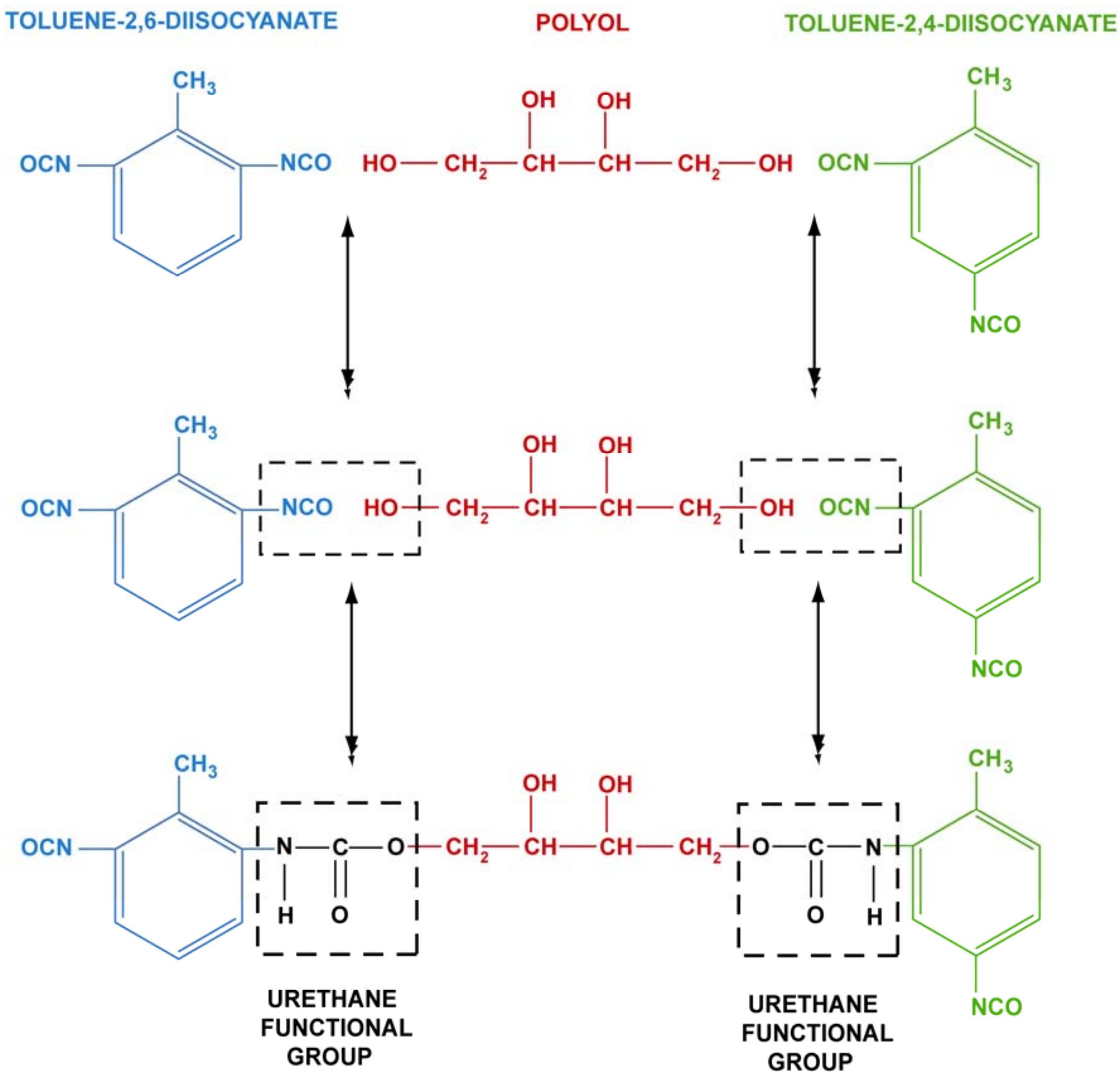
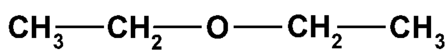
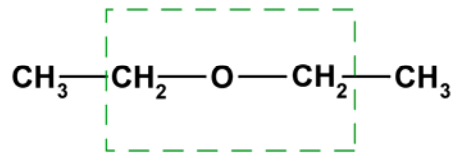


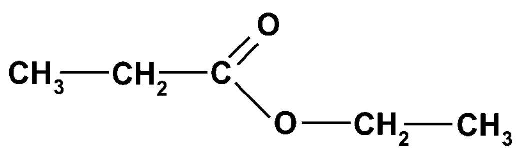
Figure H-3. Reacting Isocyanate Compounds with Polyols to Form Polyurethane.



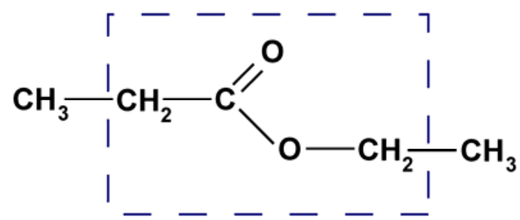
ETHYL ETHER



ETHER FUNCTIONAL GROUP



ACETYL ACETATE



ESTER FUNCTIONAL GROUP

Figure H-4. Examples of Ether and Ester Functional Groups.

H.3 REFERENCES FOR APPENDIX H

1. "Polyurethanes," in *Fire Retardant Materials*, Edited by A.R. Horrocks and D. Price, Woodhead Publishing Limited, Cambridge England, 2001, pp.243-245.

2. *Fire Protection Handbook*, *Seventeenth Edition*, A.E. Cote, Editor-in-Chief, National Fire Protection Association, Quincy, MA, p. 3-111, 2001.

3. Troitzsch, J., "The Burning of Plastics", Chapter 4 in *International Plastics Flammability Handbook*, Second Edition, Hanser Publishers, New York, NY, 1983, pp 16 – 30.

4. "Polyurethanes," in *Fire Retardant Materials*, Edited by A.R. Horrocks and D. Price, Woodhead Publishing Limited, Cambridge England, 2001, p. 244.

5. Frisch, K.C., and Reegen, S.L., "Relationship Between Chemical Structure and Flammability Resistance of Polyurethanes," in Flame-Retardant Polymeric materials, Edited by M. Lewin, S.M. Atlas, and E.M. Pearce, Plenum Press, New York, NY, 1975, pp. 291-336.

APPENDIX I. PYROLYSIS OF POLYURETHANE FOAM

This work was contracted with the US Army Aberdeen Test Center and coordinated by Dr. Steven H. Hoke of the Chromatography Analysis Division.

U.S. Army Aberdeen Test Center

400 Colleran Road
Aberdeen Proving Ground, MD 21005-5059

WARFIGHTER CORE
APPLIED SCIENCES TEAM
CHEMISTRY UNIT

Attn: Steven H. Hoke, Ph.D.

USACHPPM
Chromatography Analysis Division
400 Colleran Road Bldg AA-363
APG, MD 21005

Project Number: None

Report Number: 2004-CC-045
Title: Combustion of Foam Panels

This report shall not be reproduced except in its entirety without the written approval of the Chemistry Unit. The results relate only to the specific samples/test item/test scenario identified within this report.

Authorized for Release:

Signature Date: 13 November 2003

Judith D. Galloway
Chief, Chemistry Unit

CSTE-DTC-AT-WC-C (70-10r) 13 November 2003

MEMORANDUM FOR USACHPPM Chromatography Analysis Division,
ATTN: Steven H. Hoke, Ph.D

SUBJECT: Combustion of Foam Panels, Laboratory Report Number 2004-CC-045

1. References:

a. Chemistry Team Internal Operating Procedure No. 360, Operation of 760 Fourier Transform Infrared Spectrometer with MCT-A detector.

b. Chemistry Team Internal Operating Procedure No. 361, FTIR Analysis of Solids using the Brill Pyrolysis Cell.

2. Two samples from foam panels were received by the Chemistry Unit. The samples were assigned sample numbers 0310027-01 and 0310027-02. See Tables 1 and 2, Enclosure 2 below for sample descriptions. The combustion products given off when these foam panels burn has become a concern. Identification of combustion products in air (21% oxygen) was requested.

3. Initial work with these samples focused on identification of the foam and adhesive on the foam. Next the foam was pyrolized in nitrogen. The final analytical determination was combustion of the foam in air. Most of the identification analysis was performed with the Continuum microscope linked with a Thermo-Nicolet Magnum FTIR optical bench. Pyrolysis and combustion were performed with a CSD pyrolysis (Brill) cell fitted in the sample compartment of the FTIR bench.

4. The samples were received wet with water. They were air dried before analysis was begun. The identification analysis was performed using a FTIR spectrometer and an Attenuated Total Reflectance accessory (ATR) and the infrared microscope accessory (Thermo Continuum). The photographs and infrared spectra are in Figures 1 to 10, Enclosure 3.

5. Identification of the foam type was performed by running the infrared spectrum of the unburned foam sample 0310027-01 (Figures 1 and 2). The spectrum produced (Figure 3.) closely matched polyester urethane foam (Figure 4.). Since foam is a polymer product made with various monomers in various ratios an exact match is not possible. This match shows the basic components that make up the bulk of the material. This foam is therefore a polyester urethane co-polymer product.

CSTE-DTC-AT-WC-C (70-10r)
MEMORANDUM FOR USACHPPM Chromatography Analysis Division
SUBJECT: Combustion of Foam Panels, Laboratory Report Number 2004-CC-045

6. The picture of a foam cell in Figure 2 shows that each cell is covered with a thick oily liquid. This liquid is not visible to the naked eye as shown in the picture in Figure 1. Identification of this liquid is essential as it is a significant component of the foam. The spectrum produced by the liquid (Figure 5.) closely matched polypropylene glycol (Figure 6.).

7. Figure 7 is a picture of the burned foam sample 0310027-02 with adhesive on the outer surface. The adhesive side of the foam was positioned against the ATR accessory and the infrared spectrum acquired (Figure 8). The library search produced the match seen in Figure 9. The best match is a latex rubber based mineral filled adhesive. A second library search was performed against a library of minerals and the library match shown in figure 10 was produced. The mineral filling in the adhesive is a silicate class compound similar to the natural mineral Kaolinite (see information with Figure 10).

8. The identification of the combustion products produced by the foam sample 0310027-01 was determined using Pyrolysis/Fourier Transform Infrared (FTIR) spectroscopy (reference 1a and 1b). See Enclosure 1 for an explanation of this technique. This type of analysis involves rapidly heating a small amount of the sample and monitoring the gas phase above the heated sample with FTIR spectroscopy. Gas products were identified using a Nicolet 760 FTIR spectrometer with an MCT-A detector. The sample was pyrolyzed (reference 1b) in a CDS Brill Cell, which fits into the sample compartment of the FTIR spectrometer so the gas products from heating could be identified in near real-time. The Brill Cell was connected to a CDS 2000 Pyrolyzer equipped with a CDS FTIR probe rod. The probe rod contains a small electrically heated ribbon upon which the samples were placed. (The ribbon can be heated up to 1350^{o}C at a variety of heating rates from 1 ^{o}C/min to 1,000,000 ^{o}C/sec. The samples (~2 mg each) were heated at 20 ^{o}C for 2 seconds then heated at a rate of 300 ^{o}C/second up to 1000 ^{o}C and held at 1000 ^{o}C for 30 seconds for this combustion study. Pyrolysis was also performed on these samples. Plots of the evolved gas phase spectra were then made. The gas spectra were searched against a database and identified.

9. Infrared spectra of pyrolysis and combustion of the samples are in Figures 11 through 19, Enclosure 3. Descriptive data on the samples is in Tables 1 and 2, Enclosure 2. Identification of the pyrolysis and combustion products is in Table 3. Since the two foam samples were identical only samples 0310027-01 was pyrolized and combusted.

10. Pyrolysis occurs when the sample is heated in a 100% nitrogen atmosphere. Initial pyrolysis products are produced about 8 seconds into the 30 second heating time. Initial products frequently contain vaporized parent molecules (the starting compound). Final pyrolysis products are what are present at the end of the run (29 to 31 seconds). The parent molecule is often converted completely into lighter weight molecules by this time.

11. The pyrolysis of foam is shown in Figures 11 to 14. The fully pyrolized foam is displayed in figure 11. A large absorption at ~2270 cm^{-1} is produced in this spectrum. The best library match; methyl isocyanate, is shown in figure 12. Figure 13 is the infrared spectrum of the pyrolized foam with all of the major absorption peaks labeled. Note that due to a lack of oxygen the amounts of carbon dioxide and carbon monoxide are low.

12. Figure 14 shows the foam pyrolysis progression. Initially the isocyanate compound (which is thought to be a mixture of C1 to C4 isocyanates) and foam vapor is detected, next carbon monoxide and carbon dioxide are formed from the foam vapor. The final pyrolysis products are an Isocyanate Compound (H_yC_xNCO), and much lesser quantities of Carbon Dioxide (CO_2), Carbon Monoxide (CO), Ethylene (C_2H_4), Acetylene (C_2H_2), Hydrogen Cyanide (HCN) and Vaporized Foam. The more oxygen starved the combustion of foam the more the gases produced will favor the final pyrolysis products. Not all of the foam is consumed in this pyrolysis. See Enclosure 4 for more information on the reaction mechanism and isocyanate compounds.

13. Combustion occurs when the sample is heated in an oxygen atmosphere. Initial combustion products are produced about 8 seconds into the 30 second heating time. Initial products frequently contain vaporized parent molecules (the starting compound). Final combustion products are what are present at the end of the run (29 to 31 seconds). The parent molecule is often converted completely into carbon dioxide and water vapor by this time.

14. The combustion of the foam is shown in Figures 15 through 18. The fully combusted foam is displayed in figure 15. A large absorption at ~2270 cm^{-1} is produced in this spectrum. The best library match; an isocyanate compound, is shown in figure 16 along with the major gases that are produced in this combustion. Figure 17 is the infrared spectrum of the pyrolized foam with all of the major absorption peaks labeled.

CSTE-DTC-AT-WC-C (70-10r)
MEMORANDUM FOR CHPPM Chromatography Analysis Division
SUBJECT: Combustion of Foam Panels, Laboratory Report Number 2004-CC-045

15. Figure 18 shows the foam combustion progression. The initial combustion products are the isocyanate compound (which is thought to be a mixture of C1 to C4 isocyanates) and foam vapor. At this point (about 6 seconds into the combustion) the products are the same as pyrolysis. As the combustion progresses (see middle and lower spectra on Figure 18.) large quantities of carbon dioxide and carbon monaoxide are produced. The final products are the Isocyanate Compound (H_yC_xNCO), Carbon Dioxide (CO_2), Carbon Monoxide (CO), Methane (CH_4), Ethylene (C_2H_4), Acetylene (C_2H_2), Hydrogen Cyanide (HCN), and Vaporized Foam. Combustion is incomplete as evidenced by the presents of carbon monoxide and foam vapor. See Enclosure 4 for more information on the reaction mechanism and isocyanate compounds.

16. Figure 19 is included to show some of the major functional chemical groups in the original foam. The aliphatic hydrocarbons produce Methane (CH_4), Ethylene (C_2H_4), Acetylene (C_2H_2), as they break down into smaller molecules during combustion. As these smaller molecules are oxidized (combusted) they form Carbon Dioxide (CO_2) and Carbon Monoxide (CO). The isocyanate compound is released from the polymer backbone by the heat of combustion and forms the mixture of C1 to C4 isocyanates. The nitrile compound is the most likely source of the hydrogen cyanide. The ester and urethane (not labeled) parts of the foam also form isocyanates (see enclosure 4 explanation of thermal degradation mechanisms). All other parts on the foam contribute to the Carbon Dioxide (CO_2) and Carbon Monoxide (CO) seen in the combustion sepctra.

17. The POC for this report is Paul Marsh, (410) 278-3024.

Enclosure 1.

Analytical Method: Fourier Transform Infrared Spectroscopy With Brill Pyrolysis Cell

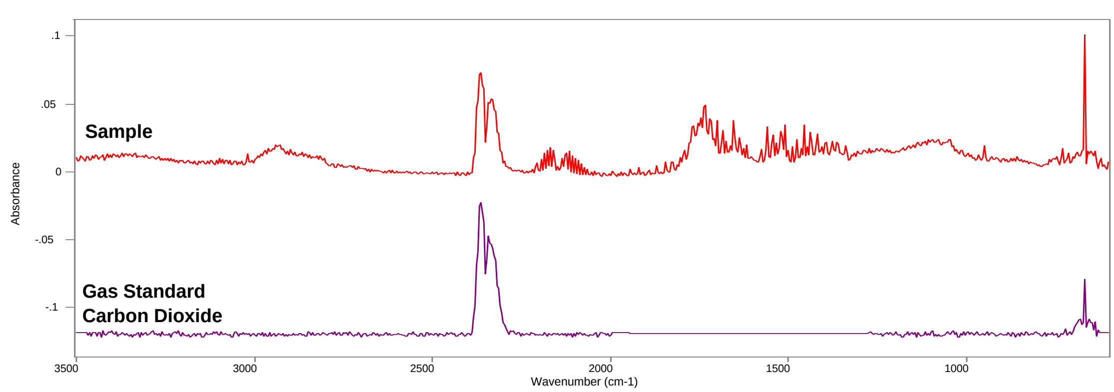
Fourier transform infrared spectroscopy (FTIR) is an analytical technique that exploits the infrared light absorbing characteristics of chemical compounds. Most major chemical functional groups i.e., alcohols, hydrocarbons, ethers etc., have specific absorption bands in the infrared region of the light spectrum. From noting which infrared frequencies a sample absorbs, the chemical structure of a sample can be determined. Quantitative information can be determined from the intensity of the absorption bands.

An FTIR spectrophotometer is the instrument used to scan the infrared light region. The instrument produces a plot of absorption vs. infrared frequency. The major parts of an FTIR spectrophotometer with Brill Pyrolysis Cell are as follows:

1. Source of infrared light (glowbar)
2. Interferometer (frequency modulator)
3. Brill pyrolysis Gas Cell (sample is held in the cell) with heated probe
4. Detector of infrared light (MCT semiconductor)
5. Computer controller with Data Base of infrared spectra

The Brill Pyrolysis Cell is an accessory that fits into the sample compartment of the FTIR spectrometer. The accessory has two parts the gas cell and pyrolysis probe. The pyrolysis probe has a filament (ribbon) that can be rapidly heated to greater than 1000 degrees Celsius. The sample is placed on this ribbon and the probe is placed in the gas cell. The gas cell is a fixed volume container that holds all the gases produced by the pyrolysis of the sample. The atmosphere in the cell can be selected to match the experiment i.e. nitrogen for pyrolysis or nitrogen oxygen mixture for combustion. The cell can be set for static or dynamic flow. The infrared beam passes through the cell and the gases are detected by the FTIR.

To determine the chemical makeup of samples, they must be compared to reference standards. Libraries of gas samples are available to identify the gases detected.



Enclosure 2.

Table 1. Foam Sample Identification

Sample Number	**Common Name**	**Description**
0310027-01	Gray polyester urethane foam	New Unburned foam
0310027-02	Gray polyester urethane foam	Piece 1 Foam with adhesive Piece 2 Burned Foam

Table 2. Foam Sample Descriptions

Sample Number	**Description**
0310027-01	RI1 Northwall Unburned 9/5/03
0310027-02	RI1Drummer's Box Burnt Foam 9/5/03

Table 3. Foam Pyrolysis and Combustion Products

Sample Number	**Test**	**Expected Combustion Products**
0310027-01	**Pyrolysis**	Isocyanate Compound (H_xC_xNCO), Carbon Dioxide (CO_2), Carbon Monoxide (CO), Ethylene (C_2H_4), Acetylene (C_2H_2), Hydrogen Cyanide (HCN), Vaporized Foam
0310027-01	**Combustion**	Isocyanate Compound (H_xC_xNCO), Carbon Dioxide (CO_2), Carbon Monoxide (CO), Methane (CH_4), Ethylene (C_2H_4), Acetylene (C_2H_2), Hydrogen Cyanide (HCN), Vaporized Foam

Enclosure 3.

Identification

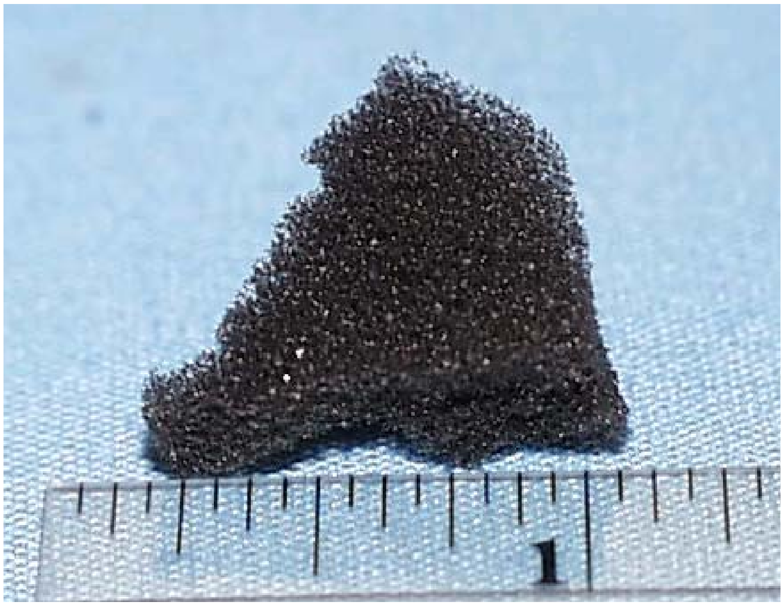


Figure 1. Sample 0310027-01 unburned foam.

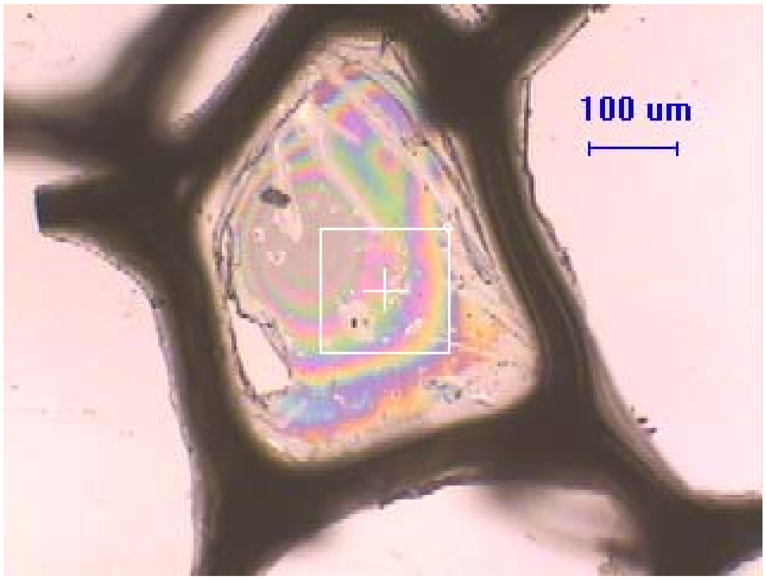


Figure 2. Microscope picture of sample 0310027-01 unburned foam at 100X magnification. This is a picture of one foam cell. All of the foam cells outer edges are covered in a thick clear liquid. This cell has the liquid actually spanning the open area of the cell.

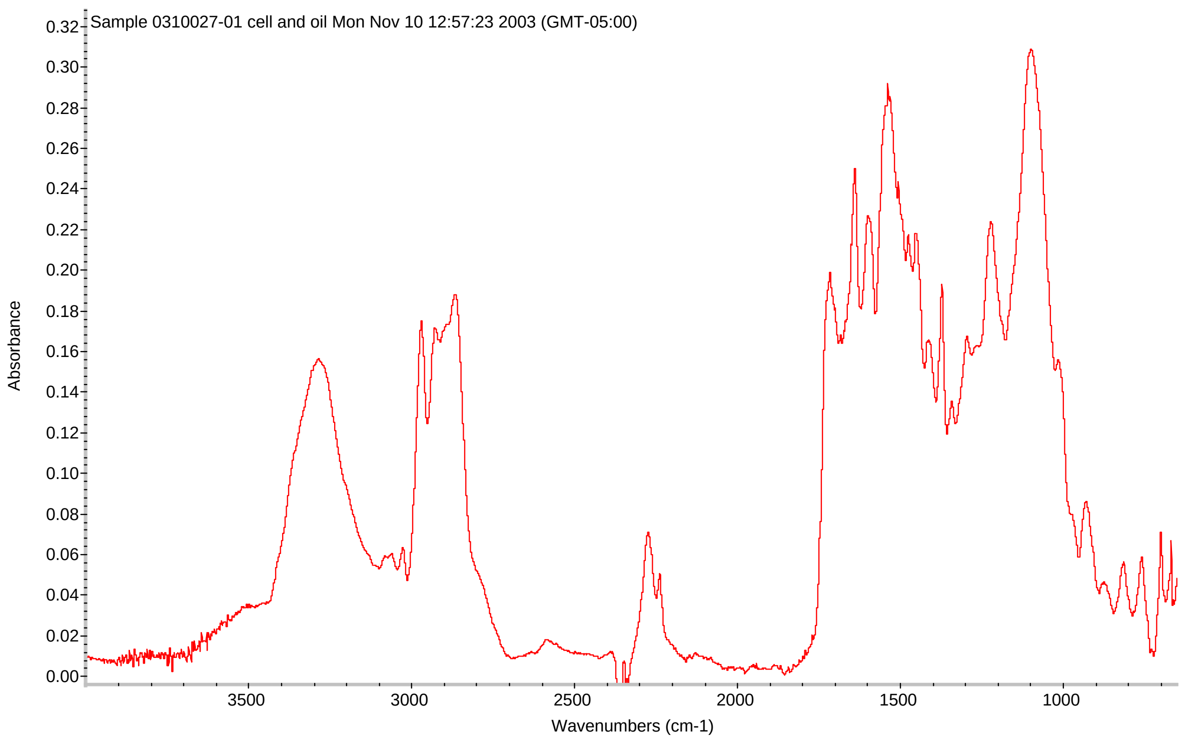


Figure 3. Infrared spectrum of sample unburned gray foam.

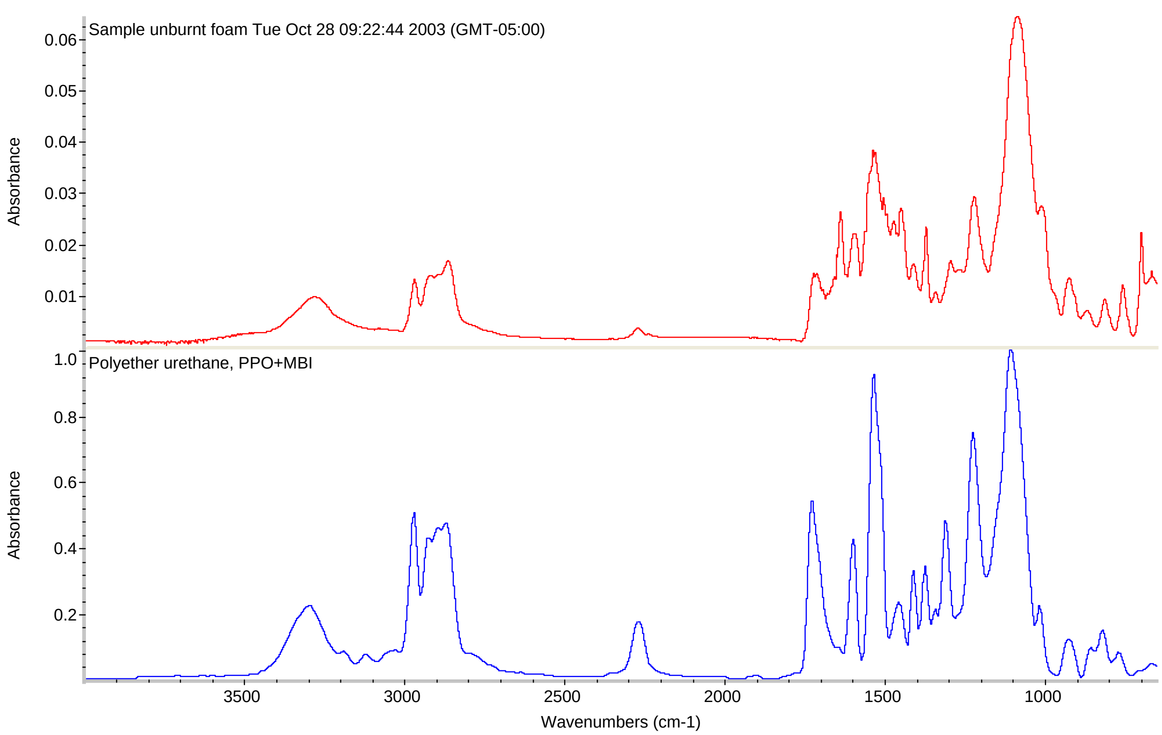


Figure 4. Infrared spectrum of sample unburned gray foam (top), best library match polyester urethane foam (bottom).

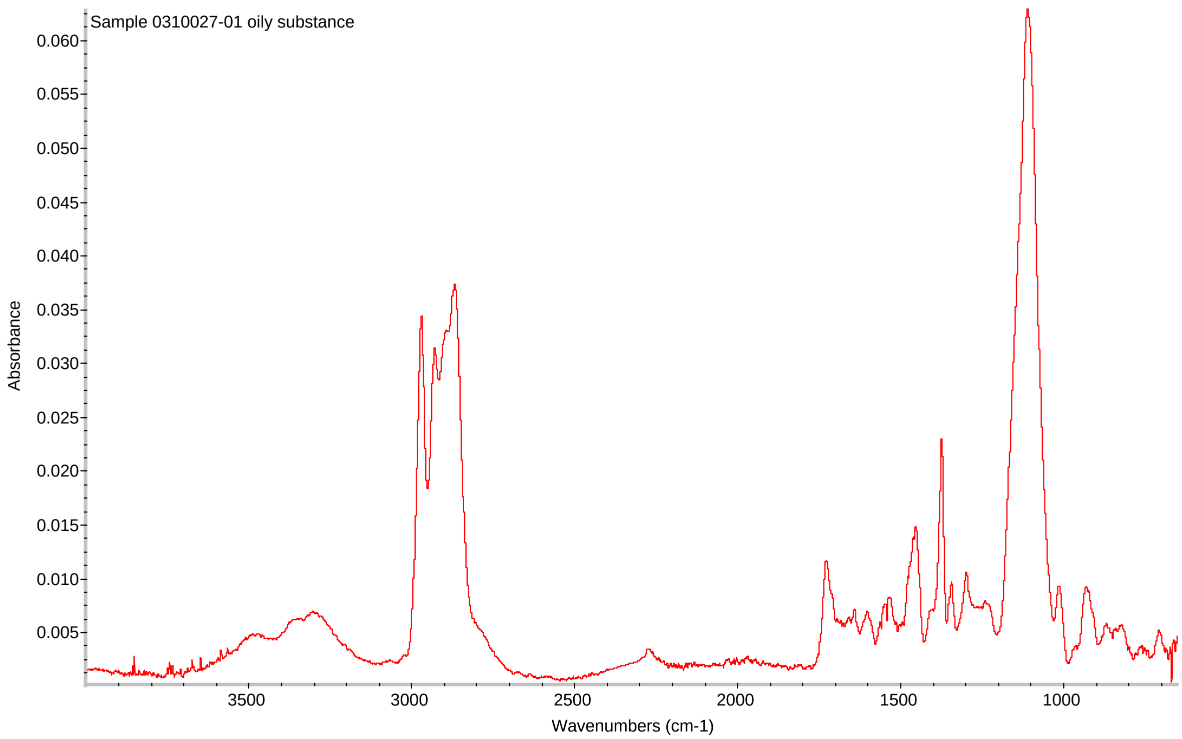


Figure 5. Infrared spectrum of sample oil on unburned gray foam.

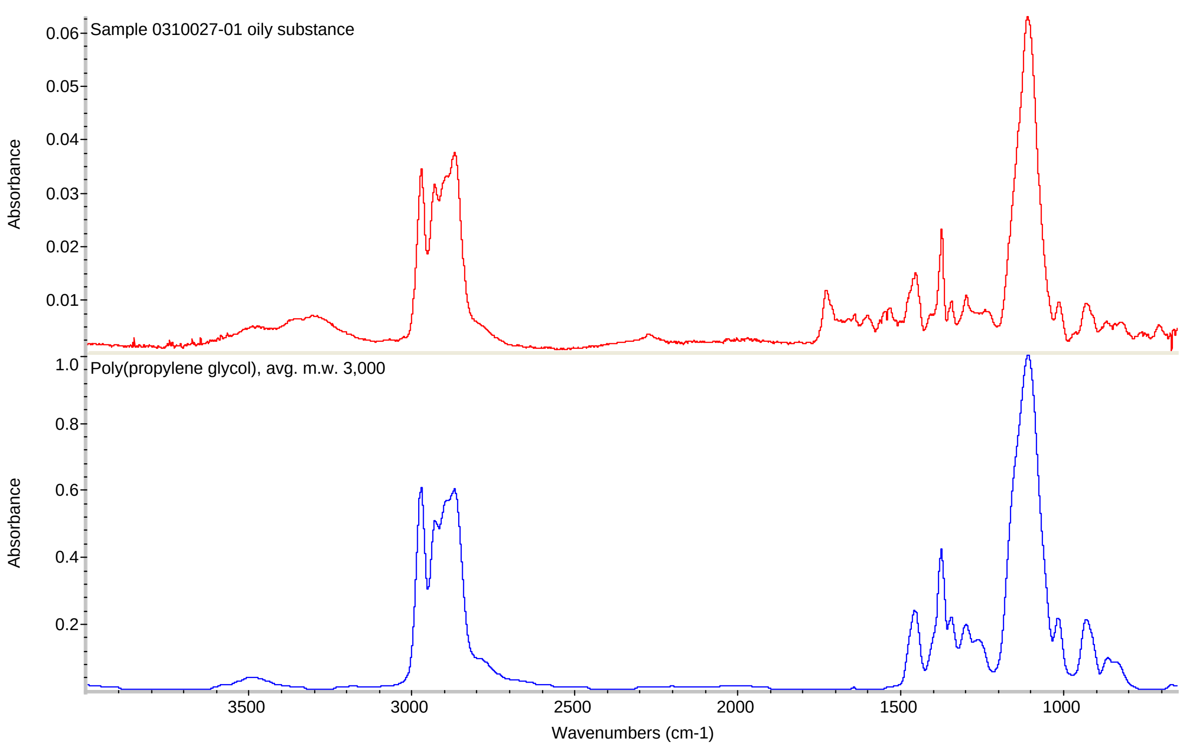


Figure 6. Infrared spectrum of sample oil on unburned gray foam (top), best library match polypropylene glycol (bottom).

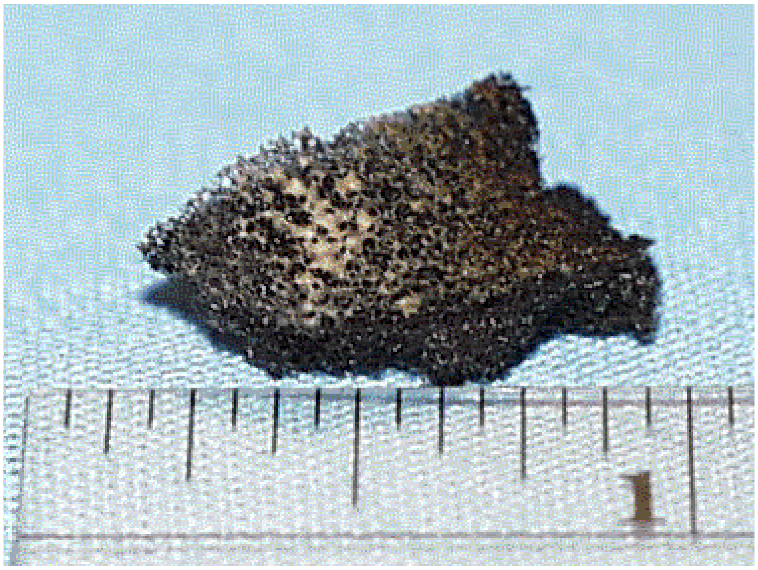


Figure 7. Sample 0310027-02 piece1 foam with adhesive.

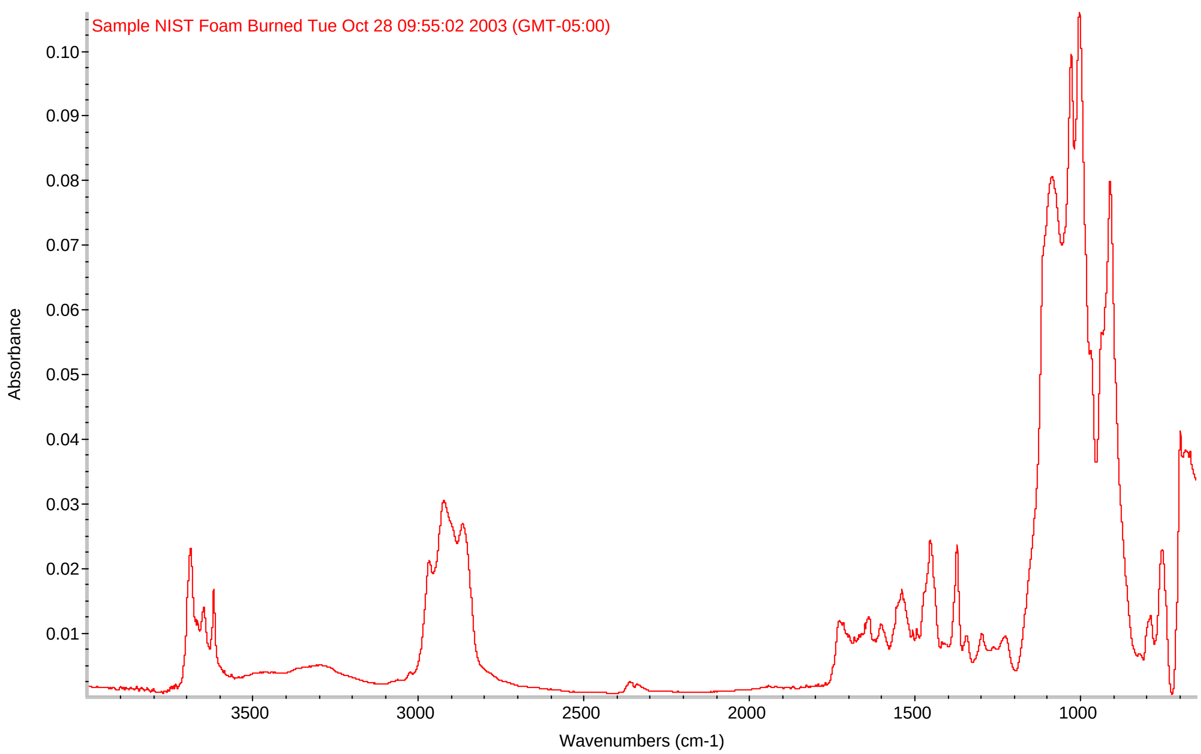


Figure 8. Infrared spectrum of sample foam adhesive.

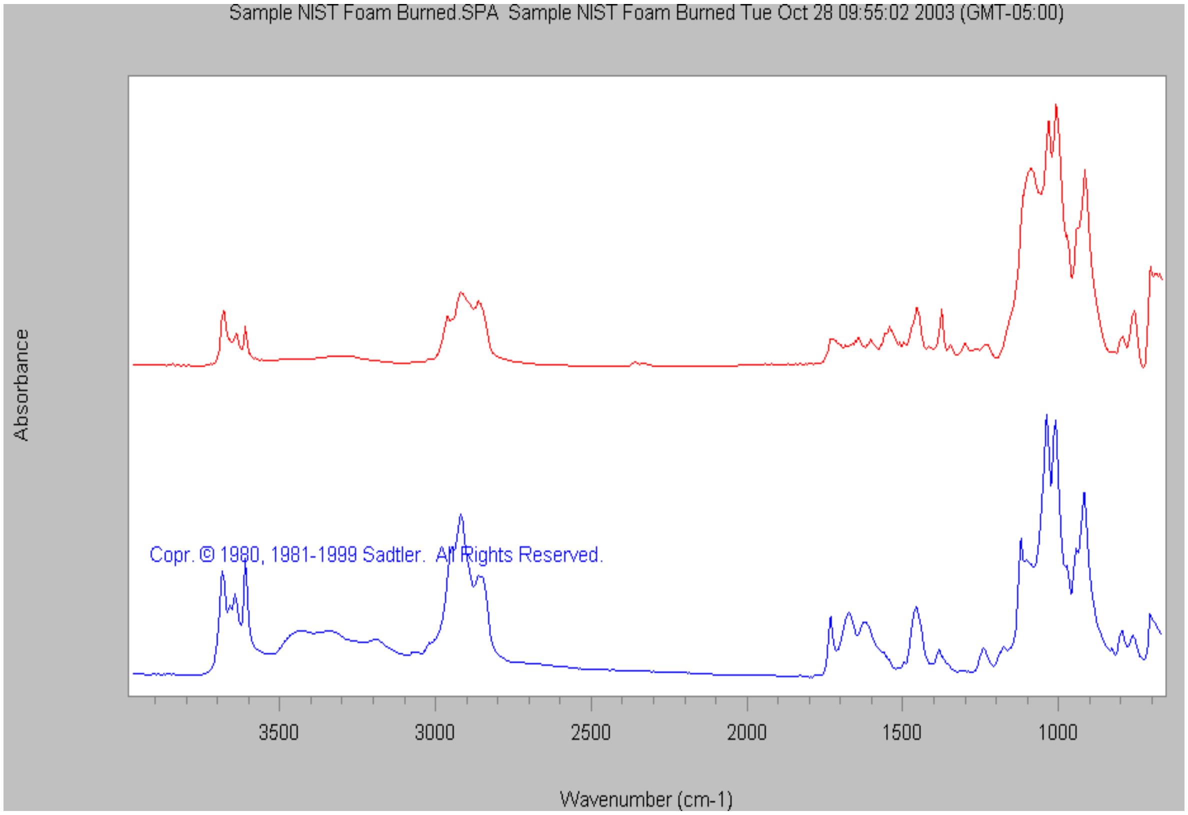


Figure 9. Infrared spectrum of foam adhesive (top), best library match a mineral filled latex based adhesive (bottom).

Database Information:
WELDWOOD MULTI-PURPOSE FLOOR ADHESIVE

Chemical Description= LATEX-BASED ADHESIVE
Content= Solids Content= 55%
Density= (Specific Gravity)= 1.17 g/ml
FlashPt= (PMCC) 100 ^{o}C Flash and Fire
Weight= 9.5 LBS/GAL

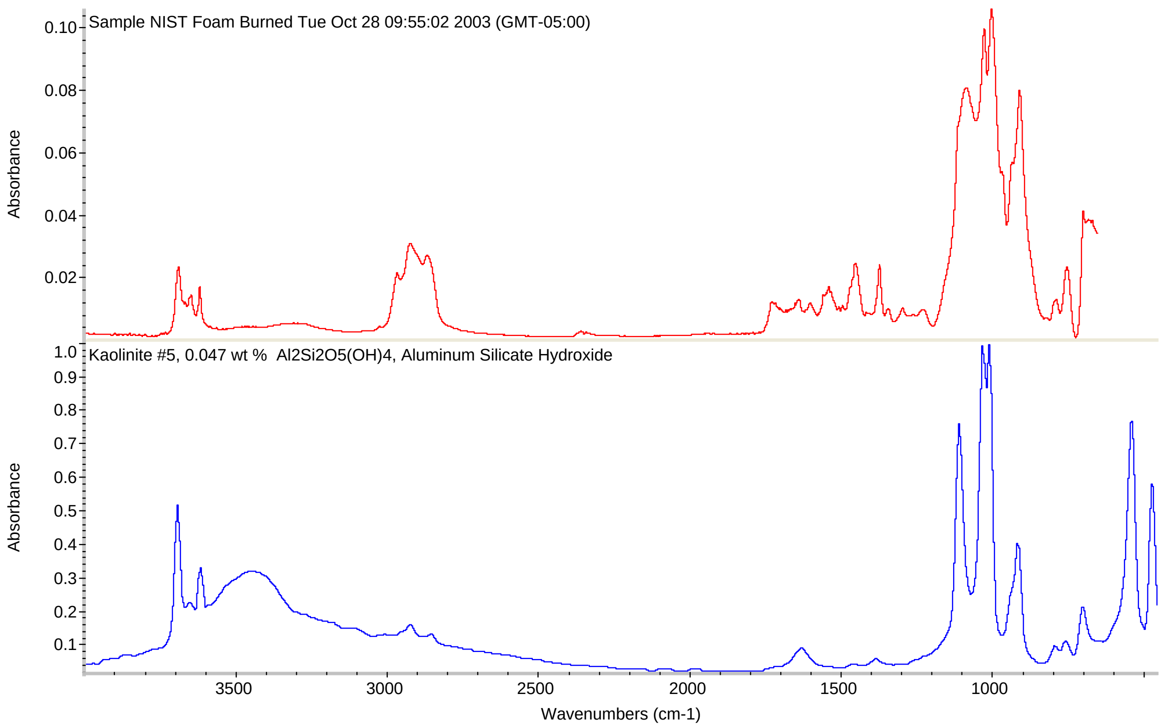


Figure 10. Infrared spectrum of sample foam adhesive (top), best library match of the mineral filler kaolinite $Al_2Si_2O_5(OH)_4$, (bottom).

Database Information on KAOLINITE

:

- **<u>Chemistry:</u> $Al_2Si_2O_5(OH)_4$, Aluminum Silicate Hydroxide**
- **<u>Uses:</u> In the production of ceramics, as a filler for paint, rubber and plastics and the largest use is in the paper industry to produce a glossy paper such as is used in most magazines.**

Pyrolysis

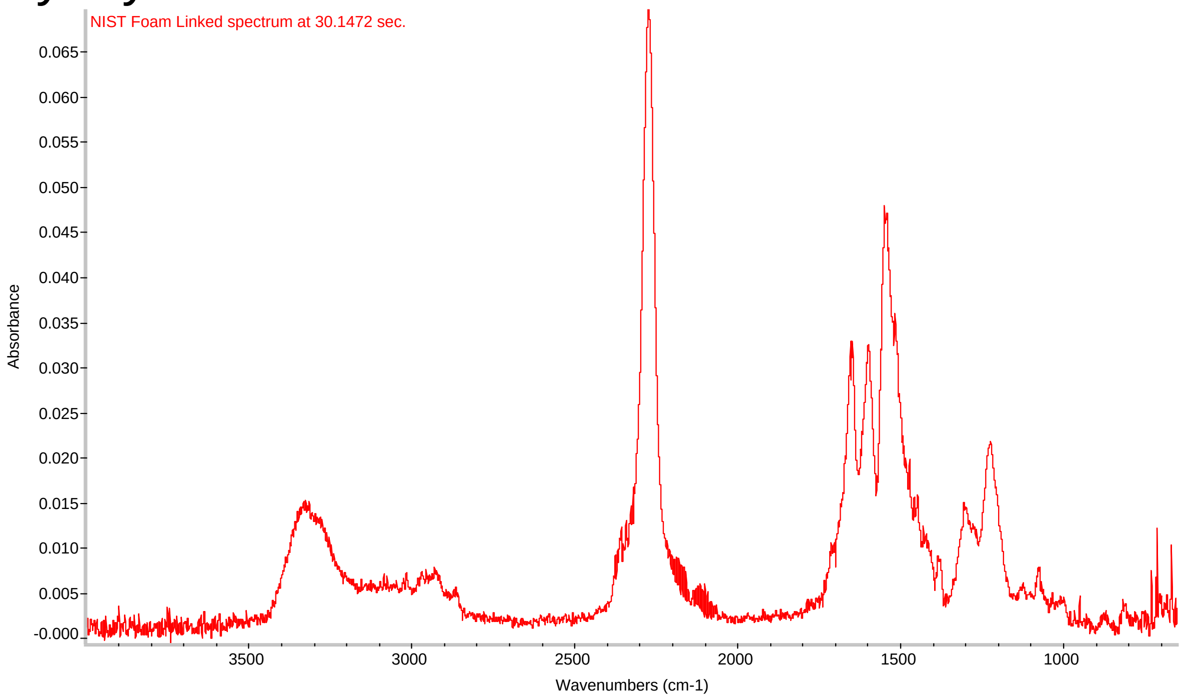


Figure 11. Infrared spectrum of Foam Pyrolysis. The isocyanate peak 2270 cm^{-1} is from a class of compounds with the general formula H_xC_xHNO. These compounds are very toxic.

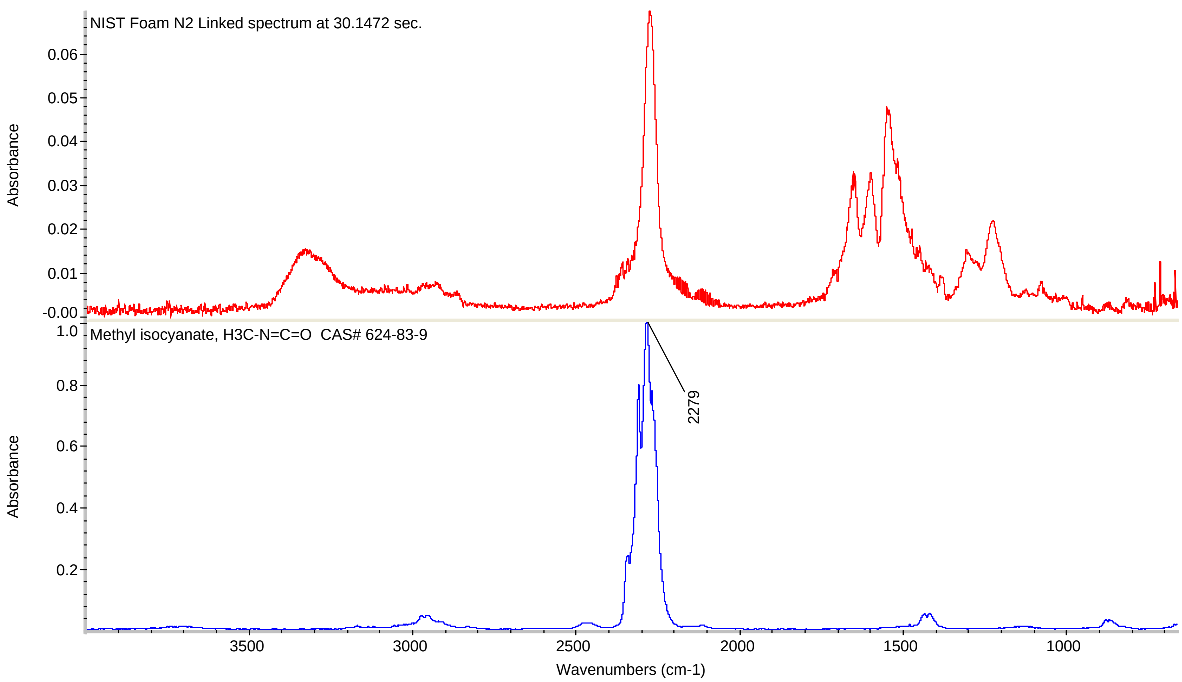


Figure 12. Infrared spectrum of sample pyrolized foam (top). Best library match is methyl isocyanate (peak ~2270 cm^{-1}). This is a match to a class of isocyanate compounds. Methyl, Propyl, and even Butyl isocyanate have spectra that cannot be distinguished at this resolution.

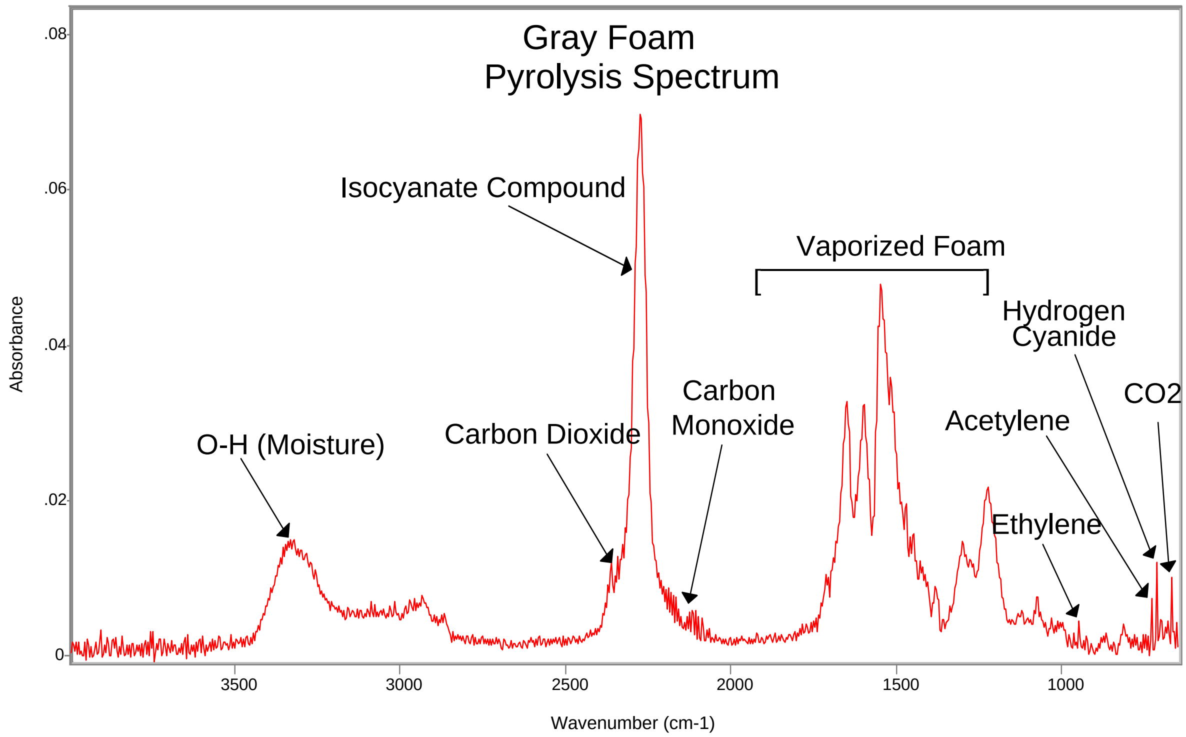


Figure 13. Infrared spectrum of gray foam pyrolysis with gases labeled. The more oxygen starved the combustion the more the final products will be similar to the pyrolysis products.

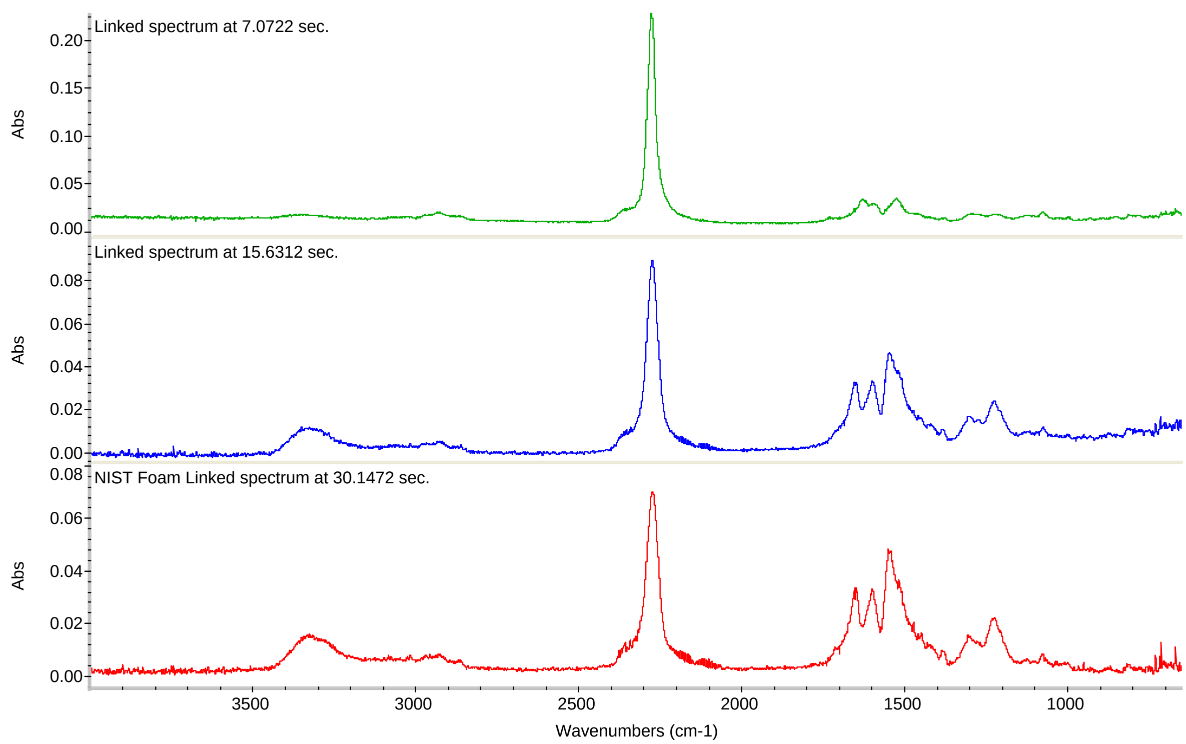


Figure 14. Infrared spectrum of Foam pyrolysis progression.

Combustion

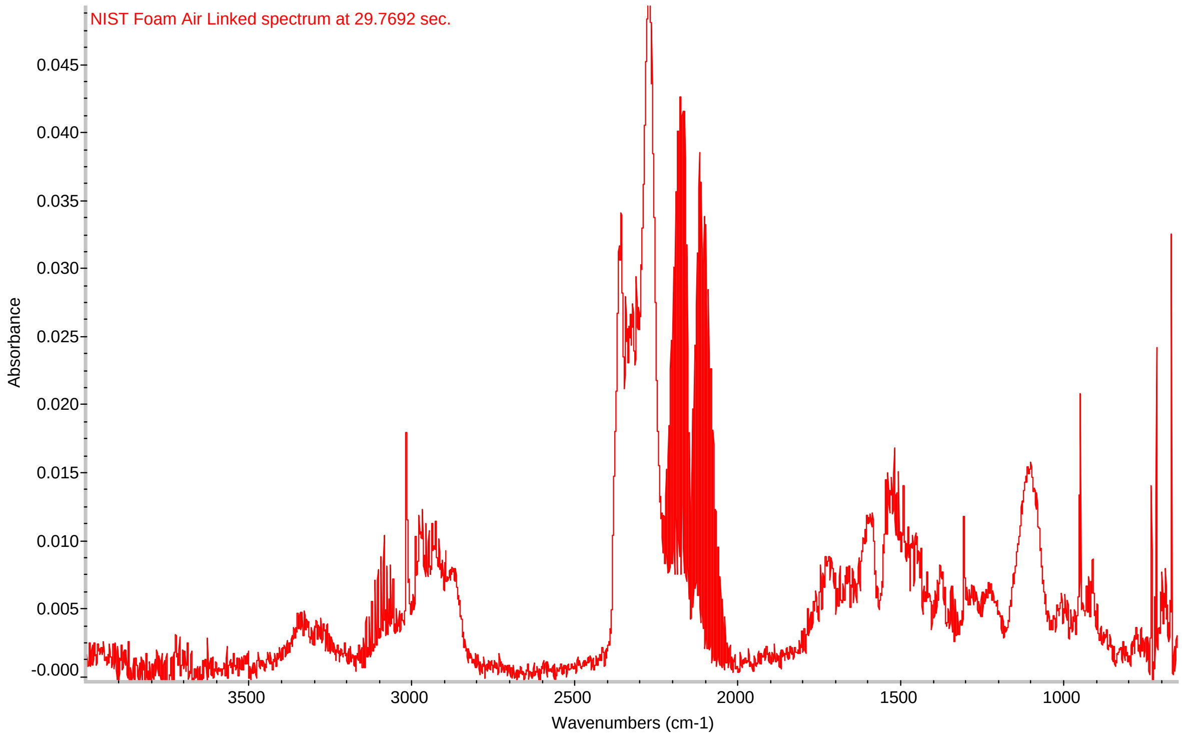


Figure 15. Infrared spectrum of Foam Combustion in air.

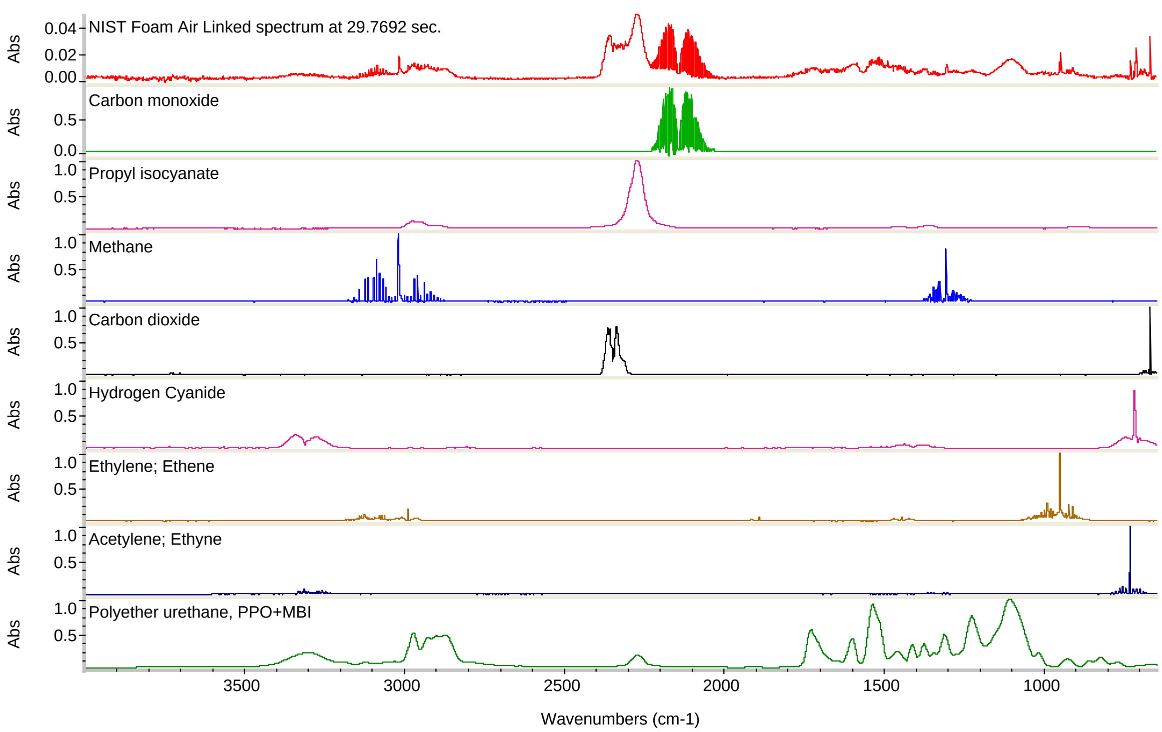


Figure 16. Infrared spectrum of Foam Combustion (top) and identified gases below.

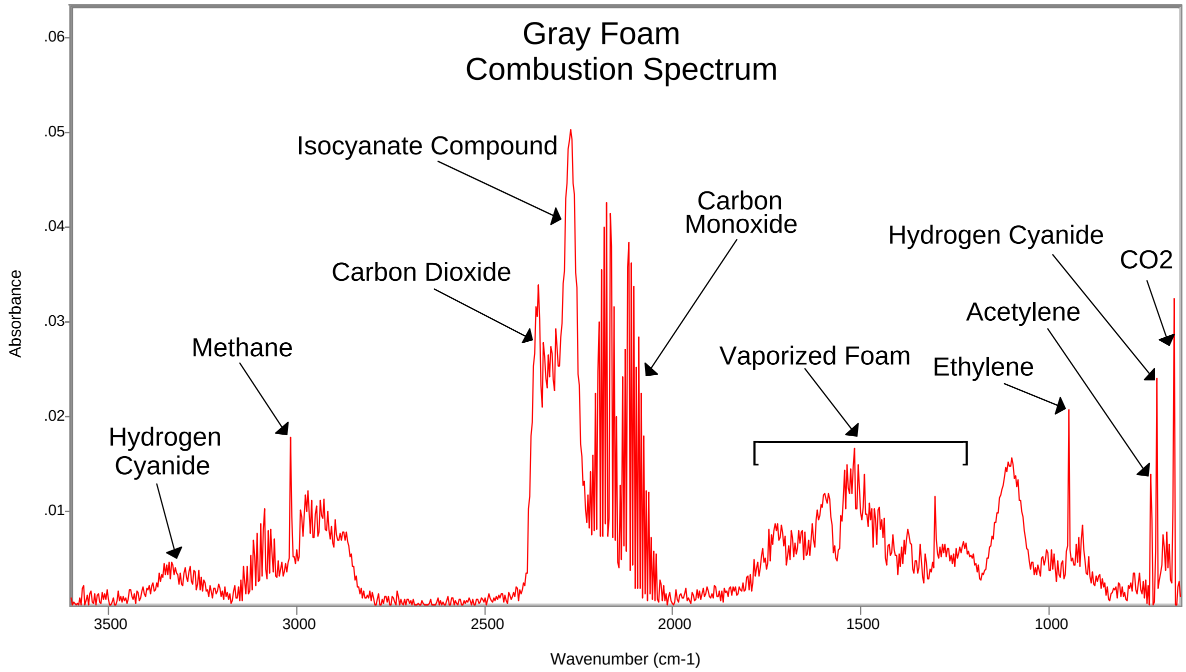


Figure 17. Infrared spectrum of Gray foam combustion with combustion gases labeled

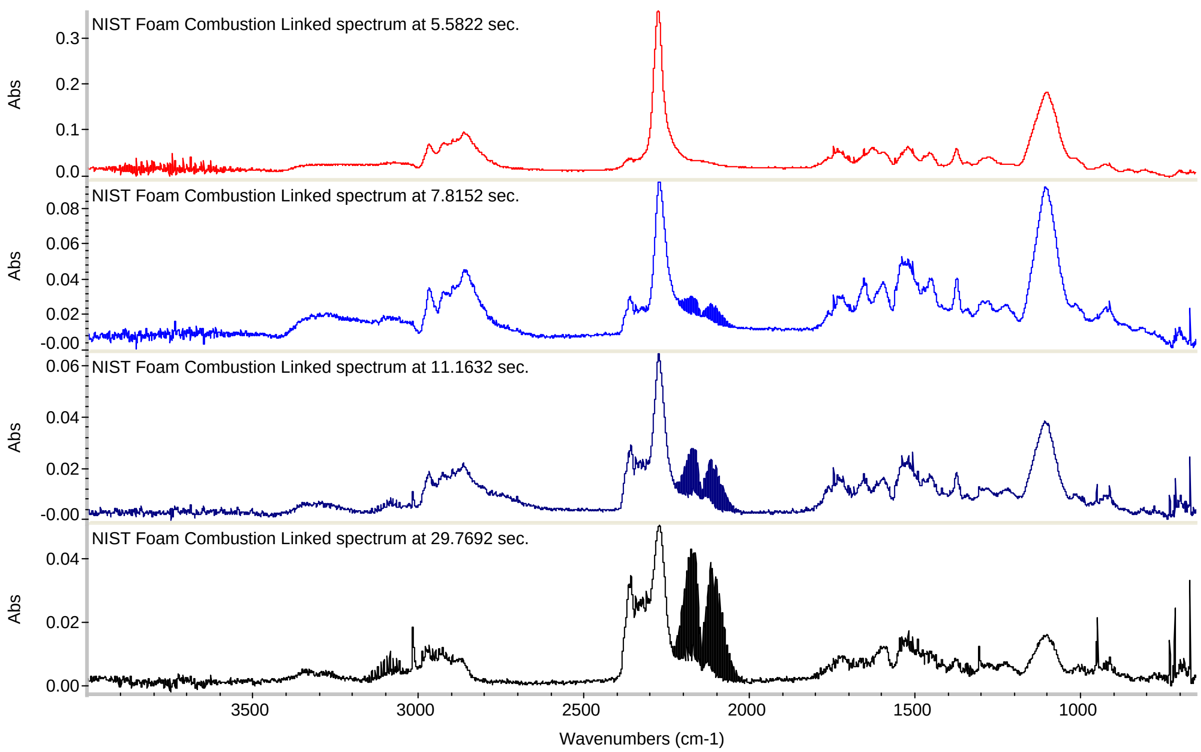


Figure 18. Infrared spectrum of Foam Combustion progression. Note the growth of the carbon monoxide peak (centered at 2150 cm^{-1}) as the combustion progresses from 5 to 30 seconds. The isocyantate compound peak (~2270 cm^{-1}) dominates each spectrum. The polypropylene peak (~1100 cm^{-1}) is decreasing showing that the oily polypropylene (glycol?) compound is being consumed as the combustion progresses.

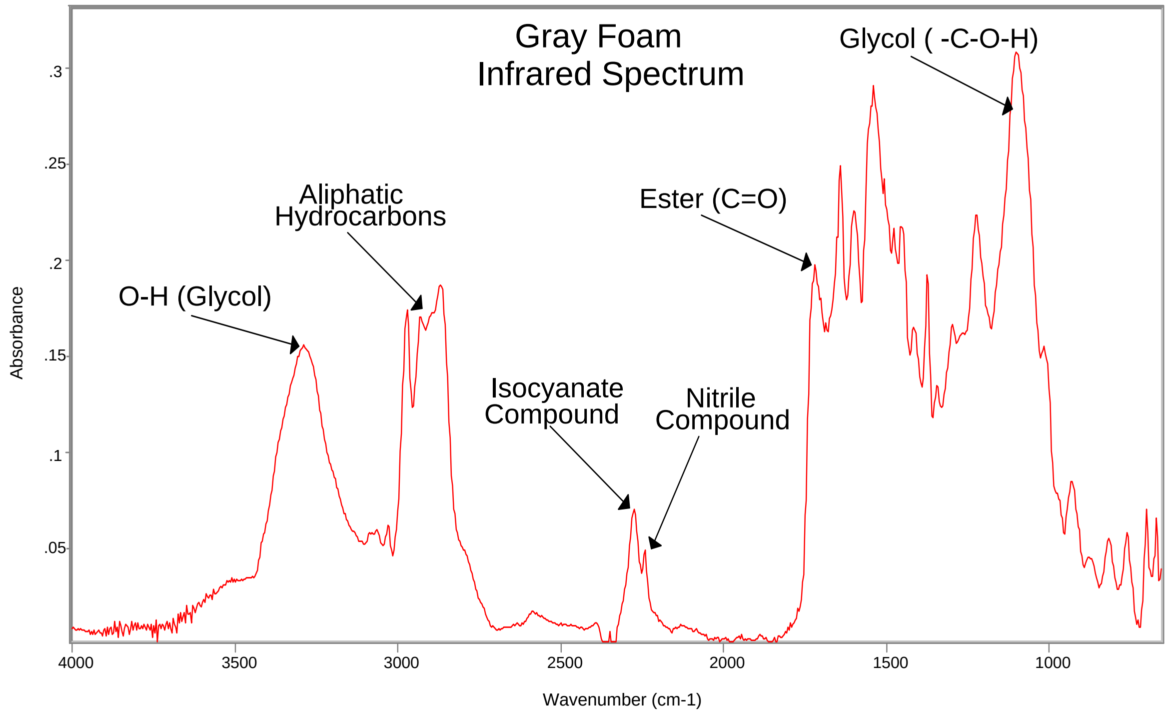
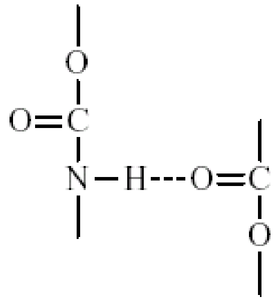


Figure 19. Infrared spectrum of gray polyether urethane foam with major structures labeled.

Enclosure 4.

Background Information:

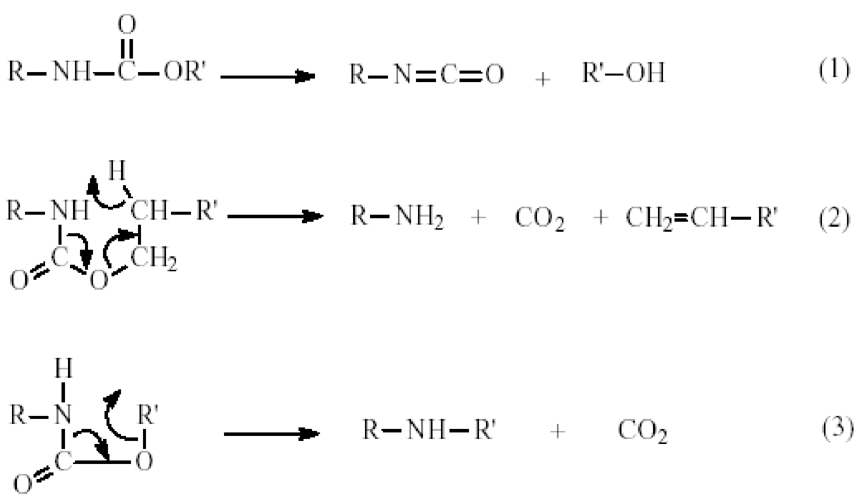


Urethane-Ester

Figure 1. Basic chemical structure of polyester urethane foam.

The chemical structure of the foam as shown in Figure 1 consists of two parts. The left side of the figure shows the urethane (OC=ONH) structure, the right side shows the ester (OC=O) structure.

The thermal degradation mechanism of polyurethane is very complicated. It has been suggested that polyurethanes break down by a combination of three independent pathways: (1) dissociation to the original polyol and isocyanate; (2) formation of a primary amine, an alkene, and a carbon dioxide in a concerted reaction involving a six-membered cyclic transition state; (3) formation of a secondary amine and carbon dioxide through a four-membered ring transition state, as shown in Scheme 2.2.[143-147]



Reference: pg. 50 of http://scholar.lib.vt.edu/theses/available/etd-72698-13572/unrestricted/Disswhl2.pdf

From the referenced combustion mechanism above pathway 1 which produces isocyanates must be the dominant combustion pathway. The large isocyanate peak in both the pyrolysis and combustion spectra of Figure 2 support this.

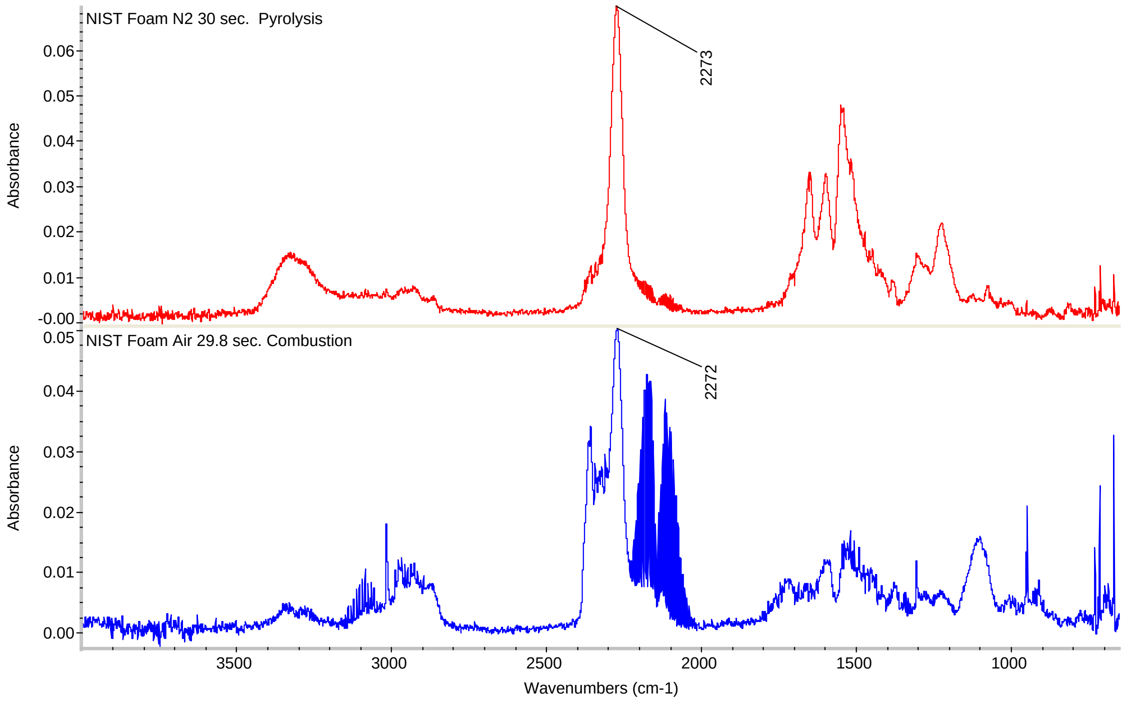


Figure 2. Infrared spectrum of foam pyrolysis gases (top) and combustion gases (bottom). The dominate peak in each spectrum is the peak at ~2270 cm^{-1}). This peak most closely matches isocyanate compounds (see figure 3). The related isocyanide compounds are not a good match (see figure 4) because their absorbance is too far from 2270 cm^{-1}.

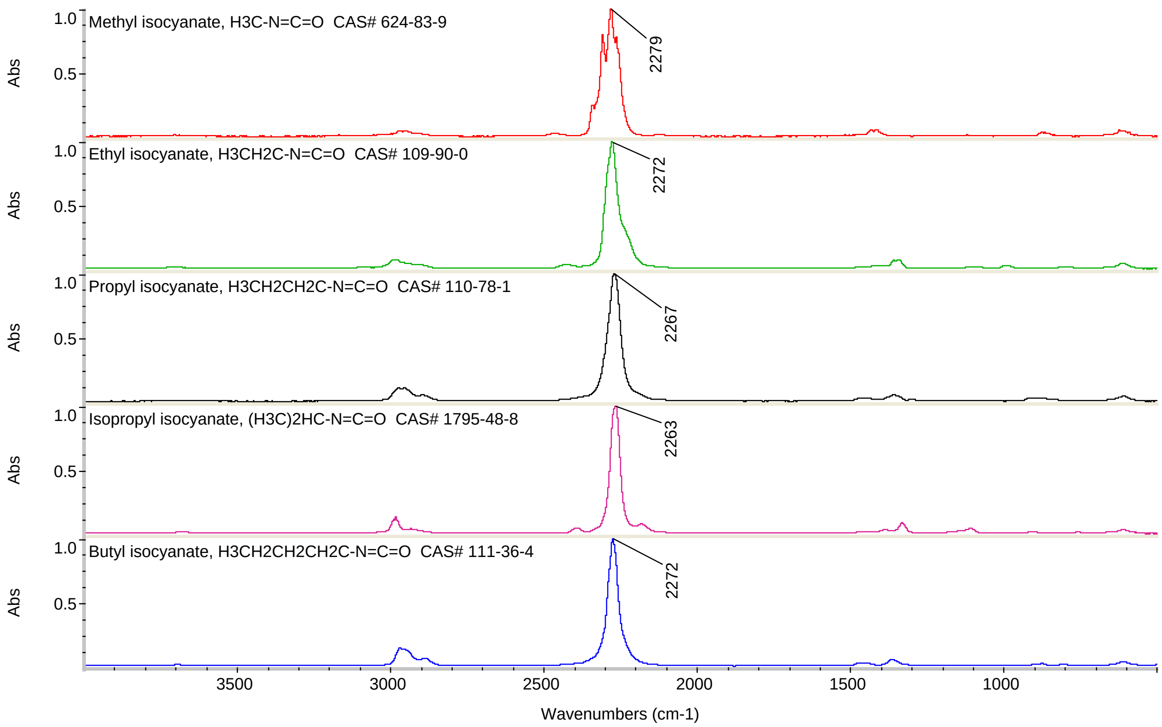


Figure 3. Infrared spectra of selected isocyanate compounds all with absorbance's in the 2270 +/- 9 cm^{-1} range. These are some of the most likely compounds to match the 2270 cm^{-1} peak in the pyrolysis and combustion spectra (Figure 2.).

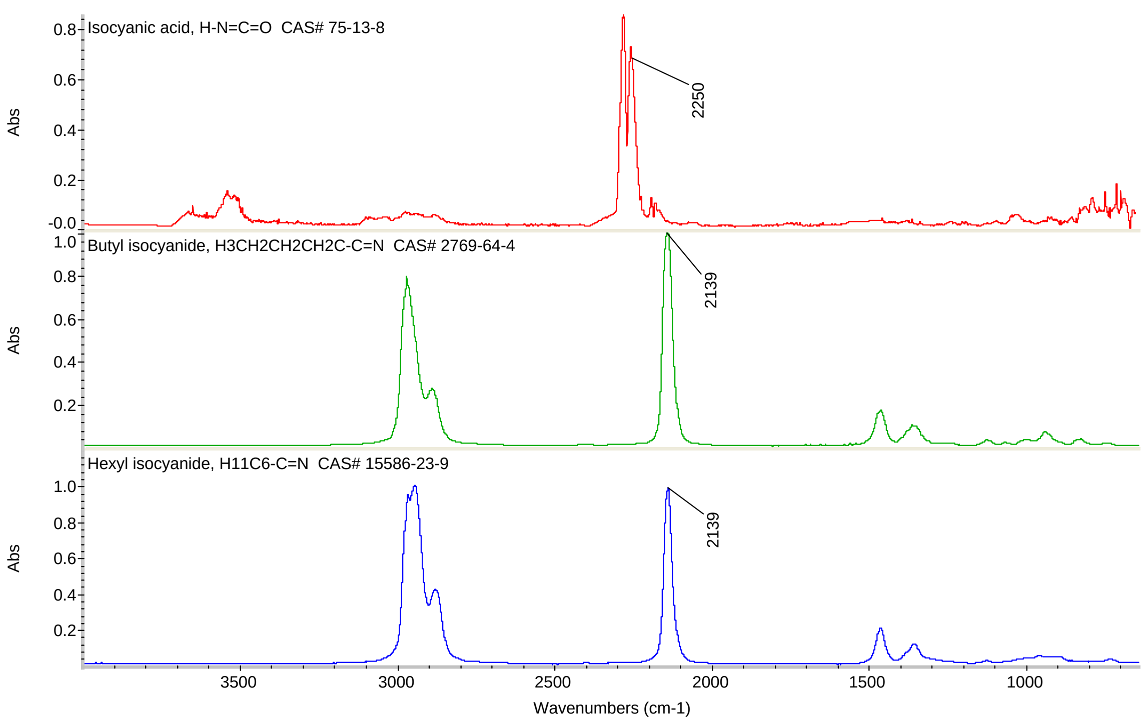


Figure 4. Infrared spectra of selected isocyanide compounds. These have a slightly different structure than the isocyanate compounds in Figure 3. These do not match the 2270 cm^{-1} peak in the pyrolysis and combustion spectra (Figure 2.).

APPENDIX J. HYDROGEN CYANIDE ANALYSIS

J.1 HYDROGEN CYANIDE REPORT

This work was contracted with the US Army Aberdeen Test Center and performed by Dr. Steven H. Hoke of the Chromatography Analysis Division.

TEST #: 1 Sprinkler September 5, 2003

TEST #: 2 No Sprinkler September 10, 2003

ORGANIZATION: NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY, GAITHERSBURG, MD

TEST FIXTURE: Rhode Island Test

SETUP: Two sampling positions were used to conduct real-time hydrogen cyanide analysis on two different test days at NIST. The two sampling positions were designated position 1 (West – NIST Location D) and position 2 (East- NIST Location C), and were 3.66 m and 1.83 m west of the stage, respectively. Each sample position was located 1.5 m off the floor and 2.74 m from the south wall of the compartment (Figure J-1).

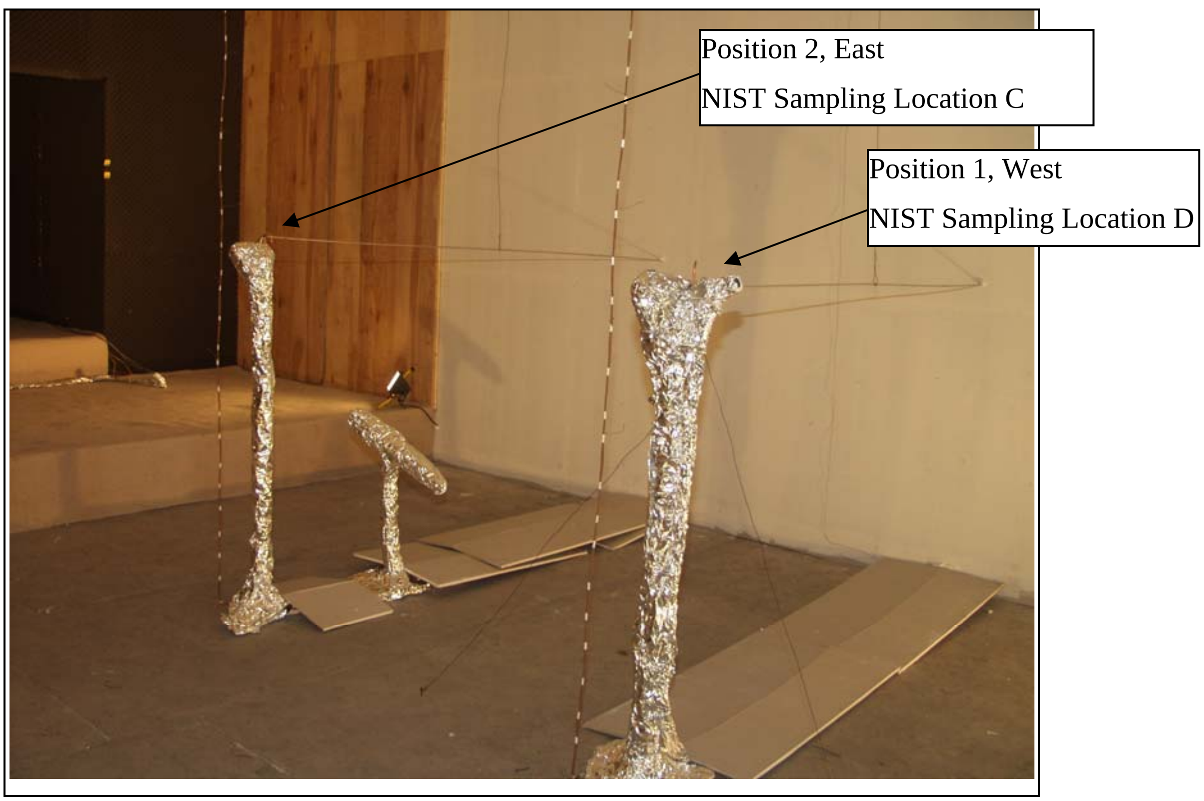


Figure J-1. Sampling positions inside Rhode Island test fixture.

The Sampling equipment was located on a table just outside the south wall of the compartment. Air samples were taken through a ¼-in. o.d. 304 stainless steel tubing. An additional 3 ft. of stainless steel tubing was placed on the outside to provide for cooling of the hot sample gases. A stainless steel 4-port sampling manifold using Swagelok tees was attached to the end of each sample line. Red silicone tubing was used to attach samplers to the manifold (Figure J-2).

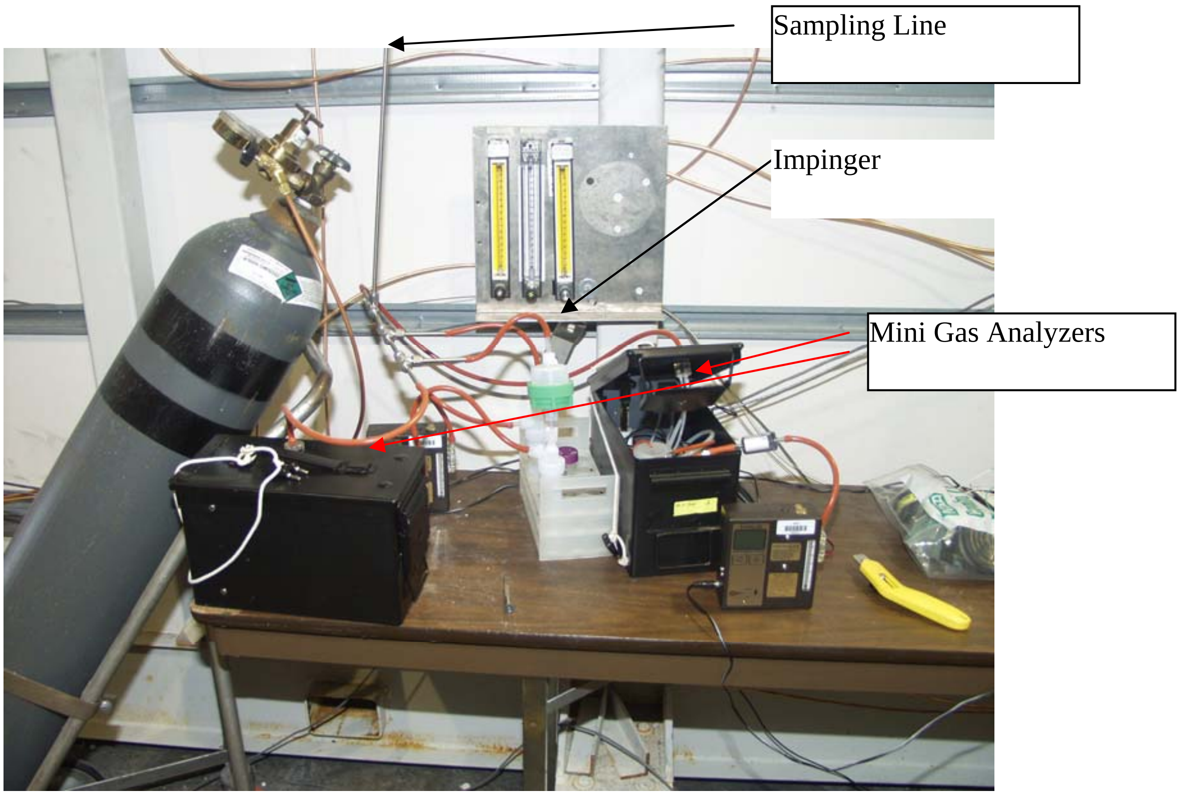


Figure J-2. Sampling set up at Position 1 for test 1.

At each sampling position two impinger samples were taken, one with a filter and one without. Each of these impingers used 0.1 M KOH as trapping solution. For the first test two mini gas real-time cyanide analyzers were used at position 1 and a suitcase-size version of the analyzer was used at position 2. For test 2 a mini gas analyzer was used at each position. Airflow rates were measured and recorded before each test. Voltage signals from the analyzers were recorded on data loggers and also sent to the main control computer.

With the high gas temperatures anticipated a 3-ft. extension of stainless steel tubing was attached between the exterior wall and the sampling manifold. To determine the cooling effect this had on the sample gases, a T type thermocouple was attached to the stainless steel tubing just outside the wall and one just before the sampling manifold. A Fluke model 2635A Hydra Series II Data Bucket collected data from each of the two thermocouples. This data was only collected for the second test because higher temperatures were anticipated.

After the second test both of the 9-ft. stainless steel lines were removed from the test fixture and rinsed in a vertical position with 10 mL of 0.1 M KOH.

Upon returning to the laboratory the filters were weighed and then placed in a screw cap-polypropylene test tube with 10 mL of 0.1 M KOH.

After each test the contents of the impingers were transferred to a test tube and labeled.

Impinger samples were analyzed according to NIOSH Method 7904.

The real-time mini gas analyzers as described elsewhere (Paper submitted to J. Process Anal. Chem. for publication) were modified to use an off-the-shelf cyanide combination electrode and 0.1 M KOH as the trapping solution. Calibration standards were prepared in 0.1 M KOH using KCN at levels of 2, 5, 10, and 30-ppm cyanide. This corresponds to an upper and lower calibration limit in air of 153 and 10 ppm HCN, respectively. The gas analyzer showed linearity up to 1284 ppm HCN in air, so the high values obtained during the second test can be considered valid.

RESULTS:

Figures J-3 to J-5 show real-time results from the three HCN gas analyzers used for test 1conducted on 5 Sept 03. The automatic sprinkler system activated at about 25 sec.; therefore, there was very little HCN produced.

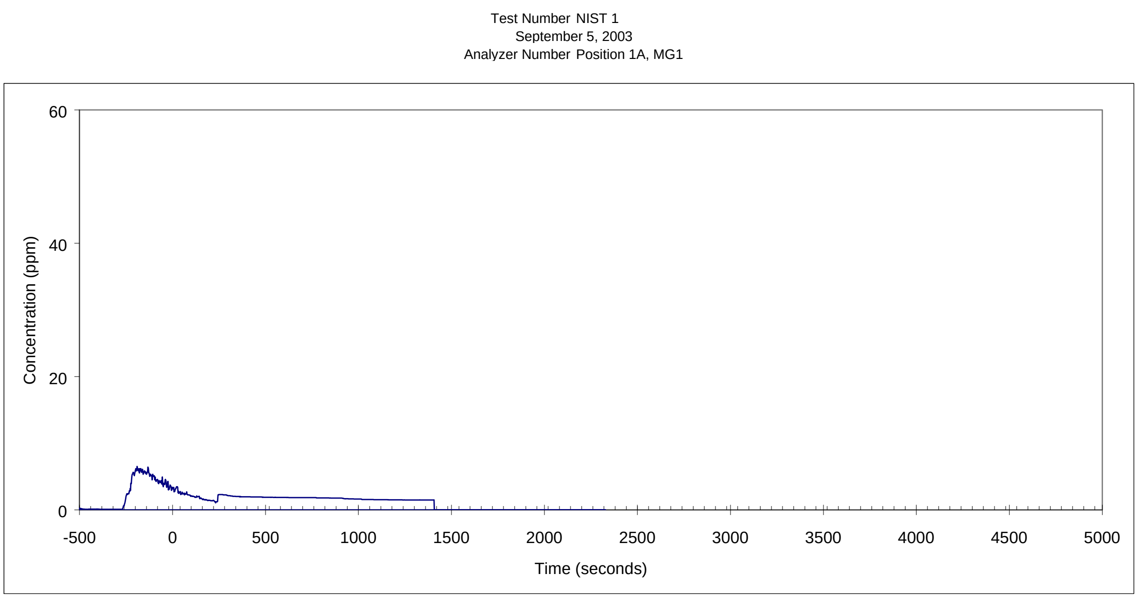


Figure J-3. Hydrogen cyanide response from mini gas analyzer located at position 1.

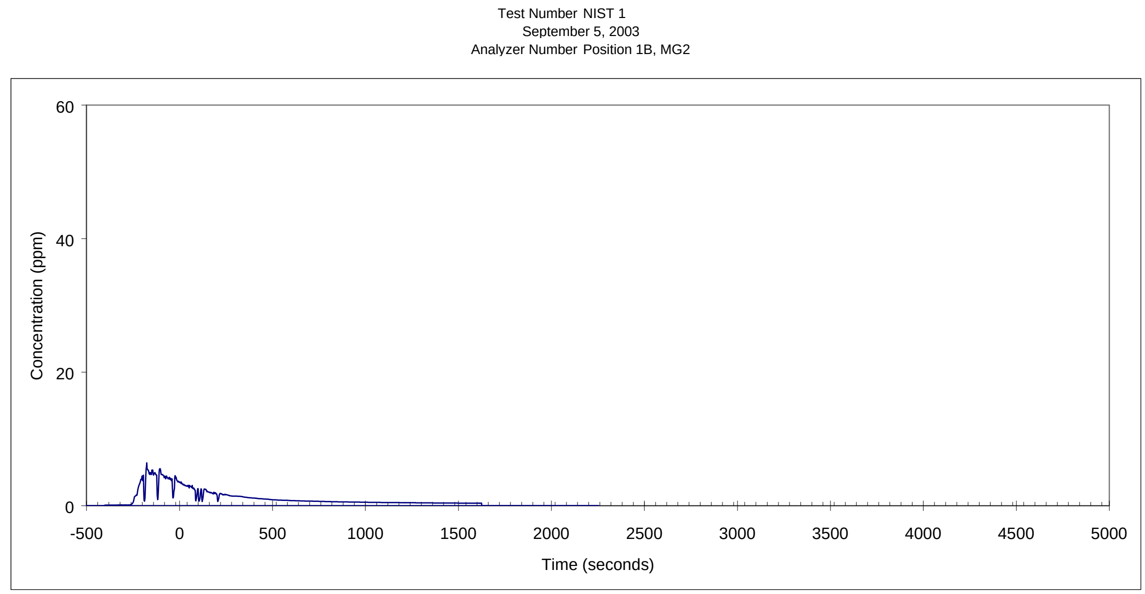


Figure J-4. Hydrogen cyanide response from mini gas analyzer located at position 1.

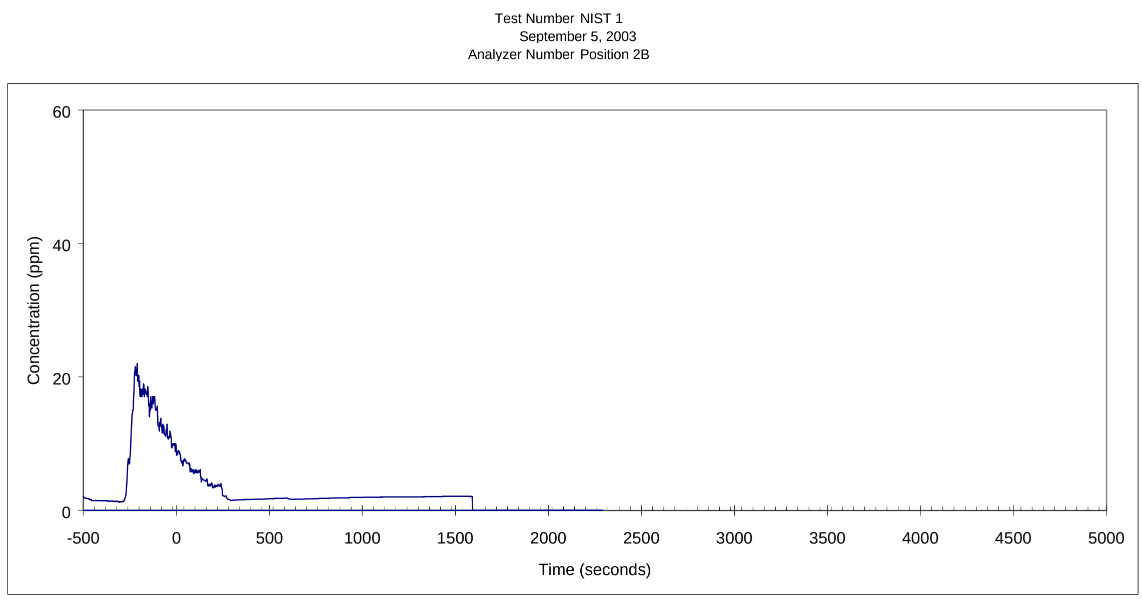


Figure J-5. Hydrogen cyanide response from large gas analyzer located at position 2.

Figures J-6 and J-7 show real-time results from the two mini gas HCN analyzers used for test 2 conducted on 10 Sept 03. This fire burned much longer and as indicated by the response produced much higher values of HCN.

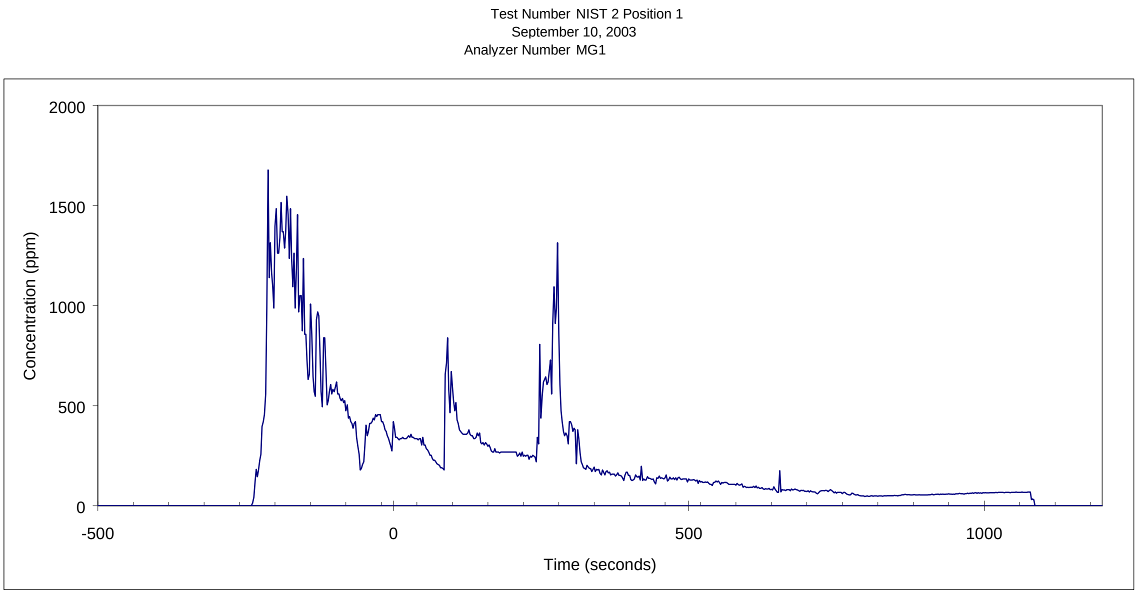


Figure J-6. Hydrogen cyanide response from mini gas 1 located at position 1

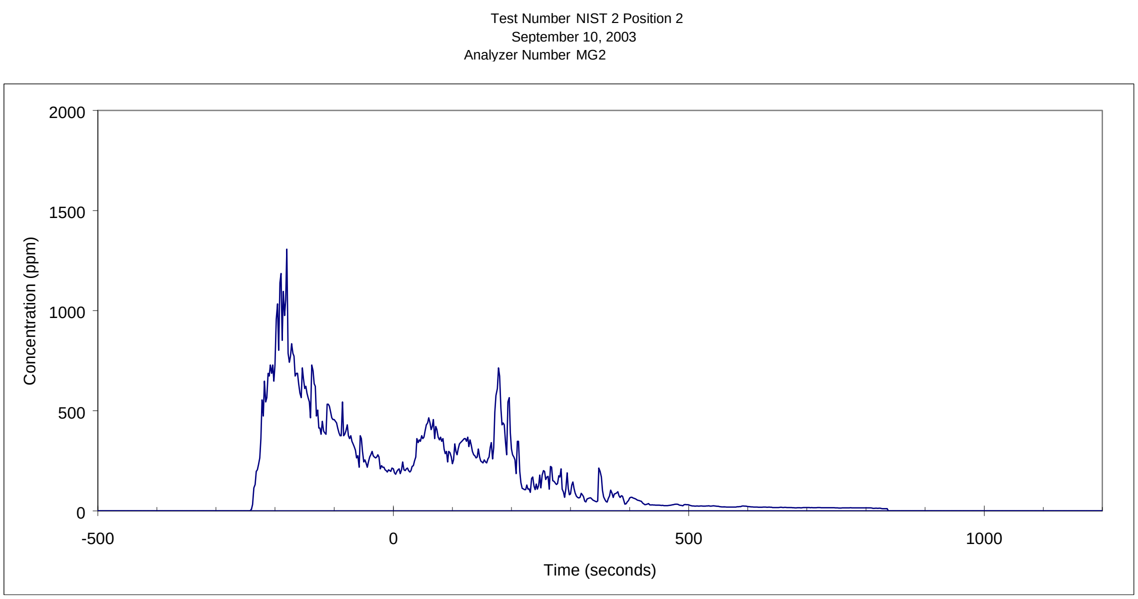


Figure J-7. Hydrogen cyanide response from mini gas 2 located at position 2.

Impinger and filter samples were analyzed according to NIOSH method 7904.

Table J-1. Impinger data for Rhode Island Tests.
(All values reported in ppm HCN for the indicated run time.)

Position	Test Date	Impinger ppm HCN	Impinger (Filter) ppm HCN	Filter ppm HCN	Run Time
1 (West) (NIST Sample Location D)	5 Sept 03	5.0	4.7	BDL	8 min.
2 (East) (NIST Sample Location D)	5 Sept 03	5.1	5.0	BDL	8 min.
1 (West) (NIST Sample Location D)	10 Sept 03	213	153	BDL	1.67 min.
2 (East) (NIST Sample Location D)	10 Sept 03	248	176	BDL	1.67 min.

BDL= Below Detection Limit of 2.5 ppm.

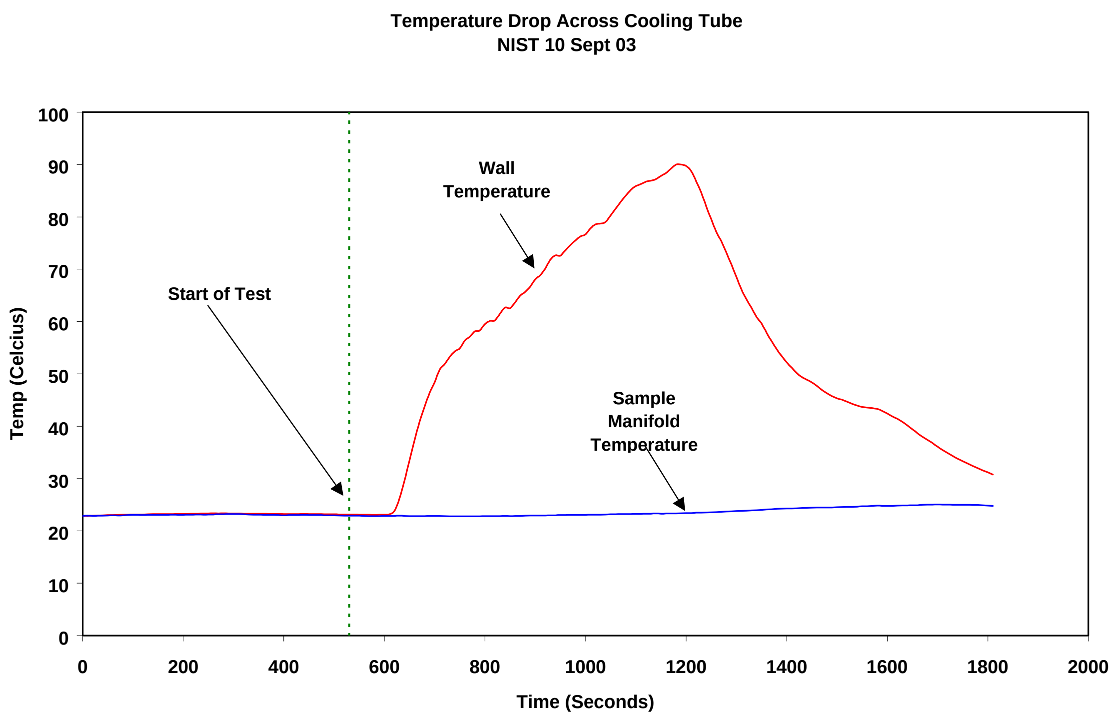
For example at Position 1on 5 Sept 03 the impinger measured an 8-min. TWA of 5 ppm HCN. At Position 1 on 10 Sept 03, a TWA of 213 ppm HCN was measured over a time of 1.67 min.

The impinger values may be low compared to the gas analyzer values because the impinger bubbler may not quantitatively collect aerosol forms of HCN.

The impingers behind the filters were expected to be lower than those of the impingers with no filters because any HCN collected on the filters, as aerosols would not be part of the impinger measurement. Because of the large amount of particulate matter on the filter, it was decided to estimate the total weight on the filter prior to cyanide analysis. However, any aerosol forms of HCN on the filters from test 2 were lost because of the time required to obtain filter weights.

The filters were photographed after the second test because they appeared to have a large amount of particulate matter on them (photographs were not available to include in this report). For this reason it was decided to weigh the filters in an attempt to estimate exposure to total particulate matter. Since the filters were not pre-weighed, six new filters were weighed from the same pack to establish a tare weight. The weight of the filter from position 1 was significantly different from the mean so that <5% of the time we would be wrong in making that assumption. The difference between the mean filter weight and that of position 1 was 24.540 mg. This calculates to an exposure level of 12,649 mg/m^3. This is considerably higher than the OSHA PEL TWA of 15 mg/m^3 (see attachment J-1). The weight of the filter from position 2 was not significantly different from the mean.

The data from the two thermocouples was recorded at 10-sec. intervals. The figure below shows that the 3-ft. extension successfully cooled the sample gases prior to entering any of the sampling devices.



After the first test one of the 9-ft. line was rinsed with 10 mL of 0.1 M KOH. After test 2 both of the 9-ft. stainless steel sample lines were rinsed. For the second test both of the rinses has a yellow tinge; however, line 2 rinse was much darker. Analysis of all three samples for anions by ion chromatography showed a small amount of chloride and a very large amount of sulfate ion. The amount of HCN measured in the rinse samples represented only a few percent of the total HCN measured.

Two foam samples, one unburned and one partially burned, from the test on 5 Sept 03, were submitted to the FTIR lab at the Aberdeen Test Center for analysis. The pyrolysis and combustion analysis both showed the presence of hydrogen cyanide and organo ioscyanates, which could include methyl isocyanate. According to NIOSH and OSHA methyl isocyanate is much more of an exposure hazard than hydrogen cyanide (Appendix FF-2 and FF-3).

The attached report summarizes the FTIR work. This FTIR technique could be a valuable tool for predicting the types of compounds to sample for prior to conducting the actual test burn. In this way the proper sampling devices could be obtained and the calibration ranges could be adjusted to match anticipated levels of combustion products produced in a fire.

Steven H. Hoke Ph.D., CIH

USACHPPM

Bldg. 363

APG, MD 21005-5059

Phone 410-278-2269

Fax 410-278-9622

Steven.hoke@apg.amedd.army.mil

J.2 NIOSH POCKET GUIDE TO CHEMICAL HAZARDS

J.2.1 Particulates not otherwise regulated

CAS RTECS

Synonyms & Trade Names
"Inert" dusts, Nuisance dusts, PNOR [Note: Includes all inert or nuisance dusts, whether mineral, inorganic, not listed specifically in 1910.1000.] **DOD ID & Guide**

Exposure Limits NIOSH REL: See Appendix D

OSHA PEL: TWA 15 mg/m^3 (total) TWA 5 mg/m^3 (resp)

IDLH N.D. See: IDLH INDEX **Conversion**

Physical Description
Dusts from solid substances without specific occupational exposure standards.

Properties vary depending upon the specific solid.

Incompatibilities & Reactivities
Varies

Measurement Methods
NIOSH 0500, 0600
See: NMAM or OSHA Methods

Personal Protection & Sanitation
Skin: No recommendation
Eyes: No recommendation
Wash skin: No recommendation
Remove: No recommendation
Change: No recommendation **First Aid** (See procedures)
Eye: Irrigate immediately

Breathing: Fresh air

Important additional information about respirator selection
Respirator Recommendations To be added later

Exposure Routes inhalation, skin and/or eye contact

Symptoms Irritation eyes, skin, throat, upper respiratory system

Target Organs Eyes, skin, respiratory system

See also: INTRODUCTION

J.2.2 Methyl isocyanate

CAS 624-83-9

CH_3NCO RTECS NQ9450000

Synonyms & Trade Names
Methyl ester of isocyanic acid, MIC **DOT ID & Guide** 2480 155

Exposure Limits NIOSH REL: TWA 0.02 ppm (0.05 mg/m^3) [skin]

OSHA PEL: TWA 0.02 ppm (0.05 mg/m^3) [skin]

IDLH 3 ppm See: 624839 **Conversion** 1 ppm = 2.34 mg/m^3

Physical Description: Colorless liquid with a sharp, pungent odor.

MW: 57.1	BP: 102 - 104°F	FRZ: -49°F	Sol (59°F): 10%	VP: 348 mmHg	IP: 10.67 eV
Sp.Gr: 0.96	Fl.P: 19°F	UEL: 26%	LEL: 5.3%		

Class IB Flammable Liquid: Fl.P. below 73°F and BP at or above 100°F.

Incompatibilities & Reactivities
Water, oxidizers, acids, alkalis, amines, iron, tin, copper [Note: Usually contains inhibitors to prevent polymerization.]

Measurement Methods
OSHA 54
See: NMAM or OSHA Methods

Personal Protection & Sanitation
Skin: Prevent skin contact
Eyes: Prevent eye contact
Wash skin: When contaminated
Remove: When wet (flammable)
Change: No recommendation
Provide: Eyewash, Quick drench **First Aid** (See procedures)
Eye: Irrigate immediately
Skin: Water flush immediately
Breathing: Respiratory support
Swallow: Medical attention immediately

Important additional information about respirator selection
Respirator Recommendations NIOSH/OSHA
Up to 0.2 ppm: (APF = 10) Any supplied-air respirator*
Up to 0.5 ppm: (APF = 25) Any supplied-air respirator operated in a continuous-flow mode*
Up to 1 ppm: (APF = 50) Any self-contained breathing apparatus with a full facepiece/(APF = 50) Any supplied-air respirator with a full facepiece
Up to 3 ppm: (APF = 2000) Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode
Emergency or planned entry into unknown concentrations or IDLH conditions: (APF = 10,000) Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode/(APF = 10,000) Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained positive-pressure breathing apparatus
Escape: (APF = 50) Any air-purifying, full-facepiece respirator (gas mask) with a chin-style, front- or back-mounted organic vapor canister/Any appropriate escape-type, self-contained breathing apparatus

Exposure Routes inhalation, skin absorption, ingestion, skin and/or eye contact

Symptoms Irritation eyes, skin, nose, throat; respiratory sensitization, cough, pulmonary secretions, chest pain, dyspnea (breathing difficulty); asthma; eye, skin damage; in animals: pulmonary edema

Target Organs Eyes, skin, respiratory system See also: INTRODUCTION See ICSC CARD: 0004 See MEDICAL TESTS: 0143

J.2.3 Hydrogen cyanide

CAS 74-90-8

HCN **RTECS** MW6825000

Synonyms & Trade Names

Formonitrile, Hydrocyanic acid, Prussic acid

DOT ID & Guide

1051 117 (>20% solution)
1051 117 (anhydrous)
1613 154 (</=20% solution)

Exposure Limits

NIOSH REL: ST 4.7 ppm (5 mg/m^3) [skin]

OSHA PEL†: TWA 10 ppm (11 mg/m^3) [skin]

IDLH 50 ppm See: 74908 **Conversion** 1 ppm = 1.10 mg/m^3

Physical Description
Colorless or pale-blue liquid or gas (above 78°F) with a bitter, almond-like odor. [Note: Often used as a 96% solution in water.]

MW: 27.0	BP: 78°F (96%)	FRZ: 7°F (96%)	Sol: Miscible	VP: 630 mmHg	IP: 13.60 eV
Sp.Gr: 0.69	Fl.P: 0°F (96%)	UEL: 40.0%	LEL: 5.6%	Class IA Flammable Liquid Flammable Gas	

Incompatibilities & Reactivities
Amines, oxidizers, acids, sodium hydroxide, calcium hydroxide, sodium carbonate, caustics, ammonia [Note: Can polymerize at 122-140°F.]

Measurement Methods
NIOSH 6010
See: NMAM or OSHA Methods

Personal Protection & Sanitation
Skin: Prevent skin contact
Eyes: Prevent eye contact
Wash skin: When contaminated
Remove: When wet (flammable)
Change: No recommendation
Provide: Eyewash, Quick drench **First Aid** (See procedures)
Eye: Irrigate immediately
Skin: Water flush immediately
Breathing: Respiratory support
Swallow: Medical attention immediately

Important additional information about respirator selection
Respirator Recommendations NIOSH
Up to 47 ppm: (APF = 10) Any supplied-air respirator
Up to 50 ppm: (APF = 25) Any supplied-air respirator operated in a continuous-flow mode/(APF = 50) Any self-contained breathing apparatus with a full facepiece/(APF = 50) Any supplied-air respirator with a full facepiece
Emergency or planned entry into unknown concentrations or IDLH conditions: (APF = 10,000) Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode/(APF = 10,000) Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained positive-pressure breathing apparatus
Escape: (APF = 50) Any air-purifying, full-facepiece respirator (gas mask) with a chin-style, front- or back-mounted canister providing protection against the compound of concern/Any appropriate escape-type, self-contained breathing apparatus

Exposure Routes inhalation, skin absorption, ingestion, skin and/or eye contact

Symptoms Asphyxia; lassitude (weakness, exhaustion), headache, confusion; nausea, vomiting; increased rate and depth of respiration or respiration slow and gasping; thyroid, blood changes

Target Organs central nervous system, cardiovascular system, thyroid, blood

See also: INTRODUCTION See ICSC CARD: 0492 See MEDICAL TESTS: 0117

APPENDIX K. CODE COMPARISON TABLES

Table K-1. Code comparison between IBC [1] and NFPA 5000 [2]

Table K-2. Code comparison between IFC [3] and NFPA 1 [4]

REFERENCES

[1] *2003 International Building Code*, International Code Council, Inc., Country Club Hills, IL, 2002.

[2] *NFPA 5000, Building Construction and Safety Code*, National Fire Protection Association, Quincy, MA, 2002

[3] *2003 International Fire Code*, International Code Council, Inc., Country Club Hills, IL, 2002.

[4] *NFPA 1, Uniform Fire Code*, National Fire Protection Association, Quincy, MA, 2003

Table K-1. Code Comparison of IBC and NFPA 5000

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
	Chapter 1	Administration						
General	101.2	Scope.	The provisions of this code shall apply to the construction, alteration, movement, enlargement, replacement, repair, equipment, use and occupancy, location, maintenance, removal and demolition of every building or structure or any appurtenances connected or attached to such buildings or structures.	Scope	1.3.1	Buildings and Structures.	The provisions of the Code shall apply to the construction, alteration, repair, equipment, use and occupancy, maintenance, relocation, and demolition of every building or structure, or any appurtenances connected or attached to such buildings or structures within the jurisdiction.	Similar
General	101.3	Intent.	The purpose of this code is to establish the minimum requirements to safeguard the public health, safety and general welfare through structural strength, means of egress facilities, stability, sanitation, adequate light and ventilation, energy conservation, and safety to life and property from fire and other hazards attributed to the built environment and to provide safety to fire fighters and emergency responders during emergency operations.	Purpose	1.2	Purpose.	The purpose of the Code is to provide minimum design regulations to safeguard life, health, property, and public welfare and to minimize injuries by regulating and controlling the permitting, design, construction, quality of materials, use and occupancy, location, and maintenance of all buildings and structures within the jurisdiction and certain equipment specifically regulated herein.	Similar
General	101.4	Referenced codes.	The other codes listed in Sections 101.4.1 through 101.4.7 and referenced elsewhere in this code shall be considered part of the requirements of this code.	Referenced publications	2.1	General.	The documents or portions thereof listed in this chapter are referenced within this Code and shall be considered part of the requirements of this document.	Similar-Different standards are cited that cover the same issues.
General	101.4.3	Mechanical.	The provisions of the *International Mechanical Code* shall apply to the installation, alterations, repairs, and replacement of mechanical systems, including equipment, appliances, fixtures, fittings, and/or appurtenances, including ventilating, heating, cooling, air-conditioning, and refrigeration systems, incinerators, and other energy-related systems.	Referenced publications	50.1	General	2000 Uniform Mechanical Code	Similar-Different standards are cited that cover the same issues.
General	101.4.4	Plumbing.	The provisions of the *International Plumbing Code* shall apply to the installation, alteration, repair, and replacement of plumbing systems, including equipment, appliances, fixtures, fittings, and appurtenances, and where connected to a water or sewage system.	Referenced publications	53.1	IAPMO Publications.	UPC, Uniform Plumbing Code, 2000.	Similar-Different standards are cited that cover the same issues.
General	101.4.6	Fire prevention.	The provisions of the *International Fire Code* shall apply to matters affecting or relating to structures, processes, and premises from the hazard of fire or explosion arising from the storage, handling, or use of structures, materials, or devices; from conditions hazardous to life, property, or public welfare in the occupancy of structures or premises; and from the construction, extension, repair, alteration, or removal of fire suppression and alarm systems or fire hazards in the structure or on the premises from occupancy or operation.	Referenced publications	2.2	NFPA Publications.	NFPA 1, Fire Prevention Code, 2000 edition. Specific sections only.	Similar-Different standards are cited that cover the same issues.
Applicability	102.1	General.	Where, in any specific case, different sections of this code specify different materials, methods of construction or other requirements, the most restrictive shall govern. Where there is a conflict between a general requirement and a specific requirement, the specific requirement shall be applicable.	Not addressed	Not addressed	Not addressed		Different-IBC recognizes possible inconsistencies within its own code.

DRAFT

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
Applicability	102.4	Referenced codes and standards.	The codes and standards referenced in this code shall be considered part of the requirements of this code to the prescribed extent of each such reference. Where differences occur between provisions of the code and referenced codes and standards, the provisions of this code shall apply.	Application	1.3.2	References to Requirements of Other Codes or Standards	Where the requirements of a referenced code or standard differ from the requirements of this Code, the requirements of this Code shall govern.	Similar
Applicability	102.6	Existing Structures.	The legal occupancy of any structure existing on the date of adoption of this code shall be permitted to continue without change, except as is specifically covered in this code, the International Property Maintenance Code or the International Fire Code, or as is deemed necessary by the building official for the general safety and welfare of the occupants and the public.	Compliance of buildings and structures.	1.7.5.2.2	Existing Installations.	Buildings in existence at the time of the adoption of this Code shall be permitted to have their existing use or occupancy continued if such use or occupancy was legal at the time of the adoption of this Code, provided such continued use is not dangerous to life.	Similar
Duties and Powers of Building Official	104.1	General.	The building official is hereby authorized and directed to enforce the provisions of this code. The building official shall have the authority to render interpretations of this code and to adopt policies and procedures in order to clarify the application of its provisions. Such interpretations, policies and procedures shall be in compliance with the intent and purpose of this code. Such policies and procedures shall not have the effect of waiving requirements specifically provided for in this code.	Building Permits, Plans and Specifications, and Inspections.	1.7.6.3.2.1	Examination of plans.	The authority having jurisdiction shall examine all plans and applications for permits and amendments thereto for their compliance with this Code. If the applications or the plans do not conform to the requirements of all pertinent laws, the authority having jurisdiction shall reject such application for a building permit in writing, stating the reasons therefore. Plans that are rejected shall be returned for corrections. If, upon examination, the application, plans, and specifications are found to comply with the requirements of this Code, the plans shall be signed by the authority having jurisdiction or its deputy and shall be stamped “approved.”	Similar
Duties and Powers of Building Official	104.2	Applications and permits.	The building official shall receive applications, review construction documents and issue permits for the erection, and alteration, demolition and moving of buildings and structures, inspect the premises for which such permits have been issued and enforce compliance with the provisions of this code.	Building Permits, Plans and Specifications, and Inspections.	1.7.6.1.1.1	Permits required.	No person, firm, or corporation shall erect, construct, enlarge, alter, repair, relocate, improve, convert, or demolish any building, structure, or part thereof in the jurisdiction, or cause the same to be done, without first obtaining from the authority having jurisdiction a separate building permit for the work to be accomplished for each such building, structure, or temporary structure. Permits shall not be required for the following: (List of items)	Similar
Duties and Powers of Building Official	104.3	Notices and orders.	The building official shall issue all necessary notices or orders to ensure compliance with this code	Building Permits, Plans and Specifications, and Inspections.	1.7.6.5.1	Permit Card.	When plans, specifications, and application for permit have been approved and the required fee has been paid, the authority having jurisdiction will issue a permit for the work. With each permit, the authority having jurisdiction shall issue a weather-resistant permit card bearing the legal description of the property, the nature of the work being done, the names of the owner and builder or contractor, and other pertinent information. The permit card shall be posted and maintained in legible condition in a conspicuous place within 200 ft (60 m) of the construction area during the entire time period the work authorized by the permit is in progress.	Similar
Duties and Powers of Building Official	104.4	Inspections.	The building official shall make all of the required inspections, or the building official shall have the authority to accept reports of inspection by approved agencies or individuals. Reports of such inspections shall be in writing and be certified by a responsible	Building Permits, Plans and Specifications, and Inspections.	1.7.6.6.1.1	Inspection Requirements.	Before issuing a permit, the authority having jurisdiction shall be permitted to inspect any building or structure for which an application has been received for a permit to enlarge, alter, repair, relocate, demolish, or change the occupancy thereof.	Similar

DRAFT

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			officer of such approved agency or by the responsible individual. The building official is authorized to engage such expert opinion as deemed necessary to report upon unusual technical issues that arise, subject to the approval of the appointing authority.				The authority having jurisdiction shall inspect all buildings and structures from time to time during the work for which a permit was issued and on completion of the work. The authority having jurisdiction shall cause to be kept a record of every inspection and of all violations of this Code and of the correction and disposition of such violations.	
Duties and Powers of Building Official	104.6	Right of entry.	Where it is necessary to make an inspection to enforce the provisions of this code, or where the building official has reasonable cause to believe that there exists in a structure or upon a premises a condition which is contrary to or in violation of this code which makes the structure or premises unsafe, dangerous or hazardous, the building official is authorized to enter the structure or premises at reasonable times to inspect or to perform the duties imposed by this code, provided that if such structure or premises be occupied that credentials be presented to the occupant and entry requested. If such structure or premises is unoccupied, the building official shall first make a reasonable effort to locate the owner or other person having charge or control of the structure or premises and request entry. If entry is refused, the building official shall have recourse to the remedies provided by law to secure entry.	Building Permits, Plans and Specifications, and Inspections.	1.7.6.6.1.5	Inspection Requirements.	The authority having jurisdiction shall make or cause to be made the inspections required in 1.7.6.6.1. Written reports of inspectors employed by approved inspection services shall be permitted, provided that, after investigation, the authority having jurisdiction is satisfied as to the qualifications and reliability of the inspection service. No certificate called for by any of these requirements shall be based on such reports, unless the reports are in writing and are certified by the officer of the agency who made the inspection. Reports issued by inspection services engaged by the owner, designer, or contractor of a building shall be promptly forwarded to the authority having jurisdiction for its information and records.	Similar
Duties and Powers of Building Official	104.7	Department records.	The building official shall keep official records of applications received, permits and certificates issued, fees collected, reports of inspections, and notices and orders issued. Such records shall be retained in the official records for the period required for retention of public records.	Building Permits, Plans and Specifications, and Inspections.	1.7.6.6.4	Inspection Reports.	The authority having jurisdiction shall keep a record of all inspections made, results, plans filed, surveys made, and certificates of occupancy issued.	Similar
Duties and Powers of Building Official	104.9	Approved materials and equipment.	Materials, equipment and devices approved by the building official shall be constructed and installed in accordance with such approval.	Equivalency.	1.5.4	Standards.	Construction systems, materials, or methods of design referred to in this Code shall be considered as standards of quality and strength. New or alternative construction systems, materials, or methods of design shall be at least equal to, and shall meet the intent of, these standards for the corresponding use intended.	Similar
Duties and Powers of Building Official	104.9.1	Used materials and equipment.	The use of used materials which meet the requirements of this code for new materials is permitted. Used equipment and devices shall not be reused unless approved by the building official.	Not addressed	Not addressed	Not addressed		Different-Not addressed by NFPA 5000 in Chapter 15.
Duties and Powers of Building Official	104.10	Modifications.	Wherever there are practical difficulties involved in carrying out the provisions of this code, the building official shall have the authority to grant modifications for individual cases, upon application of the owner or owner's representative, provided the building official shall first find that special individual reason makes the strict letter of this code impractical and the modification is in compliance with the intent and purpose of this code and that such modification does not lessen health, accessibility, life and fire safety, or structural requirements. The details of action granting modifications shall be recorded and entered in the files	Building Permits, Plans and Specifications, and Inspections.	1.7.6.3.2.2	Examination of Plans.	When practical difficulties are involved in carrying out the requirements of this Code, the authority having jurisdiction shall be permitted to grant modifications for individual cases. Such permission shall require, first, a finding that a special individual reason makes strict compliance impractical and, second, that the modification is in conformance with the intent and purpose of the Code. Fire protection and structural integrity shall not be lessened.	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			of the department of building safety.					
Duties and Powers of Building Official	104.11	Alternative materials, design & methods of construction & equipment.	The provisions of this code are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method on work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety.	Equivalency.	1.5.3	Permitted Alternatives.	The provisions of this Code shall not be construed to prevent the use of construction systems, materials, or methods of design, or interpolations, calculations, evaluations, or similar evidence based on test data acceptable to the authority having jurisdiction, as alternatives to the standards and provisions set forth in this Code. Such alternatives shall be permitted to be offered for approval, and their consideration shall be as provided in 1.5.2 through 1.5.8.	Similar
Permits	105.1	Required.	Any owner or authorized agent who intends to construct, enlarge, alter, repair, move, demolish, or change the occupancy of a building or structure, or to erect, install, enlarge, alter, repair, remove, convert or replace any electrical, gas, mechanical or plumbing system, the installation of which is regulated by this code, or to cause any such work to be done, shall first make application to the building official and obtain the required permit	Building Permits, Plans and Specifications, and Inspections.	1.7.6.1.1.1	Permits required.	No person, firm, or corporation shall erect, construct, enlarge, alter, repair, relocate, improve, convert, or demolish any building, structure, or part thereof in the jurisdiction, or cause the same to be done, without first obtaining from the authority having jurisdiction a separate building permit for the work to be accomplished for each such building, structure, or temporary structure. Permits shall not be required for the following: (List of items)	Similar
Permits	105.2	Work exempt from permit.	Exemptions from permit requirements of this code shall not be deemed to grant authorization for any work to be done in any manner in violation of the provisions of this code or any other laws or ordinances of this jurisdiction. Permits shall not be required for the following: Building: 1. One-story detached accessory structures used as tool and storage sheds, playhouses and similar uses, provided the floor area does not exceed 120 square feet (11.15 m2). 2. Fences not over 6 feet (1829 mm) high. 3. Oil derricks. 4. Retaining walls which are not over 4 feet (1219 mm) in height measured from the bottom of the footing to the top of the wall, unless supporting a surcharge or impounding Class I, II or III-A liquids. 5. Water tanks supported directly on grade if the capacity does not exceed 5,000 gallons (18 925 L) and the ratio of height to diameter or width does not exceed 2 to 1. 6. Sidewalks and driveways not more than 30 inches (762 mm) above grade and not over any basement or story below and which are not part of an accessible route. 7. Painting, papering, tiling, carpeting, cabinets, counter tops and similar finish work. 8. Temporary motion picture, television and theater stage sets and scenery. 9. Prefabricated swimming pools accessory to a Group R-3 occupancy, as applicable in Section 101.2, which are less than 24 inches (610 mm) deep, do not exceed 5,000 gallons (18 925 L) and are installed entirely above ground. 10. Shade cloth structures constructed for nursery or agricultural purposes and not including service systems. 11. Swings and other playground equipment accessory to	Building Permits, Plans and Specifications, and Inspections.	1.7.6.1.1.1	Permits required.	No person, firm, or corporation shall erect, construct, enlarge, alter, repair, relocate, improve, convert, or demolish any building, structure, or part thereof in the jurisdiction, or cause the same to be done, without first obtaining from the authority having jurisdiction a separate building permit for the work to be accomplished for each such building, structure, or temporary structure. Permits shall not be required for the following: (List of items)	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			detached one- and two-family dwellings. 12. Window awnings supported by an exterior wall which do not project more than 54 inches (1372 mm) from the exterior wall and do not require additional support of Group R-3, as applicable in Section 101.2, and Group U occupancies. 13. Movable cases, counters and partitions not over 5 feet 9 inches (1753 mm) in height. Electrical: Repairs and maintenance: Minor repair work, including the replacement of lamps or the connection of approved portable electrical equipment to approved permanently installed receptacles. Radio and television transmitting stations: The provisions of this code shall not apply to electrical equipment used for radio and television transmissions, but do apply to equipment and wiring for power supply, the installations of towers and antennas. Temporary testing systems: A permit shall not be required for the testing or servicing of electrical equipment or apparatus. Gas: 1. Portable heating appliance. 2. Replacement of any minor part that does not alter approval of equipment or make such equipment unsafe. Mechanical: 1. Portable heating appliance. 2. Portable ventilation equipment. 3. Portable cooling unit. 4. Steam, hot or chilled water piping within any heating or cooling equipment regulated by this code. 5. Replacement of any part which does not alter its approval or make it unsafe. 6. Portable evaporative cooler. 7. Self-contained refrigeration system containing 10 pounds (4.54 kg) or less of refrigerant and actuated by motors of 1 horsepower (746 W) or less. Plumbing: 1. The stopping of leaks in drains, water, soil, waste or vent pipe provided, however, that if any concealed trap, drain pipe, water, soil, waste or vent pipe becomes defective and it becomes necessary to remove and replace the same with new material, such work shall be considered as new work and a permit shall be obtained and inspection made as provided in this code. 2. The clearing of stoppages or the repairing of leaks in pipes, valves or fixtures, and the removal and reinstallation of water closets, provided such repairs do not involve or require the replacement or rearrangement of valves, pipes or fixtures.					
Permits	105.2.1	Emergency repairs.	Where equipment replacements and repairs must be performed in an emergency situation, the permit application shall be submitted within the next working business day to the building official.	Unsafe Buildings and Fire Hazards.	1.7.5.3.7.1	Emergency Action.	When, in the opinion of the authority having jurisdiction, an imminent danger exists, the authority having jurisdiction shall be authorized to order the occupants to vacate, or temporarily close for use or occupancy, the rights-of-way, sidewalks, streets, or adjacent buildings or nearby areas. The authority having jurisdiction shall have the authority to institute such other temporary safeguards as deemed necessary. The authority having jurisdiction shall be authorized to employ the necessary labor and materials to perform the required work. The authority	Different-NFPA does not have time limit.

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
							having jurisdiction shall promptly notify the local emergency services of buildings posted as unsafe and ordered to be vacated. The authority having jurisdiction shall also notify the emergency services when unsafe conditions have been remedied and the building is safe for occupancy and use.	
Permits	105.2.2	Repairs.	Application or notice to the building official is not required for ordinary repairs to structures, replacement of lamps or the connection of approved portable electrical equipment to approved permanently installed receptacles. Such repairs shall not include the cutting away of any wall, partition or portion thereof, the removal or cutting of any structural beam or load-bearing support, or the removal or change of any required means of egress, or rearrangement of parts of a structure affecting the egress requirements; nor shall ordinary repairs include addition to, alteration of, replacement or relocation of any standpipe, water supply, sewer, drainage, drain leader, gas, soil, waste, vent or similar piping, electric wiring or mechanical or other work affecting public health or general safety	Building Permits, Plans and Specifications, and Inspections.	1.7.6.1.1.1	Permits required.	No person, firm, or corporation shall erect, construct, enlarge, alter, repair, relocate, improve, convert, or demolish any building, structure, or part thereof in the jurisdiction, or cause the same to be done, without first obtaining from the authority having jurisdiction a separate building permit for the work to be accomplished for each such building, structure, or temporary structure. Permits shall not be required for the following: (List of items)	Similar
Permits	105.3	Application for permit.	To obtain a permit, the applicant shall first file an application therefore in writing on a form furnished by the department of building safety for that purpose. Such application shall: 1. Identify and describe the work to be covered by the permit for which application is made. 2. Describe the land on which the proposed work is to be done by legal description, street address or similar description that will readily identify and definitely locate the proposed building or work. 3. Indicate the use and occupancy for which the proposed work is intended. 4. Be accompanied by construction documents and other information as required in Section 106.3. 5. State the valuation of the proposed work. 6. Be signed by the applicant, or the applicant's authorized agent. 7. Give such other data and information as required by the building official.	Building Permits, Plans and Specifications, and Inspections.	1.7.6.2.1	Application Requirements.	To obtain a permit, the applicant shall first file an application therefore in writing on a form supplied for that purpose by the department of building and safety. Such application shall include the following: (List of items)	Similar
Permits	105.3.1	Action on application.	The building official shall examine or cause to be examined applications for permits and amendments thereto within a reasonable time after filing. If the application or the construction documents do not conform to the requirements of pertinent laws, the building official shall reject such application in writing, stating the reasons therefore. If the building official is satisfied that the proposed work conforms to the requirements of this code and laws and ordinances applicable thereto, the building official shall issue a permit therefore as soon as practicable.	Building Permits, Plans and Specifications, and Inspections.	1.7.6.3.2.1	Examination of plans.	The authority having jurisdiction shall examine all plans and applications for permits and amendments thereto for their compliance with this Code. If the applications or the plans do not conform to the requirements of all pertinent laws, the authority having jurisdiction shall reject such application for a building permit in writing, stating the reasons therefore. Plans that are rejected shall be returned for corrections. If, upon examination, the application, plans, and specifications are found to comply with the requirements of this Code, the plans shall be signed by the authority having jurisdiction or its deputy and shall be stamped "approved."	Similar
Permits	105.4	Validity of permit.	The issuance or granting of a permit shall not be construed to be a permit for, or an approval of, any violation of any of the provisions of this code or of any other ordinance of the jurisdiction. Permits presuming	Building Permits, Plans and Specifications,	1.7.6.5.2.1	Compliance with the Code.	Issuing or granting of a permit or approval of plans and specifications by the authority having jurisdiction shall not be construed to be a permit for, or an approval of, any violations of any of the provisions of	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			to give authority to violate or cancel the provisions of this code or other ordinances of the jurisdiction shall not be valid. The issuance of a permit based on construction documents and other data shall not prevent the building official from requiring the correction of errors in the construction documents and other data. The building official is also authorized to prevent occupancy or use of a structure where in violation of this code or of any other ordinances of this jurisdiction.	and Inspections.			this Code. No permit presuming to give authority to violate or cancel any of the provisions of this Code shall be valid, except insofar as the performance of the work that it authorizes is lawful.	
Construction Documents	106.1	Submittal documents.	Construction documents, special inspection and structural observation programs, and other data shall be submitted in one or more sets with each application for a permit. The construction documents shall be prepared by a registered design professional where required by the statutes of the jurisdiction in which the project is to be constructed. Where special conditions exist, the building official is authorized to require additional construction documents to be prepared by a registered design professional. Exception: The building official is authorized to waive the submission of construction documents and other data not required to be prepared by a registered design professional if it is found that the nature of the work applied for is such that review of construction documents is not necessary to obtain compliance with this code.	Building Permits, Plans and Specifications, and Inspections.	1.7.6.3.1.1	Plans and Specifications Requirements.	Each application for a permit shall be accompanied by two sets of plans, specifications, and calculations when required by the authority having jurisdiction.	Similar
Construction Documents	106.1.1	Information on construction documents.	Construction documents shall be dimensioned and drawn upon suitable material. Electronic media documents are permitted to be submitted when approved by the building official. Construction documents shall be of sufficient clarity to indicate the location, nature and extent of the work proposed and show in detail that it will conform to the provisions of this code and relevant laws, ordinances, rules and regulations, as determined by the building official.	Building Permits, Plans and Specifications, and Inspections.	1.7.6.3.1.4	Plans and Specifications Requirements.	Plans shall be drawn to scale, shall be identified by name of designer and owner on every sheet, and shall be mechanically reproduced prints on substantial paper or cloth. A plot plan shall show all occupied and unoccupied parts of the lot or lots. The use, name, and occupancy of all parts of the building shall be shown, including all foundations, wall sections, floor plans, elevations, and structural details. Mechanical, plumbing, electrical, fire sprinkler, and alarm details shall be shown on the plans and represent the designs for those disciplines, along with such other information to show clearly the nature, character, and location of the proposed work.	Similar
Construction Documents	106.1.1.1	Fire protection system shop drawings.	Shop drawings for the fire protection system(s) shall be submitted to indicate conformance with this code and the construction documents and shall be approved prior to the start of system installation. Shop drawings shall contain all information as required by the referenced installation standards in Chapter 9.	Building Permits, Plans and Specifications, and Inspections.	1.7.6.3.1.7	Plans and Specifications Requirements.	The construction documents and shop drawings submitted to the authority having jurisdiction shall contain sufficient detail for evaluation of the protected hazards and the effectiveness of the system. The shop drawings for the installation of fire protection systems shall be submitted for review and approval prior to the installation of a fire protection system.	Similar
Construction Documents	106.1.2	Means of egress.	The construction documents shall show in sufficient detail the location, construction, size and character of all portions of the means of egress in compliance with the provisions of this code. In other than occupancies in Groups R-2, R-3, as applicable in Section 101.2, and I-1, the construction documents shall designate the number of occupants to be accommodated on	Plans and Specifications	1.7.6.3.1.4		Plans shall be drawn to scale, shall be identified by name of designer and owner on every sheet, and shall be mechanically reproduced prints on substantial paper or cloth. A plot plan shall show all occupied and unoccupied parts of the lot or lots. The use, name, and occupancy of all parts of the building shall be shown, including all foundations, wall	Similar

DRAFT

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			every floor, and in all rooms and spaces.				sections, floor plans, elevations, and structural details. Mechanical, plumbing, electrical, fire sprinkler, and alarm details shall be shown on the plans and represent the designs for those disciplines, along with such other information to show clearly the nature, character, and location of the proposed work.	
Construction Documents	106.1.3	Exterior wall envelope.	Construction documents for all buildings shall describe the exterior wall envelope in sufficient detail to determine compliance with this code. The construction documents shall provide details of the exterior wall envelope as required, including flashing, intersections with dissimilar materials, corners, end details, control joints, intersections at roof, eaves or parapets, means of drainage, water-resistive membrane and details around openings. The construction documents shall include manufacturer's installation instructions that provide supporting documentation that the proposed penetration and opening details described in the construction documents maintain the weather resistance of the exterior wall envelope. The supporting documentation shall fully describe the exterior wall system, which was tested, where applicable, as well as the test procedure used.	Plans and Specifications	1.7.6.3.1.4		Plans shall be drawn to scale, shall be identified by name of designer and owner on every sheet, and shall be mechanically reproduced prints on substantial paper or cloth. A plot plan shall show all occupied and unoccupied parts of the lot or lots. The use, name, and occupancy of all parts of the building shall be shown, including all foundations, wall sections, floor plans, elevations, and structural details. Mechanical, plumbing, electrical, fire sprinkler, and alarm details shall be shown on the plans and represent the designs for those disciplines, along with such other information to show clearly the nature, character, and location of the proposed work.	Similar
Construction Documents	106.2	Site plan.	The construction documents submitted with the application for permit shall be accompanied by a site plan showing to scale the size and location of new construction and existing structures on the site, distances from lot lines, the established street grades and the proposed finished grades and, as applicable, flood hazard areas, floodways, and design flood elevations; and it shall be drawn in accordance with an accurate boundary line survey. In the case of demolition, the site plan shall show construction to be demolished and the location and size of existing structures and construction that are to remain on the site or plot. The building official is authorized to waive or modify the requirement for a site plan when the application for permit is for alteration or repair or when otherwise warranted.	Surveyor's Certificate Requirements	1.7.6.2.2		Application for permit for new construction and additions shall be accompanied by a registered land surveyor's certificate and plan in duplicate on which shall be indicated clearly the following:	Similar
Construction Documents	106.5	Retention of construction documents.	One set of approved construction documents shall be retained by the building official for a period of not less than 180 days from date of completion of the permitted work, or as required by state or local laws	Building Permits, Plans and Specifications, and Inspections.	1.7.6.3.4.1	Approved Plans.	The authority having jurisdiction shall retain one set of the approved plans, specifications, and computations. The other set shall be kept at the building site, open to inspection at all times when the offices of the jurisdiction are open.	Property corner stakes
Inspections	109.1	General.	Construction or work for which a permit is required shall be subject to inspection by the building official and such construction or work shall remain accessible and exposed for inspection purposes until approved. Approval as a result of an inspection shall not be construed to be an approval of a violation of the provisions of this code or of other ordinances of the jurisdiction. Inspections presuming to give authority to violate or cancel the provisions of this code or of other ordinances of the jurisdiction shall not be valid. It shall	Building Permits, Plans and Specifications, and Inspections.	1.7.6.6.1.1	Inspection Requirements.	Before issuing a permit, the authority having jurisdiction shall be permitted to inspect any building or structure for which an application has been received for a permit to enlarge, alter, repair, relocate, demolish, or change the occupancy thereof. The authority having jurisdiction shall inspect all buildings and structures from time to time during the work for which a permit was issued and on completion of the work. The authority having jurisdiction shall cause to be kept a record of every	Property line dimensions

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			be the duty of the permit applicant to cause the work to remain accessible and exposed for inspection purposes. Neither the building official nor the jurisdiction shall be liable for expense entailed in the removal or replacement of any material required to allow inspection.				inspection and of all violations of this Code and of the correction and disposition of such violations.	
Inspections	109.2	Preliminary inspection.	Before issuing a permit, the building official is authorized to examine or cause to be examined buildings, structures and sites for which an application has been filed.	Building Permits, Plans and Specifications, and Inspections.	1.7.6.6.1.3	Inspection Requirements.	All construction or work for which a permit is required shall be subject to mandatory inspections by the authority having jurisdiction as prescribed in 1.7.6.6.3, and certain types of construction shall have special engineering inspections as specified in Chapter 40. Prior to issuance of a certificate of occupancy, a final inspection shall be made by the authority having jurisdiction of all construction or work for which a permit has been issued.	Existing structures and their location
Inspections	109.3	Required inspections.	The building official, upon notification, shall make the inspections set forth in Sections 109.3.1 through 109.3.10.	Building Permits, Plans and Specifications, and Inspections.	1.7.6.6.3.3	Mandatory Inspections.	The permit holder or permit holder's agent shall notify the authority having jurisdiction of the time when a given stage of construction will be ready for inspection. The authority having jurisdiction shall then make such called inspection and other inspection as necessary, and it either shall approve in writing on the permit card that stage of the construction as completed or shall notify the permit holder or permit holder's agent specifically wherein the work fails to comply with the provisions of this Code.	Existing rights-of-way
Certificate of Occupancy	110.1	Use and occupancy.	No building or structure shall be used or occupied, and no change in the existing occupancy classification of a building or structure or portion thereof shall be made until the building official has issued a certificate of occupancy therefore as provided herein. Issuance of a certificate of occupancy shall not be construed as an approval of a violation of the provisions of this code or of other ordinances of the jurisdiction	Certificate of Occupancy.	1.7.6.8.1.1	Certificate Requirements.	No building hereafter erected, altered, enlarged, or relocated or for which a change of occupancy has been made, shall be used in whole or in part until a certificate of occupancy has been issued by the authority having jurisdiction certifying that the building and occupancy are in accordance with the provisions of this Code and all other laws and regulations applying thereto. When the building or part thereof complies with the provisions of all pertinent laws and regulations, the authority having jurisdiction shall issue the certificate of occupancy for the building or part thereof. A certificate of occupancy for places of assembly shall indicate thereon, and make record of, the number of persons for whom such certificate is issued. In all manufacturing, commercial, storage, or warehouse occupancies, the design live loads shall be plainly posted.	Sidewalks
Certificate of Occupancy	110.2	Certificate issued.	After the building official inspects the building or structure and finds no violations of the provisions of this code or other laws that are enforced by the department of building safety, the building official shall issue a certificate of occupancy that contains the following: 1. The building permit number. 2. The address of the structure. 3. The name and address of the owner. 4. A description of that portion of the structure for which the certificate is issued. 5. A statement that the described portion of the structure	Certificate of Occupancy.	1.7.6.8.1.2	Certificate Requirements.	When, in the opinion of the authority having jurisdiction, any building altered or enlarged, or both, is in compliance with this Code, the owner shall be issued a letter affirming compliance in lieu of a certificate of occupancy.	Easements

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			has been inspected for compliance with the requirements of this code for the occupancy and division of occupancy and the use for which the proposed occupancy is classified. 6. The name of the building official. 7. The edition of the code under which the permit was issued. 8. The use and occupancy, in accordance with the provisions of Chapter 3. 9. The type of construction as defined in Chapter 6. 10. The design occupant load. 11. If an automatic sprinkler system is provided, whether the sprinkler system is required. 12. Any special stipulations and conditions of the building permit.					
Violations	113.1	Unlawful acts.	It shall be unlawful for any person, firm or corporation to erect, construct, alter, extend, repair, move, remove, demolish or occupy any building, structure or equipment regulated by this code, or cause same to be done, in conflict with or in violation of any of the provisions of this code.	Organization.	1.7.1.5	Unlawful Occupancy.	Whenever any building or part thereof is being used or occupied contrary to the provisions of this Code, the authority having jurisdiction is hereby authorized to order such use or occupancy discontinued and the building or part thereof vacated. Such order shall be in writing, served on the person(s) using or causing to be used such building or parts thereof. Within a 30-day period after receipt of notice or order, such building or part thereof shall be made to comply with the requirements of this Code; however, in the event of an emergency, 1.7.5.3.7 and 1.7.5.3.8 shall apply.	Street zoning and property zoning of record
Violations	113.2	Notice of violation.	The building official is authorized to serve a notice of violation or order on the person responsible for the erection, construction, alteration, extension, repair, moving, removal, demolition or occupancy of a building or structure in violation of the provisions of this code, or in violation of a permit or certificate issued under the provisions of this code. Such order shall direct the discontinuance of the illegal action or condition and the abatement of the violation.	Compliance of Buildings and Structures.	1.7.5.3.4	Notice of Violation.	At least 14 days prior to posting a noncomplying building, the authority having jurisdiction shall give the owner of the premises written notice by certified mail, addressed to the owner's last known address. If proof of service by certified mail is not completed by signed return receipt, a copy of the written notice shall be affixed to the structure concerned, and such procedure shall be considered proper service, and the time for compliance stipulated in the notice shall commence with the date on which such notice is so affixed. This written notice shall state the defects that constitute a violation of this Code and prescribe the action to be taken by the owner of the building to comply with the Code and the time within which compliance must be accomplished. Such time shall be reasonable under the circumstances of the case, subject to reasonable extension when requested in writing, for reasons that the authority having jurisdiction considers as justifying an extension of time. All extensions of time shall be by written approval of the authority having jurisdiction. In addition, this written notice shall explain the right of appeal ...	Critical elevations and building setbacks required by law
Violations	113.3	Prosecution of violation.	If the notice of violation is not complied with promptly, the building official is authorized to request the legal counsel of the jurisdiction to institute the appropriate proceeding at law or in equity to restrain, correct or abate such violation, or to require the removal or termination of the unlawful occupancy of the building or structure in violation of the provisions of this code or of the order or direction made pursuant thereto.	Compliance of Buildings and Structures.	1.7.5.3.5.1	Recording of Notice of Violation.	If the owner of the property has not complied with the requirements as stated in the notice of violation within the time specified, the authority having jurisdiction shall file an appropriate instrument in the office of the clerk of the circuit court, to be recorded in the public records of the jurisdiction in which the violation occurred, indicating that violations of this Code, and of 1.7.5.3.4 thereof, exist upon the	General block plan

DRAFT

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
							property involved.	
Violations	113.4	Violation penalties.	Any person who violates a provision of this code or fails to comply with any of the requirements thereof or who erects, constructs, alters or repairs a building or structure in violation of the approved construction documents or directive of the building official, or of a permit or certificate issued under the provisions of this code, shall be subject to penalties as prescribed by law.	Compliance of Buildings and Structures.	1.7.5.3.5.2	Recording of Notice of Violation.	The recording of the notice of violation shall constitute legal notice to all concerned, as well as to any subsequent purchasers, transferees, grantees, mortgagees, lessees, and all persons claiming or acquiring interest in the property.	Other pertinent survey data
Stop Work Order	114.1	Authority.	Whenever the building official finds any work regulated by this code being performed in a manner either contrary to the provisions of this code or dangerous or unsafe, the building official is authorized to issue a stop work order.	Organization.	1.7.1.4	Stop-Work Orders.	Whenever any work is being done contrary to provisions of this Code, the authority having jurisdiction is hereby authorized to order such work stopped. Such work shall immediately stop until authorized by the authority having jurisdiction to proceed.	Similar
Stop Work Order	114.2	Issuance.	The stop work order shall be in writing and shall be given to the owner of the property involved, or to the owner's agent, or to the person doing the work. Upon issuance of a stop work order, the cited work shall immediately cease. The stop work order shall state the reason for the order, and the conditions under which the cited work will be permitted to resume.	Organization.	1.7.1.4	Stop-Work Orders.	Whenever any work is being done contrary to provisions of this Code, the authority having jurisdiction is hereby authorized to order such work stopped. Such work shall immediately stop until authorized by the authority having jurisdiction to proceed.	Similar
Stop Work Order	114.3	Unlawful continuance.	Any person who shall continue any work after having been served with a stop work order, except such work as that person is directed to perform to remove a violation or unsafe condition, shall be subject to penalties as prescribed by law.	Organization.	1.7.1.4	Stop-Work Orders.	Whenever any work is being done contrary to provisions of this Code, the authority having jurisdiction is hereby authorized to order such work stopped. Such work shall immediately stop until authorized by the authority having jurisdiction to proceed.	Similar
Unsafe Structures and Equipment	115.1	Conditions.	Structures or existing equipment that are or hereafter become unsafe, insanitary or deficient because of inadequate means of egress facilities, inadequate light and ventilation, or which constitute a fire hazard, or are otherwise dangerous to human life or the public welfare, or that involve illegal or improper occupancy or inadequate maintenance, shall be deemed an unsafe condition. Unsafe structures shall be taken down and removed or made safe, as the building official deems necessary and as provided for in this section. A vacant structure that is not secured against entry shall be deemed unsafe	Unsafe Buildings and Fire Hazards.	1.7.5.3.1.1	Description of Unsafe Building.	All buildings that are, or that hereafter become, as follows shall be considered unsafe buildings: (List of conditions)	Similar
Unsafe Structures and Equipment	115.2	Record.	The building official shall cause a report to be filed on an unsafe condition. The report shall state the occupancy of the structure and the nature of the unsafe condition.	Unsafe Buildings and Fire Hazards.	1.7.5.3.3	Inspection of Unsafe Buildings.	The authority having jurisdiction, on his/her own initiative, or as a result of reports filed with the department of building and safety, shall examine or cause to be examined every building appearing to be or reported to be unsafe, and, if such is found to be an unsafe building as defined in 1.7.5.3.1.1, the authority having jurisdiction shall post the property on which the building is located and shall furnish the owner of such building with a written notice of violation. The manner of posting and furnishing written notice shall be as provided in 1.7.5.3.4 and 1.7.5.3.5, inclusive.	Similar
Unsafe	115.3	Notice.	If an unsafe condition is found, the building official	Unsafe	1.7.5.3.4	Notice of	At least 14 days prior to posting a noncomplying	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
Structures and Equipment			shall serve on the owner, agent or person in control of the structure, a written notice that describes the condition deemed unsafe and specifies the required repairs or improvements to be made to abate the unsafe condition, or that requires the unsafe structure to be demolished within a stipulated time. Such notice shall require the person thus notified to declare immediately to the building official acceptance or rejection of the terms of the order.	Buildings and Fire Hazards.		Violation.	building, the authority having jurisdiction shall give the owner of the premises written notice by certified mail, addressed to the owner's last known address. If proof of service by certified mail is not completed by signed return receipt, a copy of the written notice shall be affixed to the structure concerned, and such procedure shall be considered proper service, and the time for compliance stipulated in the notice shall commence with the date on which such notice is so affixed. This written notice shall state the defects that constitute a violation of this Code and prescribe the action to be taken by the owner of the building to comply with the Code and the time within which compliance must be accomplished. Such time shall be reasonable under the circumstances of the case, subject to reasonable extension when requested in writing, for reasons that the authority having jurisdiction considers as justifying an extension of time. All extensions of time shall be by written approval of the authority having jurisdiction. In addition, ...	
Unsafe Structures and Equipment	115.4	Method of service.	Such notice shall be deemed properly served if a copy thereof is (a) delivered to the owner personally; (b) sent by certified or registered mail addressed to the owner at the last known address with the return receipt requested; or (c) delivered in any other manner as prescribed by local law. If the certified or registered letter is returned showing that the letter was not delivered, a copy thereof shall be posted in a conspicuous place in or about the structure affected by such notice. Service of such notice in the foregoing manner upon the owner's agent or upon the person responsible for the structure shall constitute service of notice upon the owner.	Unsafe Buildings and Fire Hazards.	1.7.5.3.4	Notice of Violation.	At least 14 days prior to posting a noncomplying building, the authority having jurisdiction shall give the owner of the premises written notice by certified mail, addressed to the owner's last known address. If proof of service by certified mail is not completed by signed return receipt, a copy of the written notice shall be affixed to the structure concerned, and such procedure shall be considered proper service, and the time for compliance stipulated in the notice shall commence with the date on which such notice is so affixed. This written notice shall state the defects that constitute a violation of this Code and prescribe the action to be taken by the owner of the building to comply with the Code and the time within which compliance must be accomplished. Such time shall be reasonable under the circumstances of the case, subject to reasonable extension when requested in writing, for reasons that the authority having jurisdiction considers as justifying an extension of time. All extensions of time shall be by written approval of the authority having jurisdiction. In addition, ...	Similar
Unsafe Structures and Equipment	115.5	Restoration.	The structure or equipment determined to be unsafe by the building official is permitted to be restored to a safe condition. To the extent that repairs, alterations or additions are made or a change of occupancy occurs during the restoration of the structure, such repairs, alterations, additions or change of occupancy shall comply with the requirements of Section 105.2.2 and Chapter 34.	Unsafe Buildings and Fire Hazards.	1.7.5.3.8	Appeal and Review.	The owner of, or anyone having an interest in, a building that has been determined to be unsafe, concerning which a notice of violation has been served by the authority having jurisdiction as stated in the notice of violation, shall be permitted to appeal to the board of appeals, and such appeal shall be filed in accordance with the provisions of 1.7.3.6 and 1.7.3.7 prior to the expiration of the time allowed for compliance specified in such notice. In no case shall the appeal period be less than 15 days.	Similar
	Chapter 3	Use and Occupancy Classification						

DRAFT

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
Classification.	302.1.1.1	Separation.	Where Table 302.1.1 requires a fire-resistance-rated separation, the incidental use area shall be separated from the remainder of the building with a fire barrier. Where Table 302.1.1 permits an automatic fire-extinguishing system without a fire barrier, the incidental use area shall be separated by construction capable of resisting the passage of smoke.	Service Equipment, Hazardous Operations or Processes, and Storage Facilities	16.3.2.1.1		Rooms containing high-pressure boilers, refrigerating machinery of other than domestic refrigerator type, large transformers, or other service equipment subject to possible explosion shall not be located directly under or abutting required exits. All such rooms shall be separated from other parts of the building by fire barriers in accordance with Section 8.4 having a fire resistance rating of not less than 1 hour or shall be protected by automatic extinguishing systems in accordance with Section 55.3.	Similar
Classification.	302.1.1	Table 302.1.1	See Table. Specifically storage rooms over 100 square feet shall be separated with 1-hour construction or automatic fire-extinguishing system.	Hazardous Area Protection.	16.3.2.1.1	Service Equipment, Hazardous Operations or Processes, and Storage Facilities.	Rooms containing high-pressure boilers, refrigerating machinery of other than domestic refrigerator type, large transformers, or other service equipment subject to possible explosion shall not be located directly under or abutting required exits. All such rooms shall be separated from other parts of the building by fire barriers in accordance with Section 8.4 having a fire resistance rating of not less than 1 hour or shall be protected by automatic extinguishing systems in accordance with Section 55.3.	Similar
Assembly Group A	303.1	Assembly Group A.	Assembly Group A occupancy includes, among others, the use of a building or structure, or a portion thereof, for the gathering together of persons for purposes such as civic, social or religious functions, recreation, food or drink consumption or awaiting transportation. A room or space used for assembly purposes by less than 50 persons and accessory to another occupancy shall be included as a part of that occupancy. Assembly areas with less than 750 square feet (69.7 m2) and which are accessory to another occupancy according to Section 302.2.1 are not assembly occupancies. .... Assembly occupancies shall include the following: ... A-2 Assembly uses intended for food and/or drink consumption, including, but not limited to: Banquet halls, Nightclubs, Restaurants, Taverns and bars.	General Definitions.	3.3.371.1	Assembly Occupancy.	An occupancy (1) used for a gathering of 50 or more persons for deliberation, worship, entertainment, eating, drinking, amusement, awaiting transportation, or similar uses; or (2) used as a special amusement building, regardless of occupant load.	Similar-NFPA does not have sub-classifications.
	Chapter 4	Special Detailed Requirements Based on Use and Occupancy						
Stages and Platforms	410.1	Applicability.	The provisions of this section shall apply to all parts of buildings and structures that contain stages or platforms and similar appurtenances as herein defined.	Special Provisions.	16.4.5	Stages and Platforms.	Stages and Platforms.	Similar
Stages and Platforms	410.2	Definitions.	The following words and terms shall, for the purposes of this section and as used elsewhere in this code, have the meanings shown herein. FLY GALLERY. A raised floor area above a stage from which the movement of scenery and operation of other stage effects are controlled. GRIDIRON. The structural framing over a stage supporting equipment for hanging or flying scenery and other stage effects. PINRAIL. A rail on or above a stage through which belaying pins are inserted and to which lines are fastened. PLATFORM. A raised area within a building used for..., the presentation of music, ...wherein there are no	Special Provisions.	3.3.516	Stage.	A space within a building used for entertainment and utilizing drops or scenery or other stage effects.	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			overhead hanging curtains, drops, scenery or stage effects other than lighting and sound. A temporary platform is one installed for not more than 30 days. PROSCENIUM WALL. The wall that separates the stage from the auditorium or assembly seating area. STAGE. A space within a building utilized for entertainment or presentations, which includes overhead hanging curtains, drops, scenery or stage effects other than lighting and sound...					
Stages and Platforms	410.3	Stages.	Stage construction shall comply with Sections 410.3.1 through 410.3.7.	Stages and Platforms.	16.4.5.2	Stage Construction.	Stage Construction.	Similar
Stages and Platforms	410.3.1	Stage construction.	Stages shall be constructed of materials as required for floors for the type of construction of the building in which such stages are located. Exceptions: 1. Stages of Type IIB or IV construction with a nominal 2-inch (51 mm) wood deck, provided that the stage is separated from other areas in accordance with Section 410.3.5. 2. In buildings of Type IIA, IIIA and VA construction, a fire-resistance-rated floor is not required, provided the space below the stage is equipped with an automatic fire-extinguishing system in accordance with Section 903 or 904. 3. In all types of construction, the finished floor shall be constructed of wood or approved noncombustible materials. Openings through stage floors shall be equipped with tight-fitting, solid wood trap doors with approved safety locks.	Stages and Platforms.	16.4.5.2.1	Stage Construction.	Regular stages shall be constructed of materials as required for the type of construction of the building in which they are located. In all cases, the finished floor shall be permitted to be of wood.	Similar
Stages and Platforms	410.3.1.1	Stage height and area.	Stage areas shall be measured to include the entire performance area and adjacent backstage and support areas not separated from the performance area by fire-resistance-rated construction. Stage height shall be measured from the lowest point on the stage floor to the highest point of the roof or floor deck above the stage.	Stages and Platforms.	16.4.5.2.2	Stage Construction.	Legitimate stages shall be constructed of materials required for Type I buildings, except that the area extending from the proscenium opening to the back wall of the stage, and for a distance of 6 ft (183 cm) beyond the proscenium opening on each side, shall be permitted to be constructed of steel or heavy timber covered with a wood floor not less than 1½ in. (3.8 cm) in actual thickness.	Different-NFPA only for stages. The structure in the Station was not a stage but a platform.
Stages and Platforms	410.3.3	Exterior stage doors.	Where protection of openings is required, exterior exit doors shall be protected with fire doors that comply with Section 715. Exterior openings that are located on the stage for means of egress or loading and unloading purposes, and that are likely to be open during occupancy of the theater, shall be constructed with vestibules to prevent air drafts into the auditorium.	Not addressed	Not addressed	Not addressed		Different-NFPA does not directly address egress from stages.
Stages and Platforms	410.3.4	Proscenium wall.	Where the stage height is greater than 50 feet (15 240 mm), all portions of the stage shall be completely separated from the seating area by a proscenium wall with not less than a 2-hour fire-resistance rating extending continuously from the foundation to the roof.	Stages and Platforms.	16.4.5.5	Proscenium Walls.	Legitimate stages shall be completely separated from the seating area by a proscenium wall of not less than 2-hour fire-resistive noncombustible or limited-combustible construction. The proscenium wall shall extend at least 4 ft (122 cm) above the roof of the auditorium in combustible construction. All openings in the proscenium wall of a legitimate stage shall be protected by a fire assembly having a 1½-hour fire protection rating. Exception No. 1: The main proscenium opening used for viewing performances shall be provided with an automatic-closing fire-resistive curtain as described in 16.4.5.6. Exception No. 2: Proscenium walls shall not be	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
							required in smoke-protected assembly seating facilities constructed and operated in accordance with 16.4.2.	
Stages and Platforms	410.3.5	Proscenium curtain.	The proscenium opening of every stage with a height greater than 50 feet (15 240 mm) shall be provided with a curtain of approved material or an approved water curtain complying with Section 903.3.1.1. The curtain shall be designed and installed to intercept hot gases, flames and smoke, and to prevent a glow from a severe fire on the stage from showing on the auditorium side for a period of 20 minutes. The closing of the curtain from the full open position shall be affected in less than 30 seconds, but the last 8 feet (2438 mm) of travel shall require not less than 5 seconds.	Stages and Platforms.	16.4.5.5	Proscenium Walls.	Legitimate stages shall be completely separated from the seating area by a proscenium wall of not less than 2-hour fire-resistive noncombustible or limited-combustible construction. The proscenium wall shall extend at least 4 ft (122 cm) above the roof of the auditorium in combustible construction. All openings in the proscenium wall of a legitimate stage shall be protected by a fire assembly having a 1½-hour fire protection rating. Exception No. 1: The main proscenium opening used for viewing performances shall be provided with an automatic-closing fire-resistive curtain as described in 16.4.5.6. Exception No. 2: Proscenium walls shall not be required in smoke-protected assembly seating facilities constructed and operated in accordance with 16.4.2.	Similar
Stages and Platforms	410.3.6	Scenery.	Combustible materials used in sets and scenery shall be rendered flame resistant in accordance with Section 805 and the International Fire Code. Foam plastics and materials containing foam plastics shall comply with Section 2603 and the International Fire Code.	Not addressed	Not addressed	Not addressed		Similar. NFPA addresses in NFPA 1 as it is considered an operational matter.
Stages and Platforms	410.3.7	Stage ventilation.	Emergency ventilation shall be provided for stages larger than 1,000 square feet (93 m2) in floor area, or with a stage height greater than 50 feet (15 240 mm). Such ventilation shall comply with Section 410.3.7.1 or 410.3.7.2	Stages and Platforms.	16.4.5.4.2	Roof Vents.	(A) Two or more vents shall be located near the center of, and above the highest part of, the stage area. (B) The vents shall be raised above the roof and shall provide a net-free vent area equal to 5 percent of the stage area. (C) Vents shall be constructed to open automatically by approved heat-activated devices. (D) Supplemental means shall be provided for manual operation and periodic testing of the ventilator from the stage floor. (E) Vents shall be labeled.	Similar
Stages and Platforms	410.4	Platform construction.	Permanent platforms shall be constructed of materials as required for the type of construction of the building in which the permanent platform is located. Permanent platforms are permitted to be constructed of fire-retardant-treated wood for Type I, II, and IV construction where the platforms are not more than 30 inches (762mm) above the main floor, and not more than one-third of the room floor area and not more than 3,000 square feet (279 m2) in area. Where the space beneath the permanent platform is used for storage or any other purpose other than equipment, wiring or plumbing, the floor construction shall not be less than 1-hour fire-resistant construction. Where the space beneath the permanent platform is used only for equipment, wiring or plumbing, the underside of the permanent platform need not be protected.	Stages and Platforms.	16.4.5.1	Platform Construction.	Temporary platforms shall be permitted to be constructed of any materials. The space between the floor and the platform above shall not be used for any purpose other than electrical wiring to platform equipment.(A) Permanent platforms shall be constructed of materials as required for the type of construction of the building in which the permanent platform is located, except that the finished floor shall be permitted to be of wood in all types of construction.(B) Where the space beneath the platform is used for storage or any purpose other than equipment wiring or plumbing, the floor shall not be of less than 1-hour fire-resistive construction.	Similar
Stages and	410.5	Dressing and	Dressing and appurtenant rooms shall comply with	Not addressed	Not	Not addressed		Different-NFPA

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
Platforms		appurtenant rooms.	Sections 410.5.1 through 410.5.4.		addressed			does not address.
Stages and Platforms	410.5.2	Separation from each other.	Dressing rooms, scene docks, property rooms, workshops, storerooms and compartments appurtenant to the stage shall be separated from each other by fire barrier wall and horizontal assemblies, or both, with not less than a 1-hour fire-resistance rating with approved opening protectives.	Accessory Rooms.	16.4.5.3		Workshops, storerooms, permanent dressing rooms, and other accessory spaces contiguous to stages shall be separated from each other and other building areas by 1-hour fire resistance–rated construction and protected openings. Exception: A separation shall not be required for stages having a floor area not exceeding 1000 ft2 (93 m2).	Similar
Stages and Platforms	410.5.3	Opening protectives.	Openings other than to trunk rooms and the necessary doorways at stage level shall not connect such rooms with the stage, and such openings shall be protected with fire door assemblies that comply with Section 715	Not addressed	Not addressed	Not addressed		Different-NFPA does not address.
Stages and Platforms	410.5.4	Stage exits.	At least one approved means of egress shall be provided from each side of the stage; and from each side of the space under the stage. At least one means of escape shall be provided from each fly gallery and from the gridiron. A steel ladder, alternating tread stairway or spiral stairway is permitted to be provided from the gridiron to a scuttle in the stage roof.	Number of Exits	16.2.4.6		A second means of egress shall not be required from lighting and access catwalks, galleries, and gridirons where a means of escape to a floor or a roof is provided. Ladders, alternating tread devices, or spiral stairs shall be permitted in such means of escape.	Similar
Stages and Platforms	410.6	Automatic sprinkler system.	Stages shall be equipped with an automatic fire-extinguishing system in accordance with Chapter 9. The system shall be installed under the roof and gridiron, in the tie and fly galleries and in places behind the proscenium wall of the stage and in dressing rooms, lounges, workshops and storerooms accessory to such stages. Exceptions: 1. Sprinklers are not required under stage areas less than 4 feet (1219 mm) in clear height utilized exclusively for storage of tables and chairs, provided the concealed space is separated from the adjacent spaces by not less than 5/8-inch (15.9 mm) Type X gypsum board. 2. Sprinklers are not required for stages 1,000 square feet (93m2) or less in area and 50 feet (15 240 mm) or less in height where curtains, scenery or other combustible hangings are not retractable vertically. Combustible hangings shall be limited to a single main curtain, borders, legs and a single backdrop.	Stages and Platforms.	16.4.5.9	Fire Protection.	Every stage shall be protected by an approved, supervised automatic sprinkler system installed in compliance with Section 55.3. The protection shall be provided throughout the stage and in storerooms, workshops, permanent dressing rooms, and other accessory spaces contiguous to such stages. Exception No. 1: Sprinklers shall not be required for stages of 1000 ft2 (93 m2) or less and of 50 ft (15 m) or less in height where curtains, scenery, or other combustible hangings are not retractable vertically. Combustible hangings shall be limited to a single main curtain, borders, legs, and a single backdrop. Exception No. 2: Sprinklers shall not be required under stage areas less than 4 ft (1.2 m) in clear height used exclusively for chair or table storage and lined on the inside with -in. (1.6-cm) Type X gypsum wallboard or an approved equivalent.	Similar
Stages and Platforms	410.7	Standpipes.	Standpipe systems shall be provided in accordance with Section 905.	Stages and Platforms.	16.4.5.10	Standpipes or Hose Connections.	Regular stages over 1000 ft2 (93 m2) in area and all legitimate stages shall be equipped with 1½-in. (38-mm) hose lines for first aid fire fighting at each side of the stage. Hose connections shall be in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems, unless Class II or Class III standpipes in accordance with NFPA 14, Standard for the Installation of Standpipe, Private Hydrant, and Hose Systems, are used.	Similar
	Chapter 5	General Building Heights and Areas						
General Height and Area Limitations	503.1	General.	The height and area for buildings of different construction types shall be governed by the intended use of the building and shall not exceed the limits in Table 503 except as modified hereafter. Each part of a building included within the exterior walls or the	Height and Area Limitations.	7.4.1	General.	Except as modified in Section 7.4 through Section 7.6, the heights and areas of buildings, based on their intended occupancy and type of construction classification, shall not exceed the limits set forth in Table 7.4.1 where the values in Table 7.4.1 for	Similar-NFPA has slightly different base values.

DRAFT

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			exterior walls and fire walls where provided shall be permitted to be a separate building.				sprinklered buildings apply to buildings protected throughout with an approved, electrically supervised automatic sprinkler system in accordance with 55.3.1.1(1).	
General Height and Area Limitations	503	Table 0503.	See Table.	Height and Area Limitations.	7.4.1	General.	Table 7.4.1	Similar-NFPA has slightly different base values.
Area Modifications	506.1	General.	The areas limited by Table 503 shall be permitted to be increased due to frontage (If) and automatic sprinkler system protection (Is) in accordance with the following: (Equation 5-1)	Area Increases Permitted.	7.6.2	Area Increase.	The floor areas specified in Table 7.4.1 shall be permitted to be increased to account for frontage (I f) and automatic sprinkler protection (Is) in accordance with the following equation: (7.1)	Similar
Area Modifications	506.2	Frontage increase.	Every building shall adjoin or have access to a public way to receive an area increase for frontage. Where a building has more than 25 percent of its perimeter on a public way or open space having a minimum width of 20 feet (6096 mm), the frontage increase shall be determined in accordance with the following: (Equation 5-2)	Area Increases Permitted.	7.6.2.1	Frontage Increase.	When a building has more than 25 percent of its perimeter fronting or facing on a public way or open space having a minimum width of 20 ft (6 m), the frontage increase shall be determined in accordance with the following equations: (7.2) (7.3)	Similar
Area Modifications	506.3	Automatic sprinkler system increase.	Where a building is protected throughout with an approved automatic sprinkler system in accordance with Section 903.3.1.1, the area limitation in Table 503 is permitted to be increased by an additional 200 percent (Is = 200 percent) for multistory buildings and an additional 300 percent (Is = 300 percent) for single-story buildings. These increases are permitted in addition to the height and story increases in accordance with Section 504.2. Exceptions: 1. Buildings with an occupancy in Group H-1, H-2 or H-3. 2. Fire-resistance rating substitution in accordance with Table 601, Note d.	Area Increases Permitted.	7.6.2.2	Automatic Sprinkler Increase	Buildings protected with an approved, electrically supervised automatic sprinkler system in accordance with NFPA 13 shall be permitted to have the following sprinkler (Is) area increases: (1) 200 percent (Is = 200) for buildings of two stories or more (2) 300 percent (Is = 300) for single-story buildings	Similar
Area Modifications	506.4	Area determination.	The maximum area of a building with more than one story shall be determined by multiplying the allowable area of the first floor (Aa), as determined in Section 506.1, by the number of stories as listed below. 1. For two-story buildings, multiply by 2; 2. For three-story or higher buildings, multiply by 3; and, 3. No story shall exceed the allowable area per floor (Aa), as determined in Section 506.1 for the occupancies on that floor. Exceptions: 1. Unlimited area buildings in accordance with Section 507. 2. The maximum area of a building equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.2 shall be determined by multiplying the allowable area per floor (Aa), as determined in Section 506.1 by the number of stories.	Area Increases Permitted.	7.6.2	Area Increase.	The floor areas specified in Table 7.4.1 shall be permitted to be increased to account for frontage (I f) and automatic sprinkler protection (Is) in accordance with the following equation: (7.1)	Similar
	Chapter 6	Types of Construction						
Construction Classification	602.1	General.	Building and structures erected or to be erected, altered, or extended in height or area shall be classified in one of the construction types defined in Sections 602.2 through 602.5. The building elements shall have a fire-resistance rating not less than that	Construction Types.	7.2.1.1	General.	All buildings and parts of buildings hereafter constructed shall conform to the requirements for the specific types of construction as provided in this chapter and shall comply with the applicable requirements of other chapters and sections of this	Similar

DRAFT

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			specified in Table 601 and exterior walls shall have a fire-resistance rating not less than that specified in Table 602.				Code.	
Construction Classification	602.5	Type V.	Type V construction is that type of construction in which the structural elements, exterior walls and interior walls are of any materials permitted by this code	Construction Types.	7.2.6	Type V (111 or 000) Construction.	Type V (111 or 000) construction shall be that type in which exterior walls, bearing walls, columns, beams, girders, trusses, arches, floors, and roofs are entirely or partially of wood or other approved material.	Similar
	Chapter 7	Fire-Resistance-Rated Construction						
Concealed Spaces	717.1	General.	Fireblocking and draftstopping shall be installed in combustible concealed locations in accordance with this section. Fireblocking shall comply with Section 717.2. Draftstopping in floor/ceiling spaces and attic spaces shall comply with Sections 717.3 and 717.4, respectively. The permitted use of combustible materials in concealed spaces of noncombustible buildings shall be limited to the applications indicated in Section 717.5.	Concealed Spaces.	8.14.1.1	Draft Stops.	Any concealed combustible space in which building materials having a flame spread index greater than Class A are exposed shall be draftstopped as follows: (1) Every unoccupied attic space shall be subdivided by draftstops into areas not to exceed 3000 ft2 (280 m2). (2) Any concealed space between the ceiling and the floor or roof above shall be draftstopped for the full depth of the space along the line of support for the floor or roof structural members and, if necessary, at other locations to form areas not to exceed 1000 ft2 (93 m2) for any space between the ceiling and floor and 3000 ft2 (280 m2) for any space between the ceiling and roof.	Similar
Concealed Spaces	717.2	Fireblocking.	In combustible construction, fireblocking shall be installed to cut off concealed draft openings (both vertical and horizontal) and shall form an effective barrier between floors, between a top story and a roof or attic space. Fireblocking shall be installed in the locations specified in Sections 717.2.2 through 717.2.7.	Concealed Spaces.	8.14.2.1	Fireblocks.	Concealed spaces constructed of combustible materials shall be fireblocked as follows: (1) In exterior and interior stud walls, at ceilings and floor levels (2) In combustible stud walls and partitions including furred spaces, placed so that the maximum dimension of a concealed space is 8 ft (2440 mm) (3) At all interconnections between concealed vertical and horizontal spaces such as those that occur at soffits, drop ceilings, and cove ceiling (4) In concealed spaces between stair stringers at the top and bottom of the run (5) At openings around vents, pipes, and ducts at ceiling and floor levels (6) In the spaces between chimneys and wood framing, which are to be solidly filled with approved materials	Similar
Concealed Spaces	717.2.1	Fireblocking materials.	Fireblocking shall consist of 2-inch nominal lumber or two thicknesses of 1-inch nominal lumber with broken lap joints or one thickness of 0.719-inch wood structural panel with joints backed by 0.719-inch wood structural panel or one thickness of 0.75-inch particleboard with joints backed by 0.75-inch particleboard. Gypsum board, cement fiber board, batts or blankets of mineral wool or glass fiber or other approved materials installed in such a manner as to be securely retained in place shall be permitted as an acceptable fireblock. Batts or blankets of mineral or glass fiber or other approved nonrigid materials shall be permitted for compliance with the 10-foot horizontal	Concealed Spaces.	8.14.2.3	Fireblocks.	Fireblocks shall consist of one of the following: (1) Nominal 2-in. (51-mm) lumber of two thicknesses of nominal 1-in. (25-mm) lumber with broken lap joints; one thickness of -in. (18-mm) wood structural panel with joints backed by -in. (18-mm) wood structural panel; or one thickness of ¾-in. (19-mm) particleboard with joints backed by ¾-in. (19-mm) particleboard(2) Gypsum board, cement fiber board, batts or blankets of mineral wool or glass fiber, or other approved materials that are capable of resisting the free passage of fire and smoke within the concealed space installed in such a manner as to be securely retained in place	Similar

DRAFT

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			fireblocking in walls constructed using parallel rows of studs or staggered studs. Loose-fill insulation material shall not be used as a fireblock unless specifically tested in the form and manner intended for use to demonstrate its ability to remain in place and to retard the spread of fire and hot gases. The integrity of fireblocks shall be maintained.					
Concealed Spaces	717.2.2	Concealed wall spaces.	Fireblocking shall be provided in concealed spaces of stud walls and partitions, including furred spaces, and parallel rows of studs or staggered studs, as follows: a. Vertically at the ceiling and floor levels. b. Horizontally at intervals not exceeding 10 feet (3048 mm).	Concealed Spaces.	8.14.2.1	Fireblocks.	Concealed spaces constructed of combustible materials shall be fireblocked as follows: (1) In exterior and interior stud walls, at ceilings and floor levels (2) In combustible stud walls and partitions including furred spaces, placed so that the maximum dimension of a concealed space is 8 ft (2440 mm) (3) At all interconnections between concealed vertical and horizontal spaces such as those that occur at soffits, drop ceilings, and cove ceiling (4) In concealed spaces between stair stringers at the top and bottom of the run (5) At openings around vents, pipes, and ducts at ceiling and floor levels (6) In the spaces between chimneys and wood framing, which are to be solidly filled with approved materials	Similar
Concealed Spaces	717.2.3	Connections between horizontal and vertical spaces.	Fireblocking shall be provided at Interconnections between concealed vertical stud wall or partition spaces and concealed horizontal spaces created by an assembly of floor joists or trusses, and between concealed vertical and horizontal spaces such as occur at soffits, drop ceilings, cove ceilings and similar locations.	Concealed Spaces.	8.14.2.1	Fireblocks.	Concealed spaces constructed of combustible materials shall be fireblocked as follows: (1) In exterior and interior stud walls, at ceilings and floor levels (2) In combustible stud walls and partitions including furred spaces, placed so that the maximum dimension of a concealed space is 8 ft (2440 mm) (3) At all interconnections between concealed vertical and horizontal spaces such as those that occur at soffits, drop ceilings, and cove ceiling (4) In concealed spaces between stair stringers at the top and bottom of the run (5) At openings around vents, pipes, and ducts at ceiling and floor levels (6) In the spaces between chimneys and wood framing, which are to be solidly filled with approved materials	Similar
Concealed Spaces	717.2.5	Ceiling and floor openings.	Where annular space protection is provided in accordance with Exception 6 of Section 707.2, Exception 1 of Section 712.4.2, or Section 712.4.3, fireblocking shall be installed at openings around vents, pipes, ducts, chimneys and fireplaces at ceiling and floor levels, with an approved material to resist the free passage of flame and the products of combustion. Factory-built chimneys and fireplaces shall be fireblocked in accordance with UL 103 and UL 127.	Concealed Spaces.	8.14.2.1	Fireblocks.	Concealed spaces constructed of combustible materials shall be fireblocked as follows: (1) In exterior and interior stud walls, at ceilings and floor levels(2) In combustible stud walls and partitions including furred spaces, placed so that the maximum dimension of a concealed space is 8 ft (2440 mm)(3) At all interconnections between concealed vertical and horizontal spaces such as those that occur at soffits, drop ceilings, and cove ceiling(4) In concealed spaces between stair stringers at the top and bottom of the run(5) At openings around vents, pipes, and ducts at ceiling and floor levels(6) In the spaces between chimneys and wood framing, which	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
							are to be solidly filled with approved materials	
Concealed Spaces	717.2.6	Architectural trim.	Fireblocking shall be installed within concealed spaces of exteriorwall finish and other exterior architectural elements where permitted to be of combustible construction in Section 1406 or where erected with combustible frames, at maximum intervals of 20 feet (6096 mm). If noncontinuous, such elements shall have closed ends, with at least 4 inches (102 mm) of separation between sections. Exceptions: 1. Fireblocking of cornices is not required in single-family dwellings, as applicable in Section 101.2. Fireblocking of cornices of a two-family dwelling as applicable in Section 101.2 is required only at the line of dwelling unit separation. 2. Fireblocking shall not be required where installed on noncombustible framing and the face of the exterior wall finish exposed to the concealed space is covered by one of the following materials: 2.1. Aluminum having a minimum thickness of 0.019 inch (0.5 mm). 2.2. Corrosion-resistant steel having a base metal thickness not less than 0.016 inch (0.4 mm) at any point. 2.3. Other approved noncombustible materials.	Concealed Spaces.	8.14.2.1	Fireblocks.	Concealed spaces constructed of combustible materials shall be fireblocked as follows: (1) In exterior and interior stud walls, at ceilings and floor levels (2) In combustible stud walls and partitions including furred spaces, placed so that the maximum dimension of a concealed space is 8 ft (2440 mm) (3) At all interconnections between concealed vertical and horizontal spaces such as those that occur at soffits, drop ceilings, and cove ceiling (4) In concealed spaces between stair stringers at the top and bottom of the run (5) At openings around vents, pipes, and ducts at ceiling and floor levels (6) In the spaces between chimneys and wood framing, which are to be solidly filled with approved materials	Similar
Concealed Spaces	717.2.7	Concealed sleeper spaces.	Where wood sleepers are used for laying wood flooring on masonry or concrete fire-resistance-rated floors, the space between the floor slab and the underside of thewood flooring shall be filled with an approved material to resist the free passage of flame and products of combustion or fireblocked in such a manner that there will be no open spaces under the flooring that will exceed 100 square feet (9.3m2) in area and such space shall be filled solidly under permanent partitions so that there is no communication under the flooring between adjoining rooms. Exceptions: 1. Fireblocking is not required for slab-on-grade floors in gymnasiums. 2. Fireblocking is required only at the juncture of each alternate lane and at the ends of each lane in a bowling facility.	Concealed Spaces.	8.14.2.1	Fireblocks.	Concealed spaces constructed of combustible materials shall be fireblocked as follows: (1) In exterior and interior stud walls, at ceilings and floor levels (2) In combustible stud walls and partitions including furred spaces, placed so that the maximum dimension of a concealed space is 8 ft (2440 mm) (3) At all interconnections between concealed vertical and horizontal spaces such as those that occur at soffits, drop ceilings, and cove ceiling (4) In concealed spaces between stair stringers at the top and bottom of the run (5) At openings around vents, pipes, and ducts at ceiling and floor levels (6) In the spaces between chimneys and wood framing, which are to be solidly filled with approved materials	Similar
Concealed Spaces	717.3	Draftstopping in floors.	In combustible construction, draftstopping shall be installed to subdivide floor/ceiling assemblies in the locations prescribed in Sections 717.3.2 through 717.3.3.	Concealed Spaces.	8.14.1.1	Draft Stops.	Any concealed combustible space in which building materials having a flame spread index greater than Class A are exposed shall be draftstopped as follows: (1) Every unoccupied attic space shall be subdivided by draftstops into areas not to exceed 3000 ft2 (280 m2).(2) Any concealed space between the ceiling and the floor or roof above shall be draftstopped for the full depth of the space along the line of support for the floor or roof structural members and, if necessary, at other locations to form areas not to exceed 1000 ft2 (93 m2) for any space between the ceiling and floor and 3000 ft2 (280 m2) for any space between the ceiling and roof.	Similar
Concealed Spaces	717.3.1	Draftstopping materials.	Draftstopping materials shall not be less than 0.5-inch (12.7 mm) gypsum board, 0.375-inch (9.5 mm) wood	Concealed Spaces.	8.14.1.3	Draft Stops.	Draftstopping materials shall be not less than ½-in. (13-mm) gypsum board, -in. (12-mm) wood structural	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			structural panel, 0.375-inch (9.5 mm) particleboard or other approved materials adequately supported. The integrity of draftstops shall be maintained.				panel, or other approved materials adequately supported.	
Concealed Spaces	717.3.3	Draftstopping materials.	In other groups (non R-use groups), draftstopping shall be installed so that horizontal floor areas do not exceed 1,000 square feet. Draftstopping is not required in buildings equipped throughout with an automatic sprinkler system.	Concealed Spaces.	8.14.1.1	Draft Stops.	Any concealed combustible space in which building materials having a flame spread index greater than Class A are exposed shall be draftstopped as follows: (1) Every unoccupied attic space shall be subdivided by draftstops into areas not to exceed 3000 ft2 (280 m2). (2) Any concealed space between the ceiling and the floor or roof above shall be draftstopped for the full depth of the space along the line of support for the floor or roof structural members and, if necessary, at other locations to form areas not to exceed 1000 ft2 (93 m2) for any space between the ceiling and floor and 3000 ft2 (280 m2) for any space between the ceiling and roof.	Similar
Concealed Spaces	717.4	Draftstopping in attics.	In combustible construction, draftstopping shall be installed to subdivide attic spaces and concealed roof spaces in the locations prescribed in Sections 717.4.2 and 717.4.3. Ventilation of concealed roof spaces shall be maintained in accordance with Section 1203.2.	Concealed Spaces.	8.14.1.1	Draft Stops.	Any concealed combustible space in which building materials having a flame spread index greater than Class A are exposed shall be draftstopped as follows: (1) Every unoccupied attic space shall be subdivided by draftstops into areas not to exceed 3000 ft2 (280 m2). (2) Any concealed space between the ceiling and the floor or roof above shall be draftstopped for the full depth of the space along the line of support for the floor or roof structural members and, if necessary, at other locations to form areas not to exceed 1000 ft2 (93 m2) for any space between the ceiling and floor and 3000 ft2 (280 m2) for any space between the ceiling and roof.	Similar
Thermal- and Sound-Insulating Materials	719.1	General.	Insulating materials, including facings such as vapor retarders and vapor-permeable membranes, similar coverings, and all layers of single and multilayer reflective foil insulations, shall comply with the requirements of this section. Where a flame spread index or a smoke-developed index is specified in this section, such index shall be determined in accordance with ASTM E 84. Any material that is subject to an increase in flame spread index or smoke-developed index beyond the limits herein established through the effects of age, moisture, or other atmospheric conditions shall not be permitted. Exceptions: 1. Fiberboard insulation shall comply with Chapter 23. 2. Foam plastic insulation shall comply with Chapter 26. 3. Duct and pipe insulation and duct and pipe coverings and linings in plenums shall comply with the International Mechanical Code.	Insulating Materials.	8.16.1.1	Flame Spread.	Where a flame spread index or a smoke developed index is specified in Section 8.16, such index shall be determined in accordance with the requirements of NFPA 255, Standard Method of Test of Surface Burning Characteristics of Building Materials, or ASTM E 84, Standard Test Method of Surface Burning Characteristics of Building Materials.	Similar
Thermal- and Sound-Insulating Materials	719.2	Concealed installation.	Insulating materials, where concealed as installed in buildings of any type of construction, shall have a flame spread index of not more than 25 and a smoke-developed index of not more than 450. Exception:	Insulating Materials.	8.16.2.1	Concealed Insulation.	Insulating materials shall meet the following criteria: (1) When concealed as installed in buildings of any type construction, insulating materials shall have a flame spread index of not more than 75 and a smoke	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			Cellulose loose-fill insulation that is not spray applied, complying with the requirements of Section 719.6, shall only be required to meet the smoke-developed index of not more than 450.				developed index of not more than 450. (2) Cellulose loose-fill insulation that is not spray applied and that complies with the requirements of 8.16.6 shall be required to meet only a smoke developed index of not more than 450.	
Thermal- and Sound-Insulating Materials	719.3	Exposed installation.	Insulating materials, where exposed as installed in buildings of any type of construction, shall have a flame spread index of not more than 25 and a smoke-developed index of not more than 450. Exception: Cellulose loose-fill insulation that is not spray applied complying with the requirements of Section 719.6 shall only be required to meet the smoke-developed index of not more than 450.	Exposed Insulation.	8.16.3.1	General.	Insulating materials shall meet the following criteria: (1) When exposed as installed in buildings of any type construction, insulating materials shall have a flame spread index of not more than 25 and a smoke developed index of not more than 450. (2) Cellulose loose-fill insulation that is not spray applied and that complies with the requirements of 8.16.6 shall be required to meet only a smoke developed index of not more than 450.	Similar
	Chapter 8	Interior Finishes						
General	801.1.1	Interior finishes.	These provisions shall limit the allowable flame spread and smoke development based on location and occupancy classification. Exceptions: 1. Materials having a thickness less than 0.036 inch (0.9 mm) applied directly to the surface of walls or ceilings. 2. Exposed portions of structural members complying with the requirements for buildings of Type IV construction in Section 602.4 shall not be subject to interior finish requirements.	Interior Finish	10.1.2	General.	Materials applied, in total thickness of less than in. (0.90 mm), directly to the surface of walls and ceilings shall be exempt from tests simulating actual installation if they meet the requirements of Class A interior wall or ceiling finish when tested in accordance with 10.3.1 using inorganic reinforced cement board as the substrate material.	Similar
General	801.2.2	Foam plastics.	Foam plastics shall not be used as interior finish or trim except as provided in Section 2603.7 or 2604.	Specific Materials.	10.4.3	Cellular or Foamed Plastic.	Cellular or foamed plastic materials shall not be used as interior wall and ceiling finish, unless specifically permitted by 10.4.3.1 or 10.4.3.2.	Similar
Wall and Ceiling Finishes	803.1	General.	Interior wall and ceiling finishes shall be classified in accordance with ASTM E 84. Such interior finish materials shall be grouped in the following classes in accordance with their flame spread and smoke-developed indexes. Class A: Flame spread 0-25; smoke-developed 0-450. Class B: Flame spread 26-75; smoke-developed 0-450. Class C: Flame spread 76-200; smoke-developed 0-450. Exception: Materials, other than textiles, tested in accordance with Section 803.2	Interior Finish	10.3.2	Interior Wall or Ceiling Finish Testing and Classification.	Products required to be tested in accordance with NFPA 255 or ASTM E 84 shall be grouped in the classes described in 10.3.2(A) through 10.3.2(C) in accordance with their flame spread and smoke development, except as indicated in 10.3.3.	Similar
Wall and Ceiling Finishes	803.2	Interior wall or ceiling finishes other than textiles.	Interior wall or ceiling finishes, other than textiles, shall be permitted to be tested in accordance with NFPA 286. Finishes tested in accordance with NFPA 286 shall comply with Section 803.2.1.	Interior Finish	10.3.6	Interior Wall or Ceiling Finish Testing and Classification.	Products tested in accordance with NFPA 265, Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Wall Coverings in Full Height Panels and Walls, shall comply with the criteria of 10.3.6.1 or 10.3.6.2. Products tested in accordance with NFPA 286 shall comply with the criteria of 10.3.6.3.	Similar
Wall and Ceiling Finishes	803.2.1	Acceptance criteria.	During the 40 kW exposure, the interior finish shall comply with Item 1. During the 160 kW exposure, the interior finish shall comply with Item 2. During the entire test, the interior finish shall comply with Item 3. 1. During the 40kW exposure, flames shall not spread to the ceiling. 2. During the 160 kW exposure, the interior finish shall comply with the following: 2.1. Flame shall not spread to the outer extremity of the sample on any wall or ceiling. 2.2. Flashover, as	Interior Finish	10.3.6.3	Interior Wall or Ceiling Finish Testing and Classification.	The following conditions shall be met when using the test protocol of NFPA 286: (1) Flame shall not spread to the ceiling during the 40-kW exposure. (2) During the 160-kW exposure, the following criteria shall be met: (a) Flame shall not spread to the outer extremities of the sample on the 8-ft × 12-ft (2.4-m × 3.7-m) wall. (b) Flashover shall not occur.	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			defined in NFPA 286, shall not occur. 3. The total smoke released throughout the NFPA 286 test shall not exceed 1,000 m2.				(3) For new installations, the total smoke released throughout the test shall not exceed 1000 m2.	
Wall and Ceiling Finishes	803.3	Stability.	Interior finish materials regulated by this chapter shall be applied or otherwise fastened in such a manner that such materials will not readily become detached where subjected to room temperatures of 200°F (93°C) for not less than 30 minutes.	Not addressed	Not addressed	Not addressed		Different-NFPA does not address.
Wall and Ceiling Finishes	803.4.1	Direct attachment and furred construction.	Where walls and ceilings are required by any provision in this code to be of fire-resistance-rated or noncombustible construction, the interior finish material shall be applied directly against such construction or to furring strips not exceeding 1.75 inches (44 mm) applied directly against such surfaces. The intervening spaces between such furring strips shall be filled with inorganic or Class A material or shall be fireblocked at a maximum of 8 feet (2438 mm) in any direction in accordance with Section 717.	Not addressed	Not addressed	Not addressed		Different-NFPA does not address.
Wall and Ceiling Finishes	803.4.2	Set-out construction.	Where walls and ceilings are required to be of fire-resistance-rated or noncombustible construction and walls are set out or ceilings are dropped distances greater than specified in Section 803.4.1, Class A finish materials shall be used except where interior finish materials are protected on both sides by an automatic sprinkler system or attached to noncombustible backing or furring strips installed as specified in Section 803.4.1. The hangers and assembly members of such dropped ceilings that are below the main ceiling line shall be of noncombustible materials, except that in Type III and V construction, fire-retardant-treated wood shall be permitted. The construction of each set-out wall shall be of fire-resistance- rated construction as required elsewhere in this code.	Not addressed	Not addressed	Not addressed		Different-NFPA does not address.
Wall and Ceiling Finishes	803.5	Interior finish requirements based on group.	Interior wall and ceiling finish shall have a flame spread index not greater than that specified in Table 803.5 for the group and location designated. Interior wall and ceiling finish materials, other than textiles, tested in accordance with NFPA 286 and meeting the acceptance criteria of Section 803.2.1, shall be permitted to be used where a Class A classification in accordance with ASTM E 84 is required.	Interior Finish	10.3.1.2	Interior Wall or Ceiling Finish Testing and Classification.	Interior wall and ceiling finish tested in accordance with NFPA 286, Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth, and meeting the conditions of 10.3.6.3 shall be permitted to be used where a Class A classification in accordance with NFPA 255 or ASTM E 84 is required.	Similar
Wall and Ceiling Finishes	Table 803.5	Interior Wall and Ceiling Finish Requirements by Occupancy (Table)	Use-Group A-2 (Non-Sprinklered): Vertical exits and exit passageways, Class A; Exit access corridors and other exitways, Class A (Lobby areas may be Class B); Rooms and enclosed spaces, Class B (Occupant Load ≤ 300, Class C permitted).	Protection.	16.3.3	Interior Finish.	Interior finish shall be in accordance with Chapter 10. 16.3.3.2 Interior wall and ceiling finish materials complying with Chapter 10 shall be Class A or Class B in all corridors and lobbies and shall be Class A in enclosed stairways. 16.3.3.3 Interior wall and ceiling finish materials complying with Chapter 10 shall be Class A or Class B in general assembly areas having occupant loads of more than 300 and shall be Class A, Class B, or Class C in assembly areas having occupant loads of 300 or fewer.	Similar

DRAFT

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
Wall and Ceiling Finishes	803.8	Insulation.	Thermal and acoustical insulation shall comply with Section 719	Insulating Materials.	8.16	Flame Spread.	Insulating materials, including vapor barriers, breather papers, facings, and similar coverings, and every layer of multilayer reflective foil insulations, shall comply with the requirements of Section 8.16.	Similar
Wall and Ceiling Finishes	803.9	Acoustical ceiling systems.	The quality, design, fabrication and erection of metal suspension systems for acoustical tile and lay-in panel ceilings in buildings or structures shall conform with generally accepted engineering practice, the provisions of this chapter and other applicable requirements of this code	Not addressed	Not addressed	Not addressed		Similar. With not specifically addressed by NFPA 5000, general provisions within the code impose similar requirements.
Wall and Ceiling Finishes	803.9.1	Materials and installation.	Acoustical materials complying with the interior finish requirements of Section 803 shall be installed in accordance with the manufacturer's recommendations and applicable provisions for applying interior finish.	Not addressed	10.3.1	Interior Wall; Ceiling	Interior wall or ceiling finish that is required elsewhere in this Code to be Class A. Class B. or Class C shall be classified based on test resuults from NFP 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials,* or ASTM E 84, *Standard Test Method of Surface Burning Characteristics of Building Materials*, except as indicated in 10.3.1.1 or 10.3.1.2	Similar
Decorations and Trim	805.1	General.	In occupancies of Groups A, E, I, R-1 and dormitories in Group R-2, curtains, draperies, hangings and other decorative materials suspended from walls or ceilings shall be flame resistant in accordance with Section 805.2 and NFPA 701 or noncombustible. In Groups I-1 and I-2, combustible decorations shall be flame retardant unless the decorations, such as photographs and paintings, are of such limited quantities that a hazard of fire development or spread is not present. In Group I-3, combustible decorations are prohibited.	Not addressed	Not addressed	Not addressed		Similar. NFPA addresses in NFPA 1 as it is considered an operational matter.
Decorations and Trim	805.1.1	Non-combustible materials.	The permissible amount of noncombustible decorative material shall not be limited.	Not addressed	Not addressed	Not addressed		Similar. NFPA addresses in NFPA 1 as it is considered an operational matter.
Decorations and Trim	805.1.2	Flame-resistant materials.	The permissible amount of flame-resistant decorative materials shall not exceed 10 percent of the aggregate area of walls and ceilings. Exception: In auditoriums of Group A, the permissible amount of flame-resistant decorative material shall not exceed 50 percent of the aggregate area of walls and ceilings where the building is equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 and the material is installed in accordance with Section 803.3.	Not addressed	Not addressed	Not addressed		Similar. NFPA addresses in NFPA 1 as it is considered an operational matter.
Decorations and Trim	805.2	Acceptance criteria and reports.	Where required to be flame resistant, decorative materials shall be tested by an approved agency and pass Test 1 or 2, as appropriate, described in NFPA 701 or such materials shall be noncombustible. Reports of test results shall be prepared in accordance with NFPA 701 and furnished to the building official	Not addressed	Not addressed	Not addressed		Similar. NFPA addresses in NFPA 1 as it is considered an operational matter.

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			upon request.					
Decorations and Trim	805.3	Foam plastic.	Plastic used as trim in any occupancy shall comply with Section 2604.2.	Plastics.	48.5.1	Specific Requirements — Interior Finish and Trim.	All plastic materials installed as interior finish or trim shall comply with requirements of Chapter 10.	Similar
	Chapter 9	Fire Protection Systems						
General	901.6	Supervisory service.	Where required, fire protection systems shall be monitored by an approved supervising station in accordance with NFPA 72.	Detection, Alarm, and Communications Systems.	55.3.2.1	Supervisory Signals	Where electrically supervised automatic sprinkler systems are required by another section of this Code, supervisory attachments shall be installed and monitored for integrity in accordance with NFPA 72, and a distinctive supervisory signal shall be provided to indicate a condition that would impair the satisfactory operation of the sprinkler system.	Similar
General	901.6.1	Automatic sprinkler systems.	Automatic sprinkler systems shall be monitored by an approved supervising station. A supervising station is not required for automatic sprinkler systems protecting one- and two- family dwellings or limited area systems serving fewer than 20 sprinklers.	Detection, Alarm, and Communications Systems.	55.3.2.1	Supervisory Signals	Where electrically supervised automatic sprinkler systems are required by another section of this Code, supervisory attachments shall be installed and monitored for integrity in accordance with NFPA 72, and a distinctive supervisory signal shall be provided to indicate a condition that would impair the satisfactory operation of the sprinkler system.	Similar
Automatic Sprinkler Systems	903.2.1	Group A.	An automatic sprinkler system shall be provided throughout buildings and portions thereof used as Group A occupancies as provided in this section. For Group A-1, A-2, A-3 and A-4 occupancies, the automatic sprinkler system shall be provided throughout the floor area where the Group A-1, A-2, A-3 or A-4 occupancy is located, and in all floors between the Group A occupancy and the level of exit discharge. For Group A-5 occupancies, the automatic sprinkler system shall be provided in the spaces indicated in Section 903.2.1.5.	Extinguishment Requirements.	16.3.5.1.1	Sprinkler Systems.	Buildings containing assembly occupancies with occupant loads greater than 300 shall be protected by an approved, supervised automatic sprinkler system installed in accordance with Section 55.3 as follows: (1) Throughout the story containing the assembly occupancy (2) Throughout all stories below the story containing the assembly occupancy (3) In the case of an assembly occupancy located below the level of exit discharge, throughout all stories intervening between that story and the level of exit discharge, including the level of exit discharge	Different-NFPA requirements based on occupancy load only.
Automatic Sprinkler Systems	903.2.1.2	Group A-2.	An automatic sprinkler system shall be provided for Group A-2 occupancies where one of the following conditions exists: 1. The fire area exceeds 5,000 square feet. 2. The fire area has an occupant load of 300 or more. 3. The fire area is located on a floor other than the level of exit discharge. 3. The fire area is located on a floor other than the level of exit discharge. Exception: Areas used exclusively as participant sports areas where the main floor area is located at the same level as the level of exit discharge of the main entrance and exit.	Extinguishment Requirements.	16.3.5.1.1	Sprinkler Systems.	Buildings containing assembly occupancies with occupant loads greater than 300 shall be protected by an approved, supervised automatic sprinkler system installed in accordance with Section 55.3 as follows: (1) Throughout the story containing the assembly occupancy (2) Throughout all stories below the story containing the assembly occupancy (3) In the case of an assembly occupancy located below the level of exit discharge, throughout all stories intervening between that story and the level of exit discharge, including the level of exit discharge	Different-NFPA requirements based on occupancy load only.
Automatic Sprinkler Systems	903.2.1.2	Group A-2.	An automatic sprinkler system shall be provided for Group A-2 occupancies where one of the following conditions exists: 1. The fire area exceeds 5,000 square feet. 2. The fire area has an occupant load of 300 or more. 3. The fire area is located on a floor other than the level of exit discharge. 3. The fire area is	Extinguishment Requirements.	16.1.6	Occupant Load	The occupant load, in number of persons for whom means of egress and other provisions are required, shall be determined on the basis of the occupant load factors of Table 11.3.1.2 that are characteristic of the use of the space or shall be determined as the maximum probable population of the space under	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			located on a floor other than the level of exit discharge. Exception: Areas used exclusively as participant sports areas where the main floor area is located at the same level as the level of exit discharge of the main entrance and exit.				consideration, whichever is greater. In areas not in excess of 10,000 ft2 (930 m2), the occupant load shall not exceed one person in 5 ft2 (0.46 m2); in areas in excess of 10,000 ft2 (930 m2), the occupant load shall not exceed one person in 7 ft2 (0.65 m2).	
Automatic Sprinkler Systems	903.3.1	Standards.	Sprinkler systems shall be designed and installed in accordance with Section 903.3.1.1, 903.3.1.2 or 903.3.1.3.	Automatic Sprinklers.	55.3.1.1	General.	Each automatic sprinkler system required by another section of this Code shall be in accordance with one of the following: (1) NFPA 13, Standard for the Installation of Sprinkler Systems(2) NFPA 13R, Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height(3) NFPA 13D, Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes	Similar
Automatic Sprinkler Systems	903.3.1.1	NFPA 13 sprinkler systems.	Where the provisions of this code require that a building or portion thereof be equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1, sprinklers shall be installed throughout in accordance with NFPA 13 except as provided in Section 903.3.1.1.1.	Automatic Sprinklers.	55.3.1.1	General.	Each automatic sprinkler system required by another section of this Code shall be in accordance with one of the following: (1) NFPA 13, Standard for the Installation of Sprinkler Systems (2) NFPA 13R, Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height (3) NFPA 13D, Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes	Similar
Automatic Sprinkler Systems	903.3.4	Actuation.	Automatic sprinkler systems shall be automatically actuated unless specifically provided for in this code.	Automatic Sprinklers.	55.3.1.1	General.	Each automatic sprinkler system required by another section of this Code shall be in accordance with one of the following: (1) NFPA 13, Standard for the Installation of Sprinkler Systems (2) NFPA 13R, Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height (3) NFPA 13D, Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes	Similar-Automatic response required by NFPA 13.
Automatic Sprinkler Systems	903.3.5	Water supplies.	Water supplies for automatic sprinkler systems shall comply with this section and the standards referenced in Section 903.3.1. The potable water supply shall be protected against backflow in accordance with the requirements of this section and the International Plumbing Code.	Automatic Sprinklers.	55.3.1.1	General.	Each automatic sprinkler system required by another section of this Code shall be in accordance with one of the following: (1) NFPA 13, Standard for the Installation of Sprinkler Systems (2) NFPA 13R, Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height (3) NFPA 13D, Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes	Similar
Automatic Sprinkler Systems	903.3.7	Fire department connections.	The location of fire department connections shall be approved by the building official.	Automatic Sprinklers.	55.3.1.1	General.	Each automatic sprinkler system required by another section of this Code shall be in accordance with one of the following: (1) NFPA 13, Standard for the Installation of Sprinkler Systems(2) NFPA 13R, Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height(3) NFPA 13D, Standard for the	Similar-FD connection placement specified by NFPA 13.

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
							Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes	
Automatic Sprinkler Systems	903.4	Sprinkler system monitoring and alarms.	All valves controlling the water supply for automatic sprinkler systems, pumps, tanks, water levels and temperatures, critical air pressures and water-flow switches on all sprinkler systems shall be electrically supervised. Exceptions: 1. Automatic sprinkler systems protecting one- and two-family dwellings. 2. Limited area systems serving fewer than 20 sprinklers. 3. Automatic sprinkler systems installed in accordance with NFPA13R where a common supply main is used to supply both domestic water and the automatic sprinkler systems and a separate shutoff valve for the automatic sprinkler system is not provided. 4. Jockey pump control valves that are sealed or locked in the open position. 5. Control valves to commercial kitchen hoods, paint spray booths or dip tanks that are sealed or locked in the open position. 6. Valves controlling the fuel supply to fire pump engines that are sealed or locked in the open position. 7. Trim valves to pressure switches in dry, preaction and deluge sprinkler systems that are sealed or locked in the open position.	Electrical Supervision.	55.3.2.1.1	Supervisory Signals.	Monitoring shall include, but shall not be limited to, monitoring of control valves, fire pump power supplies and running conditions, water tank levels and temperatures, tank pressure, and air pressure on dry-pipe valves.	Similar
Alternative Automatic Fire-Extinguishing Systems	904.1	General.	Automatic fire-extinguishing systems, other than automatic sprinkler systems, shall be designed, installed, inspected, tested and maintained in accordance with the provisions of this section and the applicable referenced standards.	Other Automatic Extinguishing Equipment.	55.5.1	Alternative Systems.	In any occupancy where the character of the fuel for fire is such that extinguishment or control of the fire is accomplished by a type of automatic extinguishing system in lieu of an automatic sprinkler system, such extinguishing system shall be installed in accordance with the applicable standard referenced in Table 55.5.1.	Similar
Alternative Automatic Fire-Extinguishing Systems	904.2	Where required.	Automatic fire-extinguishing systems installed as an alternative to the required automatic sprinkler systems of Section 903 shall be approved by the building official. Automatic fire-extinguishing systems shall not be considered alternatives for the purposes of exceptions or reductions permitted by other requirements of this code. 3. Size, placement and position of nozzles or discharge orifices. 4. Location and identification of audible and visible alarm devices. 5. Identification of devices with proper designations. 6. Operating instructions.	Other Automatic Extinguishing Equipment.	55.5.1	Alternative Systems.	In any occupancy where the character of the fuel for fire is such that extinguishment or control of the fire is accomplished by a type of automatic extinguishing system in lieu of an automatic sprinkler system, such extinguishing system shall be installed in accordance with the applicable standard referenced in Table 55.5.1.	Similar
Alternative Automatic Fire-Extinguishing Systems	904.2.1	Hood System suppression.	Each required commercial kitchen exhaust hood and duct system required by the International Fire Code or the International Mechanical Code to have a Type I hood shall be protected with an approved automatic fire-extinguishing system installed in accordance with this code.	Fire Protection Systems and Equipment	55.10	Protection of Cooking Hazards.	Where required by another section of this Code, commercial cooking operations shall be protected in accordance with NFPA 96, Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations.	Similar-Different referenced standards have similar requirements.
Standpipe Systems	905.1	General.	Standpipe systems shall be provided in new buildings and structures in accordance with this section. Fire hose threads used in connection with standpipe systems shall be approved and shall be compatible with fire department hose threads. The location of fire department hose connections shall be approved. In buildings used for high-piled combustible storage, fire protection shall be in accordance with the International	Extinguishment Requirements.	16.3.5.2.1	Standpipes.	Class I standpipe systems shall be provided in buildings four or more stories in height, or having four or more basement levels, as specified in 55.4.1.	Different

DRAFT

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			Fire Code.					
Standpipe Systems	905.3.2	Group A.	Class I automatic wet standpipes shall be provided in nonsprinklered Group A buildings having an occupant load exceeding 1,000 persons. Exceptions: 1. Open-air-seating spaces without enclosed spaces. 2. Class I automatic dry and semiautomatic dry standpipes or manual wet standpipes are allowed in buildings where the highest floor surface used for human occupancy is 75 feet (22 860 mm) or less above the lowest level of fire department vehicle access.	Extinguishment Requirements.	16.3.5.2.1	Standpipes.	Class I standpipe systems shall be provided in buildings four or more stories in height, or having four or more basement levels, as specified in 55.4.1.	Different-NFPA standpipe requirements based on height.
	905.3.2	Group A.	Class I automatic wet standpipes shall be provided in nonsprinklered Group A buildings having an occupant load exceeding 1,000 persons. Exceptions: 1. Open-air-seating spaces without enclosed spaces. 2. Class I automatic dry and semiautomatic dry standpipes or manual wet standpipes are allowed in buildings where the highest floor surface used for human occupancy is 75 feet (22 860 mm) or less above the lowest level of fire department vehicle access.	Extinguishment Requirements.	16.3.5.2.3	Standpipes.	Class I standpipe systems shall be provided in buildings not protected throughout by an approved, supervised sprinkler system in accordance with Section 55.3 where an occupiable area is more than 150 ft (45 m) from the closest point of fire department entry into the building.	Different-NFPA standpipe requirements based on height.
Portable Fire Extinguishers	906.1	General.	Portable fire extinguishers shall be provided in occupancies and locations as required by the International Fire Code.	Extinguishment Requirements.	16.3.5.3	Portable Fire Extinguishers.	Portable fire extinguishers shall be installed in assembly occupancies in accordance with Section 55.6.	Similar
Fire Alarm and Detection Systems	907.1	General.	This section covers the application, installation, performance and maintenance of fire alarm systems and their components.	Fire Detection, Alarm, and Communication Systems.	55.2.1.2	General.	A fire alarm system shall be installed in accordance with the applicable requirements of Chapter 52 and NFPA 72®, National Fire Alarm Code®.	Similar
Fire Alarm and Detection Systems	907.2	Where required.	An approved manual, automatic or manual and automatic fire alarm system shall be provided in accordance with Sections 907.2.1 through 907.2.23. Where automatic sprinkler protection, installed in accordance with Section 903.3.1.1 or 903.3.1.2, is provided and connected to the building fire alarm system, automatic heat detection required by this section shall not be required. An approved automatic fire detection system shall be installed in accordance with the provisions of this code and NFPA72. Devices, combinations of devices, appliances and equipment shall comply with Section 907.1.2. The automatic fire detectors shall be smoke detectors, except that an approved alternative type of detector shall be installed in spaces such as boiler rooms where, during normal operation, products of combustion are present in sufficient quantity to actuate a smoke detector.	Detection, Alarm Systems	16.3.4.1	General.	Assembly occupancies with occupant loads greater than 300 and all theaters with more than one audience-viewing room shall be provided with an approved fire alarm system in accordance with Section 55.2 and 16.3.4.2 through 16.3.4.3.4.	Similar
Fire Alarm and Detection Systems	907.2.1	Group A.	A manual fire alarm system shall be installed in accordance with NFPA 72 in Group A occupancies having an occupant load of 300 or more. Portions of Group E occupancies occupied for assembly purposes shall be provided with a fire alarm system as required for the Group E occupancy. Exception: Manual fire alarm boxes are not required where the building is equipped throughout with an automatic sprinkler system and the notification appliances will activate upon sprinkler water flow.	Detection, Alarm, and Communications Systems.	16.3.4.1	General.	Assembly occupancies with occupant loads greater than 300 and all theaters with more than one audience-viewing room shall be provided with an approved fire alarm system in accordance with Section 55.2 and 16.3.4.2 through 16.3.4.3.4. Exception No. 1: Assembly occupancies that are a part of a mixed occupancy shall be permitted to be served by a common fire alarm system, provided that the individual requirements of each occupancy are met.	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
							Exception No. 2: Voice communication or public address systems complying with 16.3.4.3.3 shall not be required to comply with Section 55.2.	
	Chapter 10	Means of Egress						
Administration	1001.1	General.	Buildings or portions thereof shall be provided with a means of egress system as required by this chapter. The provisions of this chapter shall control the design, construction and arrangement of means of egress components required to provide an approved means of egress from structures and portions thereof.	Means of Egress Requirements.	16.2.1	General.	All means of egress shall be in accordance with Chapter 11 and this chapter.	Similiar-NFPA cites requirements in general the by occupancy in specific chapters.
Administration	1001.2	Minimum requirements.	It shall be unlawful to alter a building or structure in a manner that will reduce the number of exits or the capacity of the means of egress to less than required by this code. a means of escape and access for rescue in the event of an emergency. EXIT. That portion of a means of egress system which is separated from other interior spaces of a building or structure by fire-resistance-rated construction and opening protectives as required to provide a protected path of egress travel between the exit access and the exit discharge. Exits include exterior exit doors at ground level, exit enclosures, exit passageways, exterior exit stairs, exterior exit ramps and horizontal exits.	Means of Egress.	15.6.2.1.2	Number of Means of Egress.	Every story utilized for human occupancy on which there is a rehabilitation work area shall be provided with the minimum number of means of egress required by NFPA 101, Life Safety Code, for existing occupancies.	Similar
Administration	1001.3	Maintenance.	Means of egress shall be maintained in accordance with the *International Fire Code*.	Means of Egress.	11.1.10.1	Means of Egress Reliability	Maintenance. Means of egress shall be continuously maintained free of all obstructions or impediments to full instant use in the case of fire or other emergency.	Different-NFPA contains all means of egress references.
General Means of Egress	1003.2	Ceiling height.	The means of egress shall have a ceiling height of not less than 7 feet (2134 mm). Exceptions: 1. Sloped ceilings in accordance with Section 1208.2. 2. Ceilings of dwelling units and sleeping units within residential occupancies in accordance with Section 1208.2. 3. Allowable projections in accordance with Section 1003.3. 4. Stair headroom in accordance with Section 1009.2. 5. Door height in accordance with Section 1008.1.1.	General.	11.1.5	Headroom.	Means of egress shall be designed and maintained to provide headroom as provided in other sections of this Code and shall be not less than 7 ft 6 in. (2.3 m) with projections from the ceiling not less than 6 ft 8 in. (2 m) nominal height above the finished floor. The minimum ceiling height shall be maintained for not less than two-thirds of the ceiling area of any room or space, provided the ceiling height of the remaining ceiling area is not less than 6 ft 8 in. (2 m). Headroom on stairs shall be not less than 6 ft 8 in. (2 m) and shall be measured vertically above a plane parallel to and tangent with the most forward projection of the stair tread.	Different-NFPA uses 7'-6"
General Means of Egress	1003.3	Protruding objects.	Protruding objects shall comply with the requirements of Sections 1003.3.1 through 1003.3.4.	Width.	11.2.1.2.2	Clear Width.	Clear width shall be measured as follows: (1) Clear width shall be measured at the narrowest point in the door opening. (2) For swinging doors, clear width shall be measured between the face of the door and the stop. (3) Clear width shall be measured without subtracting for the obstructions permitted by 11.2.1.2.3.2 and 11.2.1.2.3.3.	Different-NFPA simply uses clear width.
General Means of Egress	1003.3.1	Headroom.	Protruding objects are permitted to extend below the minimum ceiling height required by Section 1003.2 provided a minimum headroom of 80 inches (2032 mm) shall be provided for any walking surface,	General.	11.1.5	Headroom.	Means of egress shall be designed and maintained to provide headroom as provided in other sections of this Code and shall be not less than 7 ft 6 in. (2.3 m) with projections from the ceiling not less than 6 ft 8	Different-NFPA uses 7'- 6"

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			including walks, corridors, aisles and passageways. Not more than 50 percent of the ceiling area of a means of egress shall be reduced in height by protruding objects. Exception: Door closers and stops shall not reduce headroom to less than 78 inches (1981 mm). A barrier shall be provided where the vertical clearance is less than 80 inches (2032 mm) high. The leading edge of such a barrier shall be located 27 inches (686 mm) maximum above the floor.				in. (2 m) nominal height above the finished floor. The minimum ceiling height shall be maintained for not less than two-thirds of the ceiling area of any room or space, provided the ceiling height of the remaining ceiling area is not less than 6 ft 8 in. (2 m). Headroom on stairs shall be not less than 6 ft 8 in. (2 m) and shall be measured vertically above a plane parallel to and tangent with the most forward projection of the stair tread.	
General Means of Egress	1003.3.2	Freestanding objects.	A free-standing object mounted on a post or pylon shall not overhang that post or pylon more than 12 inches (305 mm) where the lowest point of the leading edge is more than 27 inches (686mm) and less than 80 inches (2032 mm) above the walking surface. Where a sign or other obstruction is mounted between posts or pylons and the clear distance between the posts or pylons is greater than 12 inches (305 mm), the lowest edge of such sign or obstruction shall be 27 inches (685 mm) maximum or 80 inches (2030 mm) minimum above the finish floor or ground. Exception: This requirement shall not apply to sloping portions of handrails serving stairs and ramps.	Means of Egress Reliability.	11.1.10.2.1	Furnishings and Decorations in Means of Egress.	No furnishings, decorations, or other objects shall obstruct the access to, egress from, or visibility of exits.	Similar
General Means of Egress	1003.3.3	Horizontal projections.	Structural elements, fixtures or furnishings shall not project horizontally from either side more than 4 inches (102 mm) over any walking surface between the heights of 27 inches (686 mm) and 80 inches (2032 mm) above the walking surface. Exception: Handrails serving stairs and ramps are permitted to protrude 4.5 inches (114 mm) from the wall.	Protruding Objects.	12.5		Protruding objects on circulation paths shall comply with ICC/ANSI A117.1, Section 307.	Similar
General Means of Egress	1003.4	Floor surface.	Walking surfaces of the means of egress shall have a slip-resistant surface and be securely attached.	Walking Surfaces in the Means of Egress.	11.1.6.4	Slip Resistance.	Walking surfaces shall be slip resistant under foreseeable conditions. The walking surface of each element in the means of egress shall be uniformly slip resistant along the natural path of travel.	Similar
General Means of Egress	1003.5	Elevation change.	Where changes in elevation of less than 12 inches (305 mm) exist in the means of egress, sloped surfaces shall be used. Where the slope is greater than one unit vertical in 20 units horizontal (5-percent slope), ramps complying with Section 1010 shall be used. Where the difference in elevation is 6 inches (152 mm) or less, the ramp shall be equipped with either handrails or floor finish materials that contrast with adjacent floor finish materials. Exceptions: 1. A single step with a maximum riser height of 7 inches (178 mm) is permitted for buildings with occupancies in Groups F, H, R-2 and R-3 as applicable in Section 101.2, and Groups S and U at exterior doors not required to be accessible by Chapter 11. 2. A stair with a single riser or with two risers and a tread is permitted at locations not required to be accessible by Chapter 11, provided that the risers and treads comply with Section 1009.3, the minimum depth of the tread is 13 inches (330 mm) and at least one handrail complying with Section 1009.11 is provided within 30 inches (762 mm) of the centerline of the normal path of egress	General.	11.1.7	Changes in Level in Means of Egress.	Changes in level in means of egress shall be achieved by an approved means of egress where the elevation difference exceeds 21 in. (53.3 cm). 11.1.7.2* Changes in level in means of egress not in excess of 21 in. (53.3 cm) shall be achieved either by a ramp complying with the requirements of 11.2.5 or by a stair complying with the requirements of 11.2.2. 11.1.7.2.1 Where a ramp is used to meet the requirement of 11.1.7.2, the presence and location of ramped portions of walkways shall be readily apparent. 11.1.7.2.2 Where a stair is used to meet the requirement of 11.1.7.2, the tread depth of such stair shall be not less than 13 in. (33 cm). 11.1.7.2.3 Tread depth in industrial equipment access areas as provided in 29.2.5.3 shall be permitted. 11.1.7.2.4. The presence and location of each step shall be readily apparent.	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			travel on the stair. 3. An aisle serving seating that has a difference in elevation less than 12 inches (305 mm) is permitted at locations not required to be accessible by Chapter 11, provided that the risers and treads comply with Section 1024.11 and the aisle is provided with a handrail complying with Section 1024.13. Any change in elevation in a corridor serving nonambulatory persons in a Group I-2 occupancy shall be by means of a ramp or sloped walkway.					
General Means of Egress	1003.6	Means of egress continuity.	The path of egress travel along a means of egress shall not be interrupted by any building element other than a means of egress component as specified in this chapter. Obstructions shall not be placed in the required width of a means of egress except projections permitted by this chapter. The required capacity of a means of egress system shall not be diminished along the path of egress travel.	Arrangement of Means of Egress.	11.5.4.3	Accessible Means of Egress.	Each required accessible means of egress shall be continuous from each accessible occupied area to a public way or area of refuge in accordance with 11.2.12.2.2.	Similar
Occupant Load	1004.1	Design occupant load.	In determining means of egress requirements, the number of occupants for whom means of egress facilities shall be provided shall be established by the largest number computed in accordance with Sections 1004.1.1 through 1004.1.3.	Occupant Load.	11.3.1.1	Sufficient Capacity for Occupant Load.	The total capacity of the means of egress for any story, balcony, tier, or other occupied space shall be sufficient for the occupant load thereof.	Similar
Occupant Load	1004.1.1	Actual number.	The actual number of occupants for whom each occupied space, floor or building is designed.	Occupant Load.	11.3.1.2	Occupant Load Factor.	The occupant load in any building or portion thereof shall be not less than the number of persons determined by dividing the floor area assigned to that use by the occupant load factor for that use, as specified in Table 11.3.1.2 and Figure 11.3.1.2. Where both gross and net area figures are given for the same occupancy, calculations shall be made by applying the gross area figure to the gross area of the portion of the building devoted to the use for which the gross area figure is specified, and by applying the net area figure to the net area of the use for which the net area figure is specified.	Similar
Occupant Load	1004.1.2	Number by Table 1004.1.2.	The number of occupants computed at the rate of one occupant per unit of area as prescribed in Table 1004.1.2.	Occupant Load.	11.3.1.2	Occupant Load Factor.	The occupant load in any building or portion thereof shall be not less than the number of persons determined by dividing the floor area assigned to that use by the occupant load factor for that use, as specified in Table 11.3.1.2 and Figure 11.3.1.2. Where both gross and net area figures are given for the same occupancy, calculations shall be made by applying the gross area figure to the gross area of the portion of the building devoted to the use for which the gross area figure is specified, and by applying the net area figure to the net area of the use for which the net area figure is specified.	Similar
Occupant Load	1004.3	Posting of occupant load.	Every room or space that is an assembly occupancy shall have the occupant load of the room or space posted in a conspicuous place, near the main exit or exit access doorway from the room or space. Posted signs shall be of an approved legible permanent design and shall be maintained by the owner or authorized agent.	Not addressed	Not addressed	Not addressed		Similar. NFPA addresses in NFPA 1 as it is considered an operational matter.

DRAFT

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
Occupant Load	1004.7	Fixed seating.	For areas having fixed seats and aisles, the occupant load shall be determined by the number of fixed seats installed therein. For areas having fixed seating without dividing arms, the occupant load shall not be less than the number of seats based on one person for each 18 inches (457 mm) of seating length. The occupant load of seating booths shall be based on one person for each 24 inches (610 mm) of booth seat length measured at the backrest of the seating booth.	Occupant Load.	11.3.1.2	Occupant Load Factor.	The occupant load in any building or portion thereof shall be not less than the number of persons determined by dividing the floor area assigned to that use by the occupant load factor for that use, as specified in Table 11.3.1.2 and Figure 11.3.1.2. Where both gross and net area figures are given for the same occupancy, calculations shall be made by applying the gross area figure to the gross area of the portion of the building devoted to the use for which the gross area figure is specified, and by applying the net area figure to the net area of the use for which the net area figure is specified.	Similar
Egress Width	1005.1	Minimum required egress width.	The means of egress width shall not be less than required by this section. The total width of means of egress in inches (mm) shall not be less than the total occupant load served by the means of egress multiplied by the factors in Table 1005.1 and not less than specified elsewhere in this code. Multiple means of egress shall be sized such that the loss of any one means of egress shall not reduce the available capacity to less than 50 percent of the required capacity. The maximum capacity required from any story of a building shall be maintained to the termination of the means of egress. Exception: Means of egress complying with Section 1024.	Arrangement of Means of Egress.	11.5.1.3	General.	Where more than one exit is required from a building or portion thereof, such exits shall be remotely located from each other and shall be arranged and constructed to minimize the possibility that more than one has the potential to be blocked by any one fire or other emergency condition.	Different-NFPA does not state 50% rule.
Egress Width	1005.2	Door encroachment.	Doors opening into the path of egress travel shall not reduce the required width to less than one-half during the course of the swing. When fully open, the door shall not project more than 7 inches (178 mm) into the required width. Exception: The restrictions on a door swing shall not apply to doors within individual dwelling units and sleeping units of Group R-2 and dwelling units of Group R-3.	Doors.	11.2.1.4.3	Swing and Force to Open.	During its swing, any door in a means of egress shall leave not less than one-half of the required width of an aisle, corridor, passageway, or landing unobstructed and shall not project more than 7 in. (17.8 cm) into the required width of an aisle, corridor, passageway, or landing when fully open. Doors shall not open directly onto a stair without a landing. The landing shall have a width not less than the width of the door. (See 11.2.1.3.)	Similar
Means of Egress Illumination	1006.1	Illumination required.	The means of egress, including the exit discharge, shall be illuminated at all times the building space served by the means of egress is occupied. Exceptions: 1. Occupancies in Group U. 2. Aisle access ways in Group A. 3. Dwelling units and sleeping units in Groups R-1, R-2 and R-3. 4. Sleeping units of Group I occupancies.	Illumination of Means of Egress.	11.8.1.1	General.	Illumination of means of egress shall be provided in accordance with Section 11.8 for every building and structure where required in Chapter 16 through Chapter 30. For the purposes of this requirement, exit access shall include only designated stairs, aisles, corridors, ramps, escalators, and passageways leading to an exit. For the purposes of this requirement, exit discharge shall include only designated stairs, aisles, corridors, ramps, escalators, walkways, and exit passageways leading to a public way.	Similar
Means of Egress Illumination	1006.2	Illumination level.	The means of egress illumination level shall not be less than 1 foot-candle (11 lux) at the floor level. Exception: For auditoriums, theaters, concert or opera halls and similar assembly occupancies, the illumination at the floor level is permitted to be reduced during performances to not less than 0.2 foot-candle (2.15 lux) provided that the required illumination is automatically restored upon activation of a premise's fire alarm system where such system is provided.	Illumination of Means of Egress.	11.8.1.3	General.	The floors and other walking surfaces within an exit and within the portions of the exit access and exit discharge designated in 11.8.1.1 shall be illuminated to values of at least 1 ft-candle (10 lux) measured at the floor. Exception No. 1: In assembly occupancies, the illumination of the floors of exit access shall be at least 0.2 ft-candle (2 lux) during performances or projections involving directed light.	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
							Exception No. 2: The requirement of 11.8.1.3 shall not apply where operations or processes require low lighting levels.	
Means of Egress Illumination	1006.3	Illumination emergency power.	The power supply for means of egress illumination shall normally be provided by the premise's electrical supply. In the event of power supply failure, an emergency electrical system shall automatically illuminate the following areas: 1. Exit access corridors, passageways and aisles in rooms and spaces, which require two or more means of egress. 2. Exit access corridors and exit stairways located in buildings required to have two or more exits. 3. Exterior egress components at other than the level of exit discharge until exit discharge is accomplished for buildings required to have two or more exits. 4. Interior exit discharge elements, as permitted in Section 1023.1, in buildings required to have two or more exits. 5. The portion of the exterior exit discharge immediately adjacent to exit discharge doorways in buildings required to have two or more exits. The emergency power system shall provide power for a duration of not less than 90 minutes and shall consist of storage batteries, unit equipment or an on-site generator. The installation of the emergency power system shall be in accordance with Section 2702.	Illumination of Means of Egress.	11.8.2.1	Sources of Illumination.	Illumination of means of egress shall be from a source considered reliable by the authority having jurisdiction.	Similar
Means of Egress Illumination	1006.4	Performance of system.	Emergency lighting facilities shall be arranged to provide initial illumination that is at least an average of 1 foot-candle (11 lux) and a minimum at any point of 0.1 foot-candle (1 lux) measured along the path of egress at floor level. Illumination levels shall be permitted to decline to 0.6 foot-candle (6 lux) average and a minimum at any point of 0.06 foot-candle (0.6 lux) at the end of the emergency lighting time duration. A maximum-to-minimum illumination uniformity ratio of 40 to 1 shall not be exceeded.	Emergency Lighting.	11.9.2.1	Performance of System.	Emergency illumination shall be provided for not less than 1½ hours in the event of failure of normal lighting. Emergency lighting facilities shall be arranged to provide initial illumination that is not less than an average of 1 ft-candle (10 lux) and, at any point, not less than 0.1 ft-candle (1 lux), measured along the path of egress at floor level. Illumination levels shall be permitted to decline to not less than an average of 0.6 ft-candle (6 lux) and, at any point, not less than 0.06 ft-candle (0.6 lux) at the end of the required 1½ hours. A maximum-to-minimum illumination uniformity ratio of 40 to 1 shall not be exceeded.	Similar
Doors, Gates and Turnstiles	1008.1	Doors.	Means of egress doors shall meet the requirements of this section. Doors serving a means of egress system shall meet the requirements of this section and Section 1017.2. Doors provided for egress purposes in numbers greater than required by this code shall meet the requirements of this section. Means of egress doors shall be readily distinguishable from the adjacent construction and finishes such that the doors are easily recognizable as doors. Mirrors or similar reflecting materials shall not be used on means of egress doors. Means of egress doors shall not be concealed by curtains, drapes, decorations or similar materials.	Means of Egress Components.	11.2.1.1.2	Doors.	Every door and every principal entrance that is required to serve as an exit shall be designed and constructed so that the way of egress travel is obvious and direct. Windows that, because of their physical configuration or design and the materials used in their construction, have the potential to be mistaken for doors shall be made inaccessible to the occupants by barriers or railings.	Similar
Doors, Gates and Turnstiles	1008.1.1	Size of doors.	The minimum width of each door opening shall be sufficient for the occupant load thereof and shall provide a clear width of not less than 32 inches. Clear	Means of Egress Components.	11.2.1.2.4	Minimum Door Width.	Door openings in means of egress shall be not less than 32 in. (81 cm) in clear width unless one of the following conditions exists:	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			openings of doorways with swinging doors shall be measured between the face of the door and the stop, with the door open 90 degrees. Where this section requires a minimum clear width of 32 inches and a door opening includes two door leaves without a mullion, one leaf shall provide a clear opening width of 32 inches. The maximum width of a swinging door leaf shall be 48 inches nominal... The height of doors shall not be less than 80 inches. Exceptions: ... 3. Door openings to storage closets less than 10 square feet in area shall not be limited by the minimum width ...				(1) Where a pair of doors is provided, not less than one of the doors shall provide not less than a 32-in. (81-cm) clear width opening. (2) Exit access doors serving a room not exceeding 70 ft2 (6.5 m2) and not required to be accessible to persons with severe mobility impairments shall be not less than 24 in. (61 cm) in door leaf width. (3) Doors serving a building or portion thereof not required to be accessible to persons with severe mobility impairments shall be permitted to be 28 in. (71 cm) in door leaf width.	
Doors, Gates and Turnstiles	1008.1.1.1	Projections into clear width.	There shall not be projections into the required clear width lower than 34 inches (864 mm) above the floor or ground. Projections into the clear opening width between 34 inches (864 mm) and 80 inches (2032 mm) above the floor or ground shall not exceed 4 inches (102 mm).	Width.	11.2.1.2.3.3	Measurement.	Projections exceeding 80 in. (2030 mm) above the floor shall not be considered reductions in width.	Similar
Doors, Gates and Turnstiles	1008.1.2	Door swing.	Egress doors shall be side-hinged swinging. Exceptions: 1. Private garages, office areas, factory and storage areas with an occupant load of 10 or less... 4. In other than Group H occupancies, revolving doors complying with Section 1008.1.3.1. 5. In other than Group H occupancies, horizontal sliding doors complying with Section 1008.1.3.3 are permitted in a means of egress. 6. Power-operated doors in accordance with Section 1008.1.3.1... The opening force for interior side-swinging doors without closers shall not exceed a 5-pound force. For other side swinging, sliding and folding doors, the door latch shall release when subjected to a 15-pound force. The door shall be set in motion when subjected to a 30-pound force. The door shall swing to a full-open position when subjected to a 15-pound force. Forces shall be applied to the latch side.	Doors.	11.2.1.4.1	Swing and Force to Open.	Any door in a means of egress shall be of the side-hinged or pivoted-swinging type. The door shall be designed and installed so that it is capable of swinging from any position to the full required width of the opening in which it is installed.	Similar
Doors, Gates and Turnstiles	1008.1.4	Floor elevation.	There shall be a floor or landing on each side of a door. Such floor or landing shall be at the same elevation on each side of the door. Landings shall be level except for exterior landings, which are permitted to have a slope not to exceed 0.25 unit vertical in 12 units horizontal (2-percent slope). Exceptions: ... 2. Exterior doors as provided for in Section 1003.5, Exception 1, and Section 1017.2, which are not on an accessible route... 4. Variations in elevation due to differences in finish materials, but not more than 0.5 inch (12.7 mm)...	Floor Level	11.2.1.3	Landings.	The elevation of the floor surfaces on both sides of a door shall not vary by more than ½ in. (1.3 cm). The elevation shall be maintained on both sides of the doorway for a distance not less than the width of the widest leaf. Thresholds at doorways shall not exceed ½ in. (1.3 cm) in height. Raised thresholds and floor level changes in excess of ¼ in. (0.64 cm) at doorways shall be beveled with a slope not steeper than 1 in 2.	Similar
Doors, Gates and Turnstiles	1008.1.5	Landings at doors.	Landings shall have a width not less than the width of the stairway or the door, whichever is the greater. Doors in the fully open position shall not reduce a required dimension by more than 7 inches (178 mm). When a landing serves an occupant load of 50 or more, doors in any position shall not reduce the landing to less than one-half its required width. Landings shall have a length measured in the direction of travel of not less than 44 inches (1118 mm).	Doors.	11.2.1.4.3	Swing and Force to Open.	During its swing, any door in a means of egress shall leave not less than one-half of the required width of an aisle, corridor, passageway, or landing unobstructed and shall not project more than 7 in. (17.8 cm) into the required width of an aisle, corridor, passageway, or landing when fully open. Doors shall not open directly onto a stair without a landing. The landing shall have a width not less than the width of the door. (See 11.2.1.3.)	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			Exception: Landing length in the direction of travel in Group R-3 as applicable in Section 101.2 and Group U and within individual units of Group R-2 as applicable in Section 101.2, need not exceed 36 inches (914 mm).					
Doors, Gates and Turnstiles	1008.1.6	Thresholds.	Thresholds at doorways shall not exceed 0.75 inch (19.1 mm) in height for sliding doors serving dwelling units or 0.5 inch (12.7 mm) for other doors. Raised thresholds and floor level changes greater than 0.25 inch (6.4 mm) at doorways shall be beveled with a slope not greater than one unit vertical in two units horizontal (50-percent slope). Exception: The threshold height shall be limited to 7 3/4 inches (197 mm) where the occupancy is Group R-2 or R-3 as applicable in Section 101.2, the door is an exterior door that is not a component of the required means of egress and the doorway is not on an accessible route.	Doors.	11.2.1.3	Floor Level.	The elevation of the floor surfaces on both sides of a door shall not vary by more than ½ in. (1.3 cm). The elevation shall be maintained on both sides of the doorway for a distance not less than the width of the widest leaf. Thresholds at doorways shall not exceed ½ in. (1.3 cm) in height. Raised thresholds and floor level changes in excess of ¼ in. (0.64 cm) at doorways shall be beveled with a slope not steeper than 1 in 2.	Similar
Doors, Gates and Turnstiles	1008.1.7	Door arrangement.	Space between two doors in series shall be 48 inches (1219 mm) minimum plus the width of a door swinging into the space. Doors in series shall swing either in the same direction or away from the space between doors.	Doors.	11.2.1.4.1	Swing and Force to Open.	Any door in a means of egress shall be of the side-hinged or pivoted-swinging type. The door shall be designed and installed so that it is capable of swinging from any position to the full required width of the opening in which it is installed.	Different-NFPA: 48" not cited.
Doors, Gates and Turnstiles	1008.1.8	Door operations.	Except as specifically permitted by this section egress doors shall be readily operable from the egress side without the use of a key or special knowledge or effort.	Doors.	11.2.1.5.1	Locks, Latches, and Alarm Devices.	Doors shall be arranged to be opened readily from the egress side whenever the building is occupied. Locks, if provided, shall not require the use of a key, a tool, or special knowledge or effort for operation from the inside of the building.Exception No. 1: The requirement of 11.2.1.5.1 shall not apply where otherwise provided in Chapter 19, Chapter 20, and Chapter 21.Exception No. 2: Exterior doors shall be permitted to have key-operated locks from the egress side, provided that the following criteria are met: (1) Use of this exception shall be permitted in Chapter 16 through Chapter 31 for the specific occupancy.(2) On or adjacent to the door, a readily visible, durable sign with letters not less than 1 in. (2.5 cm) high on a contrasting background shall be provided and shall read as follows: THIS DOOR TO REMAIN UNLOCKED WHEN THE BUILDING IS OCCUPIED. (3) The locking device shall be a type that is readily distinguishable as locked.(4) A key shall be immediately available to any occupant inside the building when it is locked.	Similar
Doors, Gates and Turnstiles	1008.1.8.3	Locks and latches.	Locks and latches shall be permitted to prevent operation of doors where any of the following exists: 1. Places of detention or restraint. 2. In buildings in occupancy Group A having an occupant load of 300 or less, Groups B, F, M and S, and in churches, the main exterior door or doors are permitted to be equipped with key-operated locking devices from the egress side provided: 2.1 The locking device is readily distinguishable as locked, 2.2 A readily visible durable sign is posted on the egress side on or adjacent to the door stating: THIS DOOR TO REMAIN UNLOCKED	Doors.	11.2.1.5.1	Locks, Latches, and Alarm Devices.	Doors shall be arranged to be opened readily from the egress side whenever the building is occupied. Locks, if provided, shall not require the use of a key, a tool, or special knowledge or effort for operation from the inside of the building. Exception No. 1: The requirement of 11.2.1.5.1 shall not apply where otherwise provided in Chapter 19, Chapter 20, and Chapter 21. Exception No. 2: Exterior doors shall be permitted to have key-operated locks from the egress side, provided that the following criteria are met:	Similar

DRAFT

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			WHEN BUILDING IS OCCUPIED...2.3 The use of the key-operated locking device is revocable by the building official for due cause...				(1) Use of this exception shall be permitted in Chapter 16 through Chapter 31 for the specific occupancy. (2) On or adjacent to the door, a readily visible, durable sign with letters not less than 1 in. (2.5 cm) high on a contrasting background shall be provided and shall read as follows: THIS DOOR TO REMAIN UNLOCKED WHEN THE BUILDING IS OCCUPIED. (3) The locking device shall be a type that is readily distinguishable as locked. (4) A key shall be immediately available to any occupant inside the building when it is locked.	
Doors, Gates and Turnstiles	1008.1.9	Panic and fire exit hardware.	Where panic and fire exit hardware is installed, it shall comply with the following: 1. The actuating portion of the releasing device shall extend at least one-half of the door leaf width. 2. A maximum unlatching force of 15 pounds (67 N). Each door in a means of egress from an occupancy of Group A or E having an occupant load of 100 or more and any occupancy of Group H-1, H-2, H-3 or H-5 shall not be provided with a latch or lock unless it is panic hardware or fire exit hardware. If balanced doors are used and panic hardware is required, the panic hardware shall be the push-pad type and the pad shall not extend more than one-half the width of the door measured from the latch side.	Doors.	11.2.1.7.1	Panic Hardware and Fire Exit Hardware.	Where a door is required to be equipped with panic hardware or fire exit hardware, such hardware shall meet the following criteria: (1) It shall consist of a cross bar or push pad, the actuating portion of which extends across not less than one-half of the width of the door leaf and not less than 34 in. (86 cm), but not more than 48 in. (122 cm), above the floor.(2) It shall be constructed so that a horizontal force not to exceed 15 lbs (66 N) actuates the cross bar or push pad and latches.	Similar
Stairways and Handrails	1009.1	Stairway width.	The width of stairways shall be determined as specified in Section 1005.1, but such width shall not be less than 44 inches (1118 mm). See Section 1007.3 for accessible means of egress stairways. Exceptions: 1. Stairways serving an occupant load of 50 or less shall have a width of not less than 36 inches (914 mm). 2. Spiral stairways as provided for in Section 1009.9. 3. Aisle stairs complying with Section 1024. 4. Where a stairway lift is installed on stairways serving occupancies in Group R-3, or within dwelling units in occupancies in Group R-2, both as applicable in Section 101.2, a clear passage width not less than 20 inches (508 mm) shall be provided. If the seat and platform can be folded when not in use, the distance shall be measured from the folded position.	Stairs.	11.2.2.2.1	General.	Stairs used as a component in the means of egress shall conform to the general requirements of Section 11.1 and to the special requirements of 11.2.2. Exception: The requirement of 11.2.2.1 shall not apply to aisle stairs as provided in Chapter 16.	Similar
Stairways and Handrails	1009.2	Headroom.	Stairways shall have a minimum headroom clearance of 80 inches (2032 mm) measured vertically from a line connecting the edge of the nosings. Such headroom shall be continuous above the stairway to the point where the line intersects the landing below, one tread depth beyond the bottom riser. The minimum clearance shall be maintained the full width of the stairway and landing. Exception: Spiral stairways complying with Section 1009.9 are permitted a 78-inch (1981 mm) headroom clearance.	Means of Egress	11.1.5	Headroom.	Means of egress shall be designed and maintained to provide headroom as provided in other sections of this Code and shall be not less than 7 ft 6 in. (2.3 m) with projections from the ceiling not less than 6 ft 8 in. (2 m) nominal height above the finished floor. The minimum ceiling height shall be maintained for not less than two-thirds of the ceiling area of any room or space, provided the ceiling height of the remaining ceiling area is not less than 6 ft 8 in. (2 m). Headroom on stairs shall be not less than 6 ft 8 in. (2 m) and shall be measured vertically above a plane parallel to and tangent with the most forward projection of the stair tread.	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
Stairways and Handrails	1009.3	Stair treads and risers.	Stair riser heights shall be 7-in maximum and 4-in minimum. Stair tread depths shall be 11-in minimum. The riser height shall be measured vertically between the leading edges of adjacent treads. The greatest riser height within any flight of stairs shall not exceed the smallest by more than 0.375-in. The tread depth shall be measured horizontally between the vertical planes of the foremost projection of adjacent treads and at right angle to the tread's leading edge. The greatest tread depth within any flight of stairs shall not exceed the smallest by more than 0.375-in. Winder treads shall have a minimum tread depth of 11-in measured at a right angle to the tread's leading edge at a point 12-in from the side where the treads are narrower and a minimum tread depth of 10-in. The greatest winder tread depth at the 12-inch walk line within any flight of stairs shall not exceed the smallest by more than 0.375-in. Excptns.:...2. Winders in accordance with Section 1009.8... 4. Aisle stairs in assembly seating areas where the stair pitch or slope is set, for sightline reasons, by the slope of the adjacent seating area in accordance with Section 1024.11.2...	Stairs.	11.2.2.2.1	General.	Stairs used as a component in the means of egress shall conform to the general requirements of Section 11.1 and to the special requirements of 11.2.2.Exception: The requirement of 11.2.2.1 shall not apply to aisle stairs as provided in Chapter 16.	Similar
Stairways and Handrails	1009.3.1	Dimensional uniformity.	Stair treads and risers shall be of uniform size and shape. The tolerance between the largest and smallest riser or between the largest and smallest tread shall not exceed 0.375-in. Exceptions: 1. Nonuniform riser dimensions of aisle stairs complying with Section 1024.11.2. 2. Consistently shaped winders, complying with Section 1009.8, differing from rectangular treads in the same stairway flight. Where the bottom or top riser adjoins a sloping public way, walkway or driveway having an established grade and serving as a landing, the bottom or top riser is permitted to be reduced along the slope to less than 4-in in height with the variation in height of the bottom or top riser not to exceed one unit vertical in 12 units horizontal (8-percent slope) of stairway width. The nosings or leading edges of treads at such nonuniform height risers shall have a distinctive marking stripe, different from any other nosing marking provided on the stair flight. The distinctive marking stripe shall be visible in descent of the stair and shall have a slip-resistant surface.	Stair Details.	11.2.2.3.6	Dimensional Uniformity.	There shall be no variation in excess of 0.25 in. (0.5 cm) in the depth of adjacent treads or in the height of adjacent risers, and the tolerance between the largest and smallest riser or between the largest and smallest tread shall not exceed in. (1 cm) in any flight.	Similar
Stairways and Handrails	1009.3.2	Profile.	The radius of curvature at the leading edge of the tread shall be not greater than 0.5 inch (12.7 mm). Beveling of nosings shall not exceed 0.5 inch (12.7 mm). Risers shall be solid and vertical or sloped from the underside of the leading edge of the tread above at an angle not more than 30 degrees (0.52 rad) from the vertical. The leading edge (nosings) of treads shall project not more than 1.25 inches (32 mm) beyond the tread below and all projections of the leading edges shall be of uniform size, including the leading edge of	Stair Details.	11.2.2.3.3	Tread and Landing Surfaces.	Stair treads and landings shall be solid, without perforations, and free of projections or lips that could trip stair users. If not vertical, risers shall be permitted to slope under the tread at an angle not to exceed 30 degrees from vertical, but the permitted projection of the nosing shall not exceed 1½ in. (3.8 cm).	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			the floor at the top of a flight. Exceptions: 1. Solid risers are not required for stairways that are not required to comply with Section 1007.3, provided that the opening between treads does not permit the passage of a sphere with a diameter of 4 inches (102 mm). 2. Solid risers are not required for occupancies in Group I-3.					
Stairways and Handrails	1009.4	Stairway landings.	There shall be a floor or landing at the top and bottom of each stairway. The width of landings shall not be less than the width of stairways they serve. Every landing shall have a minimum dimension measured in the direction of travel equal to the width of the stairway. Such dimension need not exceed 48 inches (1219 mm) where the stairway has a straight run. Exceptions: 1. Aisle stairs complying with Section 1024. 2. Doors opening onto a landing shall not reduce the landing to less than one-half the required width. When fully open, the door shall not project more than 7 inches (178 mm) into a landing.	Stair Details.	11.2.2.3.2	Landings.	Stairs shall have landings at door openings. Stairs and intermediate landings shall continue with no decrease in width along the direction of egress travel. In new buildings, every landing shall have a dimension measured in the direction of travel that is not less than the width of the stair.	Similar
Stairways and Handrails	1009.5	Stairway construction.	All stairways shall be built of materials consistent with the types permitted for the type of construction of the building, except that wood handrails shall be permitted for all types of construction.	Stair Details.	11.2.2.3.1.2	Construction.	All components of a stairway, including platforms and landings, shall be constructed of materials consistent with the types permitted for floor construction, based on the type of construction of the building, except that wood handrails shall be permitted for all types of construction. All walking surfaces of a stairway shall be capable of supporting the loads specified in Chapter 35.	Similar
Stairways and Handrails	1009.5.1	Stairway walking surface.	The walking surface of treads and landings of a stairway shall not be sloped steeper than one unit vertical in 48 units horizontal (2-percent slope) in any direction. Stairway treads and landings shall have a solid surface. Finish floor surfaces shall be securely attached. Exception: In Group F, H and S occupancies, other than areas of parking structures accessible to the public, openings in treads and landings shall not be prohibited provided a sphere with a diameter of 11/8 inches (29 mm) cannot pass through the opening.	Stair Details.	11.2.2.3.4	Tread Slope.	Tread slope shall not exceed ¼ in./ft (2 cm/m) (a slope of 1 in 48).	Similar
Stairways and Handrails	1009.11	Handrails.	Stairways shall have handrails on each side. Handrails shall be adequate in strength and attachment in accordance with Section 1607.7. Handrails for ramps, where required by Section 1010.8, shall comply with this section. Exceptions: 1. Aisle stairs complying with Section 1024 provided with a center handrail need not have additional handrails. 2. Stairways within dwelling units, spiral stairways and aisle stairs serving seating only on one side are permitted to have a handrail on one side only. 3. Decks, patios and walkways that have a single change in elevation where the landing depth on each side of the change of elevation is greater than what is required for a landing do not require handrails. 4. In Group R-3 occupancies, a change in elevation consisting of a single riser at an entrance or egress door does not require handrails. 5.	Guards and Handrails.	11.2.2.4.1.1	Handrails.	Stairs and ramps shall have handrails on both sides unless otherwise permitted in 11.2.2.4.1.6.	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			Changes in room elevations of only one riser within dwelling units and sleeping units in Group R-2 and R-3 occupancies do not require handrails.					
Stairways and Handrails	1009.11.1	Height.	Handrail height, measured above stair tread nosings, or finish surface of ramp slope, shall be uniform, not less than 34 inches (864 mm) and not more than 38 inches (965 mm).	Guards and Handrails.	11.2.2.4.4	Handrail Details.	Handrails on stairs and ramps shall have a consistent height of not less than 34 in. (86 cm) and not more than 38 in. (96 cm) above the surface of the stair tread or ramp walking surface, measured vertically to the top of the rail from the leading edge of the stair tread or the ramp walking surface.	Similar
Stairways and Handrails	1009.11.2	Intermediate handrails.	Intermediate handrails are required so that all portions of the stairway width required for egress capacity are within 30 inches (762 mm) of a handrail. On monumental stairs, handrails shall be located along the most direct path of egress travel.	Guards and Handrails.	11.2.2.4.1.2	Handrails.	In addition, handrails shall be provided within 30 in. (76 cm) of all portions of the required egress width of new stairs.	Similar
Stairways and Handrails	1009.11.3	Handrail graspability.	Handrails with a circular cross section shall have an outside diameter of at least 1.25 inches (32 mm) and not greater than 2 inches (51 mm) or shall provide equivalent graspability. If the handrail is not circular, it shall have a perimeter dimension of at least 4 inches (102 mm) and not greater than 6.25 inches (160 mm) with a maximum cross-section dimension of 2.25 inches (57 mm). Edges shall have a minimum radius of 0.01 inch (0.25 mm).	Guards and Handrails.	11.2.2.4.4	Handrail Details.	Handrails on stairs and ramps shall have a consistent height of not less than 34 in. (86 cm) and not more than 38 in. (96 cm) above the surface of the stair tread or ramp walking surface, measured vertically to the top of the rail from the leading edge of the stair tread or the ramp walking surface.	Similar
Stairways and Handrails	1009.11.4	Continuity.	Handrail-gripping surfaces shall be continuous, without interruption by newel posts or other obstructions. Exceptions: 1. Handrails within dwelling units are permitted to be interrupted by a newel post at a stair landing. 2. Within a dwelling unit, the use of a volute, turnout or starting easing is allowed on the lowest tread. 3. Handrail brackets or balusters attached to the bottom surface of the handrail that do not project horizontally beyond the sides of the handrail within 1.5 inches (38 mm) of the bottom of the handrail shall not be considered to be obstructions and provided further that for each 0.5 inch (13 mm) of additional handrail perimeter dimension above 4 inches (102 mm), the vertical clearance dimension of 1.5 inches (38 mm) shall be permitted to be reduced by 0.125 inch (3 mm).	Guards and Handrails.	11.2.2.4.4	Handrail Details.	Handrails on stairs and ramps shall have a consistent height of not less than 34 in. (86 cm) and not more than 38 in. (96 cm) above the surface of the stair tread or ramp walking surface, measured vertically to the top of the rail from the leading edge of the stair tread or the ramp walking surface.	Similar
Stairways and Handrails	1009.11.5	Handrail extensions.	Handrails shall return to a wall, guard or the walking surface or shall be continuous to the handrail of an adjacent stair flight. Where handrails are not continuous between flights, the handrails shall extend horizontally at least 12 inches (305mm) beyond the top riser and continue to slope for the depth of one tread beyond the bottom riser. Exceptions: 1. Handrails within a dwelling unit that is not required to be accessible need extend only from the top riser to the bottom riser. 2. Aisle handrails in Group A occupancies in accordance with Section 1024.13.	Guards and Handrails.	11.2.2.4.4	Handrail Details.	Handrails on stairs and ramps shall have a consistent height of not less than 34 in. (86 cm) and not more than 38 in. (96 cm) above the surface of the stair tread or ramp walking surface, measured vertically to the top of the rail from the leading edge of the stair tread or the ramp walking surface.	Similar
Stairways and Handrails	1009.11.6	Clearance.	Clear space between a handrail and a wall or other surface shall be a minimum of 1.5 inches (38 mm). A handrail and a wall or other surface adjacent to the handrail shall be free of any sharp or abrasive		11.2.2.4.4	Handrail Details.	Handrails on stairs and ramps shall have a consistent height of not less than 34 in. (86 cm) and not more than 38 in. (96 cm) above the surface of the stair tread or ramp walking surface, measured	Similar- NFPA requires 2-1/4 inches and IBC requires 1-1/2

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			elements.				vertically to the top of the rail from the leading edge of the stair tread or the ramp walking surface.	inches"
Ramps	1010.1	Scope.	The provisions of this section shall apply to ramps used as a component of a means of egress. Exceptions: 1. Other than ramps that are part of the accessible routes providing access in accordance with Sections 1108.2.2 through 1108.2.4.1, ramped aisles within assembly rooms or spaces shall conform with the provisions in Section 1024.11. 2. Curb ramps shall comply with ICC A117.1. 3. Vehicle ramps in parking garages for pedestrian exit access shall not be required to comply with Sections 1010.3 through 1010.9 when they are not an accessible route serving accessible parking spaces, other required accessible elements or part of an accessible means of egress.	Ramps.	11.2.5.1	General.	Every ramp used as a component in a means of egress shall conform to the general requirements of Section 11.1 and to the requirements of 11.2.5.	Similar
Ramps	1010.2	Slope.	Ramps used as part of a means of egress shall have a running slope not steeper than one unit vertical in 12 units horizontal (8-percent slope). The slope of other ramps shall not be steeper than one unit vertical in eight units horizontal (12.5-percent slope). Exception: Aisle ramp slope in occupancies of Group A shall comply with Section 1024.11.	Ramps.	11.2.5.2	Dimensional Criteria.	Dimensional criteria for ramps shall be in accordance with Table 11.2.5.2.	Similar
Ramps	1010.3	Cross slope.	The slope measured perpendicular to the direction of travel of a ramp shall not be steeper than one unit vertical in 48 units horizontal (2-percent slope).	Ramps.	11.2.5.2	Dimensional Criteria.	Dimensional criteria for ramps shall be in accordance with Table 11.2.5.2.	Similar
Ramps	1010.4	Vertical rise.	The rise for any ramp run shall be 30 inches (762 mm) maximum.	Ramps.	11.2.5.2	Dimensional Criteria.	Dimensional criteria for ramps shall be in accordance with Table 11.2.5.2.	Similar
Ramps	1010.5	Minimum dimensions.	The minimum dimensions of means of egress ramps shall comply with Sections 1010.5.1 through 1010.5.3.	Ramps.	11.2.5.2	Dimensional Criteria.	Dimensional criteria for ramps shall be in accordance with Table 11.2.5.2.	Similar
Ramps	1010.5.1	Width.	The minimum width of a means of egress ramp shall not be less than that required for corridors by Section 1016.2. The clear width of a ramp and the clear width between handrails, if provided, shall be 36 inches (914 mm) minimum.	Ramps.	11.2.5.2	Dimensional Criteria.	Dimensional criteria for ramps shall be in accordance with Table 11.2.5.2.	Similar
Ramps	1010.5.2	Headroom.	The minimum headroom in all parts of the means of egress ramp shall not be less than 80 inches (2032 mm).	Means of Egress	11.1.5	Headroom.	Means of egress shall be designed and maintained to provide headroom as provided in other sections of this Code and shall be not less than 7 ft 6 in. (2.3 m) with projections from the ceiling not less than 6 ft 8 in. (2 m) nominal height above the finished floor. The minimum ceiling height shall be maintained for not less than two-thirds of the ceiling area of any room or space, provided the ceiling height of the remaining ceiling area is not less than 6 ft 8 in. (2 m). Headroom on stairs shall be not less than 6 ft 8 in. (2 m) and shall be measured vertically above a plane parallel to and tangent with the most forward projection of the stair tread.	Similar
Ramps	1010.5.3	Restrictions.	Means of egress ramps shall not reduce in width in the direction of egress travel. Projections into the required ramp and landing width are prohibited. Doors opening onto a landing shall not reduce the clear width to less than 42 inches (1067 mm).	Arrangement of Means of Egress.	1.2.5.3.2	Landings.	Ramp landings shall comply with 11.2.5.3.2(A) and 11.2.5.3.2(B): (A) Ramps shall have landings located at the top, at the bottom, and at doors opening onto the ramp. The slope of the landing shall not be steeper than 1 in 48. Every landing shall have a width not less than the width of the ramp. Every	Similar

DRAFT

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
							landing shall be not less than 60 in. (152 cm) long in the direction of travel. (B) Any changes in travel direction shall be made only at landings. Ramps and intermediate landings shall continue with no decrease in width along the direction of egress travel.	
Ramps	1010.6	Landings.	Ramps shall have landings at the bottom and top of each ramp, points of turning, entrance, exits and at doors. Landings shall comply with Sections 1010.6.1 through 1010.6.5.	Ramp Details.	11.2.5.3.2	Landings.	Ramp landings shall comply with 11.2.5.3.2(A) and 11.2.5.3.2(B): (A) Ramps shall have landings located at the top, at the bottom, and at doors opening onto the ramp. The slope of the landing shall not be steeper than 1 in 48. Every landing shall have a width not less than the width of the ramp. Every landing shall be not less than 60 in. (152 cm) long in the direction of travel. (B) Any changes in travel direction shall be made only at landings. Ramps and intermediate landings shall continue with no decrease in width along the direction of egress travel.	Similar
Ramps	1010.6.1	Slope.	Landings shall have a slope not steeper than one unit vertical in 48 units horizontal (2-percent slope) in any direction. Changes in level are not permitted.	Ramp Details.	11.2.5.3.2	Landings.	Ramp landings shall comply with 11.2.5.3.2(A) and 11.2.5.3.2(B):(A) Ramps shall have landings located at the top, at the bottom, and at doors opening onto the ramp. The slope of the landing shall not be steeper than 1 in 48. Every landing shall have a width not less than the width of the ramp. Every landing shall be not less than 60 in. (152 cm) long in the direction of travel.(B) Any changes in travel direction shall be made only at landings. Ramps and intermediate landings shall continue with no decrease in width along the direction of egress travel.	Similar
Ramps	1010.6.2	Width.	The landing shall be at least as wide as the widest ramp run adjoining the landing.	Ramp Details.	11.2.5.3.2	Landings.	Ramp landings shall comply with 11.2.5.3.2(A) and 11.2.5.3.2(B): (A) Ramps shall have landings located at the top, at the bottom, and at doors opening onto the ramp. The slope of the landing shall not be steeper than 1 in 48. Every landing shall have a width not less than the width of the ramp. Every landing shall be not less than 60 in. (152 cm) long in the direction of travel. (B) Any changes in travel direction shall be made only at landings. Ramps and intermediate landings shall continue with no decrease in width along the direction of egress travel.	Similar
Ramps	1010.6.3	Length.	The landing length shall be 60 inches (1525 mm) minimum. Exception: Landings in nonaccessible Group R-2 and R-3 individual dwelling units, as applicable in Section 101.2, are permitted to be 36 inches (914mm) minimum.	Ramp Details.	11.2.5.3.2	Landings.	Ramp landings shall comply with 11.2.5.3.2(A) and 11.2.5.3.2(B): (A) Ramps shall have landings located at the top, at the bottom, and at doors opening onto the ramp. The slope of the landing shall not be steeper than 1 in 48. Every landing shall have a width not less than the width of the ramp. Every landing shall be not less than 60 in. (152 cm) long in the direction of travel. (B) Any changes in travel direction shall be made only at landings. Ramps and intermediate landings shall continue with no decrease in width along the direction of egress travel.	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
Ramps	1010.6.4	Change in direction.	Where changes in direction of travel occur at landings provided between ramp runs, the landing shall be 60 inches by 60 inches (1524 mm by 1524 mm) minimum.	Ramp Details.	11.2.5.3.2	Landings.	Ramp landings shall comply with 11.2.5.3.2(A) and 11.2.5.3.2(B): (A) Ramps shall have landings located at the top, at the bottom, and at doors opening onto the ramp. The slope of the landing shall not be steeper than 1 in 48. Every landing shall have a width not less than the width of the ramp. Every landing shall be not less than 60 in. (152 cm) long in the direction of travel. (B) Any changes in travel direction shall be made only at landings. Ramps and intermediate landings shall continue with no decrease in width along the direction of egress travel.	Similar
Ramps	1010.7	Ramp construction.	All ramps shall be built of materials consistent with the types permitted for the type of construction of the building; except that wood handrails shall be permitted for all types of construction. Ramps used as an exit shall conform to the applicable requirements of Sections 1019.1 and 1019.1.1 through 1019.1.3 for vertical exit enclosures.	Ramp Details.	11.2.5.3.1	Construction.	Ramp construction shall be as follows: (1) All ramps serving as required means of egress shall be of permanent fixed construction.(2) Each ramp in buildings required by this Code to be of Type I or Type II construction shall be noncombustible or limited-combustible throughout. The ramp floor and landings shall be solid and without perforations.	Similar
Ramps	1010.7.1	Ramp surface.	The surface of ramps shall be of slip-resistant materials that are securely attached.	Walking Surfaces in the Means of Egress.	11.1.6.4	Slip Resistance.	Walking surfaces shall be slip resistant under foreseeable conditions. The walking surface of each element in the means of egress shall be uniformly slip resistant along the natural path of travel.	Similar
Ramps	1010.8	Handrails.	Ramps with a rise greater than 6 inches (152 mm) shall have handrails on both sides complying with Section 1009.11.	Ramps.	11.2.5.4	Guards and Handrails.	Guards complying with 11.2.2.4 shall be provided for ramps. Handrails complying with 11.2.2.4 shall be provided along both sides of a ramp run with a rise greater than 6 in. (15.2 cm). The height of handrails and guards shall be measured vertically to the top of the guard or rail from the walking surface adjacent thereto.	Similar
Ramps	1010.9	Edge protection.	Edge protection complying with Section 1010.9.1 or 1010.9.2 shall be provided on each side of ramp runs and at each side of ramp landings. Exceptions: 1. Edge protection is not required on ramps not required to have handrails, provided they have flared sides that comply with the ICC A117.1 curb ramp provisions. 2. Edge protection is not required on the sides of ramp landings serving an adjoining ramp run or stairway. 3. Edge protection is not required on the sides of ramp landings having a vertical drop-off of not more than 0.5 inch (13 mm) within 10 inches (254 mm) horizontally of the required landing area.	Ramp Details.	11.2.5.3.3	Drop-offs.	Ramps and landings with drop-offs shall have curbs, walls, railings, or projecting surfaces that prevent people from traveling off the edge of the ramp. Curbs or barriers shall be not less than 2 in. (5.1 cm) in height.	Similar
Ramps	1010.9.1	Railings.	A rail shall be mounted below the handrail 17 inches to 19 inches (432 mm to 483 mm) above the ramp or landing surface.	Ramps.	11.2.5.4	Guards and Handrails.	Guards complying with 11.2.2.4 shall be provided for ramps. Handrails complying with 11.2.2.4 shall be provided along both sides of a ramp run with a rise greater than 6 in. (15.2 cm). The height of handrails and guards shall be measured vertically to the top of the guard or rail from the walking surface adjacent thereto.	Similar
Ramps	1010.9.2	Curb or barrier.	A curb or barrier shall be provided that prevents the passage of a 4-inch-diameter (102 mm) sphere, where any portion of the sphere is within 4 inches (102 mm) of the floor or ground surface.	Ramps.	11.2.5.4	Guards and Handrails.	Guards complying with 11.2.2.4 shall be provided for ramps. Handrails complying with 11.2.2.4 shall be provided along both sides of a ramp run with a rise greater than 6 in. (15.2 cm). The height of handrails	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
							and guards shall be measured vertically to the top of the guard or rail from the walking surface adjacent thereto.	
Ramps	1010.1	Guards.	Guards shall be provided where required by Section 1012 and shall be constructed in accordance with Section 1012.	Ramps.	11.2.5.4	Guards and Handrails.	Guards complying with 11.2.2.4 shall be provided for ramps. Handrails complying with 11.2.2.4 shall be provided along both sides of a ramp run with a rise greater than 6 in. (15.2 cm). The height of handrails and guards shall be measured vertically to the top of the guard or rail from the walking surface adjacent thereto.	Similar
Exit Signs	1011.1	Where required.	Exits and exit access doors shall be marked by an approved exit sign readily visible from any direction of egress travel. Access to exits shall be marked by readily visible exit signs in cases where the exit or the path of egress travel is not immediately visible to the occupants. Exit sign placement shall be such that no point in an exit access corridor is more than 100 feet (30 480 mm) or the listed viewing distance for the sign, whichever is less, from the nearest visible exit sign. Exceptions: 1. Exit signs are not required in rooms or areas, which require only one exit or exit access. 2. Main exterior exit doors or gates which obviously and clearly are identifiable as exits need not have exit signs where approved by the building official...	Marking of Means of Egress.	11.10.1.1	Where Required.	Means of egress shall be marked in accordance with Section 11.10 where required in Chapter 16 through Chapter 30.	Similar
Exit Signs	1011.2	Illumination.	Exit signs shall be internally or externally illuminated. Exception: Tactile signs required by Section 1011.3 need not be provided with illumination.	Marking of Means of Egress.	11.10.1.3	Exit Door Tactile Signage	Tactile signage shall be located at each exit door requiring an exit sign, shall comply with ICC/ANSI A117.1 and shall read as follows: EXIT	Similar
Exit Signs	1011.3	Tactile exit signs.	A tactile sign stating EXIT and complying with ICC A117.1 shall be provided adjacent to each door to an egress stairway, an exit passageway and the exit discharge.	Signs.	12.16.4	Exit Doors.	Exit doors shall be identified by tactile signs in accordance with 11.10.1.3.	Similar
Exit Signs	1011.4	Internally illuminated exit signs.	Internally illuminated exit signs shall be listed and labeled and shall be installed in accordance with the manufacturer's instructions and Section 2702. Exit signs shall be illuminated at all times.	Internally Illuminated Signs.	11.10.7.1	Listing.	Internally illuminated signs shall be listed in accordance with UL 924, Standard for Emergency Lighting and Power Equipment.	Similar
Exit Signs	1011.5	Externally illuminated exit signs.	Externally illuminated exit signs shall comply with Sections 1011.5.1 through 1011.5.3.	Externally Illuminated Signs.	11.10.6.1	Size of Signs.	Externally illuminated signs required by 11.10.1 and 11.10.2 shall have the word "exit" or other appropriate wording in plainly legible letters not less than 6 in. (15.2 cm) high, with the principal strokes of letters not less than ¾ in. (1.9 cm) wide. The word "exit" shall have letters of a width not less than 2 in. (5 cm), except the letter "I", and the minimum spacing between letters shall be not less than in. (1 cm). Signs larger than the minimum established in this requirement shall have letter widths, strokes, and spacing in proportion to their height. Exception No. 1: The requirement of 11.10.6.1 shall not apply to marking required by 11.10.1.3 and 11.10.1.5. Exception No. 2: Where approved by the authority having jurisdiction, pictograms shall be permitted.	Similar
Exit Signs	1011.5.2	Exit sign illumination.	The face of an exit sign illuminated from an external source shall have an intensity of not less than 5 foot-	Illumination of Signs.	11.10.5.2	Continuous Illumination.	Every sign required to be illuminated by 11.10.6.3 and 11.10.7 shall be continuously illuminated as	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			candles (54 lux).				required under the provisions of Section 11.8. Exception: Illumination for signs shall be permitted to flash on and off upon activation of the fire alarm system.	
Exit Signs	1011.5.3	Power source.	Exit signs shall be illuminated at all times. To ensure continued illumination for a duration of not less than 90 minutes in case of primary power loss, the sign illumination means shall be connected to an emergency power system provided from storage batteries, unit equipment or an on-site generator. The installation of the emergency power system shall be in accordance with Section 2702. Exception: Approved exit sign illumination means that provide continuous illumination independent of external power sources for a duration of not less than 90 minutes, in case of primary power loss, are not required to be connected to an emergency electrical system.	Illumination of Signs.	11.10.5.2	Continuous Illumination.	Every sign required to be illuminated by 11.10.6.3 and 11.10.7 shall be continuously illuminated as required under the provisions of Section 11.8. Exception: Illumination for signs shall be permitted to flash on and off upon activation of the fire alarm system.	Similar
Guards	1012.1	Where required.	Guards shall be located along open-sided walking surfaces, mezzanines, industrial equipment platforms, stairways, ramps and landings which are located more than 30-in above the floor or grade below. Guards shall be adequate in strength and attachment in accordance with Section 1607.7. Guards shall also be located along glazed sides of stairways, ramps and landings that are located more than 30-in above the floor or grade below where the glazing provided does not meet the strength and attachment requirements in Section 1607.7. Exception: Guards are not required for the following locations: 1. On the loading side of loading docks or piers. 2. On the audience side of stages and raised platforms, including steps leading up to the stage and raised platforms. 3. On raised stage and platform floor areas such as runways, ramps and side stages used for entertainment or presentations... 5. At elevated walking surfaces appurtenant to stages and platforms for access to and utilization of special lighting or equipment... 7. In assembly seating where guards in accordance with Section 1024.14 are permitted and provided.	Special Means of Egress Features—Guards and Railings.	16.2.11.4	Guards at Side and Back of Seating Areas.	Guards complying with the guard requirements of 11.2.2.4 shall be provided and shall be of a height not less than 42 in. (107 cm) above the aisle, aisle access way, or footboard where the floor elevation is more than 30 in. (76 cm) above the floor or grade to the side or back of seating. 11.1.8 Guards. Guards in accordance with 11.2.2.4 shall be provided at the open sides of means of egress that exceed 30 in. (76 cm) above the floor or grade below.	Different-NFPA 5000 Chapter on Assembly address guards only in terms of aisles.
Guards	1012.2	Height.	Guards shall form a protective barrier not less than 42 inches (1067 mm) high, measured vertically above the leading edge of the tread, adjacent walking surface or adjacent seatboard. Exceptions: 1. For occupancies in Group R-3, and within individual dwelling units in occupancies in Group R-2, both as applicable in Section 101.2, guards whose top rail also serves as a handrail shall have a height not less than 34 inches (864 mm) and not more than 38 inches (965 mm) measured vertically from the leading edge of the stair tread nosing. 2. The height in assembly seating areas shall be in accordance with Section 1024.14.	Guards and Handrails.	11.2.2.4.5	Guard Details.	(A) The height of guards required in 11.1.8 shall be measured vertically to the top of the guard from the surface adjacent thereto.(B) Guards shall be not less than 42 in. (107 cm) high.Exception: The requirement of 11.2.2.4.5(B) shall not apply where otherwise provided in 16.2.11.(C)* Open guards shall have intermediate rails or an ornamental pattern such that a sphere 4 in. (10.1 cm) in diameter shall not be capable of passing through any opening up to a height of 34 in. (86 cm).Exception No. 1: The triangular openings formed by the riser, tread, and bottom element of a guardrail at the open side of a stair shall be of such size that a sphere 6 in. (15.2 cm) in diameter shall not be capable of passing through the triangular opening.	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
Guards	1012.3	Opening limitations.	Open guards shall have balusters or ornamental patterns such that a 4-inch-diameter sphere cannot pass through any opening up to a height of 34 inches. From a height of 34 inches to 42 inches above the adjacent walking surfaces, a sphere 8 inches in diameter shall not pass. Exceptions: 1. The triangular openings formed by the riser, tread and bottom rail at the open side of a stairway shall be of a maximum size such that a sphere of 6 inches in diameter cannot pass through the opening. 2. At elevated walking surfaces for access to and use of electrical, mechanical or plumbing systems or equipment, guards shall have balusters or be of solid materials such that a sphere with a diameter of 21 inches cannot pass through any opening...4. In assembly seating areas, guards at the end of aisles where they terminate at a fascia of boxes, balconies and galleries shall have balusters or ornamental patterns such that a 4-inch-diameter sphere cannot pass through any opening up to a height of 26 inches. From a height of 26 inches to 42 inches above the adjacent walking surfaces, a sphere 8 inches in diameter shall not pass.	Guards and Handrails.	11.2.2.4.5	Guard Details.	(A) The height of guards required in 11.1.8 shall be measured vertically to the top of the guard from the surface adjacent thereto. (B) Guards shall be not less than 42 in. (107 cm) high. Exception: The requirement of 11.2.2.4.5(B) shall not apply where otherwise provided in 16.2.11. (C)* Open guards shall have intermediate rails or an ornamental pattern such that a sphere 4 in. (10.1 cm) in diameter shall not be capable of passing through any opening up to a height of 34 in. (86 cm). Exception No. 1: The triangular openings formed by the riser, tread, and bottom element of a guardrail at the open side of a stair shall be of such size that a sphere 6 in. (15.2 cm) in diameter shall not be capable of passing through the triangular opening.	Similar
Exit Access	1013.1	General.	The exit access arrangement shall comply with Sections 1013 through 1016 and the applicable provisions of Sections 1003 through 1012.	Arrangement of Means of Egress.	11.5.1.1	General.	Exits shall be located and exit access shall be arranged so that exits are readily accessible at all times.	Similar
Exit Access	1013.2	Egress through intervening spaces.	Egress from a room or space shall not pass through adjoining or intervening rooms or areas, except where such adjoining rooms or areas are accessory to the area served; are not a high-hazard occupancy and provide a discernible path of egress travel to an exit. Egress shall not pass through kitchens, storage rooms, closets or spaces used for similar purposes. An exit access shall not pass through a room that can be locked to prevent egress. Means of egress from dwelling units or sleeping areas shall not lead through other sleeping areas, toilet rooms or bathrooms. Exceptions: 1. Means of egress are not prohibited through a kitchen area serving adjoining rooms constituting part of the same dwelling unit or sleeping unit...	Arrangement of Means of Egress.	11.5.1.8	General.	Exit access from rooms or spaces shall be permitted to be through adjoining or intervening rooms or areas, provided that such adjoining rooms are accessory to the area served. Foyers, lobbies, and reception rooms constructed as required for corridors shall not be construed as intervening rooms. Exit access shall be arranged so that it is not necessary to pass through any area identified under hazardous area protection in Chapter 16 through Chapter 30.	Similar
Exit Access	1013.3	Common path of egress travel.	In occupancies other than Groups H-1, H-2 and H-3, the common path of egress travel shall not exceed 75 feet (22 860 mm). In occupancies in Groups H-1, H-2, and H-3, the common path of egress travel shall not exceed 25 feet (7620 mm). Exceptions: 1. The length of a common path of egress travel in an occupancy in Groups B, F and S shall not be more than 100 feet (30 480 mm), provided that the building is equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1. 2. Where a tenant space in an occupancy in Groups B, S and U has an occupant load of not more than 30, the length of a common path of egress travel shall not be more than 100 feet (30 480 mm). 3. The length of a common	Arrangement of Means of Egress.	16.2.5.1.2	General.	Common paths of travel shall be permitted for the first 20 ft (6.1 m) from any point where serving any number of occupants and for the first 75 ft (23 m) from any point where serving not more than 50 occupants.	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			path of egress travel in occupancies in Group I-3 shall not be more than 100 feet (30 480 mm).					
Exit and Exit Access Doorways	1014.1	Exit or exit access doorways required.	Two exits or exit access doorways from any space shall be provided where one of the following conditions exists: 1. The occupant load of the space exceeds the values in Table 1014.1. 2. The common path of egress travel exceeds the limitations of Section 1013.3. 3. Where required by Sections 1014.3, 1014.4 and 1014.5. Exception: Group I-2 occupancies shall comply with Section 1013.2.2.	Number of Means of Egress.	11.4.1.1	General.	The number of means of egress from any balcony, mezzanine, story, or portion thereof shall be not less than two.	Similar
Exit and Exit Access Doorways	1014.2	Exit or exit access doorway arrangement.	Required exits shall be located in a manner that makes their availability obvious. Exits shall be unobstructed at all times. Exit and exit access doorways shall be arranged in accordance with Sections 1014.2.1 and 1014.2.2.	Arrangement of Means of Egress.	11.5.1.1	General.	Exits shall be located and exit access shall be arranged so that exits are readily accessible at all times.	Similar
Exit and Exit Access Doorways	1014.2.1	Two exits or exit access doorways.	Where two exits or exit access doorways are required from any portion of the exit access, the exit doors or exit access doorways shall be placed a distance apart equal to not less than one-half of the length of the maximum overall diagonal dimension of the building or area to be served measured in a straight line between exit doors or exit access doorways. Interlocking or scissor stairs shall be counted as one exit stairway. Exceptions: 1. Where exit enclosures are provided as a portion of the required exit and are interconnected by a 1-hour fire-resistance-rated corridor conforming to the requirements of Section 1016, the required exit separation shall be measured along the shortest direct line of travel within the corridor. 2. Where a building is equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 or 903.3.1.2, the separation distance of the exit doors or exit access doorways shall not be less than one-third of the length of the maximum overall diagonal dimension of the area served.	Arrangement of Means of Egress.	11.5.1.4	General.	Where two exits or exit access doors are required, they shall be located at a distance from one another not less than one-half the length of the maximum overall diagonal dimension of the building or area to be served, measured in a straight line between the nearest edge of the exit doors or exit access doors. Where exit enclosures are provided as the required exits and are interconnected by not less than a 1-hour fire resistance–rated corridor, exit separation shall be permitted to be measured along the line of travel within the corridor. Exception: In buildings protected throughout by an approved, supervised automatic sprinkler system in accordance with Section 55.3, the minimum separation distance between two exits or exit access doors measured in accordance with 11.5.1.4 shall be not less than one-third the length of the maximum overall diagonal dimension of the building or area to be served.	Similar
Exit and Exit Access Doorways	1014.2.2	Three or more exits or exit access doorways.	Where access to three or more exits is required, at least two exit doors or exit access doorways shall be placed a distance apart equal to not less than one-half of the length of the maximum overall diagonal dimension of the area served measured in a straight line between such exit doors or exit access doorways. Additional exits or exit access doorways shall be arranged a reasonable distance apart so that if one becomes blocked, the others will be available. Exception: Where a building is equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 or 903.3.1.2, the separation distance of at least two of the exit doors or exit access doorways shall not be less than one-third of the length of the maximum overall diagonal dimension of the area served.	Arrangement of Means of Egress.	11.5.1.5	General.	Where more than two exits or exit access doors are required, at least two of the required exits or exit access doors shall be arranged to comply with the minimum separation distance requirement. The other exits or exit access doors shall be located so that, if one becomes blocked, the others are available.	Similar
Exit and Exit Access Doorways	1014.6	Stage means of egress.	Where two means of egress are required, based on the stage size or occupant load, one means of egress shall be provided on each side of the stage.	Arrangement of Means of Egress.	11.5.1.4	General.	Where two exits or exit access doors are required, they shall be located at a distance from one another not less than one-half the length of the maximum	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
							overall diagonal dimension of the building or area to be served, measured in a straight line between the nearest edge of the exit doors or exit access doors. Where exit enclosures are provided as the required exits and are interconnected by not less than a 1-hour fire resistance–rated corridor, exit separation shall be permitted to be measured along the line of travel within the corridor. Exception: In buildings protected throughout by an approved, supervised automatic sprinkler system in accordance with Section 55.3, the minimum separation distance between two exits or exit access doors measured in accordance with 11.5.1.4 shall be not less than one-third the length of the maximum overall diagonal dimension of the building or area to be served.	
Exit and Exit Access Doorways	1015.1	Travel distance limitations.	Exits shall be so located on each story such that the maximum length of exit access travel, measured from the most remote point within a story to the entrance to an exit along the natural and unobstructed path of egress travel, shall not exceed the distances given in Table 1015.1. Where the path of exit access includes unenclosed stairways or ramps within the exit access or includes unenclosed exit ramps or stairways as permitted in Section 1019.1, the distance of travel on such means of egress components shall also be included in the travel distance measurement. The measurement along stairways shall be made on a plane parallel and tangent to the stair tread nosings in the center of the stairway. Exceptions: ... 3. Where an exit stair is permitted to be unenclosed in accordance with Exception 8 or 9 of Section 1019.1, the travel distance shall be measured from the most remote point within a building to an exit discharge.	Means of Egress Requirements.	16.2.6	Travel Distance to Exits.	Exits shall be arranged so that the total length of travel from any point to reach an exit does not exceed 200 ft (60 m) in any assembly occupancy. Exception No. 1: The travel distance shall not exceed 250 ft (75 m) in assembly occupancies protected throughout by an approved, supervised automatic sprinkler system in accordance with Section 55.3. Exception No. 2: The requirement of 16.2.6 shall not apply to smoke-protected assembly seating as permitted by 16.4.2.8 and its exception.	Similar
Exit and Exit Access Doorways	Table 1015.1	Exit access travel distance.	Occupancy A (without sprinkler system): 200 ft	Means of Egress Requirements.	16.2.6	Travel Distance to Exits.	Exits shall be arranged so that the total length of travel from any point to reach an exit does not exceed 200 ft (60 m) in any assembly occupancy. Exception No. 1: The travel distance shall not exceed 250 ft (75 m) in assembly occupancies protected throughout by an approved, supervised automatic sprinkler system in accordance with Section 55.3. Exception No. 2: The requirement of 16.2.6 shall not apply to smoke-protected assembly seating as permitted by 16.4.2.8 and its exception.	Similar
Exits	1017.1	General.	Exits shall comply with Sections 1017 through 1022 and the applicable requirements of Sections 1003 through 1012. An exit shall not be used for any purpose that interferes with its function as a means of egress. Once a given level of exit protection is achieved, such level of protection shall not be reduced until arrival at the exit discharge.	Separation of Means of Egress.	11.1.3.2.2	Exits.	An exit enclosure shall provide a continuous protected path of travel to an exit discharge.	Similar
Exits	1017.2	Exterior exit doors.	Buildings or structures used for human occupancy shall have at least one exterior door that meets the	Means of Egress.	11.7.2	Discharge from Exits.	Not more than 50 percent of the required number of exits, and not more than 50 percent of the required	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			requirements of Section 1008.1.1.				egress capacity, shall be permitted to discharge through areas on the level of exit discharge, provided that the criteria of 11.7.2(A) through 11.7.2(C) are met. (A) Discharge shall lead to a free and unobstructed way to the exterior of the building, and such way is readily visible and identifiable from the point of discharge from the exit. (B) The level of discharge shall be protected throughout by an approved, automatic sprinkler system in accordance with Section 55.3, or the portion of the level of discharge used for discharge shall be protected by an approved, automatic sprinkler system in accordance with Section 55.3 and shall be separated from the nonsprinklered portion of the floor by a fire resistance rating meeting the requirements for the enclosure of exits. (See 11.1.3.2.1.) Exception: The requirement of 11.7.2(B) shall not apply where the discharge area is a vestibule or foyer meeting all of the following: (1) The depth from the exterior of the building shall be not more than 10 ft (3 m), and the length shall be not more than 30 ft (9.1 m). (2) The foyer shall be separated from the remainder of the level of discharge by construction providing protection not less than the equivalent of wired glass in steel frames. (3) The foyer shall serve only as means of egress and shall include an exit directly to the outside.	
Exits	1017.2.1	Detailed requirements.	Exterior exit doors shall comply with the applicable requirements of Section 1008.1.	Means of Egress Components.	11.2.1.1.1	Doors.	A door assembly in a means of egress shall conform to the general requirements of Section 11.1 and to the special requirements of 11.2.1. Such an assembly shall be designated as a door.	Similar
Exits	1017.2.2	Arrangement.	Exterior exit doors shall lead directly to the exit discharge or the public way.	Means of Egress.	11.7.1	Discharge from Exits.	Exits shall terminate directly at a public way or at an exterior exit discharge. Yards, courts, open spaces, or other portions of the exit discharge shall be of required width and size to provide all occupants with a safe access to a public way. Exception No. 1: The requirement of 11.7.1 shall not apply to interior exit discharge as otherwise provided in 11.7.2. Exception No. 2: The requirement of 11.7.1 shall not apply to rooftop exit discharge as otherwise provided in 11.7.6. Exception No. 3: Means of egress shall be permitted to terminate in an exterior area of refuge as provided in 21.2.7.1.	Similar
Number of Exits and Continuity	1018.1	Minimum number of exits.	All rooms and spaces within each story shall be provided with and have access to the minimum number of approved independent exits as required by Table 1018.1 based on the occupant load, except as modified in Section 1014.1 or 1018.2. For the purposes of this chapter, occupied roofs shall be	Means of Egress.	11.4.1.4	Number of Means of Egress.	The occupant load of each story considered individually shall be required to be used in computing the number of means of egress at each story, provided that the required number of means of egress is not decreased in the direction of egress travel.	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			provided with exits as required for stories. The required number of exits from any story, basement or individual space shall be maintained until arrival at grade or the public way.					
Exterior Exit Ramps and Stairways	1022.2	Use in a means of egress.	Exterior exit ramps and stairways shall not be used as an element of a required means of egress for occupancies in Group I-2. For occupancies in other than Group I-2, exterior exit ramps and stairways shall be permitted as an element of a required means of egress for buildings not exceeding six stories or 75 feet (22 860 mm) in height.	Special Provisions for Outside Stairs.	11.2.2.7.3	Separation and Protection of Outside Stairs.	Outside stairs shall be separated from the interior of the building by construction with the fire resistance rating required for enclosed stairs with fixed or self-closing opening protectives. This construction shall extend vertically from the ground to a point 10 ft (3 m) above the topmost landing of the stairs or to the roofline, whichever is lower, and to a point not less than 10 ft (3 m) horizontally.Exception No. 1: Outside stairs serving an exterior exit access balcony that has two remote outside stairways or ramps shall be permitted to be unprotected.Exception No. 2: Outside stairs serving not in excess of two adjacent stories, including the story of exit discharge, shall be permitted to be unprotected where there is a remotely located second exit.Exception No. 3: The fire resistance rating of the separation extending 10 ft (3 m) from the stairs shall not be required to exceed 1 hour where openings have not less than a ¾-hour fire protection rating.	Different-NFPA 5000 not limited by height.
Exterior Exit Ramps and Stairways	1022.3	Open side.	Exterior exit ramps and stairways serving as an element of a required means of egress shall be open on at least one side. An open side shall have a minimum of 35 square feet (3.3m2) of aggregate open area adjacent to each floor level and the level of each intermediate landing. The required open area shall be located not less than 42 inches (1067 mm) above the adjacent floor or landing level.	Special Provisions for Outside Stairs.	11.2.2.7.6	Openness.	Outside stairs shall be not less than 50 percent open on one side and shall be arranged to restrict the accumulation of smoke.	Similar
Exterior Exit Ramps and Stairways	1022.4	Side yards.	The open areas adjoining exterior exit ramps or stairways shall be either yards, courts or public ways; the remaining sides are permitted to be enclosed by the exterior walls of the building.	Special Provisions for Outside Stairs.	11.2.2.7.3	Separation and Protection of Outside Stairs.	Outside stairs shall be separated from the interior of the building by construction with the fire resistance rating required for enclosed stairs with fixed or self-closing opening protectives. This construction shall extend vertically from the ground to a point 10 ft (3 m) above the topmost landing of the stairs or to the roofline, whichever is lower, and to a point not less than 10 ft (3 m) horizontally. Exception No. 1: Outside stairs serving an exterior exit access balcony that has two remote outside stairways or ramps shall be permitted to be unprotected. Exception No. 2: Outside stairs serving not in excess of two adjacent stories, including the story of exit discharge, shall be permitted to be unprotected where there is a remotely located second exit. Exception No. 3: The fire resistance rating of the separation extending 10 ft (3 m) from the stairs shall not be required to exceed 1 hour where openings have not less than a ¾-hour fire protection rating.	Different-NFPA 5000 not limited by height.
Exterior Exit Ramps and Stairways	1022.5	Location.	Exterior exit ramps and stairways shall be located in accordance with Section 1023.3.	Special Provisions for Outside Stairs.	11.2.2.7.3	Separation and Protection of Outside Stairs.	Outside stairs shall be separated from the interior of the building by construction with the fire resistance rating required for enclosed stairs with fixed or self-	Different-NFPA 5000 not limited by height.

DRAFT

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
							closing opening protectives. This construction shall extend vertically from the ground to a point 10 ft (3 m) above the topmost landing of the stairs or to the roofline, whichever is lower, and to a point not less than 10 ft (3 m) horizontally.Exception No. 1: Outside stairs serving an exterior exit access balcony that has two remote outside stairways or ramps shall be permitted to be unprotected.Exception No. 2: Outside stairs serving not in excess of two adjacent stories, including the story of exit discharge, shall be permitted to be unprotected where there is a remotely located second exit.Exception No. 3: The fire resistance rating of the separation extending 10 ft (3 m) from the stairs shall not be required to exceed 1 hour where openings have not less than a ¾-hour fire protection rating.	
Exterior Exit Ramps and Stairways	1022.6	Exterior ramps and stairway protection.	Exterior exit ramps and stairways shall be separated from the interior of the building as required in Section 1019.1. Openings shall be limited to those necessary for egress from normally occupied spaces. Exceptions: ... 2. Separation from the interior of the building is not required where the exterior ramp or stairway is served by an exterior ramp and/or balcony that connects two remote exterior stairways or other approved exits, with a perimeter that is not less than 50 percent open. To be considered open, the opening shall be a minimum of 50 percent of the height of the enclosing wall, with the top of the openings no less than 7 feet (2134 mm) above the top of the balcony. ...	Special Provisions for Outside Stairs.	11.2.2.7.3	Separation and Protection of Outside Stairs.	Outside stairs shall be separated from the interior of the building by construction with the fire resistance rating required for enclosed stairs with fixed or self-closing opening protectives. This construction shall extend vertically from the ground to a point 10 ft (3 m) above the topmost landing of the stairs or to the roofline, whichever is lower, and to a point not less than 10 ft (3 m) horizontally. Exception No. 1: Outside stairs serving an exterior exit access balcony that has two remote outside stairways or ramps shall be permitted to be unprotected. Exception No. 2: Outside stairs serving not in excess of two adjacent stories, including the story of exit discharge, shall be permitted to be unprotected where there is a remotely located second exit. Exception No. 3: The fire resistance rating of the separation extending 10 ft (3 m) from the stairs shall not be required to exceed 1 hour where openings have not less than a ¾-hour fire protection rating.	Different-NFPA 5000 not limited by height.
Exit Discharge	1023.1	General.	Exits shall discharge directly to the exterior of the building. The exit discharge shall be at grade or shall provide direct access to grade. The exit discharge shall not reenter a building. Exceptions: 1. A maximum of 50 percent of the number and capacity of the exit enclosures is permitted to egress through areas on the level of discharge provided all of the following are met... 2. A maximum of 50 percent of the number and capacity of the exit enclosures is permitted to egress through a vestibule provided all of the following are met: 2.1. The entire area of the vestibule is separated from areas below by construction conforming to the fire-resistance rating for the exit enclosure. 2.2. The depth from the exterior of the building is not greater than 10 feet and the length is not greater than 30 feet. 2.3. The area is separated from the remainder of the level of exit discharge by construction providing protection at least the equivalent of approved wired	Means of Egress.	11.7.1	Discharge from Exits.	Exits shall terminate directly at a public way or at an exterior exit discharge. Yards, courts, open spaces, or other portions of the exit discharge shall be of required width and size to provide all occupants with a safe access to a public way. Exception No. 1: The requirement of 11.7.1 shall not apply to interior exit discharge as otherwise provided in 11.7.2. Exception No. 2: The requirement of 11.7.1 shall not apply to rooftop exit discharge as otherwise provided in 11.7.6. Exception No. 3: Means of egress shall be permitted to terminate in an exterior area of refuge as provided in 21.2.7.1.	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			glass in steel frames. 2.4. The area is used only for means of egress and exits directly to the outside....					
Exit Discharge	1023.2	Exit discharge capacity.	The capacity of the exit discharge shall be not less than the required discharge capacity of the exits being served.	Capacity of Means of Egress.	11.3.1.1	Sufficient Capacity for Occupant Load.	The total capacity of the means of egress for any story, balcony, tier, or other occupied space shall be sufficient for the occupant load thereof.	Similar
Exit Discharge	1023.3	Exit discharge location.	Exterior balconies, stairways and ramps shall be located at least 10 feet (3048 mm) from adjacent lot lines and from other buildings on the same lot unless the adjacent building exterior walls and openings are protected in accordance with Section 704 based on fire separation distance.	Capacity of Means of Egress.	11.3.1.1	Sufficient Capacity for Occupant Load.	The total capacity of the means of egress for any story, balcony, tier, or other occupied space shall be sufficient for the occupant load thereof.	Similar
Exit Discharge	1023.4	Exit discharge components.	Exit discharge components shall be sufficiently open to the exterior so as to minimize the accumulation of smoke and toxic gases.	Enclosure and Protection of Stairs.	11.7	Discharge from Exits	Exits shall terminate directly at a public way or at an exterior exit discharge. Yards, courts, open spaces, or other portions of the exit discharge shall be of required width and size to provide all occupants with a safe access to a public way.	Similar
Exit Discharge	1023.6	Access to a public way.	The exit discharge shall provide a direct and unobstructed access to a public way. Exception: Where access to a public way cannot be provided, a safe dispersal area shall be provided where all of the following are met: 1. The area shall be of a size to accommodate 5 sq ft per person, 2. The area shall be located on the same property at least 50 ft away, 3. The area shall be permanently maintained and identified, and 4. The area shall be provided with a safe and unobstructed path of travel from the building.	Means of Egress.	11.7.1	Discharge from Exits.	Exits shall terminate directly at a public way or at an exterior exit discharge. Yards, courts, open spaces, or other portions of the exit discharge shall be of required width and size to provide all occupants with a safe access to a public way. Exception No. 1: The requirement of 11.7.1 shall not apply to interior exit discharge as otherwise provided in 11.7.2. Exception No. 2: The requirement of 11.7.1 shall not apply to rooftop exit discharge as otherwise provided in 11.7.6. Exception No. 3: Means of egress shall be permitted to terminate in an exterior area of refuge as provided in 21.2.7.1.	Similar
Assembly	1024.1	General.	Occupancies in Group A which contain seats, tables, displays, equipment or other material shall comply with this section.	Assembly Occupancies	16.1.1.1	General Requirements.	The requirements of this chapter shall apply to new buildings or portions thereof used as an assembly occupancy.	Similar
Assembly	1024.2	Assembly main exit.	Group A occupancies that have an occupant load of greater than 300 shall be provided with a main exit. The main exit shall be of sufficient width to accommodate not less than one-half of the occupant load, but such width shall not be less than the total required width of all means of egress leading to the exit. Where the building is classified as a Group A occupancy, the main exit shall front on at least one street or an unoccupied space of not less than 10 feet (3048 mm) in width that adjoins a street or public way. Exception: In assembly occupancies where there is no well-defined main exit or where multiple main exits are provided, exits shall be permitted to be distributed around the perimeter of the building provided that the total width of egress is not less than 100 percent of the required width.	Capacity of Means of Egress.	16.2.3.3	Main Entrance/Exit.	Every assembly occupancy shall be provided with a main entrance/exit. The main entrance/exit shall be of sufficient width to accommodate one-half of the total occupant load and shall be at the level of exit discharge or shall connect to a stairway or ramp leading to a street. Each level of an assembly occupancy shall have access to the main entrance/exit, and such access shall have sufficient capacity to accommodate 50 percent of the occupant load of such levels. Where the main entrance/exit from an assembly occupancy is through a lobby or foyer, the aggregate capacity of all exits from the lobby or foyer shall be permitted to provide the required capacity of the main entrance/exit, regardless of whether all such exits serve as entrances to the building.... Exception No. 2: In assembly occupancies where there is no well-defined main entrance/exit, exits shall be permitted to be distributed around the	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
							perimeter of the building, provided that the total exit width furnishes a minimum of 100 percent of the width needed to accommodate the permitted occupant load.	
Assembly	1024.3	Assembly other exits.	In addition to having access to a main exit, each level of an occupancy in Group A having an occupant load of greater than 300 shall be provided with additional exits that shall provide an egress capacity for at least one-half of the total occupant load served by that level and comply with Section 1014.2. Exception: In assembly occupancies where there is no well-defined main exit or where multiple main exits are provided, exits shall be permitted to be distributed around the perimeter of the building provided that the total width of egress is not less than 100 percent of the required width.	Capacity of Means of Egress.	16.2.3.3	Main Entrance/Exit.	Every assembly occupancy shall be provided with a main entrance/exit. The main entrance/exit shall be of sufficient width to accommodate one-half of the total occupant load and shall be at the level of exit discharge or shall connect to a stairway or ramp leading to a street. Each level of an assembly occupancy shall have access to the main entrance/exit, and such access shall have sufficient capacity to accommodate 50 percent of the occupant load of such levels. Where the main entrance/exit from an assembly occupancy is through a lobby or foyer, the aggregate capacity of all exits from the lobby or foyer shall be permitted to provide the required capacity of the main entrance/exit, regardless of whether all such exits serve as entrances to the building....Exception No. 2: In assembly occupancies where there is no well-defined main entrance/exit, exits shall be permitted to be distributed around the perimeter of the building, provided that the total exit width furnishes a minimum of 100 percent of the width needed to accommodate the permitted occupant load.	Similar
Assembly	1024.4	Foyers and lobbies.	In Group A-1 occupancies, where persons are admitted to the building at times when seats are not available and are allowed to wait in a lobby or similar space, such use of lobby or similar space shall not encroach upon the required clear width of the means of egress. Such waiting areas shall be separated from the required means of egress by substantial permanent partitions or by fixed rigid railings not less than 42 inches (1067 mm) high. Such foyer, if not directly connected to a public street by all the main entrances or exits, shall have a straight and unobstructed corridor or path of travel to every such main entrance or exit.	Occupant Load.	16.1.6.1	Waiting Spaces.	In theaters and other assembly occupancies where persons are admitted to the building at times when seats are not available to them, or when the permitted occupant load has been reached based on 16.1.6 and persons are allowed to wait in a lobby or similar space until seats or space is available, such use of a lobby or similar space shall not encroach upon the required clear width of exits. Such waiting shall be restricted to areas other than the required means of egress. Exits shall be provided for such waiting spaces on the basis of one person for each 3 ft2 (0.28 m2) of waiting space area. Such exits shall be in addition to the exits specified for the main auditorium area and shall conform in construction and arrangement to the general rules for exits given in this chapter.	Similar
Assembly	1024.5	Interior balcony and gallery means of egress.	For balconies or galleries having a seating capacity of over 50 located in Group A occupancies, at least two means of egress shall be provided, one from each side of every balcony or gallery, with at least one leading directly to an exit.	Means of Egress Requirements.	16.2.4.3	Number of Exits.	Balconies or mezzanines having an occupant load not greater than 50 shall be permitted to be served by a single means of egress, and such means of egress shall be permitted to lead to the floor below.	Similar
Assembly	1024.6	Width of means of egress for assembly.	The clear width of aisles and other means of egress shall comply with Section 1024.6.1 where smoke-protected seating is not provided and with Section 1024.6.2 or 1024.6.3 where smoke-protected seating is provided. The clear width shall be measured to walls, edges of seating and tread edges except for permitted projections.	Arrangement of Means of Egress.	16.2.5.4.4	General Requirements for Access and Egress Routes within Assembly Areas.	The width of aisle access ways and aisles shall provide sufficient egress capacity for the number of persons accommodated by the catchment area served by the aisle access way or aisle in accordance with 16.2.3.1 or, for smoke-protected assembly seating, in accordance with 16.4.2. Where aisle access ways or aisles converge to form a single	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
							path of egress travel, the required egress capacity of that path shall not be less than the combined required capacity of the converging aisle access ways and aisles.	
Assembly	1024.6.1	Without smoke protection.	The clear width of the means of egress shall provide sufficient capacity in accordance with all of the following, as applicable: 1. At least 0.3 inch of width for each occupant served shall be provided on stairs having riser heights 7 inches or less and tread depths 11 inches or greater, measured horizontally between tread nosing. 2. At least 0.005 inch of additional stair width for each occupant shall be provided for each 0.10 inch of riser height above 7 inches. 3. Where egress requires stair descent, at least 0.075 inch of additional width for each occupant shall be provided on those portions of stair width having no handrail within a horizontal distance of 30 inches. 4. Ramped means of egress, where slopes are steeper than one unit vertical in 12 units horizontal (8-percent slope), shall have at least 0.22 inch of clear width for each occupant served. Level or ramped means of egress, where slopes are not steeper than one unit vertical in 12 units horizontal (8-percent slope), shall have at least 0.20 inch of clear width for each occupant served.	Capacity of Means of Egress.	16.2.3.1	General.	The capacity of means of egress shall be in accordance with Section 11.3 or, for means of egress serving theater-type seating or similar seating arranged in rows, in accordance with 16.2.3.2, or, for smoke-protected assembly seating, in accordance with 16.4.2.	Similar
Assembly	1024.7	Travel distance.	Exits and aisles shall be so located that the travel distance to an exit door shall not be greater than 200 feet (60 960 mm) measured along the line of travel in nonsprinklered buildings. Travel distance shall not be more than 250 feet (76 200 mm) in sprinklered buildings. Where aisles are provided for seating, the distance shall be measured along the aisles and aisle access way without travel over or on the seats. Exceptions: 1. Smoke-protected assembly seating: The travel distance from each seat to the nearest entrance to a vomitory or concourse shall not exceed 200 feet (60 960 mm). The travel distance from the entrance to the vomitory or concourse to a stair, ramp or walk on the exterior of the building shall not exceed 200 feet (60 960 mm). 2. Open-air seating: The travel distance from each seat to the building exterior shall not exceed 400 feet (122 m). The travel distance shall not be limited in facilities of Type I or II construction.	Means of Egress Requirements.	16.2.6	Travel Distance to Exits.	Exits shall be arranged so that the total length of travel from any point to reach an exit does not exceed 200 ft (60 m) in any assembly occupancy. Exception No. 1: The travel distance shall not exceed 250 ft (75 m) in assembly occupancies protected throughout by an approved, supervised automatic sprinkler system in accordance with Section 55.3. Exception No. 2: The requirement of 16.2.6 shall not apply to smoke-protected assembly seating as permitted by 16.4.2.8 and its exception.	Similar
Assembly	1024.8	Common path of travel.	The common path of travel shall not exceed 30 feet (9144 mm) from any seat to a point where a person has a choice of two paths of egress travel to two exits. Exceptions: 1. For areas serving not more than 50 occupants, the common path of travel shall not exceed 75 feet (22 860 mm). 2. For smoke-protected assembly seating, the common path of travel shall not exceed 50 feet (15 240 mm).	Arrangement of Means of Egress.	16.2.5.5.4	Aisle Access ways Serving Seating Not at Tables.	Rows of seating served by an aisle or doorway at one end only shall have a path of travel not exceeding 30 ft (9.1 m) in length from any seat to an aisle. The 12-in. (30.10-cm) minimum clear width of aisle access way between such rows shall be increased by 0.6 in. (15 mm) for every seat over a total of seven. Exception: The requirements of 16.2.5.5.4 shall not apply to smoke-protected assembly seating as permitted by 16.4.2.5 and 16.4.2.6.	Similar
	Chapter 26	Plastic						

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
Definitions	2602.1	General.	2602.1 General. The following words and terms shall, for the purposes of this chapter and as used elsewhere in this code, have the meanings shown herein. FOAM PLASTIC INSULATION. A plastic that is intentionally expanded by the use of a foaming agent to produce a reduced-density plastic containing voids consisting of open or closed cells distributed throughout the plastic for thermal insulating or acoustical purposes and that has a density less than 20 pounds per cubic foot (pcf) (320 kg/m3).	Special Definitions.	48.2.1	Foam Plastic Insulation.	A cellular plastic used for thermal insulating or acoustical applications, having a density of 20 lb/ft3 (320 kg/m3) or less, containing open or closed cells, formed by a foaming agent.	Similar
Foam Plastic Insulation	2603.1	General.	The provisions of this section shall govern the requirements and uses of foam plastic insulation in buildings and structures.	Plastics.	48.1	Scope.	All plastic materials used in or on buildings or structures shall meet the requirements in this chapter.	Similar
Foam Plastic Insulation	2603.2	Labeling and identification.	Packages and containers of foam plastic insulation and foam plastic insulation components delivered to the job site shall bear the label of an approved agency showing the manufacturer's name, the product listing, product identification and information sufficient to determine that the end use will comply with the code requirements.	General Criteria—Foam Plastic Insulation.	48.3.1.1	Product Identification.	A label of an approved agency shall appear on foam plastic insulation products, packages, or containers and components delivered to a job site.	Similar
Foam Plastic Insulation	2603.3	Surface-burning characteristics.	Unless otherwise indicated in this section, foam plastic insulation and foam plastic cores of manufactured assemblies shall have a flame spread index of not more than 75 and a smoke-developed index of not more than 450 where tested in the maximum thickness intended for use in accordance with ASTM E 84. Loose fill-type foam plastic insulation shall be tested as board stock for the flame spread index and smoke-developed index. Exceptions.	General Criteria—Foam Plastic Insulation.	48.3.2.1	Surface-burning Characteristics.	Unless otherwise permitted by 48.3.2.3, foam plastic insulation or foam plastic cores of manufactured assemblies and components shall be tested in accordance with NFPA 255, Standard Method of Test of Surface Burning Characteristics of Building Materials, at the maximum thickness intended for use and shall have a flame spread index of 75 or less and a smoke developed index of 450 or less.	Similar
Foam Plastic Insulation	2603.4	Thermal barrier.	Except as provided for in Sections 2603.4.1 and 2603.8, foam plastic shall be separated from the interior of a building by an approved thermal barrier of 0.5-inch (12.7mm) gypsum wallboard or equivalent thermal barrier material that will limit the average temperature rise of the unexposed surface to not more than 250°F (120°C) after 15 minutes of fire exposure, complying with the standard time-temperature curve of ASTM E 119. The thermal barrier shall be installed in such a manner that it will remain in place for 15 minutes based on FM 4880, UL 1040, NFPA 286 (added - editor note) or UL 1715. Combustible concealed spaces shall comply with Section 717.	General Criteria—Foam Plastic Insulation.	48.3.3.1	Thermal Barrier.	Foam plastic insulation and components shall be separated from the interior of a building and from plenums by an approved thermal barrier of 0.5-in. (12.7-mm) gypsum wallboard or equivalent material that will limit the average temperature rise of the unexposed surface to not more than 250°F (139°C) after 15 minutes of fire exposure complying with the standard time-temperature curve of NFPA 251, Standard Methods of Tests of Fire Endurance of Building Construction and Materials.	Similar
Foam Plastic Insulation	2603.4.1	Thermal barrier not required.	The thermal barrier specified in Section 2603.4 is not required under the conditions set forth in Sections 2603.4.1.1 through 2603.4.1.13	General Criteria—Foam Plastic Insulation.	48.3.3.4	Thermal Barrier.	The requirements of 48.3.3.1 through 48.3.3.3 shall not apply where otherwise permitted by the following:	Similar
Foam Plastic Insulation	2603.4.1.4	Exterior walls-one-story buildings.	For one-story buildings, foam plastic having a flame spread index of 25 or less, and a smoke-developed index of not more than 450, shall be permitted without thermal barriers in or on exterior walls in a thickness not more than 4 inches (102 mm) where the foam plastic is covered by a thickness of not less than 0.032-inch-thick (0.81 mm) aluminum or corrosion-	General Criteria—Foam Plastic Insulation.	48.3.3.4	Thermal Barrier.	The requirements of 48.3.3.1 through 48.3.3.3 shall not apply where otherwise permitted by the following:	Similar

DRAFT

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			resistant steel having a base metal thickness of 0.0160 inch (0.41 mm) and the building is equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1.					
Foam Plastic Insulation	2603.8	Special approval.	Foam plastic shall not be required to comply with the requirements of Sections 2603.4 through 2603.7, where specifically approved based on large-scale tests such as, but not limited to, FM 4880, UL 1040, NFPA 286 or UL 1715. Such testing shall be related to the actual end-use configuration and be performed on the finished manufactured foam plastic assembly in the maximum thickness intended for use. Foam plastics that are used as interior finish on the basis of special tests shall also conform to the flame spread requirements of Chapter 8. Assemblies tested shall include seams, joints and other typical details used in the installation of the assembly and shall be tested in the manner intended for use	Specific Application Requirements—Foam Plastic Insulation.	48.4.4.1	Alternate Testing and Approval.	The requirements of 48.3.3 through 48.4.3 shall be permitted to be replaced by special testing, and the approval of foam plastic shall be based on large-scale tests such as, but not limited to, the following: (1) UL 1715, Standard for Safety for Fire Test of Interior Finish Material (2) UL 1040, Standard for Fire Test of Insulated Wall Construction (3) FM 4880, Approval Standard for Class 1 Insulated Wall or Wall and Roof/Ceiling Panels; Plastic Interior Finish Materials; Plastic Exterior Building Panels; Wall/Ceiling Coating Systems; Interior or Exterior Finish Systems (4) NFPA 286, Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth	Similar
Interior Finish and Trim	2604.1	General.	Plastic materials installed as interior finish or trim shall comply with Chapter 8. Foam plastics shall only be installed as interior finish where approved in accordance with the special provisions of Section 2603.8. Foam plastics that are used as interior finish shall also meet the flame spread index requirements for interior finish in accordance with Chapter 8. Foam plastics installed as interior trim shall comply with Section 2604.2.	Plastics.	48.5.1	Specific Requirements — Interior Finish and Trim.	All plastic materials installed as interior finish or trim shall comply with requirements of Chapter 10.	Similar
Interior Finish and Trim	2604.2	Interior trim.	Foam plastic used as interior trim shall comply with Sections 2604.2.1 through 2604.2.4.	Plastics.	48.5.1	Specific Requirements — Interior Finish and Trim.	All plastic materials installed as interior finish or trim shall comply with requirements of Chapter 10.	Similar
Interior Finish and Trim	2604.2.1	Interior trim.	The minimum density of the interior trim shall be 20 pcf (320 kg/m3).	Plastics.	48.5.3	Specific Requirements — Interior Finish and Trim.	Foam plastics used, as interior trim shall meet all of the following requirements: (1) They shall have a minimum density of 20 lb/ft3 (320 kg/m3). (2) They shall have a maximum thickness of 0.5 in. (12.7 mm) and a maximum width of 8 in. (204 mm). (3) They shall constitute no more than 10 percent of the total wall and ceiling area of any room or space. (4) They shall have a flame spread index of 75 or less when tested per NFPA 255.	Similar
Interior Finish and Trim	2604.2.2	Thickness.	The maximum thickness of the interior trim shall be 0.5 inch (12.7 mm) and the maximum width shall be 8 inches (204 mm).	Plastics.	48.5.3	Specific Requirements — Interior Finish and Trim.	Foam plastics used as interior trim shall meet all of the following requirements: (1) They shall have a minimum density of 20 lb/ft3 (320 kg/m3). (2) They shall have a maximum thickness of 0.5 in. (12.7 mm) and a maximum width of 8 in. (204 mm). (3) They shall constitute no more than 10 percent of the total wall and ceiling area of any room or space. (4) They shall have a flame spread index of 75 or less when tested per NFPA 255.	Similar

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
Interior Finish and Trim	2604.2.3	Area limitation.	The interior trim shall not constitute more than 10 percent of the aggregate wall and ceiling area of any room or space.	Plastics.	48.5.3	Specific Requirements — Interior Finish and Trim.	Foam plastics used as interior trim shall meet all of the following requirements: (1) They shall have a minimum density of 20 lb/ft3 (320 kg/m3).(2) They shall have a maximum thickness of 0.5 in. (12.7 mm) and a maximum width of 8 in. (204 mm).(3) They shall constitute no more than 10 percent of the total wall and ceiling area of any room or space.(4) They shall have a flame spread index of 75 or less when tested per NFPA 255.	Similar
Interior Finish and Trim	2604.2.4	Flame spread.	The flame spread index shall not exceed 75 where tested in accordance with ASTM E 84. The smoke-developed index shall not be limited.	Plastics.	48.5.3	Specific Requirements — Interior Finish and Trim.	Foam plastics used as interior trim shall meet all of the following requirements: (1) They shall have a minimum density of 20 lb/ft3 (320 kg/m3). (2) They shall have a maximum thickness of 0.5 in. (12.7 mm) and a maximum width of 8 in. (204 mm). (3) They shall constitute no more than 10 percent of the total wall and ceiling area of any room or space. (4) They shall have a flame-spread index of 75 or less when tested per NFPA 255.	Similar
	Chapter 34	Existing Structures						
Existing Structures - General	3401.1	Scope	The provisions of this chapter shall control the alteration, repair, addition and change of occupancy of existing structures. Exception: Existing bleachers, grandstands and folding and telescopic seating shall comply with ICC 300-02.	Administration.	15.1.1.1	Purpose and Intent.	The purpose of this chapter is to encourage the continued use or reuse of legally existing buildings and structures. The intent of this chapter is to permit repairs, renovations, modifications, reconstructions, additions, and changes of use that maintain or improve the health, safety, and welfare of occupants in existing buildings, without requiring full compliance with the other sections of this Code, the mechanical code, plumbing code, fire code, electrical code, boiler safety code, energy code, elevator code, or accessibility code, except for proportional additional work as specified in this chapter.	Similar
Existing Structures - General	3401.2	Maintenance.	Buildings and structures, and parts thereof, shall be maintained in a safe and sanitary condition. Devices or safeguards, which are required by this code, shall be maintained in conformance with the code edition under which installed. The owner or the owner's designated agent shall be responsible for the maintenance of buildings and structures. To determine compliance with this subsection, the building official shall have the authority to require a building or structure to be re-inspected. The requirements of this chapter shall not provide the basis for removal or abrogation of fire protection and safety systems and devices in existing structures.	Maintenance of Buildings and Property	1.7.5.2.2	Existing Installations.	Buildings in existence at the time of the adoption of this Code shall be permitted to have their existing use or occupancy continued if such use or occupancy was legal at the time of the adoption of this Code, provided such continued use is not dangerous to life.	
Existing Structures - General	3401.3	Compliance with other codes.	Alterations, repairs, additions and changes of occupancy to existing structures shall comply with the provisions for alterations, repairs, additions and changes of occupancy in the International Fire Code, International Fuel Gas Code, International Plumbing Code, International Property Maintenance Code, International Private Sewage Disposal Code, International Mechanical Code, International	Compliance.	15.1.2.4	Compliance with Other Codes.	Buildings, elements, components, or systems in compliance with other sections of this Code, or the current edition of the mechanical code, plumbing code, fire code, electrical code, boiler safety code, energy code, elevator code, or accessibility code, shall not be required to comply with any more restrictive requirement of this chapter.	Similar

DRAFT

IBC Section Title	IBC Section Number	IBC Number Title	Text	NFPA 5000 Section Title	NFPA 5000 Section Number	NFPA 5000 Number Title	Text	Analysis
			Residential Code and ICC Electrical Code.					
Existing Structures - Additions, Alterations or Repairs	3403.1	Existing buildings or structures.	Additions or alterations to any building or structure shall conform to the requirements of the code for new construction. Additions or alterations shall not be made to an existing building or structure, which will cause the existing building, or structure to be in violation of any provisions of this code. An existing building plus additions shall comply with the height and area provisions of for a new structure. Exception: For buildings and structures in flood hazard areas established in Section 1612.3, any additions, alterations or repairs that constitute substantial improvement of the existing structure, as defined in Section 1612.2, shall comply with the flood design requirements for new construction and all aspects of the existing structure shall be brought into compliance with the requirements for new construction for flood design.	Additions.	15.8.1.1	General Requirements.	An addition to a building or structure shall comply with other sections of this Code, the mechanical code, plumbing code, fire code, electrical code, boiler safety code, energy code, elevator code, and accessibility code without requiring the existing building or structure to comply with any requirements of those codes or of this Code.	Similar
Existing Structures - Additions, Alterations or Repairs	3403.3	Nonstructural.	Nonstructural. Nonstructural alterations or repairs to an existing building or structure are permitted to be made of the same materials of which the building or structure is constructed, provided that they do not adversely affect any structural member or the fire-resistance rating of any part of the building or structure.	Compliance.	15.1.2.4	Compliance with Other Codes.	Buildings, elements, components, or systems in compliance with other sections of this Code, or the current edition of the mechanical code, plumbing code, fire code, electrical code, boiler safety code, energy code, elevator code, or accessibility code, shall not be required to comply with any more restrictive requirement of this chapter.	Similar
Existing Buildings - Compliance Alternatives	3410.1	Compliance.	The provisions of this section are intended to maintain or increase the current degree of public safety, health and general welfare in existing buildings while permitting repair, alteration, addition and change of occupancy without requiring full compliance with Chapters 2 through 33, or Sections 3401.3, and 3403 through 3407, except where compliance with other provisions of this code is specifically required in this section.	Administration.	15.1.1.1	Purpose and Intent.	The purpose of this chapter is to encourage the continued use or reuse of legally existing buildings and structures. The intent of this chapter is to permit repairs, renovations, modifications, reconstructions, additions, and changes of use that maintain or improve the health, safety, and welfare of occupants in existing buildings, without requiring full compliance with the other sections of this Code, the mechanical code, plumbing code, fire code, electrical code, boiler safety code, energy code, elevator code, or accessibility code, except for proportional additional work as specified in this chapter.	Different-NFPA 5000 requires compliance with NFPA *101* Existing Building provisions.
				Not addressed	Not addressed	Not addressed		

Table K-2. Code Comparison of IFC and NFPA 1

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
	Chapter 1	Administration						
General	101.01	Title	These regulations shall be known as the Fire Code of [NAME OF JURISDICTION], hereinafter referred to as “this code."	Title	1.01.02	Title.	The title of this Code shall be NFPA 1, Uniform Fire Code™, of the National Fire Protection Association.	Similar
General	101.02	Scope.	This code establishes regulations affecting or relating to structures, processes, premises and safeguards regarding: 1. The hazard of fire and explosion arising from the storage, handling or use of structures, materials or devices; 2. Conditions hazardous to life, property or public welfare in the occupancy of structures or premises; 3. Fire hazards in the structure or on the premises from occupancy or operation; 4. Matters related to the construction, extension, repair, alteration or removal of fire suppression or alarm systems.	Scope	1.01.01		The scope includes, but is not limited to, the following: (1) Inspection of permanent and temporary buildings... (2) Investigation of fires ... (3) Review of design and construction plans, drawings, and specifications ...(4) Fire and life safety education ... (5) Existing occupancies and conditions, the design and construction of new buildings, remodeling of existing buildings, and additions to existing buildings (6) Design, alteration, modification, construction, maintenance, and testing of fire protection systems and equipment (7) ...(8) ...(9) Regulation and control of special events including, but not limited to, assemblage of people, exhibits, trade shows, amusement parks, haunted houses, outdoor events, and other similar special temporary and permanent occupancies (10) Interior finish, decorations, furnishings, and other combustibles that contribute to fire spread, fire load, and smoke production (11) ...(12) ... (13) ... (14) ...	Similar
General	101.03	Intent	The purpose of this code is to establish the minimum requirements consistent with nationally recognized good practice for providing a reasonable level of life safety and property protection from the hazards of fire, explosion or dangerous conditions in new and existing buildings, structures and premises and to provide safety to fire fighters and emergency responders during emergency operations.	Purpose	1.02	Purpose	The purpose of this Code is to prescribe minimum requirements necessary to establish a reasonable level of fire and life safety and property protection from the hazards created by fire, explosion, and dangerous conditions.	Similar
Applicability	102.01	Construction and design provisions.	The construction and design provisions of this code shall apply to: 1. Structures, facilities and conditions arising after the adoption of this code. 2. Existing structures, facilities and conditions not legally in existence at the time of adoption of this code. 3. Existing structures, facilities and conditions when identified in specific sections of this code. 4. Existing structures, facilities and conditions that, in the opinion of the code official, constitute a distinct hazard to life or property.	Application	1.03.01	Application	This Code shall apply to both new and existing conditions.	Similar, NFPA 1 applies to all existing buildings. IFC only applies if conditions 1 throught 4 exist.
				Occupancy	10.03.02		Existing buildings that are occupied at the time of adoption of this Code shall remain in use provided that the following conditions are met: (1) The occupancy classification remains the same. (2) No condition deemed hazardous to life or property exists that would constitute an imminent danger	Similar
Applicability	102.04	Application of building code	The design and construction of new structures shall comply with the *International Building Code.* Repairs, alterations and additions to existing structures shall comply with the *International*	Building Code	10.01.03	Building Code	Where a building code has been adopted, all new construction shall comply with this Code and with the building code adopted by the AHJ.	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
			Existing Building Code.					
General Authority and Responsibility	104.02	Applications and permits	The fire code official is authorized to receive applications, review construction documents and issue permits for construction regulated by this code, issue permits for operations regulated by this code, inspect the premises for which such permits have been issued and enforce compliance with the provisions of this code.	Permits and Approvals	1.12.01		The AHJ shall be authorized to establish and issue permits, certificates, notices, approvals, or orders pertaining to fire control and fire hazards pursuant to Section 1.12.	Similar
General Authority and Responsibility	104.03	Right of Entry	Whenever it is necessary to make an inspection to enforce the provisions of this code, or whenever the fire code official has reasonable cause to believe that there exists in a building or upon any premises any conditions or violations of this code which make the building or premises unsafe, dangerous or hazardous, the fire code official shall have the authority to enter the building or premises at all reasonable times to inspect or to perform the duties imposed upon the fire code official by this code. If such building or premises is occupied, the fire code official shall present credentials to the occupant and request entry. If such building or premises is unoccupied, the fire code official shall first make a reasonable effort to locate the owner or other person having charge or control of the building or premises and request entry. If entry is refused, the fire code official has recourse to every remedy provided by law to secure entry.	Inspection	1.07.05.03		To the full extent permitted by law, any AHJ engaged in fire prevention and inspection work shall be authorized at all reasonable times to enter and examine any building, structure, marine vessel, vehicle, or premises for the purpose of making fire safety inspections.	Similar
General Authority and Responsibility	104.03.01	Warrant	When the fire code official has first obtained a proper inspection warrant or other remedy provided by law to secure entry, an owner or occupant or person having charge, care or control of the building or premises shall not fail or neglect, after proper request is made as herein provided, to permit entry therein by the fire code official for the purpose of inspection and examination pursuant to this code.	Inspection	1.07.05.04		Before entering, the AHJ shall obtain the consent of the occupant thereof or obtain a court warrant authorizing entry for the purpose of inspection except in those instances where an emergency exists.	Similar
General Authority and Responsibility	104.04	Identification	The fire code official shall carry proper identification when inspecting structures or premises in the performance of duties under this code.	Inspection	1.07.05.06		Persons authorized to enter and inspect buildings, structures, marine vessels, vehicles, and premises as herein set forth shall be identified by credentials issued by the governing authority.	Similar
Permits	104.06.01	Approvals	A record of approvals shall be maintained by the fire code official and shall be available for public inspection during business hours in accordance with applicable laws.	Records and Reports	1.11.01		A record of examinations, approvals, equivalencies, and alternates shall be maintained by the AHJ and shall be available for public inspection during business hours in accordance with applicable laws.	Similar
Permits	104.06.02	Inspections.	The fire code official shall keep a record of each inspection made, including notices and orders issued, showing the findings and disposition of each.	Records and Reports	1.11.02		The AHJ shall keep a record of all fire prevention inspections, including the date of such inspections and a summary of any violations found to exist, the date of the services of notices, and a record of the final disposition of all violations.	Similar
General Authority and	104.06.04	Administrative	Application for modification, alternative methods or materials and the final decision of the fire code	Equivalencies, Alternatives, and	1.4.1	Equivalencies	Nothing in this Code is intended to prevent the use of systems, methods, or devices of equivalent or	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
Responsibility			official shall be in writing and shall be officially recorded in the permanent records of the fire code official.	Modifications			superior quality, strength, fire resistance, effectiveness, durability, and safety to those prescribed by this Code, provided technical documentation is submitted to the AHJ to demonstrate equivalency and the system, method, or device is approved for the intended purpose.	
Permits	105.01.01	Permits required	Permits required by this code shall be obtained from the fire code official. Permit fees, if any, shall be paid prior to issuance of the permit. Issued permits shall be kept on the premises designated therein at all times and shall be readily available for inspection by the fire code official.	Permits and Approvals	1.12.02.01		Applications for permits shall be accompanied by such data as required by the AHJ and fees as required by the jurisdiction.	Similar
Permits	105.02	Application	Application for a permit required by this code shall be made to the fire code official in such form and detail as prescribed by the fire code official. Applications for permits shall be accompanied by such plans as prescribed by the fire code official.	Permits and Approvals	1.12.02		Applications for permits shall be made to the AHJ on forms provided by the jurisdiction and shall include the applicant's answers in full to inquiries set forth on such forms.	Similar
Permits	105.02.04	Action on application	The fire code official shall examine or cause to be examined applications for permits and amendments hereto within a reasonable time after filing. If the application or the construction documents do not conform to the requirements of pertinent laws, the fire code official shall reject such application in writing, stating the reasons therefore. If the fire code official is satisfied that the proposed work or operation conforms to the requirements of this code and laws and ordinances applicable thereto, the fire code official shall issue a permit therefore as soon as practicable.	Permits and Approvals	1.12.02.02		The AHJ shall review all applications submitted and issue permits as required.	Similar
				Permits and Approvals	1.12.02.03		If an application for a permit is rejected by the AHJ, the applicant shall be advised of the reasons for such rejection.	Similar
Conditions of Permit	105.03.03	Occupancy prohibited before approval	The building or structure shall not be occupied prior to the fire code official issuing a permit that indicates that applicable provisions of this code have been met.	Occupancy	10.03.01		No new construction or existing building shall be occupied in whole or in part in violation of the provisions of this Code.	Similar
Permits	105.06	Required operational permits.	The fire code official is authorized to issue operational permits for the operations set forth in Sections 105.6.1 through 105.6.47.	Permits and Approvals.	1.12.19		Permits shall be required in accordance with Table 1.12.19(a).	Similar
Permits	105.06.37	Pyrotechnic special effects material.	An operational permit is required for use and handling of pyrotechnic special effects material.	Display Fireworks	65.02.03	Permits.	Permits, where required, shall comply with 1.12.19.	Similar
Inspections.	106.01	Inspection authority.	The fire code official is authorized to enter and examine any building, structure, marine vessel, vehicle or premises in accordance with Section 104.3 for the purpose of enforcing this code.	Inspection	1.07.05.03		To the full extent permitted by law, any AHJ engaged in fire prevention and inspection work shall be authorized at all reasonable times to enter and examine any building, structure, marine vessel, vehicle, or premises for the purpose of making fire safety inspections.	Similar
Inspections	106.02	Inspections.	The fire code official is authorized to conduct such inspections as are deemed necessary to determine the extent of compliance with the provisions of this code and to approve reports of inspection by approved agencies or individuals. All reports of such inspections shall be prepared	Inspection	1.07.05.01		The AHJ shall be authorized to inspect, at all reasonable times, any building or premises for dangerous or hazardous conditions or materials as set forth in this Code.	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
			and submitted in writing for review and approval. Inspection reports shall be certified by a responsible officer of such approved agency or by the responsible individual. The fire code official is authorized to engage such expert opinion as deemed necessary to report upon unusual, detailed or complex technical issues subject to the approval of the governing body.					
Inspections	106.03	Concealed work	Whenever any installation subject to inspection prior to use is covered or concealed without having first been inspected, the fire code official shall have the authority to require that such work be exposed for inspection.	Inspection of Construction and Installation	1.07.11.02		Whenever any installation subject to inspection prior to use is covered or concealed without having first been inspected, the AHJ shall have the authority to require that such work be exposed for inspection.	Similar
Maintenance	107.02.01	Test and inspection records	Required test and inspection records shall be available to the fire code official at all times or such records as the fire code official designates shall be filed with the fire code official.	Owner/Occupant Responsibilities	10.02.02		The AHJ shall be permitted to require the owner, operator, or occupant to provide tests or test reports, without expense to the AHJ, as proof of compliance with the intent of this Code.	Similar
Maintenance	107.02.02	Reinspection and testing	Where any work or installation does not pass an initial test or inspection, the necessary corrections shall be made so as to achieve compliance with this code. The work or installation shall then be resubmitted to the fire code official for inspection and testing.	Owner/Occupant Responsibilities	10.02.03		The owner, operator, or occupant of a building that is deemed unsafe by the AHJ shall abate, through corrective action approved by the AHJ, the condition causing the building to be unsafe either by repair, rehabilitation, demolition, or other corrective action approved by the AHJ.	Similar
Maintenance	107.05	Owner/Occupant responsibility	Correction and abatement of violations of this code shall be the responsibility of the owner. If an occupant creates, or allows to be created, hazardous conditions in violation of this code, the occupant shall be held responsible for the abatement of such hazardous conditions.	Owner/Occupant Responsibilities	10.02.01		The owner, operator, or occupant shall be responsible for compliance with this Code.	Similar
Violations	109.02	Notice of violation	When the fire code official finds a building, premises, vehicle, storage facility or outdoor area that is in violation of this code, the fire code official is authorized to prepare a written notice of violation describing the conditions deemed unsafe and, when compliance is not immediate, specifying a time for reinspection.	Notice of Violations and Penalties	1.16.01		Whenever the AHJ determines violations of this Code, a written notice shall be issued to confirm such findings.	Similar
Violations	109.02.01	Service	A notice of violation issued pursuant to this code shall be served upon the owner, operator, occupant, or other person responsible for the condition or violation, either by personal service, mail, or by delivering the same to, and leaving it with, some person of responsibility upon the premises. For unattended or abandoned locations, a copy of such notice of violation shall be posted on the premises in a conspicuous place at or near the entrance to such premises and the notice of violation shall be mailed by certified mail with return receipt requested or a certificate of mailing, to the last known address of the owner, occupant or both.	Serving Notice	1.16.02.01		Any order or notice issued pursuant to this Code shall be served upon the owner, operator, occupant, or other person responsible for the condition or violation, either by personal service, by mail, or by delivering the same to, and leaving it with, some person of responsibility upon the premises.	Similar
Violations	109.02.03	Prosecution of violations	If the notice of violation is not complied with promptly, the fire code official is authorized to request the legal counsel of the jurisdiction to institute the appropriate legal proceedings at law	Serving Notice	1.16.04		Any person who fails to comply with the provisions of this Code or who fails to carry out an order made pursuant of this Code or violates any condition attached to a permit, approval, or certificate shall	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
			or in equity to restrain, correct or abate such violation or to require removal or termination of the unlawful occupancy of the structure in violation of the provisions of this code or of the order or direction made pursuant hereto.				be subject to the penalties established by the jurisdiction.	
Violations	109.03	Violation penalties	Persons who shall violate a provision of this code or shall fail to comply with any of the requirements thereof or who shall erect, install, alter, repair or do work in violation of the approved construction documents or directive of the fire code official, or of a permit or certificate used under provisions of this code, shall be guilty of a [SPECIFY OFFENSE], punishable by a fine of not more than [AMOUNT] dollars or by imprisonment not exceeding [NUMBER OF DAYS], or both such fine and imprisonment. Each day that a violation continues after due notice has been served shall be deemed a separate offense.	Serving Notice	1.16.05		Failure to comply with the time limits of an abatement notice or other corrective notice issued by the AHJ shall result in each day that such violation continues being regarded as a new and separate offense.	Similar
Unsafe Buildings	110.01	General.	If during the inspection of a premises, a building or structure or any building system, in whole or in part, constitutes a clear and inimical threat to human life, safety or health, the fire code official shall issue such notice or orders to remove or remedy the conditions as shall be deemed necessary in accordance with this section and shall refer the building to the building department for any repairs, alterations, remodeling, removing or demolition required.	Inspection of Construction and Installation	1.07.11.03		When any construction or installation work is being performed in violation of the plans and specifications as approved by the AHJ, a written notice shall be issued to the responsible party to stop work on that portion of the work that is in violation.	Similar
Unsafe Buildings	110.01	General	If during the inspection of a premises, a building or structure or any building system, in whole or in part, constitutes a clear and inimical threat to human life, safety or health, the fire code official shall issue such notice or orders to remove or remedy the conditions as shall be deemed necessary in accordance with this section and shall refer the building to the building department for any repairs, alterations, remodeling, removing or demolition required.	Inspection	1.07.05.02		The AHJ shall have authority to order any person(s) to remove or remedy such dangerous or hazardous condition or material. Any person(s) failing to comply with such order shall be in violation of this Code.	Similar
				Inspection	1.07.06		Where conditions exist and are deemed hazardous to life and property by the AHJ, the AHJ shall have the authority to summarily abate such hazardous conditions that are in violation of this Code.	Similar
Unsafe Buildings	110.01.01	Unsafe conditions.	Structures or existing equipment that are or hereafter become unsafe or deficient because of inadequate means of egress or which constitute a fire hazard, or are otherwise dangerous to human life or the public welfare, or which involve illegal or improper occupancy or inadequate maintenance, shall be deemed an unsafe condition. A vacant structure, which is not secured against unauthorized entry as required by Section 311, shall be deemed unsafe.	Inspection	1.07.06		Where conditions exist and are deemed hazardous to life and property by the AHJ, the AHJ shall have the authority to summarily abate such hazardous conditions that are in violation of this Code.	Similar
Stop Work Order	111.01	Order	Whenever the fire code official finds any work regulated by this code being performed in a manner contrary to the provisions of this code or in a dangerous or unsafe manner, the fire code official is authorized to issue a stop work order.	Inspection of Construction and Installation	1.07.11.03		When any construction or installation work is being performed in violation of the plans and specifications as approved by the AHJ, a written notice shall be issued to the responsible party to stop work on that portion of the work that is in	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
							violation.	
Stop Work Order	111.02	Issuance	A stop work order shall be in writing and shall be given to the owner of the property, or to the owner's agent, or to the person doing the work. Upon issuance of a stop work order, the cited work shall immediately cease. The stop work order shall state the reason for the order, and the conditions under which the cited work is authorized to resume.	Inspection of Construction and Installation.	1.07.11.04		The notice shall state the nature of the violation, and no work shall be continued on that portion until the violation has been corrected.	Similar
	Chapter 2	Definitions.						
Occupancy Classification	202	Occupancy Classification	For the purposes of this code, certain occupancies are defined as follows: A-2 Assembly uses intended for food and/or drink consumption including, but not limited to: Banquet halls Night clubs Restaurants Taverns and bars.	Assembly Occupancy	3.03.138.02	Assembly Occupancy	An occupancy (1) used for a gathering of 50 or more persons for deliberation, worship, entertainment, eating, drinking, amusement, awaiting transportation, or similar uses; or (2) used as a special amusement building, regardless of occupant load. [101:3.3]	Similar
	Chapter 3	General Precautions Against Fire						
General	301.01	Scope.	The provisions of this chapter shall govern the occupancy and maintenance of all structures and premises for precautions against fire and the spread of fire. other approved means.	Fundamental Requirements	10.01.01		Every new and existing building or structure shall be constructed, arranged, equipped, maintained, and operated in accordance with this Code so as to provide a reasonable level of life safety, property protection, and public welfare from the actual and potential hazards created by fire, explosion, and other hazardous conditions.	Similar
Ignition Sources	305.01	Clearance from ignition sources.	Clearance between ignition sources, such as light fixtures, heaters and flame-producing devices, and combustible materials shall be maintained in an approved manner.	Permits	20.01.04.02	Open Flame Devices and Pyrotechnics	No open flame devices or pyrotechnic devices shall be used in any assembly occupancy, unless otherwise permitted by the following: (1) Pyrotechnic special effect devices shall be permitted to be used on stages before proximate audiences for ceremonial or religious purposes, as part of a demonstration in exhibits, or as part of a performance, provided that both of the following criteria are met: (a) Precautions satisfactory to the AHJ are taken to prevent ignition of any combustible material. (b) Use of the pyrotechnic device complies with NFPA 1126, Standard for the Use of Pyrotechnics before a Proximate Audience. (2) Flame effects before an audience shall be permitted in accordance with NFPA 160, Standard for Flame Effects Before an Audience. (3) Open flame devices shall be permitted to be used in the following situations, provided that precautions satisfactory to the AHJ are taken to prevent ignition of any combustible material or injury to occupants: (a)* For ceremonial or religious purposes (b) On stages and platforms where part of a performance...	Similar
Open Flames	308.01	General.	This section shall control open flames, fire and burning on all premises.	Permits	20.01.04.02	Open Flame Devices and Pyrotechnics	No open flame devices or pyrotechnic devices shall be used in any assembly occupancy, unless otherwise permitted by the following:(1) Pyrotechnic special effect devices shall be permitted to be used on stages before proximate audiences for	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
							ceremonial or religious purposes, as part of a demonstration in exhibits, or as part of a performance, provided that both of the following criteria are met: (a) Precautions satisfactory to the AHJ are taken to prevent ignition of any combustible material.(b) Use of the pyrotechnic device complies with NFPA 1126, Standard for the Use of Pyrotechnics before a Proximate Audience. (2) Flame effects before an audience shall be permitted in accordance with NFPA 160, Standard for Flame Effects Before an Audience. (3) Open flame devices shall be permitted to be used in the following situations, provided that precautions satisfactory to the AHJ are taken to prevent ignition of any combustible material or injury to occupants:(a)* For ceremonial or religious purposes(b) On stages and platforms where part of a performance...	
Open Flames	308.02	Where prohibited.	A person shall not take or utilize an open flame or light in a structure, vessel, boat or other place where highly flammable, combustible or explosive material is utilized or stored. Lighting appliances shall be well secured in a glass globe and wire mesh cage or a similar approved device.	General Fire Safety	10.1.5	Fundamental Requirements.	The AHJ shall have the authority to prohibit any or all open flames or other sources of ignition where circumstances make such conditions hazardous.	Similar
Open Flames	308.03	Open flame.	A person shall not utilize or allow to be utilized, an open flame in connection with a public meeting or gathering for purposes of deliberation, worship, entertainment, amusement, instruction, education, recreation, awaiting transportation or similar purpose in assembly or educational occupancies without first obtaining a permit in accordance with Section 105.6.	Permits	20.01.04.02	Open Flame Devices and Pyrotechnics	No open flame devices or pyrotechnic devices shall be used in any assembly occupancy, unless otherwise permitted by the following:(1) Pyrotechnic special effect devices shall be permitted to be used on stages before proximate audiences for ceremonial or religious purposes, as part of a demonstration in exhibits, or as part of a performance, provided that both of the following criteria are met: (a) Precautions satisfactory to the AHJ are taken to prevent ignition of any combustible material. (b) Use of the pyrotechnic device complies with NFPA 1126, Standard for the Use of Pyrotechnics before a Proximate Audience. (2) Flame effects before an audience shall be permitted in accordance with NFPA 160, Standard for Flame Effects Before an Audience. (3) Open flame devices shall be permitted to be used in the following situations, provided that precautions satisfactory to the AHJ are taken to prevent ignition of any combustible material or injury to occupants:(a)* For ceremonial or religious purposes (b) On stages and platforms where part of a performance...	Similar
Open Flames	308.03.02	Open-flame decorative devices.	'Open-flame decorative devices shall comply with all of the following restrictions: .... 4. The device or holder shall be designed so that it will return to the upright position after being tilted to an angle of 45 degrees from vertical. Exception: Devices	Permits	20.01.04.02	Open Flame Devices and Pyrotechnics	No open flame devices or pyrotechnic devices shall be used in any assembly occupancy, unless otherwise permitted by the following:(1) Pyrotechnic special effect devices shall be permitted to be used on stages before proximate audiences for	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
			that self-extinguish if tipped over and do not spill fuel or wax at the rate of more than 0.25 teaspoon per minute (1.26 ml per minute) if tipped over. 5. The flame shall be enclosed except where openings on the side are not more than 0.375 inch (9.5mm) diameter or where openings are on the top and the distance to the top is such that a piece of tissue paper placed on the top will not ignite in 10 seconds. 6. Chimneys shall be made of noncombustible materials and securely attached to the open-flame device. Exception: A chimney is not required to be attached to any open-flame device that will self-extinguish if the device is tipped over. 7. Fuel canisters shall be safely sealed for storage. ... 9. Shades, where used, shall be made of noncombustible materials and securely attached to the open-flame device holder or chimney. 10. Candelabras with flame-lighted candles shall be securely fastened in place to prevent overturning, and shall be located away from occupants using the area and away from possible contact with drapes, curtains or other combustibles.				ceremonial or religious purposes, as part of a demonstration in exhibits, or as part of a performance, provided that both of the following criteria are met: (a) Precautions satisfactory to the AHJ are taken to prevent ignition of any combustible material.(b) Use of the pyrotechnic device complies with NFPA 1126, Standard for the Use of Pyrotechnics before a Proximate Audience. (2) Flame effects before an audience shall be permitted in accordance with NFPA 160, Standard for Flame Effects Before an Audience. (3) Open flame devices shall be permitted to be used in the following situations, provided that precautions satisfactory to the AHJ are taken to prevent ignition of any combustible material or injury to occupants:(a)* For ceremonial or religious purposes(b) On stages and platforms where part of a performance...	
Open Flames	308.03.03	Location near combustibles.	Open flames such as from candles, lanterns, kerosene heaters, and gas-fired heaters shall not be located on or near decorative material or similar combustible materials.	Permits	20.01.04.02	Open Flame Devices and Pyrotechnics	No open flame devices or pyrotechnic devices shall be used in any assembly occupancy, unless otherwise permitted by the following:(1) Pyrotechnic special effect devices shall be permitted to be used on stages before proximate audiences for ceremonial or religious purposes, as part of a demonstration in exhibits, or as part of a performance, provided that both of the following criteria are met: (a) Precautions satisfactory to the AHJ are taken to prevent ignition of any combustible material. (b) Use of the pyrotechnic device complies with NFPA 1126, Standard for the Use of Pyrotechnics before a Proximate Audience. (2) Flame effects before an audience shall be permitted in accordance with NFPA 160, Standard for Flame Effects Before an Audience. (3) Open flame devices shall be permitted to be used in the following situations, provided that precautions satisfactory to the AHJ are taken to prevent ignition of any combustible material or injury to occupants:(a)* For ceremonial or religious purposes (b) On stages and platforms where part of a performance...	Similar
Open Flames	308.03.07	Group A occupancies.	Open-flame devices shall not be used in a Group A occupancy. Exceptions: 1. Open-flame devices are allowed to be used in the following situations, provided approved precautions are taken to prevent ignition of a combustible material or injury to occupants: 1.1. Where necessary for ceremonial or religious purposes in accordance	Permits	20.01.04.02	Open Flame Devices and Pyrotechnics	No open flame devices or pyrotechnic devices shall be used in any assembly occupancy, unless otherwise permitted by the following:(1) Pyrotechnic special effect devices shall be permitted to be used on stages before proximate audiences for ceremonial or religious purposes, as part of a demonstration in exhibits, or as part of a	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
			with Section 308.3.5. 1.2. On stages and platforms as a necessary part of a performance in accordance with Section 308.3.6. 1.3. Where candles on tables are securely supported on substantial noncombustible bases and the candle flames are protected. 2. Heat-producing equipment complying with Chapter 6 and the International Mechanical Code. 3. Gas lights are allowed to be used provided adequate precautions satisfactory to the fire code official are taken to prevent ignition of combustible materials.				performance, provided that both of the following criteria are met: (a) Precautions satisfactory to the AHJ are taken to prevent ignition of any combustible material.(b) Use of the pyrotechnic device complies with NFPA 1126, Standard for the Use of Pyrotechnics before a Proximate Audience. (2) Flame effects before an audience shall be permitted in accordance with NFPA 160, Standard for Flame Effects Before an Audience. (3) Open flame devices shall be permitted to be used in the following situations, provided that precautions satisfactory to the AHJ are taken to prevent ignition of any combustible material or injury to occupants:(a)* For ceremonial or religious purposes(b) On stages and platforms where part of a performance...	
Open Flames	308.05	Open-flame devices.	Torches and other devices, machines or processes liable to start or cause fire shall not be operated or used in or upon hazardous fire areas, except by a permit in accordance with Section 105.6 secured from the fire code official. Exception: Use within inhabited premises or designated campsites which are a minimum of 30 feet (9144 mm) from grass-, grain-, brush- or forest-covered areas.	Permits	20.01.04.02	Open Flame Devices and Pyrotechnics	No open flame devices or pyrotechnic devices shall be used in any assembly occupancy, unless otherwise permitted by the following:(1) Pyrotechnic special effect devices shall be permitted to be used on stages before proximate audiences for ceremonial or religious purposes, as part of a demonstration in exhibits, or as part of a performance, provided that both of the following criteria are met: (a) Precautions satisfactory to the AHJ are taken to prevent ignition of any combustible material. (b) Use of the pyrotechnic device complies with NFPA 1126, Standard for the Use of Pyrotechnics before a Proximate Audience. (2) Flame effects before an audience shall be permitted in accordance with NFPA 160, Standard for Flame Effects Before an Audience. (3) Open flame devices shall be permitted to be used in the following situations, provided that precautions satisfactory to the AHJ are taken to prevent ignition of any combustible material or injury to occupants:(a)* For ceremonial or religious purposes (b) On stages and platforms where part of a performance...	Similar
Indoor Displays	314.03	Highly combustible goods.	The display of highly combustible goods, including but not limited to fireworks, flammable or combustible liquids, liquefied flammable gases, oxidizing materials, pyroxylin plastics and agricultural goods, in main exit access aisles, corridors, covered malls, or within 5 feet (1524 mm) of entrances to exits and exterior exit doors is prohibited when a fire involving such goods would rapidly prevent or obstruct egress.	Operating Features	20.1.4.3.3	Furnishings, Decorations, and Scenery	Furnishings or decorations of an explosive or highly flammable character shall not be used.	Similar
	Chapter 4	Emergency Planning and Preparedness						
Public Assemblages and Events	403.01	General.	When, in the opinion of the fire code official, it is essential for public safety in a place of assembly or any other place where people congregate,	Standby fire personnel	1.7.13.1	Not addressed	The AHJ shall have the authority to require standby fire personnel or an approved fire watch when potentially hazardous conditions or a	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
			because of the number of persons, or the nature of the performance, exhibition, display, contest or activity, the owner, agent or lessee shall provide one or more firewatch personnel, as required and approved, to remain on duty during the times such places are open to the public, or when such activity is being conducted. The fire watch personnel shall keep diligent watch for fires, obstructions to means of egress and other hazards during the time such place is open to the public or such activity is being conducted and take prompt measures for remediation of hazards, extinguishment of fires that occur and assist in the evacuation of the public from the structures.				reduction in a life safety feature exist due to the type of performance, display, exhibit, occupancy, contest or activity, an impairment to a fire protection feature, or the number of persons present.	
Public Assemblages and Events	403.01.02	Contents.	The public safety plan, where required by Section 403.1.1, shall address such items as emergency vehicle ingress and egress, fire protection, emergency medical services, public assembly areas and the directing of both attendees and vehicles (including the parking of vehicles), vendor and food concession distribution, and the need for the presence of law enforcement, and fire and emergency medical services personnel at the event.	Emergency Plans	10.9.2	Plan Requirements	Emergency plans shall be developed in accordance with NFPA 1600, Standard on Disaster/Emergency Management and Business Continuity Programs, and shall include the procedures for reporting of emergencies; occupant and staff response to emergencies; the type and coverage of building fire protection systems; and other items required by the AHJ.	Similar
Fire Safety and Evacuation Plans	404.01	General.	Fire safety and evacuation plans shall comply with the requirements of this section.	Emergency Plans	10.9.1	Where Required	Emergency plans shall be provided for high-rise, health care, ambulatory health care, residential board and care, assembly, day care centers, special amusement buildings, detention and correctional occupancies, underground and windowless structures, facilities storing or handling materials covered by Chapter 20, or where required by the AHJ.	Similar
Fire Safety and Evacuation Plans	404.02	Where required.	An approved fire safety and evacuation plan shall be prepared and maintained for the following occupancies and buildings. 1. Group A, other than Group A occupancies used exclusively for purposes of religious worship that have an occupant load less than 2,000. 2. Group E. 3. Group H. 4. Group I. 5. Group R-1. 6. Group R-4. 7. High-rise buildings. 8. Group M buildings having an occupant load of 500 or more persons or more than 100 persons above or below the lowest level of exit discharge. 9. Covered malls exceeding 50,000 square feet (4645 m2) in aggregate floor area. 10. Underground buildings. 11. Buildings with an atrium and having an occupancy in Group A, E or M.	Where Required	10.09.01	Where Required	Emergency plans shall be provided for high-rise, health care, ambulatory health care, residential board and care, assembly, day care centers, special amusement buildings, detention and correctional occupancies, underground and windowless structures, facilities storing or handling materials covered by Chapter 20, or where required by the AHJ.	Similar
Fire Safety and Evacuation Plans	404.03	Contents.	Fire safety and evacuation plan contents shall be in accordance with Sections 404.3.1 and 404.3.2.	Plan Requirements	10.09.02	Plan Requirements	Emergency plans shall be developed in accordance with NFPA 1600, Standard on Disaster/Emergency Management and Business Continuity Programs, and shall include the procedures for reporting of emergencies; occupant and staff response to emergencies; the type and coverage of building fire	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
							protection systems; and other items required by the AHJ.	
Fire Safety and Evacuation Plans	404.03.01	Fire evacuation plans.	Fire evacuation plans shall include the following: 1. Emergency egress or escape routes and whether evacuation of the building is to be complete or, where approved, by selected floors or areas only. 2. Procedures for employees who must remain to operate critical equipment before evacuating. 3. Procedures for accounting for employees and occupants after evacuation has been completed. 4. Identification and assignment of personnel responsible for rescue or emergency medical aid. 5. The preferred and any alternative means of notifying occupants of a fire or emergency. 6. The preferred and any alternative means of reporting fires and other emergencies to the fire department or designated emergency response organization. 7. Identification and assignment of personnel who can be contacted for further information or explanation of duties under the plan. 8. A description of the emergency voice/alarm communication system alert tone and preprogrammed voice messages, where provided.	Emergency Plans	10.9.2	Plan Requirements.	Emergency plans shall be developed in accordance with NFPA 1600, Standard on Disaster/Emergency Management and Business Continuity Programs, and shall include the procedures for reporting of emergencies; occupant and staff response to emergencies; the type and coverage of building fire protection systems; and other items required by the AHJ.	Similar
Fire Safety and Evacuation Plans	404.03.02	Fire safety plans.	Fire safety plans shall include the following: 1. The procedure for reporting a fire or other emergency. 2. The life safety strategy and procedures for notifying, relocating, or evacuating occupants. 3. Site plans indicating the following: 3.1. The occupancy assembly point. 3.2. The locations of fire hydrants. 3.3. The normal routes of fire department vehicle access. 4. Floor plans identifying the locations of the following: 4.1. Exits. 4.2. Primary evacuation routes. 4.3. Secondary evacuation routes. 4.4. Accessible egress routes. 4.5. Areas of refuge. 4.6. Manual fire alarm boxes. 4.7. Portable fire extinguishers. 4.8. Occupant-use hose stations. 4.9. Fire alarm annunciators and controls. 5. A list of major fire hazards associated with the normal use and occupancy of the premise. 6. Identification and assignment of personnel responsible for maintenance of systems and equipment installed to prevent or control fires. 7. Identification and assignment of personnel responsible for maintenance, housekeeping and controlling fuel hazard sources.	Emergency Plans.	10.9.2	Plan Requirements	Emergency plans shall be developed in accordance with NFPA 1600, Standard on Disaster/Emergency Management and Business Continuity Programs, and shall include the procedures for reporting of emergencies; occupant and staff response to emergencies; the type and coverage of building fire protection systems; and other items required by the AHJ.	Similar
Fire Safety and Evacuation Plans	404.04	Maintenance.	Fire safety and evacuation plans shall be reviewed or updated annually or as necessitated by changes in staff assignments, occupancy, or the physical arrangement of the building.	Maintenance	10.09.02.02	Maintenance.	Emergency plans shall be reviewed and updated annually. Revised plans shall be submitted for review and updates shall be provided whenever changes are made in the occupancy or physical arrangement of the building or fire protection systems or features.	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
Fire Safety and Evacuation Plans	404.05	Availability.	Fire safety and evacuation plans shall be available in the workplace for reference and review by employees, and copies shall be furnished to the fire code official for review upon request.	Plan Requirements	10.09.02	Plan Requirements	Emergency plans shall be developed in accordance with NFPA 1600, Standard on Disaster/Emergency Management and Business Continuity Programs, and shall include the procedures for reporting of emergencies; occupant and staff response to emergencies; the type and coverage of building fire protection systems; and other items required by the AHJ.	Similar
Emergency Evacuation Drills	405.01	General.	Emergency evacuation drills complying with the provisions of this section shall be conducted in the occupancies listed in Section 404.2 or when required by the fire code official. Drills shall be designed in cooperation with the local authorities.	Where Required	10.06.01	Where Required	Emergency egress and relocation drills conforming to the provisions of this Code shall be conducted as specified by the provisions of Chapter 20 of this Code or Chapters 10 through 71 of NFPA 101®, Life Safety Code®, or by appropriate action of the AHJ. Drills shall be designed in cooperation with the local authorities. [101:4.7.1]	Similar
Emergency Evacuation Drills	405.02	Frequency.	Required emergency evacuation drills shall be held at the intervals specified in Table 405.2 or more frequently where necessary to familiarize all occupants with the drill procedure.	Drill Frequency	10.06.02	Drill Frequency	Emergency egress and relocation drills, where required by Chapter 20 of this Code or Chapters 10 through 71 of NFPA 101®, Life Safety Code®, or the AHJ, shall be held with sufficient frequency to familiarize occupants with the drill procedure and to establish conduct of the drill as a matter of routine. Drills shall include suitable procedures to ensure that all persons subject to the drill participate. [101:4.7.2]	Similar
Emergency Evacuation Drills	405.02	Table 0405.02.	FIRE AND EVACUATION DRILL FREQUENCY AND PARTICIPATIONGROUP OR OCCUPANCY - FREQUENCY PARTICIPATION Group A - Quarterly Employees Group E - Monthly All occupants Group I - Quarterly on each shift Employees Group R-1 - Quarterly on each shift Employees Group R-4 - Quarterly on each shift Employees. a. The frequency shall be allowed to be modified in accordance with Section 408.3.2 b. Fire and evacuation drills in residential care assisted living facilities shall include complete evacuation of the premises in accordance with Section 408.10.5. Where occupants receive habilitation or rehabilitation training, fire prevention and fire safety practices shall be included as part of the training program.	Drills	20.1.4.6	Drills	20.1.4.6.1 The employees or attendants of assembly occupancies shall be trained and drilled in the duties they are to perform in case of fire, panic, or other emergency to effect orderly exiting. [101:12.7.6.1; 101:13.7.6.1]20.1.4.6.2 Employees or attendants of assembly occupancies shall be instructed in the proper use of portable fire extinguishers and other manual fire suppression equipment where provided. [101:12.7.6.2; 101:13.7.6.2]	Similar
Emergency Evacuation Drills	405.03	Leadership.	Responsibility for the planning and conduct of drills shall be assigned to competent persons designated to exercise leadership.	Competency	10.06.03	Competency	Responsibility for the planning and conducting of drills shall be assigned only to competent persons qualified to exercise leadership.	Similar
Emergency Evacuation Drills	405.04	Time.	Drills shall be held at unexpected times and under varying conditions to simulate the unusual conditions that occur in case of fire.	Fire Drills	10.06.05	Simulated Conditions	Drills shall be held at expected and unexpected times and under varying conditions to simulate the unusual conditions that can occur in an actual emergency. [101:4.7.4]	Similar
Emergency	405.05	Record keeping.	. Records shall be maintained of required	Fire Drills	10.06.07		A written record of each drill shall be completed by	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
Evacuation Drills			emergency evacuation drills and include the following information: 1. Identity of the person conducting the drill. 2. Date and time of the drill. 3. Notification method used. 4. Staff members on duty and participating. 5. Number of occupants evacuated. 6. Special conditions simulated. 7. Problems encountered. 8. Weather conditions when occupants were evacuated. 9. Time required to accomplish complete evacuation.				the person responsible for conducting the drill and maintained in an approved manner. [101:4.7.6]	
Employee Training and Response Procedures	406.01	General.	Employees in the occupancies listed in Section 404.2 shall be trained in the fire emergency procedures described in their fire evacuation and fire safety plans. Training shall be based on these plans and as described in Section 404.3.	Operating Features	20.01.04.06.01	Drills	20.1.4.6.1 The employees or attendants of assembly occupancies shall be trained and drilled in the duties they are to perform in case of fire, panic, or other emergency to effect orderly exiting. [101:12.7.6.1; 101:13.7.6.1]	Similar
Employee Training and Response Procedures	406.02	Frequency.	Employees shall receive training in the contents of fire safety and evacuation plans and their duties as part of new employee orientation and at least annually thereafter. Records shall be kept and made available to the fire code official upon request.	Operating Features	20.01.04.06.01	Drills	20.1.4.6.1 The employees or attendants of assembly occupancies shall be trained and drilled in the duties they are to perform in case of fire, panic, or other emergency to effect orderly exiting. [101:12.7.6.1; 101:13.7.6.1]	Similar
Employee Training and Response Procedures	406.03	Employee training program.	Employees shall be trained in fire prevention, evacuation and fire safety in accordance with Sections 406.3.1 through 406.3.3.	Operating Features	20.01.04.06.01	Drills	20.1.4.6.1 The employees or attendants of assembly occupancies shall be trained and drilled in the duties they are to perform in case of fire, panic, or other emergency to effect orderly exiting. [101:12.7.6.1; 101:13.7.6.1]	Similar
Employee Training and Response Procedures	406.03.01	Fire prevention training.	Employees shall be apprised of the fire hazards of the materials and processes to which they are exposed. Each employee shall be instructed in the proper procedures for preventing fires in the conduct of their assigned duties.	Operating Features	20.01.04.06.01	Drills	20.1.4.6.1 The employees or attendants of assembly occupancies shall be trained and drilled in the duties they are to perform in case of fire, panic, or other emergency to effect orderly exiting. [101:12.7.6.1; 101:13.7.6.1]	Similar
Employee Training and Response Procedures	406.03.02	Evacuation training.	Employees shall be familiarized with the fire alarm and evacuation signals, their assigned duties in the event of an alarm or emergency, evacuation routes, areas of refuge, exterior assembly areas, and procedures for evacuation.	Operating Features	20.01.04.06.01	Drills	20.1.4.6.1 The employees or attendants of assembly occupancies shall be trained and drilled in the duties they are to perform in case of fire, panic, or other emergency to effect orderly exiting. [101:12.7.6.1; 101:13.7.6.1]	Similar
Employee Training and Response Procedures	406.03.03	Fire safety training.	Employees assigned fire-fighting duties shall be trained to know the locations and proper use of portable fire extinguishers or other manual fire-fighting equipment and the protective clothing or equipment required for its safe and proper use.	Operating Features	20.01.04.06.02	Drills	Employees or attendants of assembly occupancies shall be instructed in the proper use of portable fire extinguishers and other manual fire suppression equipment where provided. [101:12.7.6.2; 101:13.7.6.2]	Similar
Use and Occupancy-Related Requirements	408.02	Group A occupancies.	Group A occupancies shall comply with the requirements of Sections 408.2.1 and 408.2.2 and Sections 401 through 406.	Assembly Occupancies	20.01.01	Application	New and existing assembly occupancies shall comply with Section 20.1 and the referenced edition of NFPA 101.	Similar
Use and Occupancy-Related Requirements	408.02.01	Seating plan.	The fire safety and evacuation plans for assembly occupancies shall include the information required by Section 404.3 and a detailed seating plan, occupant load, and occupant load limit. Deviations from the approved plans shall be allowed provided the occupant load limit for the occupancy is not exceeded and the aisles and exit access ways remain unobstructed.	Emergency Plans.	10.9.2	Plan Requirements	Emergency plans shall be developed in accordance with NFPA 1600, Standard on Disaster/Emergency Management and Business Continuity Programs, and shall include the procedures for reporting of emergencies; occupant and staff response to emergencies; the type and coverage of building fire protection systems; and other items required by the AHJ.	Similar
Use and	408.02.02	Announcements	In theaters, motion picture theaters, auditoriums	Operating	20.01.04.06.03	Drills	In the following assembly occupancies, an audible	Similar

DRAFT

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
Occupancy-Related Requirements			and similar assembly occupancies in Group A used for noncontinuous programs, an audible announcement shall be made not more than 10 minutes prior to the start of each program to notify the occupants of the location of the exits to be used in the event of a fire or other emergency. Exception: In motion picture theaters, the announcement is allowed to be projected upon the screen in a manner approved by the fire code official.	Features			announcement shall be made, or a projected image shall be shown, prior to the start of each program that notifies occupants of the location of the exits to be used in case of a fire or other emergency: (1) Theaters (2) Motion picture theaters (3) Auditoriums (4) Other similar assembly occupancies with occupant loads exceeding 300 where there are noncontinuous programs [101:12.7.6.3; 101:13.7.6.3]	
	Chapter 8	Interior Finish, Decorative Materials and Furnishings						
General	801.01	Scope	The provisions of this chapter shall govern furniture and furnishings, interior finishes, interior trim, decorative materials and decorative vegetation in buildings. Sections 803, 804 and 805 shall be applicable to new and existing buildings. Section 806 shall be applicable to existing buildings.	General	12.01	General	This chapter shall apply to new, existing, permanent, or temporary buildings.	Similar
				Interior Finish	12.05	Interior Finish	Interior finish in buildings and structures shall meet the requirements of NFPA 101®, Life Safety Code®, and this Code.	Similar
				Furnishings, Contents, Decorations, and Treated Finishes	12.06	Furnishings, Contents, Decorations, and Treated Finishes	Furnishings, contents, decorations, and treated finishes in buildings and structures shall meet the requirements of NFPA 101®, Life Safety Code®, and this Code.	Similar
Furnishings	803.01	General requirements.	The provisions of Sections 803.1.1 through 803.1.3 shall be applicable to all occupancies covered by Sections 803.2 through 803.7.	Interior Finish	12.05	Interior Finish.	Interior finish in buildings and structures shall meet the requirements of NFPA 101®, Life Safety Code®, and this Code.	Similar
Furnishings	803.01.01	Explosive and highly flammable materials.	Furnishings or decorations of an explosive or highly flammable character shall not be used.	Furnishings, Decorations, and Scenery	20.01.04.03.03	Furnishings, Decorations, and Scenery	Furnishings or decorations of an explosive or highly flammable character shall not be used. [101:10.3.5]	Similar
Furnishings	803.02	Group A.	The requirements in Sections 803.2.1 and 803.2.2 shall apply to occupancies in Group A.	Operating Features	20.1.4.3.6	Furnishings, Decorations, and Scenery	Exposed foamed plastic materials and unprotected materials containing foamed plastic used for decorative purposes or stage scenery shall have a heat release rate not exceeding 100 kW where tested in accordance with UL 1975, Standard for Fire Tests for Foamed Plastics Used for Decorative Purposes.	Similar
Furnishings	803.02.01	Foam plastics.	Exposed foam plastic materials and unprotected materials containing foam plastic used for decorative purposes or stage scenery or exhibit booths shall have a maximum heat release rate of 100 kilowatts (kW) when tested in accordance with UL 1975. Exceptions: 1. Individual foam plastic items or items containing foam plastic where the foam plastic does not exceed 1 pound (0.45 kg) in weight. 2. Cellular or foam plastic shall be allowed for trim not in excess of 10 percent of the wall or ceiling area, provided it is not less than 20 pounds per cubic foot (320 kg per cubic meter) in density, is limited to 0.5 inch (12.7 mm) in thickness and 4 inches (102 mm) in width, and complies with the requirements for Class B interior wall and ceiling finish, except that the smoke-developed index shall not be limited. Egress width is maintained.	Furnishings, Decorations, and Scenery	20.01.04.03.06		Exposed foamed plastic materials and unprotected materials containing foamed plastic used for decorative purposes or stage scenery shall have a heat release rate not exceeding 100 kW where tested in accordance with UL 1975, Standard for Fire Tests for Foamed Plastics Used for Decorative Purposes. [101:12.7.3.3; 101:13.7.3.3]	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
Decorations and Trim	805.03	Foam plastics.	Foam plastic used as interior trim shall comply with Sections 805.3.1 through 805.3.4	Flame-Retardant Requirements	20.01.02.02		Foamed plastics (see definition of cellular or foamed plastic in 3.3.30 of NFPA 101) shall be permitted to be used only by specific approval of the AHJ. [101:12.4.5.11.2; 101:13.4.5.11.2]	Different
Interior Finish and Decorative Materials	806.01	General.	The provisions of this section shall limit the allowable flame spread and smoke development of interior finishes and decorative materials in existing buildings based on location and occupancy classification. Exceptions: 1. Materials having a thickness less than 0.036 inch (0.9 mm) applied directly to the surface of walls and ceilings. 2. Exposed portions of structural members complying with the requirements of buildings of Type IV construction in accordance with the International Building Code shall not be subject to interior finish requirements	Features of Fire Protection	12.5	Interior Finish	Interior finish in buildings and structures shall meet the requirements of NFPA 101®, Life Safety Code®, and this Code.	Similar. The NFPA 1 requirements cite NFPA 101 provisions which track closely with NFPA 5000.
Interior Finish and Decorative Materials	806.01.02	Foam plastics.	Cellular or foam plastics shall not be used as interior finish or trim. Exceptions: 1. Cellular or foam plastic materials shall be permitted on the basis of fire tests that substantiate their combustibility characteristics for the use intended under actual fire conditions. 2. Cellular or foam plastic shall be permitted for trim not in excess of 10 percent of the wall or ceiling area, provided such trim is not less than 20 pounds per cubic foot (320 kg/m3) in density, is limited to 0.5 inch (12.7 mm) in thickness and 8 inches (203 mm) in width, and complies with the requirements for Class A or B interior wall and ceiling finish except that the smoke rating shall not be limited.	Features of Fire Protection	12.5	Interior Finish	Interior finish in buildings and structures shall meet the requirements of NFPA 101®, Life Safety Code®, and this Code.	Similar
Interior Finish and Decorative Materials	806.01.03	Obstruction of means of egress.	No decorations or other objects shall be placed to obstruct exits, access thereto, egress there from, or visibility thereof.	Means of Egress Reliability	14.4.2.1	Furnishings and Decorations in Means of Egress	No furnishings, decorations, or other objects shall obstruct exits, access thereto, egress therefrom, or visibility thereof.	Similar. NFPA has processed a Tentative Interium Amendment requiring inspection of the means of egress everyday by facility staff.
Interior Finish and Decorative Materials	806.02	Wall and ceiling finish.	Interior wall and ceiling finishes shall be classified in accordance with Section 803 of the International Building Code. Such interior finishes shall be grouped in the following classes in accordance with their flame spread and smoke-developed index. Class A: Flame spread index 0-25 Smoke-developed index 0-450 Class B: Flame spread index 26-75 Smoke-developed index 0-450 Class C: Flame spread index 76-450 Smoke-developed index 0-450 Exception: Materials, other than textiles, tested in accordance with Section 806.2.1.	Features of Fire Protection	12.5	Interior Finish	Interior finish in buildings and structures shall meet the requirements of NFPA 101®, Life Safety Code®, and this Code.	Similar
Interior Finish	806.02.01	Interior wall and	Interior wall or ceiling finishes, other than textiles,	Features of Fire	12.5	Interior Finish	Interior finish in buildings and structures shall meet	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
and Decorative Materials		ceiling finishes other than textiles.	shall be permitted to be tested in accordance with NFPA 286. Finishes tested in accordance with NFPA 286 shall comply with Section 806.2.1.1.	Protection			the requirements of NFPA 101®, Life Safety Code®, and this Code.	
Interior Finish and Decorative Materials	806.02.01.01	Acceptance criteria.	During the 40 Kw exposure, the interior finish shall comply with Item 1. During the 160 Kw exposure, the interior finish shall comply with Item 2. During the entire test, the interior finish shall comply with Item 3. 1. During the 40 Kw exposure, flames shall not spread to the ceiling. 2. During the 160 Kw exposure, the interior finish shall comply with the following: 2.1. Flame shall not spread to the outer extremity of the sample on any wall or ceiling. 2.2. Flashover, as defined in NFPA 286, shall not occur. 3. The total smoke released throughout the NFPA 286 test shall not exceed 1,000 m2.	Features of Fire Protection	12.5	Interior Finish	Interior finish in buildings and structures shall meet the requirements of NFPA 101®, Life Safety Code®, and this Code.	Similar
Interior Finish and Decorative Materials	806.02.02	Stability.	Interior finish materials regulated by this chapter shall be applied or otherwise fastened in such a manner that such materials will not readily become detached when subjected to a room temperature of 200°F (93°C) for not less than 30 minutes.	Features of Fire Protection	12.5	Interior Finish.	Interior finish in buildings and structures shall meet the requirements of NFPA 101®, Life Safety Code®, and this Code.	Similar
Interior Finish and Decorative Materials	806.03	Wall and ceiling finish requirements.	Interior wall and ceiling finish shall have a flame spread index not greater than that specified in Table 806.3 for the group and location designated. Interior wall and ceiling finish materials, other than textiles, tested in accordance with NFPA 286 and meeting the acceptance criteria of Section 806.2.1.1, shall be permitted to be used where a Class A classification in accordance with ASTM E84 is required.	Features of Fire Protection	12.5	Interior Finish	Interior finish in buildings and structures shall meet the requirements of NFPA 101®, Life Safety Code®, and this Code.	Similar
	Chapter 9	Fire Protection Systems						
Fire Protection Systems	901.01	Scope.	The provisions of this chapter shall specify where fire protection systems are required and shall apply to the design, installation, inspection, operation, testing and maintenance of all fire protection systems.	General	12.01	General	This chapter shall apply to new, existing, permanent, or temporary buildings.	Similar
Fire Protection Systems	901.08	Removal of or tampering with equipment	It shall be unlawful for any person to remove, tamper with or otherwise disturb any fire hydrant, fire detection and alarm system, fire suppression system, or other fire appliance required by this code except for the purpose of extinguishing fire, training purposes, recharging or making necessary repairs, or when approved by the fire code official.	Tampering with Fire Safety Equipment	10.08.01		No person shall render any portable or fixed fire-extinguishing system or device or any fire warning system inoperative or inaccessible.	Similar
				Tampering with Fire Safety Equipment	10.08.01.01		As necessary during emergencies, maintenance, drills, prescribed testing, alterations, or renovations, portable or fixed fire-extinguishing systems or devices or any fire warning system shall be permitted to be made inoperative or inaccessible.	Similar
Automatic Sprinkler Systems	903.02	Where required.	Approved automatic sprinkler systems in new buildings and structures shall be provided in the locations described in this section. Exception: Spaces or areas in telecommunications buildings used exclusively for telecommunications equipment, associated electrical power distribution equipment, batteries and standby	Automatic Sprinklers	13.03.02.01	Where Required	Where required by this Code or the referenced codes and standards listed in Chapter 2, automatic sprinkler systems shall be installed in accordance with 13.3.1.	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
			engines, provided those spaces or areas are equipped throughout with an automatic fire alarm system and are separated from the remainder of the building by a wall with a fire-resistance rating of not less than 1 hour and a floor/ceiling assembly with a fire-resistance rating of not less than 2 hours.					
Automatic Sprinkler Systems	903.02.01	Group A.	An automatic sprinkler system shall be provided throughout buildings and portions thereof used as Group A occupancies as provided in this section. For Group A-1, A-2, A-3, and A-4 occupancies, the automatic sprinkler system shall be provided throughout the floor area where the Group A-1, A-2, A-3 or A-4 occupancy is located, and in all floors between the Group A occupancy and the level of exit discharge. For group A-5 occupancies, the automatic sprinkler system shall be provided in the spaces indicated in Section 903.2.1.5.	Automatic Sprinklers	13.03.02.04.01	New Assembly Occupancies	Buildings containing assembly occupancies with occupant loads of more than 300 shall be protected by an approved, supervised automatic sprinkler system in accordance with Section 9.7 of NFPA 101 as follows (see also 12.1.6, 12.2.6, 12.3.2, and 12.3.6 of NFPA 101): (1) Throughout the story containing the assembly occupancy (2) Throughout all stories below the story containing the assembly occupancy (3) In the case of an assembly occupancy located below the level of exit discharge, throughout all stories intervening between that story and the level of exit discharge, including the level of exit discharge [101:12.3.5.1]	Similar
Automatic Sprinkler Systems	903.02.01.02	Group A-2.	An automatic sprinkler system shall be provided for Group A-2 occupancies where one of the following conditions exists: 1. The fire area exceeds 5,000 square feet (464.5m2); 2. The fire area has an occupant load of 300 or more; or 3. The fire area is located on a floor other than the level of exit discharge.	Automatic Sprinklers	13.03.02.04.01	New Assembly Occupancies	Buildings containing assembly occupancies with occupant loads of more than 300 shall be protected by an approved, supervised automatic sprinkler system in accordance with Section 9.7 of NFPA 101 as follows (see also 12.1.6, 12.2.6, 12.3.2, and 12.3.6 of NFPA 101): (1) Throughout the story containing the assembly occupancy (2) Throughout all stories below the story containing the assembly occupancy (3) In the case of an assembly occupancy located below the level of exit discharge, throughout all stories intervening between that story and the level of exit discharge, including the level of exit discharge [101:12.3.5.1] NFPA has processed a Tentative Interium Amendment reduces the occupant load threshold from 300 persons to 100 persons.	Similar
Portable Fire Extinguishers	906.01	Where required.	Portable fire extinguishers shall be installed in the following locations. 1. In all Group A, B, E, F, H, I , M, R-1, R-2, R-4 and S occupancies. Exception: In all Group A, B and E occupancies equipped throughout with quick- response sprinklers, fire extinguishers shall be required only in special- hazard areas. 2. Within 30 feet (9144 mm) of commercial cooking equipment. 3. In areas where flammable or combustible liquids are stored, used or dispensed. 4. On each floor of structures under construction, except Group R-3 occupancies, in accordance with Section 1415.1. 5. Where required by the sections indicated in Table 906.1. 6. Special-hazard areas, including but not limited to laboratories,	Portable Extinguishers	13.06.01.02	Where Required.	Fire extinguishers shall be provided where required by this Code as specified in Table 13.6.1.2 and the referenced codes and standards listed in Chapter 2.	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
			computer rooms and generator rooms, where required by the fire code official.					
Portable Fire Extinguishers	906.02	General requirements.	Fire extinguishers shall be selected, installed and maintained in accordance with this section and NFPA 10. Exception: The travel distance to reach an extinguisher shall not apply to the spectator seating portions of Group A-5 occupancies.	Portable Extinguishers	13.06.01.01	General Requirements	The installation, maintenance, selection, and distribution of portable fire extinguishers shall be in accordance with NFPA 10, Standard for Portable Fire Extinguishers, and Section 13.6.	Similar
Portable Fire Extinguishers	906.03	Size and Distribution	For occupancies that involve primarily Class A fire hazards, the minimum sizes and distribution shall comply with Table 906.3(1). Fire extinguishers for occupancies involving flammable or combustible liquids with depths of less than or equal to 0.25-inch (6.35 mm) shall be selected and placed in accordance with Table 906.3(2). Fire extinguishers for occupancies involving flammable or combustible liquids with a depth of greater than 0.25-inch (6.35mm)or involving combustible metals shall be selected and placed in accordance with NFPA 10. Extinguishers for Class C fire hazards shall be selected and placed on the basis of the anticipated Class A or Class B hazard.	Distribution of Fire Extinguishers	13.06.06.02.01	Fire Extinguisher Size and Placement for Class A Hazards	Minimal sizes of fire extinguishers for the listed grades of hazards shall be provided on the basis of Table 13.6.6.2.1, except as modified by 13.6.6.2.2. Fire extinguishers shall be located so that the maximum travel distances shall not exceed those specified in Table 13.6.6.2.1, except as modified by 13.6.6.2.2. (See Annex E of NFPA 10.) [10:5.2.1]	Similar
				Distribution of Fire Extinguishers	13.06.06.03.01	Fire Extinguisher Size and Placement for Class B Fires Other Than for Fires in Flammable Liquids of Appreciable Depth	Minimal sizes of fire extinguishers for the listed grades of hazard shall be provided on the basis of Table 13.6.6.3.1. Fire extinguishers shall be located so that the maximum travel distances do not exceed those specified in the table used. (See Annex E of NFPA 10.) [10:5.3.1]	Similar
				Distribution of Fire Extinguishers	13.06.06.04.02	Fire Extinguisher Size and Placement for Class B Fires in Flammable Liquids of Appreciable Depth	For flammable liquid hazards of appreciable depth, a Class B fire extinguisher shall be provided on the basis of at least two numerical units of Class B extinguishing potential per ft2 (0.0929 m2) of flammable liquid surface of the largest hazard area. AFFF- or FFFP-type fire extinguishers shall be permitted to be provided on the basis of 1-B of protection per ft2 (0.09 m2) of hazard. (For fires involving cooking grease or water-soluble flammable liquids, see 13.6.5.3 and 4.3.4 of NFPA 10.) [10:5.4.2]	Similar
				Distribution of Fire Extinguishers	13.06.06.05	Fire Extinguisher Size and Placement for Class C Hazards	Fire extinguishers with Class C ratings shall be required where energized electrical equipment can be encountered. This requirement includes situations where fire either directly involves or surrounds electrical equipment. Since the fire itself is a Class A or Class B hazard, the fire extinguishers shall be sized and located on the basis of the anticipated Class A or Class B hazard. [10:5.5]	Similar
Portable Fire Extinguishers	906.03	Table 0906.03.	FIRE EXTINGUISHERS FOR CLASS A FIRE HAZARDS	Distribution of Fire Extinguishers.	13.6.6.2.1	Fire Extinguisher Size and Placement for Class A Hazards	Minimal sizes of fire extinguishers for the listed grades of hazards shall be provided on the basis of Table 13.6.6.2.1, except as modified by 13.6.6.2.2. Fire extinguishers shall be located so that the maximum travel distances shall not exceed those specified in Table 13.6.6.2.1, except as modified by 13.6.6.2.2. (See Annex E of NFPA 10.)	Similar
Portable Fire	906.05	Conspicuous	Extinguishers shall be located in conspicuous	Portable	13.06.03.03	General	Fire extinguishers shall be conspicuously located	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
Extinguishers		location.	locations where they will be readily accessible and immediately available for use. These locations shall be along normal paths of travel, unless the fire code official determines that the hazard posed indicates the need for placement away from normal paths of travel.	Extinguishers.		Requirements.	where they will be readily accessible and immediately available in the event of fire. Preferably, they shall be located along normal paths of travel, including exits from areas. [10:1.5.3]	
Portable Fire Extinguishers	906.06	Unobstructed and unobscured.	Fire extinguishers shall not be obstructed or obscured from view. In rooms or areas in which visual obstruction cannot be completely avoided, means shall be provided to indicate the locations of extinguishers.	Portable Extinguishers.	13.06.03.06	General Requirements	Fire extinguishers shall not be obstructed or obscured from view. In large rooms, and in certain locations where visual obstructions cannot be completely avoided, means shall be provided to indicate the extinguisher location. [10:1.5.6]	Similar
Portable Fire Extinguishers	906.07	Hangers and brackets.	Hand-held portable fire extinguishers, not housed in cabinets, shall be installed on the hangers or brackets supplied. Hangers or brackets shall be securely anchored to the mounting surface in accordance with the manufacturer's installation instructions.	Portable Extinguishers.	13.06.03.07	General Requirements	Portable fire extinguishers other than wheeled extinguishers shall be installed securely on the hanger, or in the bracket supplied by the extinguisher manufacturer, or in a listed bracket approved for such purpose, or placed in cabinets or wall recesses. Wheeled fire extinguishers shall be located in a designated location. [10:1.5.7]	Similar
Fire Alarm and Detection Systems	907.01	General.	This section covers the application, installation, performance and maintenance of fire alarm systems and their components in new and existing buildings and structures. The requirements of Section 907.2 are applicable to new buildings and structures. The requirements of Section 907.3 are applicable to existing buildings and structures.	Detection, Alarm, and Communication Systems	13.07.01.01	General	Where building fire alarm systems or automatic fire detectors are required by other sections of this Code, they shall be provided in accordance with NFPA 72®, National Fire Alarm Code® and Section 13.7.	Similar
Fire Alarm and Detection Systems	907.02	Where required-new buildings and structures.	An approved manual, automatic, or manual and automatic fire alarm system shall be provided in new buildings and structures in accordance with Sections 907.2.1 through 907.2.23. Where automatic sprinkler protection installed in accordance with Section 903.3.1.1 or 903.3.1.2 is provided and connected to the building fire alarm system, automatic heat detection required by this section shall not be required. An approved automatic fire detection system shall be installed in accordance with the provisions of this code and NFPA72. Devices, combinations of devices, appliances and equipment shall comply with Section 907.1.2. The automatic fire detectors shall be smoke detectors, except that an approved alternative type of detector shall be	Detection, Alarm, and Communication Systems	13.07.02.01	Where Required	New Assembly Occupancies. Assembly occupancies with occupant loads of more than 300 and all theaters with more than one audience-viewing room shall be provided with an approved fire alarm system in accordance with 13.7.1 of this Code and 12.3.4 of NFPA 101, unless otherwise permitted by the following: (1) Assembly occupancies that are a part of a multiple occupancy protected by a mixed occupancy (see 6.1.14 of NFPA 101) shall be permitted to be served by a common fire alarm system, provided that the individual requirements of each occupancy are met. (2) Voice communication or public address systems complying with 12.3.4.3.3 of NFPA 101 shall not be required to comply with 13.7.1.4 of the Code. [101:12.3.4.1]	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
			installed in spaces such as boiler rooms where, during normal operation, products of combustion are present in sufficient quantity to actuate a smoke detector.	Detection, Alarm, and Communication Systems	13.07.02.02	Where Required	Existing Assembly Occupancies. Assembly occupancies with occupant loads of more than 300 and all theaters with more than one audience-viewing room shall be provided with an approved fire alarm system in accordance with 13.7.1.4 of this Code and 13.3.4 of NFPA 101, unless otherwise permitted by the following: (1) Assembly occupancies that are a part of a multiple occupancy protected as a mixed occupancy (see 6.1.14 of NFPA 101) shall be permitted to be served by a common fire alarm system, provided that the individual requirements of each occupancy are met. (2) Voice communication or public address systems complying with 13.3.4.3.3 of NFPA 101 shall not be required to comply with 13.7.1.4 of this Code. (3) This requirement shall not apply to assembly occupancies where, in the judgment of the AHJ, adequate alternative provisions exist or are provided for the discovery of a fire and for alerting the occupants promptly. [101:13.3.4.1]	Similar
Fire Alarm and Detection Systems	907.02.01	Group A.	A manual fire alarm system shall be installed in accordance with NFPA 72 in Group A occupancies having an occupant load of 300 or more. Portions of Group E occupancies occupied for assembly purposes shall be provided with a fire alarm system as required for the Group E occupancy. Exception: Manual fire alarm boxes are not required where the building is equipped throughout with an automatic sprinkler system and the alarm notification appliances will activate upon sprinkler water flow.	Detection, Alarm, and Communication Systems	13.07.01.04.08.01	Signal Initiation	Where required by other sections of this Code, actuation of the complete fire alarm system shall occur by any or all of the following means of initiation, but shall not be limited to such means: (1) Manual fire alarm initiation(2) Automatic detection(3) Extinguishing system operation [101:9.6.2.1]	Similar
Fire Alarm and Detection Systems	907.03	Where required-retroactive in existing buildings and structures.	An approved manual, automatic or manual and automatic fire alarm system shall be installed in existing buildings and structures in accordance with Sections 907.3.1 through 907.3.1.8. Where automatic sprinkler protection is provided in accordance with Section 903.3.1.1 or 903.3.1.2 and connected to the building fire alarm system, automatic heat detection required by this section shall not be required. An approved automatic fire detection system shall be installed in accordance with the provisions of this code and NFPA 72. Devices, combinations of devices, appliances and equipment shall be approved. The automatic fire detectors shall be smoke detectors, except an approved alternative type of detector shall be installed in spaces such as boiler rooms where, during normal operation, products of combustion are present in sufficient quantity to actuate a smoke detector. fire alarm system shall be installed in existing Group R-1 boarding and rooming houses. Exception: Buildings that have single-station smoke alarms meeting or	Detection, Alarm, and Communication Systems	13.07.02.02	Where Required	Existing Assembly Occupancies. Assembly occupancies with occupant loads of more than 300 and all theaters with more than one audience-viewing room shall be provided with an approved fire alarm system in accordance with 13.7.1.4 of this Code and 13.3.4 of NFPA 101, unless otherwise permitted by the following: (1) Assembly occupancies that are a part of a multiple occupancy protected as a mixed occupancy (see 6.1.14 of NFPA 101) shall be permitted to be served by a common fire alarm system, provided that the individual requirements of each occupancy are met. (2) Voice communication or public address systems complying with 13.3.4.3.3 of NFPA 101 shall not be required to comply with 13.7.1.4 of this Code. (3) This requirement shall not apply to assembly occupancies where, in the judgment of the AHJ, adequate alternative provisions exist or are provided for the discovery of a fire and for alerting the occupants promptly. [101:13.3.4.1]	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
			exceeding the requirements of Section 907.2.10.1 and where the fire alarm system includes at least one manual fire alarm box per floor arranged to initiate the alarm.					
	Chapter 10	Means of Egress						
General	1001.01	General.	Buildings or portions thereof shall be provided with a means of egress system as required by this chapter. The provisions of this chapter shall control the design, construction and arrangement of means of egress components required to provide an approved means of egress from structures and portions thereof. Sections 1003 through 1025 shall apply to new construction. Sections 1026 and 1027 shall apply to existing buildings. Exception: Detached one- and two-family dwellings and multiple single-family dwellings (townhouses) not more than three stories above grade plane in height with a separate means of egress and their accessory structures shall comply with the International Residential Code.	Means of Egress	14.01	Application.	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
General	1001.02	Minimum requirements.	It shall be unlawful to alter a building or structure in a manner that will reduce the number of exits or the capacity of the means of egress to less than required by this code.	Number of Means of Egress	14.9.1.2	General.	The number of means of egress from any story or portion thereof, other than for existing buildings as permitted in Chapter 12 through Chapter 42 of NFPA 101, shall be as follows: (1) Occupant load more than 500 but not more than 1000 - not less than 3(2) Occupant load more than 1000 - not less than 4	Similar
General Means of Egress	1003.01	Applicability.	The general requirements specified in Sections 1003 through 1012 shall apply to all three elements of the means of egress system, in addition to those specific requirements for the exit access, the exit and the exit discharge detailed elsewhere in this chapter.	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
General Means of Egress	1003.03	Protruding objects.	Protruding objects shall comply with the requirements of Sections 1003.3.1 through 1003.3.4.	Means of Egress	14.4.1	Means of Egress Reliability	Means of egress shall be continuously maintained free of all obstructions or impediments to full instant use in the case of fire or other emergency.	Similar
General Means of Egress	1003.03.02	Free-standing objects.	A free-standing object mounted on a post or pylon shall not overhang that post or pylon more than 12 inches (305 mm) where the lowest point of the leading edge is more than 27 inches (686mm) and less than 80 inches (2032 mm) above the walking surface. Where a sign or other obstruction is mounted between posts or pylons and the clear distance between the posts or pylons is greater than 12 inches (305 mm), the lowest edge of such sign or obstruction shall be 27 inches (685 mm) maximum or 80 inches (2030 mm) minimum above the finish floor or ground. Exception: This requirement shall not apply to sloping portions of handrails serving stairs and ramps.	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
General Means of	1003.03.03	Horizontal projections.	Structural elements, fixtures or furnishings shall not project horizontally from either side more	Capacity of Means of Egress	14.8.2.2	Measurement of Means of	Projections within the means of egress of not more than 4½ in. (114 mm) on each side shall be	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
Egress			than 4 inches (102 mm) over any walking surface between the heights of 27 inches (686 mm) and 80 inches (2032 mm) above the walking surface. Exception: Handrails serving stairs and ramps are permitted to protrude 4.5 inches (114 mm) from the wall.			Egress	permitted at a height of 38 in. (965 mm) and below.	
General Means of Egress	1003.04	Floor surface.	Walking surfaces of the means of egress shall have a slip-resistant surface and be securely attached.	Means of Egress	14.1	Application.	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
General Means of Egress	1003.05	Elevation change.	Where changes in elevation of less than 12 inches (305 mm) exist in the means of egress, sloped surfaces shall be used. Where the slope is greater than one unit vertical in 20 units horizontal (5-percent slope), ramps complying with Section 1010 shall be used. Where the difference in elevation is 6 inches (152 mm) or less, the ramp shall be equipped with either handrails or floor finish materials that contrast with adjacent floor finish materials. Exceptions: 1. ... 2. A stair with a single riser or with two risers and a tread is permitted at locations not required to be accessible by Chapter 11 of the International Building Code, provided that the risers and treads comply with Section 1009.3, the minimum depth of the tread is 13 inches (330 mm) and at least one handrail complying with Section 1009.11 is provided within 30 inches (762 mm) of the centerline of the normal path of egress travel on the stair. 3. ...	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Occupant Load	1004.01	Design occupant load.	In determining means of egress requirements, the number of occupants for whom means of egress facilities shall be provided shall be established by the largest number computed in accordance with Sections 1004.1.1 through 1004.1.3.	Capacity of Means of Egress	14.08.01.02	Occupant Load Factor	The occupant load in any building or portion thereof shall be not less than the number of persons determined by dividing the floor area assigned to that use by the occupant load factor for that use as specified in Table 14.8.1.2 and Figure 14.8.1.2. Where both gross and net area figures are given for the same occupancy, calculations shall be made by applying the gross area figure to the gross area of the portion of the building devoted to the use for which the gross area figure is specified and by applying the net area figure to the net area of the portion of the building devoted to the use for which the net area figure is specified. [101:7.3.1.2]	Similar
Occupant Load	1004.01.01	Actual number.	The actual number of occupants for whom each occupied space, floor or building is designed.	Occupant Load.	14.8.1.2	Occupant Load Factor.	The occupant load in any building or portion thereof shall be not less than the number of persons determined by dividing the floor area assigned to that use by the occupant load factor for that use as specified in Table 14.8.1.2 and Figure 14.8.1.2. Where both gross and net area figures are given for the same occupancy, calculations shall be made by applying the gross area figure to the gross area of the portion of the building devoted to the use for which the gross area figure is specified and by applying the net area figure to the net area of the portion of the building devoted to the use for which	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
							the net area figure is specified.	
Occupant Load	1004.01.02	Number by Table 1004.1.2.	The number of occupants computed at the rate of one occupant per unit of area as prescribed in Table 1004.1.2.	Capacity of Means of Egress	14.08.01.02	Occupant Load Factor	The occupant load in any building or portion thereof shall be not less than the number of persons determined by dividing the floor area assigned to that use by the occupant load factor for that use as specified in Table 14.8.1.2 and Figure 14.8.1.2. Where both gross and net area figures are given for the same occupancy, calculations shall be made by applying the gross area figure to the gross area of the portion of the building devoted to the use for which the gross area figure is specified and by applying the net area figure to the net area of the portion of the building devoted to the use for which the net area figure is specified. [101:7.3.1.2]	Similar. The IFC factor for standing space is smaller than the NFPA 1 factor.
Occupant Load	1004.03	Posting of occupant load.	Every room or space that is an assembly occupancy shall have the occupant load of the room or space posted in a conspicuous place, near the main exit or exit access doorway from the room or space. Posted signs shall be of an approved legible permanent design and shall be maintained by the owner or authorized agent.	Occupant Load Posting	20.01.04.08.03.01		Every room constituting an assembly occupancy and not having fixed seats shall have the occupant load of the room posted in a conspicuous place near the main exit from the room. [101:12.7.8.3.1; 101:13.7.8.3.1]	Similar
				Occupant Load Posting	20.01.04.08.03.02		Approved signs shall be maintained in a legible manner by the owner or authorized agent. [101:12.7.8.3.2; 101:13.7.8.3.2]	Similar
				Occupant Load Posting	20.01.04.08.03.03		Signs shall be durable and shall indicate the number of occupants permitted for each room use. [101:12.7.8.3.3; 101:13.7.8.3.3]	Similar
Egress Width	1005.01	Minimum required egress width.	The means of egress width shall not be less than required by this section. The total width of means of egress in inches (mm) shall not be less than the total occupant load served by the means of egress multiplied by the factors in Table 1005.1 and not less than specified elsewhere in this code. Multiple means of egress shall be sized such that the loss of any one means of egress shall not reduce the available capacity to less than 50 percent of the required capacity. The maximum capacity required from any story of a building shall be maintained to the termination of the means of egress. Exception: Means of egress complying with Section 1024.	Capacity of Means of Egress	14.08.03.03.01	Minimum Width	The width of any means of egress, unless otherwise provided in 14.8.3.3.1.1 through 14.8.3.3.1.3, shall be as follows: (1) Not less than that required for a given egress component in Chapter 7 or Chapter 12 through Chapter 42 of NFPA 101 (2) Not less than 36 in. (915 mm) [101:7.3.4.1]	Similar
Egress Width	1005.01	Table 1005.1.	EGRESS WIDTH PER OCCUPANT SERVED	Egress Capacity	TABLE 14.8.3.1	Capacity Factors		Similar. For non sprinkler protected buildings the factors are the same. For sprinkler protected buildings IFC allows a increase in the number of persons per inch.
Means of	1006.01	Illumination	The means of egress, including the exit	Illumination of	14.12.01.02	General	Illumination of means of egress shall be continuous	Similar

DRAFT

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
Egress Illumination		required.	discharge, shall be illuminated at all times the building space served by the means of egress is occupied. Exceptions: 1. Occupancies in Group U. 2. Aisle accessways in Group A. 3. Dwelling units and sleeping units in Groups R-1, R-2 and R-3. 4. Sleeping units of Group I occupancies.	Means of Egress			during the time that the conditions of occupancy require that the means of egress be available for use, unless otherwise provided in 14.12.1.2.2. [101:7.8.1.2]	
Means of Egress Illumination	1006.02	Illumination level.	The means of egress illumination level shall not be less than 1 foot-candle (11 lux) at the floor level. Exception: For auditoriums, theaters, concert or opera halls and similar assembly occupancies, the illumination at the floor level is permitted to be reduced during performances to not less than 0.2 foot-candle (2.15 lux) provided that the required illumination is automatically restored upon activation of a premise's fire alarm system where such system is provided.	Illumination of Means of Egress	14.12.01.03	General	The floors and other walking surfaces within an exit and within the portions of the exit access and exit discharge designated in 14.12.1.1 shall be illuminated as follows: (1) During conditions of stair use, the minimum illumination for new stairs shall be at least 10 ft-candle (108 lux), measured at the walking surfaces.(2) The minimum illumination for floors and walking surfaces, other than new stairs, shall be to values of at least 1 ft-candle (10.8 lux) measured at the floor.(3) In assembly occupancies, the illumination of the floors of exit access shall be at least 0.2 ft-candle (2.2 lux) during periods of performances or projections involving directed light.(4)* The minimum illumination requirements shall not apply where operations or processes require low lighting levels. [101:7.8.1.3]	Similar
Means of Egress Illumination	1006.03	Illumination emergency power.	The power supply for means of egress illumination shall normally be provided by the premise's electrical supply. In the event of power supply failure, an emergency electrical system shall automatically illuminate the following areas: 1. Exit access corridors, passageways and aisles in rooms and spaces, which require two or more means of egress. 2. Exit access corridors and exit stairways located in buildings required to have two or more exits. 3. Exterior egress components at other than the level of exit discharge until exit discharge is accomplished for buildings required to have two or more exits. 4. Interior exit discharge elements, as permitted in Section 1023.1, in buildings required to have two or more exits. 5. The portion of the exterior exit discharge immediately adjacent to exit discharge doorways in buildings required to have two or more exits. The emergency power system shall provide power for a duration of not less than 90 minutes and shall consist of storage batteries, unit equipment or an on-site generator. The installation of the emergency power system shall be in accordance with Section 604.	Emergency Lighting	14.13.01.01	General	Emergency lighting facilities for means of egress shall be provided in accordance with Section 14.13 for the following: (1) Buildings or structures where required in Chapter 11 through Chapter 42 of NFPA 101 (2) Underground and limited access structures as addressed in Section 11.7 of NFPA 101 (3) High-rise buildings as required by NFPA 101 (4) Doors equipped with delayed-egress locks (5) Stair shaft and vestibule of smokeproof enclosures, for which the following also apply: (a) The stair shaft and vestibule shall be permitted to include a standby generator that is installed for the smokeproof enclosure mechanical ventilation equipment. (b) The standby generator shall be permitted to be used for the stair shaft and vestibule emergency lighting power supply. [101:7.9.1.1]	Similar
Doors, Gates and Turnstiles	1008.01	Doors.	Means of egress doors shall meet the requirements of this section. Doors serving a means of egress system shall meet the requirements of this section and Section 1017.2. Doors provided for egress purposes in numbers	Means of Egress Reliability	14.04.02.01	Furnishings and Decorations in Means of Egress	No furnishings, decorations, or other objects shall obstruct exits, access thereto, egress therefrom, or visibility thereof. [101:7.1.10.2.1]	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
			greater than required by this code shall meet the requirements of this section. Means of egress doors shall be readily distinguishable from the adjacent construction and finishes such that the doors are easily recognizable as doors. Mirrors or similar reflecting materials shall not be used on means of egress doors. Means of egress doors shall not be concealed by curtains, drapes, decorations or similar materials.	Means of Egress Reliability	14.04.02.03	Furnishings and Decorations in Means of Egress	Mirrors shall not be placed on exit doors. Mirrors shall not be placed in or adjacent to any exit in such a manner as to confuse the direction of egress. [101:7.1.10.2.3]	Similar
Doors, Gates and Turnstiles	1008.01.01.01	Projections into clear width.	There shall not be projections into the required clear width lower than 34 inches (864 mm) above the floor or ground. Projections into the clear opening width between 34 inches (864 mm) and 80 inches (2032 mm) above the floor or ground shall not exceed 4 inches (102 mm).	Capacity of Means of Egress.	14.8.2.2	Measurement of Means of Egress.	Projections within the means of egress of not more than 4½ in. (114 mm) on each side shall be permitted at a height of 38 in. (965 mm) and below.	Similar
Doors, Gates and Turnstiles	1008.01.02	Door swing.	Egress doors shall be side-hinged swinging. Exceptions: 1. .... The opening force for interior side-swinging doors without closers shall not exceed a 5-pound (22 N) force. For other side-swinging, sliding and folding doors, the door latch shall release when subjected to a 15-pound (67 N) force. The door shall be set in motion when subjected to a 30-pound (133 N) force. The door shall swing to a full-open position when subjected to a 15-pound (67 N) force. Forces shall be applied to the latch side. 7. The door assembly power supply shall be electrically supervised. 8. The door shall open to the minimum required width within 10 seconds after activation of the operating device.	Doors	14.05.01.01	Swing and Force to Open	Any door in a means of egress shall be of the side-hinged or pivoted-swinging type, and shall be installed to be capable of swinging from any position to the full required width of the opening in which it is installed, unless otherwise specified in 14.5.1.1.1 through 14.5.1.1.8. [101:7.2.1.4.1]	Similar
Doors, Gates and Turnstiles	1008.01.04	Floor elevation.	There shall be a floor or landing on each side of a door. Such floor or landing shall be at the same elevation on each side of the door. Landings shall be level except for exterior landings, which are permitted to have a slope not to exceed 0.25 unit vertical in 12 units horizontal (2-percent slope). Exceptions: 1... 2. Exterior doors as provided for in Section 1003.5, Exception 1, and Section 1017.2, which are not on an accessible route. 3. In Group R-3 occupancies, the landing at an exterior doorway shall not be more than 7¾ inches (197 mm) below the top of the threshold, provided the door, other than an exterior storm or screen door, does not swing over the landing. 4. Variations in elevation due to differences in finish materials, but not more than 0.5 inch (12.7 mm). 5. Exterior decks, patios or balconies that are part of Type B dwelling units and have impervious surfaces, and that are not more than 4 inches (102 mm) below the finished floor level of the adjacent interior space of the dwelling unit.	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Doors, Gates and Turnstiles	1008.01.05	Landings at doors.	Landings shall have a width not less than the width of the stairway or the door, whichever is the greater. Doors in the fully open position shall not	Doors.	14.5.1.4	Swing and Force to Open	During its swing, any door in a means of egress shall leave not less than one-half of the required width of an aisle, a corridor, a passageway, or a	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
			reduce a required dimension by more than 7 inches (178 mm). When a landing serves an occupant load of 50 or more, doors in any position shall not reduce the landing to less than one-half its required width. Landings shall have a length measured in the direction of travel of not less than 44 inches (1118 mm). Exception: Landing length in the direction of travel in Group R-3 as applicable in Section 1001.1 and Group U and within individual units of Group R-2 as applicable in Section 1001.1, need not exceed 36 inches (914 mm).				landing unobstructed and shall project not more than 7 in. (180 mm) into the required width of an aisle, a corridor, a passageway, or a landing, when fully open, unless both of the following conditions are met: (1) The door provides access to a stair in an existing building. (2) The door meets the requirement that limits projection to not more than 7 in. (180 mm) into the required width of a stair or landing when the door is fully open.	
Doors, Gates and Turnstiles	1008.01.06	Thresholds.	Thresholds at doorways shall not exceed 0.75 inch (19.1 mm) in height for sliding doors serving dwelling units or 0.5 inch (12.7 mm) for other doors. Raised thresholds and floor level changes greater than 0.25 inch (6.4 mm) at doorways shall be beveled with a slope not greater than one unit vertical in two units horizontal (50-percent slope). Exception: The threshold height shall be limited to 7 3/4 inches (197 mm) where the occupancy is Group R-2 or R-3 as applicable in Section 1001.1, the door is an exterior door that is not a component of the required means of egress and the doorway is not on an accessible route.	Means of Egress	14.1	Application.	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Doors, Gates and Turnstiles	1008.01.07	Door arrangement.	. Space between two doors in series shall be 48 inches (1219 mm) minimum plus the width of a door swinging into the space. Doors in series shall swing either in the same direction or away from the space between doors. Exceptions: 1. The minimum distance between horizontal sliding power-operated doors in a series shall be 48 inches (1219 mm). 2. Storm and screen doors serving individual dwelling units in Groups R-2 and R-3 as applicable in Section 1001.1 need not be spaced 48 inches (1219 mm) from the other door. 3. Doors within individual dwelling units in Groups R-2 and R-3 as applicable in Section 1001.1 other than within Type A dwelling units.	Means of Egress	14.1	Application.	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Doors, Gates and Turnstiles	1008.01.09	Panic and fire exit hardware.	Where panic and fire exit hardware is installed, it shall comply with the following: 1. The actuating portion of the releasing device shall extend at least one-half of the door leaf width. 2. A maximum unlatching force of 15 pounds (67 N). Each door in a means of egress from an occupancy of Group A or E having an occupant load of 100 or more and any occupancy of Group H-1, H-2, H-3 or H-5 shall not be provided with a latch or lock unless it is panic hardware or fire exit hardware. If balanced doors are used and panic hardware is required, the panic hardware shall be the push-pad type and the pad shall not extend more than one-half the width of the door measured from the latch side.	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
Doors, Gates and Turnstiles	1008.03	Turnstiles.	Turnstiles or similar devices that restrict travel to one direction shall not be placed so as to obstruct any required means of egress. Exception: Each turnstile or similar device shall be credited with no more than a 50-person capacity where all of the following provisions are met: 1. Each device shall turn free in the direction of egress travel when primary power is lost, and upon the manual release by an employee in the area. 2. Such devices are not given credit for more than 50 percent of the required egress capacity. 3. Each device is not more than 39 inches (991 mm) high. 4. Each device has at least 16.5 inches (419 mm) clear width at and below a height of 39 inches (991 mm) and at least 22 inches (559 mm) clear width at heights above 39 inches (991 mm). Where located as part of an accessible route, turnstiles shall have at least 36 inches (914 mm) clear at and below a height of 34 inches (864 mm), at least 32 inches (813 mm) clear width between 34 inches (864 mm) and 80 inches (2032mm)and shall consist of a mechanism other than a revolving device.	Means of Egress	14.1	Application.	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Doors, Gates and Turnstiles	1008.03.01	High turnstile.	Turnstiles more than 39 inches (991 mm) high shall meet the requirements for revolving doors.	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Ramps	1010.01	Scope.	The provisions of this section shall apply to ramps used as a component of a means of egress. Exceptions: 1. Other than ramps that are part of the accessible routes providing access in accordance with Sections 1108.2.2 through 1108.2.4.1 of the International Building Code, ramped aisles within assembly rooms or spaces shall conform to the provisions in Section 1024.11. 2. Curb ramps shall comply with ICC A117.1. 3. Vehicle ramps in parking garages for pedestrian exit access shall not be required to comply with Sections 1010.3 through 1010.9 when they are not an accessible route serving accessible parking spaces, other required accessible elements or part of an accessible means of egress.	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Exit Signs	1011.01	Where required.	Exits and exit access doors shall be marked by an approved exit sign readily visible from any direction of egress travel. Access to exits shall be marked by readily visible exit signs in cases where the exit or the path of egress travel is not immediately visible to the occupants. Exit sign placement shall be such that no point in an exit access corridor is more than 100 feet (30 480 mm) or the listed viewing distance for the sign, whichever is less, from the nearest visible exit sign. Exceptions: 1. Exit signs are not required in rooms or areas which require only one exit or exit access. 2. Main exterior exit doors or gates which	Marking of Means of Egress	14.14.1.1	Where Required	Means of egress shall be marked in accordance with Section 14.14 where required in Chapter 11 through Chapter 42 of NFPA 101.	Similar

DRAFT

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
			obviously and clearly are identifiable as exits need not have exit signs where approved by the fire code official. 3. Exit signs are not required in occupancies in Group U and individual sleeping units or dwelling units in Group R-1, R-2 or R-3. 4. Exit signs are not required in sleeping areas in occupancies in Group I-3. 5. In occupancies in Groups A-4 and A-5, exit signs are not required on the seating side of vomitories or openings into seating areas where exit signs are provided in the concourse that are readily apparent from the vomitories. Egress lighting is provided to identify each vomitory or opening within the seating area in an emergency.					
Exit Signs	1011.02	Illumination.	Exit signs shall be internally or externally illuminated. Exception: Tactile signs required by Section 1011.3 need not be provided with illumination.	Illumination of Signs	14.14.5.1	General	Every sign required by 14.14.1.2 or 14.14.1.4, other than where operations or processes require low lighting levels, shall be suitably illuminated by a reliable light source. Externally and internally illuminated signs shall be legible in both the normal and emergency lighting mode.	Similar
Exit Signs	1013.01	General.	The exit access arrangement shall comply with Sections 1013 through 1016 and the applicable provisions of Sections 1003 through 1012.	Marking of Means of Egress	14.14.1.5.1	Exit Access	Access to exits shall be marked by approved, readily visible signs in all cases where the exit or way to reach the exit is not readily apparent to the occupants.	Similar
Exit Access	1013.02	Egress through intervening spaces.	Egress from a room or space shall not pass through adjoining or intervening rooms or areas, except where such adjoining rooms or areas are accessory to the area served; are not a high-hazard occupancy and provide a discernible path of egress travel to an exit. Egress shall not pass through kitchens, storage rooms, closets or spaces used for similar purposes. An exit access shall not pass through a room that can be locked to prevent egress. Means of egress from dwelling units or sleeping areas shall not lead through other sleeping areas, toilet rooms or bathrooms. Exceptions: 1. Means of egress are not prohibited through a kitchen area serving adjoining rooms constituting part of the same dwelling unit or sleeping unit. 2. Means of egress are not prohibited through adjoining or intervening rooms or spaces in a Group H occupancy when the adjoining or intervening rooms or spaces are the same or a lesser hazard occupancy group.	Arrangement of Means of Egress	14.10.2.1	Impediments to Egress	Access to an exit shall not be through kitchens, storerooms other than as provided in Chapter 36 and Chapter 37 of NFPA 101, restrooms, workrooms, closets, bedrooms or similar spaces, or other rooms or spaces subject to locking, unless passage through such rooms or spaces is permitted for the occupancy by Chapter 18, Chapter 19, Chapter 22, and Chapter 23 of NFPA 101.	Similar
Exit and Exit Access Doorways	1014.01	Exit or exit access doorways required.	Two exits or exit access doorways from any space shall be provided where one of the following conditions exists: 1. The occupant load of the space exceeds the values in Table 1014.1. 2. The common path of egress travel exceeds the limitations of Section 1013.3. 3. Where required by Sections 1014.3, 1014.4 and 1014.5. Exception: Group I-2 occupancies shall comply with Section 1013.2.2.	Number of Means of Egress.	14.9.1.1	General.	The number of means of egress from any balcony, mezzanine, story, or portion thereof shall be not less than two, except under one of the following conditions: (1) Where a single means of egress is permitted in Chapter 11 through Chapter 42 of NFPA 101 (2) Where a single means of egress is permitted for a mezzanine or balcony and the common path of travel limitations of Chapter 12 through Chapter 42	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
							of NFPA 101 are met	
Exit and Exit Access Doorways	1014.01	Table 1014.1.	SPACES WITH ONE MEANS OF EGRESS	Number of Means of Egress	14.9.1.1	General	The number of means of egress from any balcony, mezzanine, story, or portion thereof shall be not less than two, except under one of the following conditions: (1) Where a single means of egress is permitted in Chapter 11 through Chapter 42 of NFPA 101 (2) Where a single means of egress is permitted for a mezzanine or balcony and the common path of travel limitations of Chapter 12 through Chapter 42 of NFPA 101 are met	Similar
Exit and Exit Access Doorways	1014.02	Exit or exit access doorway arrangement.	Required exits shall be located in a manner that makes their availability obvious. Exits shall be unobstructed at all times. Exit and exit access doorways shall be arranged in accordance with Sections 1014.2.1 and 1014.2.2	Arrangement of Means of Egress	14.10.2.2	Impediments to Egress	Exit access and exit doors shall be designed and arranged to be clearly recognizable.	Similar
Exit and Exit Access Doorways	1014.02.01	Two exits or exit access doorways.	Where two exits or exit access doorways are required from any portion of the exit access, the exit doors or exit access doorways shall be placed a distance apart equal to not less than one-half of the length of the maximum overall diagonal dimension of the building or area to be served measured in a straight line between exit doors or exit access doorways. Interlocking or scissor stairs shall be counted as one exit stairway. Exceptions: 1. Where exit enclosures are provided as a portion of the required exit and are interconnected by a 1-hour fire-resistance-rated corridor conforming to the requirements of Section 1016, the required exit separation shall be measured along the shortest direct line of travel within the corridor. 2. Where a building is equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 or 903.3.1.2, the separation distance of the exit doors or exit access doorways shall not be less than one-third of the length of the maximum overall diagonal dimension of the area served.	Number of Means of Egress	14.10.1.3.2	General	Where two exits or exit access doors are required, they shall be placed at a distance from one another not less than one-half the length of the maximum overall diagonal dimension of the building or area to be served, measured in a straight line between the nearest edge of the exit doors or exit access doors, unless otherwise provided in 14.10.1.3.3 through 14.10.1.3.5.	Similar. NFPA 1 coonstins a provision that allows the means of egress to be closer, if it can be shown that a single event is not likely to block both means of egress.
Exit Access Travel Distance	1015.01	Travel distance limitations.	Exits shall be so located on each story such that the maximum length of exit access travel, measured from the most remote point within a story to the entrance to an exit along the natural and unobstructed path of egress travel, shall not exceed the distances given in Table 1015.1. Where the path of exit access includes unenclosed stairways or ramps within the exit access or includes unenclosed exit ramps or stairways as permitted in Section 1019.1, the distance of travel on such means of egress components shall also be included in the travel distance measurement. The measurement along stairways shall be made on a plane parallel and tangent to the stair tread nosings in the center of the stairway. Exceptions: 1. Travel distance in	Means of Egress	14.1	Application.	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar

DRAFT

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
			open parking garages is permitted to be measured to the closest riser of open stairs. 2. In outdoor facilities with open exit access components and open exterior stairs or ramps, travel distance is permitted to be measured to the closest riser of a stair or the closest slope of the ramp. 3. ...					
Exit Access Travel Distance	1015.01	Table 1015.1.	EXIT ACCESS TRAVEL DISTANCE	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Exits	1017.01	General.	Exits shall comply with Sections 1017 through 1022 and the applicable requirements of Sections 1003 through 1012. An exit shall not be used for any purpose that interferes with its function as a means of egress. Once a given level of exit protection is achieved, such level of protection shall not be reduced until arrival at the exit discharge.	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Number of Exits and Continuity	1018.01	Minimum number of exits.	All rooms and spaces within each story shall be provided with and have access to the minimum number of approved independent exits as required by Table 1018.1 based on the occupant load, except as modified in Section 1014.1 or 1018.2. For the purposes of this chapter, occupied roofs shall be provided with exits as required for stories. The required number of exits from any story, basement or individual space shall be maintained until arrival at grade or the public way.					Similar
Number of Exits and Continuity	1018.01	Table 1018.01.	MINIMUM NUMBER OF EXITS FOR OCCUPANT LOAD		TaBLE 14.8.1.2		Occupant Load Factor	Similar
Exterior Exit Ramps and Stairways	1022.01	Exterior exit ramps and stairways.	Exterior exit ramps and stairways serving as an element of a required means of egress shall comply with this section. Exception: Exterior exit ramps and stairways for outdoor stadiums complying with Section 1019.1, Exception 2.	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Exterior Exit Ramps and Stairways	1022.02	Use in a means of egress.	Exterior exit ramps and stairways shall not be used as an element of a required means of egress for occupancies in Group I-2. For occupancies in other than Group I-2, exterior exit ramps and stairways shall be permitted as an element of a required means of egress for buildings not exceeding six stories or 75 feet (22 860 mm) in height.	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Exit Discharge	1023.01	General.	Exits shall discharge directly to the exterior of the building. The exit discharge shall be at grade or shall provide direct access to grade. The exit discharge shall not reenter a building. Exceptions: 1. A maximum of 50 percent of the number and capacity of the exit enclosures is permitted to egress through areas on the level of discharge provided all of the following are met:	Discharge from Exits	14.11.2	Discharge through Areas on Level of Exit Discharge	Not more than 50 percent of the capacity of the required number of exits, and not more than 50 percent of the required egress capacity, shall be permitted to discharge through areas on the level of exit discharge, unless otherwise permitted in 14.11.2.1 and 14.11.2.2, provided that the criteria of 14.11.2.3 through 14.11.2.6 are met.	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
Exit Discharge	1023.02	Exit discharge capacity.	The capacity of the exit discharge shall be not less than the required discharge capacity of the exits being served.	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Exit Discharge	1023.03	Exit discharge location.	Exterior balconies, stairways and ramps shall be located at least 10 feet (3048 mm) from adjacent lot lines and from other buildings on the same lot unless the adjacent building exterior walls and openings are protected in accordance with Section 704 of the International Building Code based on fire separation distance.	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Exit Discharge	1023.04	Exit discharge components.	Exit discharge components shall be sufficiently open to the exterior so as to minimize the accumulation of smoke and toxic gases.	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Exit Discharge	1023.06	Access to a public way.	The exit discharge shall provide a direct and unobstructed access to a public way. Exception: Where access to a public way cannot be provided, a safe dispersal area shall be provided where all of the following are met: 1. The area shall be of a size to accommodate at least 5 square feet (0.28 m2) for each person. 2. The area shall be located on the same property at least 50 feet (15 240 mm) away from the building requiring egress. 3. The area shall be permanently maintained and identified as a safe dispersal area. 4. The area shall be provided with a safe and unobstructed path of travel from the building.	Discharge from Exits	14.11.1	Exit Termination	Exits shall terminate directly, at a public way or at an exterior exit discharge, unless otherwise provided in 14.11.1.2 through 14.11.1.4.	Similar
Assembly	1024.01	General.	Occupancies in Group A which contain seats, tables, displays, equipment or other material shall comply with this section.	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Assembly	1024.02	Assembly main exit.	Group A occupancies that have an occupant load of greater than 300 shall be provided with a main exit. The main exit shall be of sufficient width to accommodate not less than one-half of the occupant load, but such width shall not be less than the total required width of all means of egress leading to the exit. Where the building is classified as a Group A occupancy, the main exit shall front on at least one street or an unoccupied space of not less than 10 feet (3048 mm) in width that adjoins a street or public way. Exception: In assembly occupancies where there is no well-defined main exit or where multiple main exits are provided, exits shall be permitted to be distributed around the perimeter of the building provided that the total width of egress is not less than 100 percent of the required width.	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Assembly	1024.03	Assembly other exits.	In addition to having access to a main exit, each level of an occupancy in Group A having an occupant load of greater than 300 shall be provided with additional exits that shall provide an egress capacity for at least one-half of the total occupant load served by that level and comply with Section 1014.2. Exception: In	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
			assembly occupancies where there is no well-defined main exit or where multiple main exits are provided, exits shall be permitted to be distributed around the perimeter of the building provided that the total width of egress is not less than 100 percent of the required width.					
Assembly	1024.04	Foyers and lobbies.	In Group A-1 occupancies, where persons are admitted to the building at times when seats are not available and are allowed to wait in a lobby or similar space, such use of lobby or similar space shall not encroach upon the required clear width of the means of egress. Such waiting areas shall be separated from the required means of egress by substantial permanent partitions or by fixed rigid railings not less than 42 inches (1067 mm) high. Such foyer, if not directly connected to a public street by all the main entrances or exits, shall have a straight and unobstructed corridor or path of travel to every such main entrance or exit.	Means of Egress	14.1	Application.	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Assembly	1024.06	Width of means of egress for assembly.	The clear width of aisles and other means of egress shall comply with Section 1024.6.1 where smoke-protected seating is not provided and with Section 1024.6.2 or 1024.6.3 where smoke-protected seating is provided. The clear width shall be measured to walls, edges of seating and tread edges except for permitted projections.	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Assembly	1024.06.01	Without smoke protection.	The clear width of the means of egress shall provide sufficient capacity in accordance with all of the following, as applicable: 1. At least 0.3 inch (7.6 mm) of width for each occupant served shall be provided on stairs having riser heights 7 inches (178 mm) or less and tread depths 11 inches (279 mm) or greater, measured horizontally between tread nosing. 2. At least 0.005 inch (0.127 mm) of additional stair width for each occupant shall be provided for each 0.10 inch (2.5mm) of riser height above 7 inches (178 mm). 3. Where egress requires stair descent, at least 0.075 inch (1.9 mm) of additional width for each occupant shall be provided on those portions of stair width having no handrail within a horizontal distance of 30 inches (762 mm). 4. Ramped means of egress, where slopes are steeper than one unit vertical in 12 units horizontal (8-percent slope), shall have at least 0.22 inch (5.6 mm) of clear width for each occupant served. Level or ramped means of egress, where slopes are not steeper than one unit vertical in 12 units horizontal (8-percent slope), shall have at least 0.20 inch (5.1 mm) of clear width for each occupant served.	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Assembly	1024.07	Travel distance.	Exits and aisles shall be so located that the travel distance to an exit door shall not be greater than 200 feet (60 960 mm) measured along the line of	Means of Egress	14.1	Application.	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
			travel in nonsprinklered buildings. Travel distance shall not be more than 250 feet (76 200 mm) in sprinklered buildings. Where aisles are provided for seating, the distance shall be measured along the aisles and aisle accessway without travel over or on the seats. Exceptions: 1. Smoke-protected assembly seating: The travel distance from each seat to the nearest entrance to a vomitory or concourse shall not exceed 200 feet (60 960 mm). The travel distance from the entrance to the vomitory or concourse to a stair, ramp or walk on the exterior of the building shall not exceed 200 feet (60 960 mm). 2. Open-air seating: The travel distance from each seat to the building exterior shall not exceed 400 feet (122 m). The travel distance shall not be limited in facilities of Type I or II construction.					
Assembly	1024.08	Common path of travel.	The common path of travel shall not exceed 30 feet (9144 mm) from any seat to a point where a person has a choice of two paths of egress travel to two exits. Exceptions: 1. For areas serving not more than 50 occupants, the common path of travel shall not exceed 75 feet (22 860 mm). 2. For smoke-protected assembly seating, the common path of travel shall not exceed 50 feet (15 240 mm).	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Means of Egress for Existing Buildings	1026.01	General.	Means of egress in existing buildings shall comply with Sections 1003 through 1025, except as amended in Section 1026. Exception: Mean of egress conforming to the requirements of the building code under which they were constructed shall be considered as complying means of egress if, in the opinion of the fire code official, they do not constitute a distinct hazard to life.	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Means of Egress for Existing Buildings	1026.03	Exit sign illumination.	Exit signs shall be internally or externally illuminated. The face of an exit sign illuminated from an external source shall have an intensity of not less than 5 foot-candles (54 lux). Internally illuminated signs shall provide equivalent luminance and be listed for the purpose. Exception: Approved self-luminous signs that provide evenly illuminated letters shall have a minimum luminance of 0.06 foot-lamberts (0.21 cd/m2).	Marking of Means of Egress	14.14.5.1	Illumination of Signs	Every sign required by 14.14.1.2 or 14.14.1.4, other than where operations or processes require low lighting levels, shall be suitably illuminated by a reliable light source. Externally and internally illuminated signs shall be legible in both the normal and emergency lighting mode.	Similar
Means of Egress for Existing Buildings	1026.04	Power source.	Where emergency illumination is required in Section 1026.5, exit signs shall be visible under emergency illumination conditions. Exception: Approved signs that provide continuous illumination independent of external power sources are not required to be connected to an emergency electrical system.	Marking of Means of Egress	14.14.5.2.1	Illumination of Signs	Every sign required to be illuminated by 14.14.6.3 and 14.14.6.4 shall be continuously illuminated as required under the provisions of Section 7.8 of NFPA 101 unless otherwise provided in 14.14.5.2.2.	Similar
Means of Egress for Existing	1026.05	Illumination emergency power.	The power supply for means of egress illumination shall normally be provided by the premises' electrical supply. In the event of power	Marking of Means of Egress	14.14.5.2.1	Illumination of Signs	Every sign required to be illuminated by 14.14.6.3 and 14.14.6.4 shall be continuously illuminated as required under the provisions of Section 7.8 of	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
Buildings			supply failure, illumination shall be automatically provided from an emergency system for the following occupancies where such occupancies require two or more means of egress: 1. Group A having more than 50 occupants. Exception: Assembly occupancies used exclusively as a place of worship and having an occupant load of less than 300. 2. ...				NFPA 101 unless otherwise provided in 14.14.5.2.2.	
Means of Egress for Existing Buildings	1026.07	Size of doors.	The minimum width of each door opening shall be sufficient for the occupant load thereof and shall provide a clear width of not less than 28 inches (711 mm). Where this section requires a minimum clear width of 28 inches (711 mm) and a door opening includes two doors leaves without a mullion, one leaf shall provide a clear opening width of 28 inches (711 mm). The maximum width of a swinging door leaf shall be 48 inches (1219 mm) nominal. Means of egress doors in occupancy in Group I-2 used for the movement of beds shall provide a clear width not less than 41.5 inches (1054 mm). The height of doors shall not be less than 80 inches (2032 mm). Exceptions: 1. ... 2. ... 3. Width of door leafs in revolving doors that comply with Section 1003.3.1.3.1 shall not be limited. 4. ... 5. Exterior door openings in dwelling units, other than the required exit door, shall not be less than 76 inches (1930 mm) in height. 6. Exit access doors serving a room not larger than 70 square feet (6.5 m2) shall be not less than 24 inches (610 mm) in door width.	Egress Capacity	14.8.3.3.1.1	Minimum Width	The width of any means of egress, unless otherwise provided in 14.8.3.3.1.1 through 14.8.3.3.1.3, shall be as follows: (1) Not less than that required for a given egress component in Chapter 7 or Chapter 12 through Chapter 42 of NFPA 101 (2) Not less than 36 in. (915 mm)	Similar
Means of Egress for Existing Buildings	1026.08	Opening force for doors.	The opening force for interior side-swinging doors without closers shall not exceed a 5-pound (22 N) force. For other side-swinging, sliding and folding doors, the door latch shall release when subjected to a force of not more than 15 pounds (66 N). The door shall be set in motion when subjected to a force not exceeding a 30-pound (133 N) force. The door shall swing to a full-open position when subjected to a force of not more than 50 pounds (222 N). Forces shall be applied to the latch side.	Doors.	14.5.1.5	Swing and Force to Open.	The forces required to fully open any door manually in a means of egress shall not exceed 15 lbf (67 N) to release the latch, 30 lbf (133 N) to set the door in motion, and 15 lbf (67 N) to open the door to the minimum required width, unless otherwise specified in 14.5.1.5.2 through 14.5.1.5.5.	Similar
Means of Egress for Existing Buildings	1026.1	Stair dimensions for existing stairs.	Existing stairs in buildings shall be permitted to remain if the rise does not exceed 8.25 inches (210 mm) and the run is not less than 9 inches (229 mm). Existing stairs can be rebuilt. Exception: Other stairs approved by the fire code official.	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Means of Egress for Existing Buildings	1026.14	Slope of ramps.	Ramp runs utilized as part of a means of egress shall have a running slope not steeper than one unit vertical in ten units horizontal (10-percent slope). The slope of other ramps shall not be steeper than one unit vertical in eight units horizontal (12.5-percent slope).	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
Means of Egress for Existing Buildings	1026.15	Width of ramps.	Existing ramps are permitted to have a minimum width of 30 inches (762 mm) but not less than the width required for the number of occupants served as determined by Section 1005.1	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Means of Egress for Existing Buildings	1026.17.02	Table 1026.17.2.	COMMON PATH, DEAD-END AND TRAVEL DISTANCE LIMITS (by occupancy).	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Maintenance of the Means of Egress	1027.01	General.	The means of egress for buildings or portions thereof shall be maintained in accordance with this section.	Means of Egress	14.4.1	Means of Egress Reliability	Means of egress shall be continuously maintained free of all obstructions or impediments to full instant use in the case of fire or other emergency.	Similar
Maintenance of the Means of Egress	1027.02	Reliability.	Required exit accesses, exits or exit discharges shall be continuously maintained free from obstructions or impediments to full instant use in the case of fire or other emergency. Security devices affecting means of egress shall be subject to approval of the fire code official.	Means of Egress	14.4.1	Means of Egress Reliability	Means of egress shall be continuously maintained free of all obstructions or impediments to full instant use in the case of fire or other emergency.	Similar
Maintenance of the Means of Egress	1027.03	Obstructions.	A means of egress shall be free from obstructions that would prevent its use, including the accumulation of snow and ice.	Means of Egress	14.1	Application	Means of egress in new and existing buildings shall comply with this Code and the referenced edition of NFPA 101®, Life Safety Code®.	Similar
Maintenance of the Means of Egress	1027.04	Furnishings and decorations.	Furnishings, decorations or other objects shall not be placed so as to obstruct exits, access thereto, egress there from, or visibility thereof. Hangings and draperies shall not be placed over exit doors or otherwise be located to conceal or obstruct an exit. Mirrors shall not be placed on exit doors. Mirrors shall not be placed in or adjacent to any exit in such a manner as to confuse the direction of exit.	Means of Egress	14.4.2.1	Furnishings and Decorations in Means of Egress	No furnishings, decorations, or other objects shall obstruct exits, access thereto, egress therefrom, or visibility thereof.	Similar
	Chapter 33	Explosives and Fireworks						
General	3301.01	Scope.	The provisions of this chapter shall govern the possession, manufacture, storage, handling, sale and use of explosives, explosive materials, fireworks and small arms ammunition. Exceptions: 1. The Armed Forces of the United	General	65.01.01		The storage, use, and handling of explosives, fireworks and model rocketry shall comply with the requirements of this chapter, NFPA standards referenced within this chapter and Section 60.1 and Section 60.2 of this Code.	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
			States, Coast Guard or National Guard. 2. Explosives in forms prescribed by the official United States Pharmacopoeia. 3. The possession, storage and use of small arms ammunition when packaged in accordance with DOTn packaging requirements. 4. The possession, storage, and use of not more than 1 pound (0.454 kg) of commercially manufactured sporting black powder, 20 pounds (9 kg) of smokeless powder and 10,000 small arms primers for hand loading of small arms ammunition for personal consumption. 5. The use of explosive materials by federal, state and local regulatory, law enforcement and fire agencies acting in their official capacities. 6. Special industrial explosive devices, which in the aggregate contain less than 50 pounds (23 kg) of explosive materials. 7. The possession, storage and use of blank industrial- power load cartridges when packaged in accordance with DOTn packaging regulations. 8. Transportation in accordance with DOTn 49 CFR Parts 100-178. 9. Items preempted by federal regulations.	General	65.01.02		Where the provisions of this chapter or NFPA standards referenced herein conflict with the provisions of Chapter 60, the provisions of this chapter and referenced NFPA standards shall apply.	Similar
General	3301.01.03	Fireworks.	The possession, manufacture, storage, sale, handling and use of fireworks are prohibited. Exceptions: 1. Storage and handling of fireworks as permitted in Section 3304. 2. Manufacture, assembly and testing of fireworks as permitted in Section 3305. 3. The use of fireworks for display as permitted in Section 3308. 4. The possession, storage, sale, handling and use of specific types of Division 1.4G fireworks where allowed by applicable local or state laws, ordinances and regulations provided such fireworks comply with CPSC 16 CFR, Parts 1500 and 1507, and DOTn 49 CFR, Parts 100-178, for consumer fireworks.	General Requirements for Retail Sales of Consumer Fireworks	65.11.2.1	Display Fireworks and Pyrotechnic Articles	Retail sales of display fireworks and pyrotechnic articles, including the related storage and display for sale of such fireworks and articles, shall be prohibited at a consumer fireworks retail sales facility or store.	Similar
General	3301.02	Permit required.	Permits shall be required as set forth in Section 105.6 and regulated in accordance with this section.	Flame Effects Before an Audience	65.04.02		Permits, where required, shall comply with 1.12.19.	Similar
General	3301.02.03	Permit restrictions.	The fire code official is authorized to limit the quantity of explosives, explosive materials, or fireworks permitted at a given location. No person, possessing a permit for storage of explosives at any place, shall keep or store an amount greater than authorized in such permit. Only the kind of explosive specified in such a permit shall be kept or stored.	Display Fireworks	65.2.3	Permits	Permits, where required, shall comply with 1.12.19.	Similar
General	3301.02.04	Financial responsibility.	Before a permit is issued, as required by Section 3301.2, the applicant shall file with the jurisdiction a corporate surety bond in the principal sum of $100,000 or a public liability insurance policy for the same amount, for the purpose of the payment of all damages to persons or property which arise from, or are caused by, the conduct of any act	Display Fireworks	65.2.3	Permits	Permits, where required, shall comply with 1.12.19.	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
			authorized by the permit upon which any judicial judgment results. The fire code official is authorized to specify a greater or lesser amount when, in his or her opinion, conditions at the location of use indicate a greater or lesser amount is required. Government entities shall be exempt from this bond requirement.					
General	3301.02.04.02	Fireworks display.	The permit holder shall furnish a bond or certificate of insurance in an amount deemed adequate by the fire code official for the payment of all potential damages to a person or persons or to property by reason of the permitted display, and arising from any acts of the permit holder, the agent, employees or subcontractors.	Display Fireworks	65.2.3	Permits	Permits, where required, shall comply with 1.12.19.	Similar
General	3301.04	Qualifications.	Persons in charge of magazines, blasting, fireworks display, or pyrotechnic special effect operations shall not be under the influence of alcohol or drugs which impair sensory or motor skills, shall be at least 21 years of age, and shall demonstrate knowledge of all safety precautions related to the storage, handling or use of explosives, explosive materials or fireworks.	Display Fireworks	65.2.1		The construction, handling, and use of fireworks intended solely for outdoor display as well as the general conduct and operation of the display shall comply with the requirements of NFPA 1123, Code for Fireworks Display.	Similar
General	3301.05	Supervision.	The fire code official is authorized to require operations permitted under the provisions of Section 3301.2 to be supervised at any time by the fire code official in order to determine compliance with all safety and fire regulations.	Display Fireworks	65.2.3	Permits	Permits, where required, shall comply with 1.12.19.	Similar
General	3301.06	Notification.	Whenever a new explosive material storage or manufacturing site is established, including a temporary job site, the local law enforcement agency, fire department, and local emergency planning committee shall be notified 48 hours in advance, not including Saturdays, Sundays and holidays, of the type, quantity and location of explosive materials at the site.	Display Fireworks	65.2.3	Permits	Permits, where required, shall comply with 1.12.19.	Similar
General	3301.07	Seizure.	The fire code official is authorized to remove or cause to be removed or disposed of in an approved manner, at the expense of the owner, explosives, explosive materials or fireworks offered or exposed for sale, stored, possessed or used in violation of this chapter.	Display Fireworks	65.2.3	Permits	Permits, where required, shall comply with 1.12.19.	Similar
Definitions	3302.01	Definitions.	The following words and terms shall, for the purposes of this chapter and as used elsewhere in this code, have the meanings shown herein.	General.	3.01		The definitions contained in this chapter shall apply to the terms used in this code. Where terms are not included, common usage of the terms shall apply.	Similar
Definitions	3302.01	Fireworks.	Any composition or device for the purpose of producing a visible or an audible effect for entertainment purposes by combustion, deflagration or detonation that meets the definition of 1.4G fireworks or 1.3G fireworks as set forth herein.	Fireworks	3.03.91	Fireworks	Any composition or device for the purpose of producing a visible or an audible effect by combustion, deflagration, or detonation, and that meets the definition of Consumer Fireworks or Display Fireworks as set forth in this Code. [1124:3.3]	Similar
Definitions	3302.01	Fireworks 1.4G.	Formerly known as Class C, Common Fireworks.) Small fireworks devices containing restricted amounts of pyrotechnic composition designed primarily to produce visible or audible	General Definitions	3.03.91.01	Consumer Fireworks	Any small fireworks device designed primarily to produce visible effects by combustion or deflagration that complies with the construction, chemical composition, and labeling regulations of	Similar

DRAFT

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
			effects by combustion. Such 1.4G fireworks which comply with the construction, chemical composition and labeling regulations of the DOTn for Fireworks, UN 0336, and the U.S. Consumer Product Safety Commission as set forth in CPSC 16 CFR: Parts 1500 and 1507, are not explosive materials for the purpose of this code.				the U.S. Consumer Product Safety Commission, as set forth in 16 CFR 1500 and 1507. [1124:3.3]	
Definitions	3302.01	Fireworks 1.3G.	(Formerly Class B, Special Fireworks.) Large fireworks devices, which are explosive materials, intended for use in fireworks displays and designed to produce audible or visible effects by combustion, deflagration or detonation. Such 1.3G fireworks include, but are not limited to, firecrackers containing more than 130 milligrams (2 grains) of explosive composition, aerial shells containing more than 40 grams of pyrotechnic composition, and other display pieces, which exceed the limits for classification as 1.4G fireworks. Such 1.3G fireworks, are also described as Fireworks, UN0335 by the DOTn.	Display Fireworks	3.03.91.02	Display Fireworks	Large fireworks articles designed to produce visible or audible effects for entertainment purposes by combustion, deflagration, or detonation. [1124:3.3]	Similar
Definitions	3302.01	Fireworks Display.	A presentation of fireworks for a public or private gathering.	Definitions	3.3.91.2	Display Fireworks	Large fireworks articles designed to produce visible or audible effects for entertainment purposes by combustion, deflagration, or detonation.	Similar
Fireworks Display	3308.01	General.	The display of fireworks, including proximate audience displays and pyrotechnic special effects in motion picture, television, theatrical, and group entertainment productions, shall comply with this chapter and NFPA 1123 or NFPA 1126.	Pyrotechnics Before a Proximate Audience	65.03.01		The use of pyrotechnic special effects in the performing arts in conjunction with theatrical, musical, or any similar productions before a proximate audience, performers, or support personnel shall comply with NFPA 1126, Standard for the Use of Pyrotechnics before a Proximate Audience.	Similar
				Flame Effects Before an Audience	65.04.01		The use of flame effects before an audience shall comply with NFPA 160, Standard for Flame Effects Before an Audience.	Similar
Fireworks Display	3308.02	Permit application.	Prior to issuing permits for fireworks display, plans for the display, inspections of the display site, and demonstrations of the display operations shall be approved.	Permits	65.03.03	Permits	Where any of the following conditions exit, they shall comply with NFPA 1126: (1) Any indoor display of pyrotechnic special effects (2) Any outdoor use of pyrotechnic special effects at distances less than those required by NFPA 1123, Code for Fireworks Display (3) The use of pyrotechnic special effects during any videotaping, audio taping, or filming of any television, radio, or movie production if such production is before a proximate audience (4) The rehearsal of any production in which pyrotechnic special effects are used	Similar
Fireworks Display	3308.02.02	Proximate audience displays.	Where the separation distances required by Section 3308.4 and NFPA 1123 are unavailable or cannot be secured, only proximate audience displays conducted in accordance with NFPA 1126 shall be allowed. Applications for proximate audience displays shall include plans indicating the required clearances for spectators and combustibles, crowd control measures, smoke control measures, and requirements for standby	Pyrotechnics Before a Proximate Audience	65.03.01		The use of pyrotechnic special effects in the performing arts in conjunction with theatrical, musical, or any similar productions before a proximate audience, performers, or support personnel shall comply with NFPA 1126, Standard for the Use of Pyrotechnics before a Proximate Audience.	Similar

IFC Section Title	IFC Section Number	IFC Number Title	Text	NFPA 1 Section Title	NFPA 1 Section Number	NFPA 1 Number Title	Text	Analysis
			personnel and equipment when provision of such personnel or equipment is required by the fire code official.					
Fireworks Display	3308.03	Approved displays.	Approved displays shall include only the approved Division 1.3G, Division 1.4G, and Division 1.4S fireworks, shall be handled by an approved competent operator, and the fireworks shall be arranged, located, discharged and fired in a manner that will not pose a hazard to property or endanger any person.	Pyrotechnics Before a Proximate Audience	65.03.01		The use of pyrotechnic special effects in the performing arts in conjunction with theatrical, musical, or any similar productions before a proximate audience, performers, or support personnel shall comply with NFPA 1126, Standard for the Use of Pyrotechnics before a Proximate Audience.	Similar
Fireworks Display	3308.04	Clearance.	Spectators, spectator parking areas, and dwellings, buildings or structures shall not be located within the display site. Exceptions: 1. This provision shall not apply to pyrotechnic special effects and displays using Division 1.4G materials before a proximate audience in accordance with NFPA 1126. 2. This provision shall not apply to unoccupied dwellings, buildings and structures with the approval of the building owner and the fire code official.	Pyrotechnics Before a Proximate Audience	65.03.01		The use of pyrotechnic special effects in the performing arts in conjunction with theatrical, musical, or any similar productions before a proximate audience, performers, or support personnel shall comply with NFPA 1126, Standard for the Use of Pyrotechnics before a Proximate Audience.	Similar
Fireworks Display	3308.05	Storage of fireworks at display site.	The storage of fireworks at the display site shall comply with the requirements of this section and NFPA 1123 or NFPA 1126.	Pyrotechnics Before a Proximate Audience	65.03.01		The use of pyrotechnic special effects in the performing arts in conjunction with theatrical, musical, or any similar productions before a proximate audience, performers, or support personnel shall comply with NFPA 1126, Standard for the Use of Pyrotechnics before a Proximate Audience.	