

NIST Technical Note 1775

Standard Operating Procedures for Smolder Ignition Testing of Upholstery Fabrics

Mauro Zammarano, Roland H. Krämer, Szabolcs Matko, and Rick D. Davis

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U.S. Department of Commerce
Rebecca Blank, Acting Secretary

National Institute of Standards and Technology
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Abstract

This manuscript describes a methodology to measure the influence of an upholstery cover fabric to promote smoldering mass loss of a small-scale mock-up constructed of standard polyurethane foam, a cover fabric, and cotton cover cloth, and a standard cigarette. The primary test metric is total mock-up mass loss after 45 min exposure to the cigarette smoldering ignition source. The testing materials are available through NIST as Standard Reference Material (SRM) 1202: Fabric Smoldering Ignition Testing Materials.

Keywords

Polyurethane foam; smoldering; furniture; flammability; SRM 1202

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List of Acronyms

ANSI	American National Standards Institute
ASTM	American Society for Testing Materials
CPSC	Consumer Products Safety Commission
NIST	National Institute of Standards and Technology
PUF	Polyurethane Foam
RH	Relative Humidity
SRM	Standard Reference Material

1 General Description

Described here is a process for measuring the cigarette smolder propensity of fabrics using a bench scale mock-up (

Figure 1) that includes a standard polyurethane foam (PUF), standard cigarette, a cotton cloth, and cover fabric. The metric used for assessing performance is the mass loss of the PUF after 45 min exposure to the smoldering source. The testing materials are available through NIST as Standard Reference Material (SRM) 1202: Fabric Smoldering Ignition Testing Materials. The materials supplied are a reproducibly high smoldering standard polyurethane foam, a denim cover fabric, a cotton fabric, and 1196 cigarettes. The denim fabric supplied in the kit is used for determining the mass loss value, which is stated on the SRM certificate, for the PUF. In order to assess the smoldering propensity of other cover fabrics, the denim fabric must be replaced with this other fabric. The methodology is based on the test described in Consumer Products Safety Commission's Announced Proposed Regulation of Upholstered Furniture Flammability (16 CFR 1634) [1].

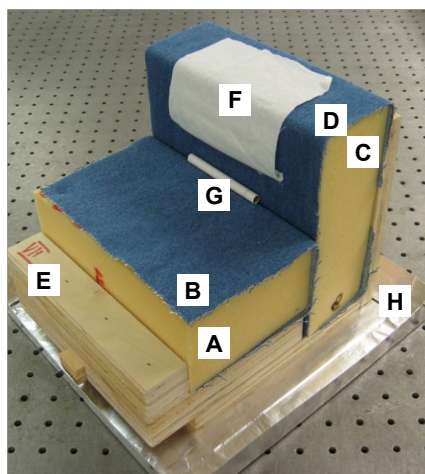


Figure 1. Fully constructed mock-up assembly before cigarette ignition. A&B: "front" foam and fabric specimens; C&D: "back" foam and fabric specimens; E: sample holder; F: cigarette cover sheeting; G: cigarette; H: aluminum foil tray

2 Personnel

SRM Technical staff complete all experimental activities, recording of environmental conditions and data, and reporting to a senior researcher (often is the Leader of the Flammability Reduction Group). The senior researcher is responsible for providing all information to the end-users (e.g.; statistician and SRM manager).

Training goals are developed on an annual basis for a SRM Technical staff. The training goals are documented and maintained in a folder located in the office of the Flammability Reduction Group leader's (A267/224).

3 Environmental Conditions

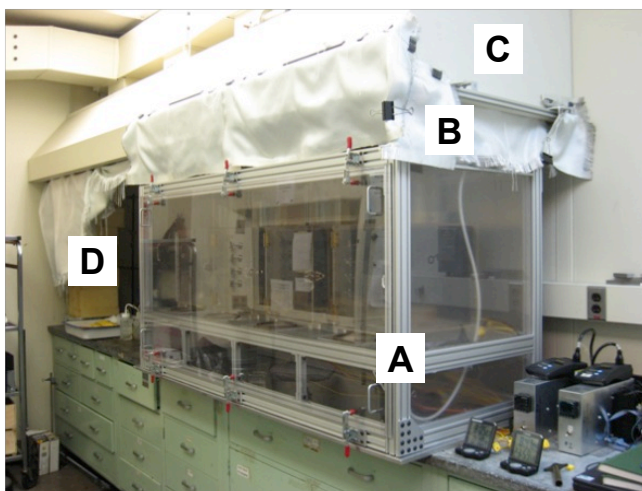
All materials are conditioned, specimens are assembled, and tests are performed at a Relative Humidity (RH) of $55 \% \pm 5 \%$ and a temperature of $22\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$.¹ Materials must be stored for a minimum of 24 hours in these conditions prior to testing. The RH and temperature values are continuously recorded using probes and controllers attached to a laboratory computer (A267/224). Values at the beginning of a test are recorded on test report sheets prior to sample ignition, which are stored in the laboratory.

Prior to conditioning the SRM materials (i.e., foam, fabric, and vacuum sealed cigarettes) are to be stored at $24\text{ }^{\circ}\text{C} \pm 4\text{ }^{\circ}\text{C}$, less than $55 \% \pm 5 \%$ RH, and in the absence of ultraviolet light and insects for no longer than 2 years, except for the SRM 1196 cigarettes. All SRM materials are to be stored without being deformed, i.e., do not wrinkle the fabrics, do not crush the foam, and do not crush the cigarettes.

An enclosure under an overhead canopy hood (

Figure 2) is used to reduce air currents that may impact performance and as an engineering safety device to isolate and remove hazard off gases from the test. Airflow immediately above the cigarette position on the mock-up is recorded just prior to placing the ignited cigarette on the substrate. The airflow value is recorded in the test report sheets prior to sample ignition. Airflow should be $130\text{ ft/min} \pm 30\text{ ft/min}$.

The testing materials are not exposed to any direct ultraviolet light during storage, conditioning, and testing. All materials can be handled without gloves. All test report sheets are located in a binder next to the testing enclosure.



¹ Over the past 2 years we have performed this test and stored the materials in laboratories without well-controlled humidity and temperature. We have found no evidence to suggest any difference in performance when the conditions of the laboratories are $24\text{ }^{\circ}\text{C} \pm 4\text{ }^{\circ}\text{C}$ and less than $55 \% \pm 5 \%$ RH.

Figure 2. A: metal enclosure with removable polycarbonate front panel; B: glass mat curtain; C: overhead hood; D: storage hood

4 Equipment

4.1 Temperature and Humidity System

A schematic of the humidity control system is provided in Figure 3, equipment description in Table 1, and maintenance schedule in Table 2. Two Newport controllers and probes (probe and controllers are calibrated together – called Humidity / Temperature controllers and recording in Table 2) are used to control the humidity and report humidity and temperature in the room. The humidity and temperature values are continuously recorded on a computer located in the laboratory. The values are checked daily using a separate set of Newport controllers and probes (called Intermittent checking of Humidity / Temperature probes in Table 2), which are placed immediately next to the other probes for this assessment. The values for all four probes are recorded in an excel spreadsheet on the laboratory computer. The probes are re-calibrated and certified annually by Newport Technical Representative. The computer is equipped with an 8 h battery back-up.

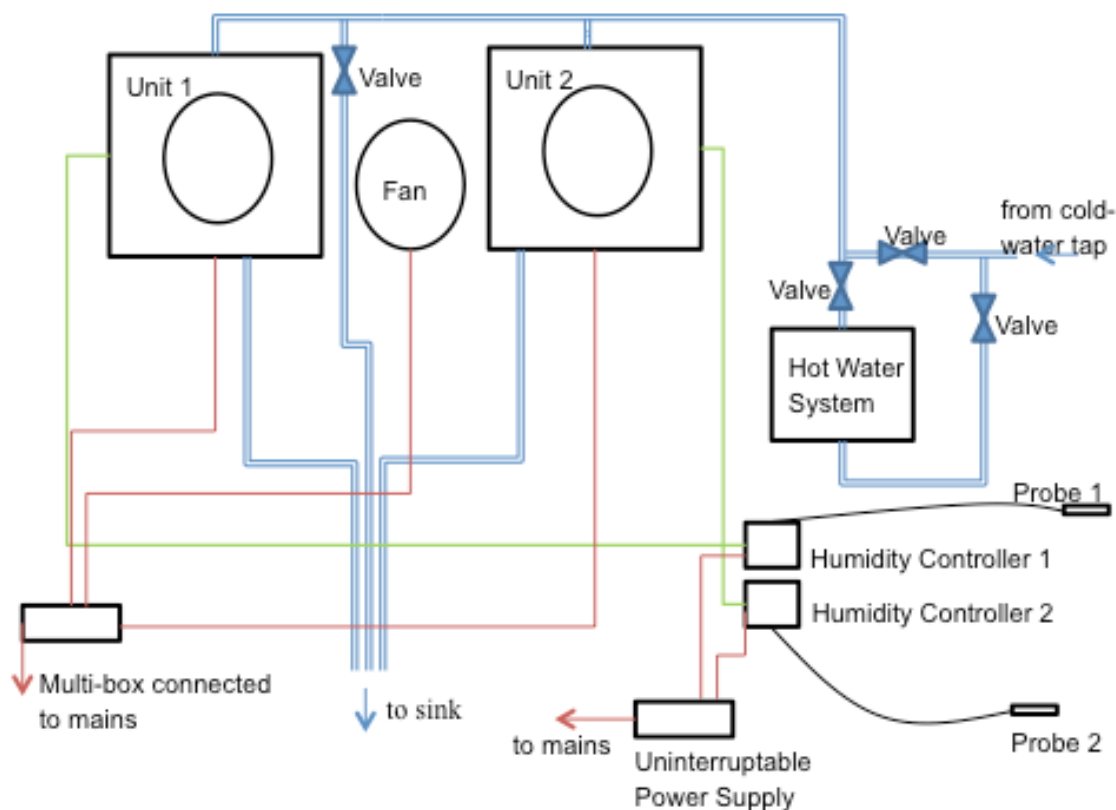


Figure 3. Schematic of humidifier system

Table 1. Humidity system components.

Component	Part Details	Last purchased
Evaporator panels	Aprilaire 1200 Water Panel	Discount Humidifiers www.discounthumidifiers.com Part code: Aprilaire1200 Also available at: http://www.aprilaireparts.com/aprilaire-1200-water-panel-humidifier-filter.html
Solenoid valve	Aprilaire 4026 Solenoid Valve Yoke 1120	Discount Humidifiers www.discounthumidifiers.com Part code: Aprilaire4026
Motor	Component of Aprilaire 1200	Never has been replaced
Hot water system	Powerstream Pro tankless electric hot water system	Never has been replaced
Humidity / Temperature controllers and recording	Newport ITH-I8DH33-5-C24 dual humidity and temperature controller and probes (calibrated together) RH \pm 2% for 10%-90% RH T \pm 0.5 °C for 5 °C-45 °C NIST traceable certificate for 25%, 50%, and 75% at 25 °C	Newport Electronics, Inc. 2229 South Yale Street, Santa Ana, CA 92704-4401 TEL (714)540-4914 / FAX:(203)968-7311 http://www.newportUS.com e-mail:sales@newportUS.com
Intermittent checking of Humidity / Temperature probes	Newport ITH-I8DH33-5, 1/8 dual humidity and temperature probes (calibrated together) RH \pm 2% for 10%-90% RH T \pm 0.5 °C for 5 °C-45 °C	Newport Electronics, Inc.

Table 2. Humidity system maintenance schedule. All equipment is inspected daily and replaced as needed unless otherwise indicated in this table.

Maintenance Task	Schedule	Date of next service
Evaporator Panels – replace	6 monthly	September 2012
Solenoids	12 monthly	October 2012
Motor	Replace only upon failure Unit 1 - replaced Sept 2011 Unit 2 - replaced Sept 2011	N/A
Control Units	Replace only upon failure Unit 1 - replaced Sept 2011 Setpoint 1 57.0% RH Setpoint 2 25 °C Unit 2 - replaced Sept 2011 Setpoint 1 56.5%RH Setpoint 2 25°C	N/A

Humidity/Temperature Controllers / Probes	Replace only upon failure Unit 1 - replaced Sept 2011 Unit 2 - replaced Sept 2011	N/A
----------------------------------------------	-------------------------------------------------------------------------------------------------------	-----

4.2 *Mass values*

Mass values are obtained using a Sartorius GW6202 mass balance that is accurate to ± 0.01 g within the normal operating environment of the laboratory used for material conditioning, sample assembly, and sample testing. The values of foam before and after testing are recorded at the beginning of every test on a test data sheet. The stability of the scale is checked weekly (during testing) with an ANSI/ASTM 6 Type I and II certified mass set purchased from Troemner Corporation (Mass Set serial number is 1366, mass range is 500 g to 0.1 g). The mass at 30 g, 30.1 g, 50 g, 50.1 g, and 80 g, 80.1 g is recorded and stored in a binder located in 224/A267. These values were selected based on typical mass values obtained when measuring the foam before and after testing and to check accuracy up to 0.1 g.

4.3 *Airflow values*

Airflow immediately above where the cigarette is placed is obtained immediately prior to placement of the ignited cigarette using a Mark 2 No. 48 Vaneometer by Dwyer Instrument Control Gauges. Prior to testing the airflow value is recorded on a test data sheet, which is stored in the laboratory.

4.4 *Calibration*

Intermediate checking of stability of the measurement tools is described, recorded, and reported as described above. The Newport controllers and probes are re-calibrated and certified annually by Temperature and Humidity group (Physical Measurement Laboratory at NIST). The Sartorius GW6202 mass balance is re-calibrated and certified annually by a Sartorius Technical Representative. The Mark 2 No. 48 Vaneometer is re-calibrated and certified annually by Fluids Metrology group (NIST). The calibration certificates are located in a binder in 224/A267.

4.5 *Specimen Holder*

A detailed description of the wooden sample holder is provided in 16 CFR 1634.12.[1]

5 **Retention of Calibration Values and Experiment Data**

All calibration and test reports are stored in B255/ 224 and must be kept for at least two years after the batch has been exhausted.

6 **Test of Consistency between Certified and Measured Values**

To ascertain whether the value of relative mass loss measured by a user, using the SRM 1202 as specified in this user's guide, is consistent with the SRM's certified value, a statistical test should

be employed to gauge the significance of the difference. One test that may possibly be employed to this end is the variant of Student's t test known as Welch's test [2], and serves to compare two averages whose true uncertainties may possibly differ.

Suppose that the certified value is x , and that the associated measurement uncertainty is $u(x)$, based on $\nu(x)$ degrees of freedom. Suppose also that y is the value measured by the user for this SRM, with associated measurement uncertainty $u(y)$ based on $\nu(y)$ degrees of freedom. Welch's test is based on $t = (x-y)/(u^2(x) + u^2(y))^{1/2}$, and on an approximate, effective number of degrees of freedom $\nu(t) = (u^2(x)+u^2(y))^2/(u^4(x)/\nu(x) + u^4(y)/\nu(y))$ — this is the so-called Welch-Satterthwaite formula that appears as Equation (G.2b) in the GUM.

Suppose that the probability of a Student's t random variable with $\nu(t)$ degrees of freedom exceeding $|t|$ (that is, the value of t without algebraic sign) is p . If $2p$ is sufficiently small, then this suggests a statistically significant difference between the true relative mass loss in the certificate and as measured by the user for the SRM.

For example, suppose the value the user measured for the SRM was the average $y = 0.27$ of 3 replicates obtained under conditions of repeatability, whose standard deviation was $s(y) = 0.08$. Noting that $\nu(y) = 3-1 = 2$, and assuming that $u^2(y) = s^2(y)/3$ (Type A evaluation), and given the information in the certificate, $x = 0.16$, $u(x) = 0.02/2.1$, $\nu(x) = 25$, one obtains $t = -2.2$ and $\nu(y) = 2.7$.

The probability that a Student's t random variable with 2.7 degrees of freedom should exceed 2.2 is 0.06. The probability of observing a value of $|t|$ at least as large as was observed, due to the vagaries of sampling alone, when there is no difference between the true values of relative mass loss corresponding to the certified value, and as measured by the user, is $2 \times 0.06 = 0.12$. Since "small" typically means 0.05 or smaller, this probability is not considered small, and the result of the test is that the value measured by the user is not inconsistent with the value reported in the certificate.

7 Safety Equipment

The equipment believed necessary for us to safely perform these tests is as follows. Please work with your safety representatives to determine what is appropriate for you.

Researchers are required to wear

- closed-toe shoes at all times,
- safety glasses at all times,
- a lab coat at all times,
- nitrile gloves as required,
- leather gloves during prep and clean up,
- and half-face respirator with organic vapor and acid cartridges as specified.

Additional safety equipment include

- carbon monoxide alarm,

- portable carbon dioxide fire extinguisher,
- spray bottles (filled with tap water),
- squirt bottles equipped with silicone tubing and syringe (filled with tap water),
- and 3.5 gal plastic bucket (filled with tap water).

8 Standard Operating Procedures

All test report sheets are located in a binder next to the testing enclosure.

8.1 Sample preparation and conditioning

Prepare the following items per test (Figure 4). If using SRM 1202, the materials have already been prepared to these specifications.

1. Two pieces of a high smoldering standard polyurethane foam measuring:
 - a) $(8.0 \times 8.0 \times 3.0) \text{ in.}^3$ $((203 \times 203 \times 76) \text{ mm}^3)$
 - b) $(8.0 \times 5.0 \times 3.0) \text{ in.}^3$ $((203 \times 127 \times 76) \text{ mm}^3)$.
2. Two pieces of covering fabric measuring
 - a) $(20.0 \times 8.0) \text{ in.}^2$ $((508 \times 203) \text{ mm}^2)$
 - b) $(13.0 \times 8.0) \text{ in.}^2$ $((330 \times 203) \text{ mm}^2)$.
3. One piece of cigarette cover sheeting (UF-400 type; Test Fabrics Inc.) measuring $(5.0 \times 5.0) \text{ in.}^2$ $((127 \times 127) \text{ mm}^2)$.
4. One SRM 1196 cigarette.
5. One wooden sample holder.[1]
6. Ten pins (to secure the fabric to the foam)

Condition items #1 through #5 at $55 \% \pm 5 \% \text{ RH}$ and $22 \text{ }^\circ\text{C} \pm 3 \text{ }^\circ\text{C}$ for 24 hrs prior to the tests.

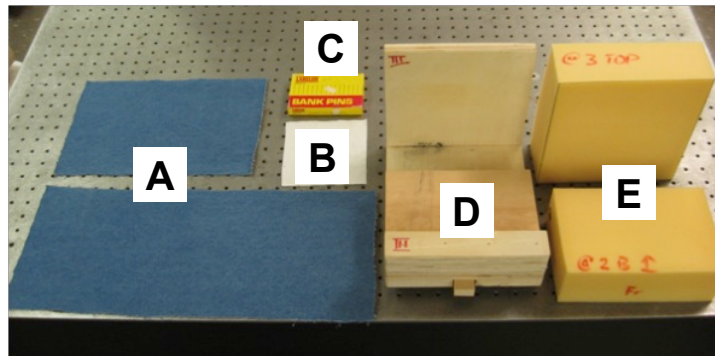


Figure 4. Items needed for assembling test specimen. A: two fabric specimens; B: cigarette cover sheeting; C: pins; D: wooden sample holder; E: two foam specimens.

8.2 Test specimen assembly

1. Record mass of fabric and foam before assembly.
2. Wrap each piece of foam securely with a piece of fabric. Pin the corners of the bigger piece of fabric to the back of the larger foam specimen ("back" specimen) with four pins at each corner of the fabric. Arrange the edges of the fabric symmetrically on the back of the foam specimen so that a 2 in. (51 mm) wide strip is left uncovered in the middle (

3. Figure 5a). Pin the smaller piece of fabric to the top and bottom of the smaller foam specimen ("front" specimen) with four pins at each corner of the fabric so that one of the $(8.0 \times 3.0) \text{ in.}^2$ ($(203 \times 76) \text{ mm}^2$) sides of the foam specimen is left uncovered (
4. Figure 5b). Measure the dimensions of the foam pieces afterwards with a ruler to make sure that the specimens have not changed shape from the pressure of handling and wrapping them (
5. Figure 5c). If the dimensions have changed by more than 5% of the value, remove fabric and reassembly again following these instructions.
6. Place the two wrapped foam specimens in the wooden sample holder. The "back" specimen is placed upright in the back of the frame; the "front" specimen is laid flat on the bottom of the frame (
7. Figure 5d).
8. Gently slide the two parts of the sample holder together (
9. Figure 5d-e).

Center the cigarette cover sheeting 2 in. (51 mm) below the top edge of the "back" foam piece and pin its top corners with two pins (

10. Figure 5f).

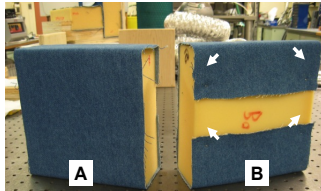
Fold the sheeting over the top of the "back" specimen (

11. Figure 5g).

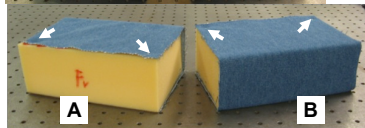
The orientation in the foam specimens (e.g., rise direction) or the sewing pattern in the fabric (

12. Figure 5h) can affect smolder propagation. Therefore, always build the assemblies by applying the same component configuration.

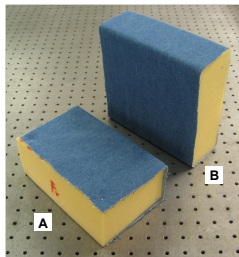
13. Place the assembled mock-up in a tray made of heavy duty aluminum foil measuring $(12.0 \times 12.0 \times 0.5) \text{ in.}^3$ ($(305 \times 305 \times 13) \text{ mm}^3$) ($(W \times L \times H)$) (Figure 1).



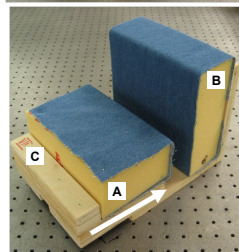
a) Wrapped "back" foam specimen. A: front view; B: back view. The white arrows indicate the locations of pins.



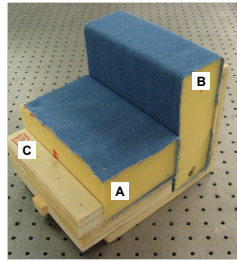
b) Wrapped "front" foam specimen. A: front view; B: back view. The white arrows indicate the locations of pins.



c) Wrapped foam specimens in their final orientation. A: "front"; B: "back" specimen.

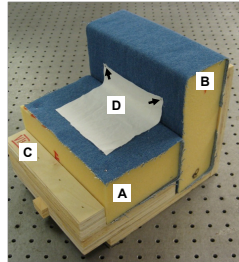


d) Loosely assembled sample holder. A: "front"; B: "back" specimen; C: frame. The white arrow indicates the movement of the front part.

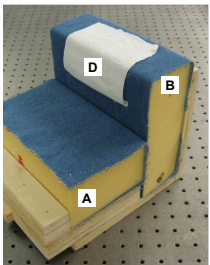


e) Tightly assembled sample holder. A: "front"; B: "back" specimen; C: frame.

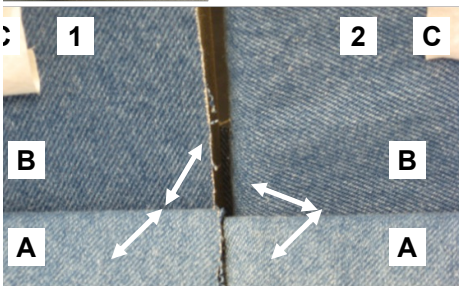
indicate the



f) Assembled mock-up. A: "front"; B: "back" specimen; C: frame; D: cigarette cover sheeting. The black arrows indicate the locations of pins.



g) Assembled mock-up. A: "front"; B: "back" specimen; C: frame; D: cigarette cover sheeting.



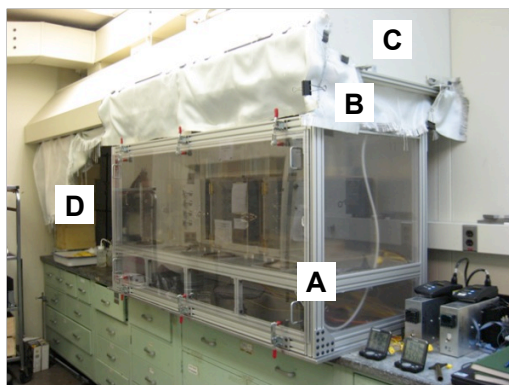
h) Test specimen with different fabric orientation. A: "front"; B: "back" fabric specimen; C: cigarette cover sheeting. The white arrows show the pattern's orientation on the top of fabric. Test specimen #1 has the same orientation. Test specimen #2 does not.

Figure 5. Steps to assembling a mock-up.

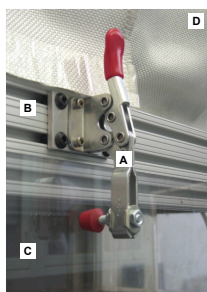
8.3 Prior to experiment

1. Ensure the smoke alarm and carbon monoxide alarm, are operating normally.
2. Ensure respirator is operating normally and cartridges have not expired.
3. Ensure water bottles and bucket are prepared and placed under the hood.
4. Ensure hood airflow is operating appropriately (Figure 6):
 - a. Clamp the front panel in place and close the left side door of the enclosure. Make sure that all of the six clamps work properly and the panel can be closed tightly (Figure 6b).
 - b. Place anemometer (in the temporarily opened gap at the top middle clamp of the enclosure (Figure 6c). To ensure all combustion are removed during the test, do not run experiments if the is less than 40 ft/min.
 - c. Remove the front panel.

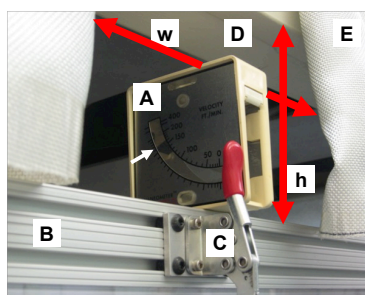
5. Ensure laboratory conditions are appropriate for testing $55\% \pm 5\%$ RH and $22\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$. If samples were stored or conditioned in the laboratory, check computer to ensure the conditions in the laboratory stayed within appropriate storage ($24\text{ }^{\circ}\text{C} \pm 4\text{ }^{\circ}\text{C}$ and less than $55\% \pm 5\%$ RH) and conditioning conditions ($55\% \pm 5\%$ RH and $22\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$)
6. Arrange the vacuum tubing of the cigarette igniter apparatus in the enclosure (Figure 6e). Install the conic nut in the back space of the overhead hood (Figure 6f) to avoid exposure to cigarette smoke when igniting the cigarette.



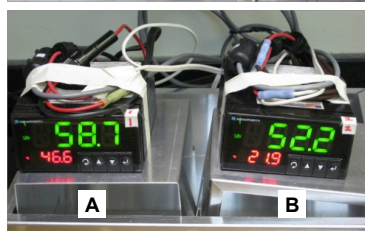
a) Workspace. A: metal enclosure with removable polycarbonate front panel and six clamps; B: glass mat curtain; C: overhead hood; D: storage hood.



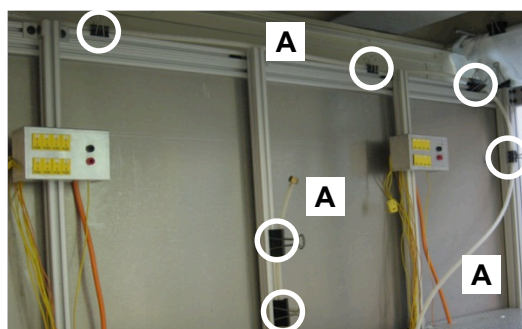
b) Securely clamped front panel. A: clamp; B: enclosure's upper crossbar; C: plastic front panel; D: glass mat curtain.



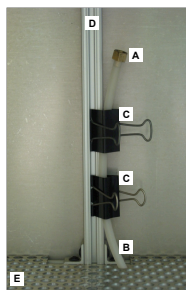
c) Hood airflow measurement. A: swing vane anemometer; B: enclosure's upper crossbar; C: enclosure's top middle clamp; D: overhead hood's bottom edge; E: glass mat curtain. The red arrows show the size of the temporary opening (w: 10 in. (254 mm); h: 6.25 in. (159 mm)). The white arrow indicates the airflow value ($\sim 150\text{ ft min}^{-1}$) read by the anemometer.



d) Instruments for relative humidity and room temperature measurement. A: display #1; B: display #2.



e) Installation of the cigarette igniter apparatus's vacuum tubing. A: vacuum tubing. The white circles indicate metal clips.

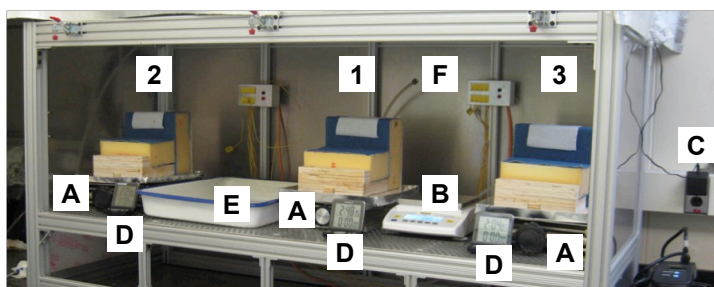


f) Placement of the cigarette igniter apparatus's conic nut. A: conic nut; B: vacuum tubing; C: metal clips; D: enclosure's back metal pole; E: perforated metal plate.

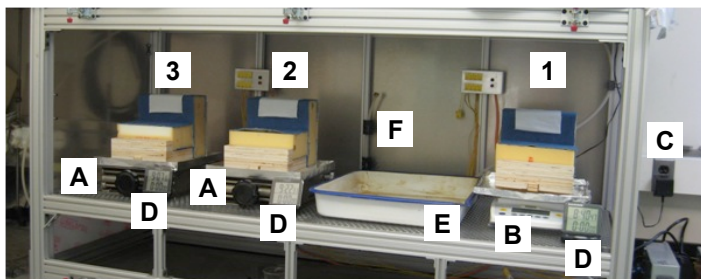
Figure 6. Test enclosure, workspace, and test preparation.

8.4 Conducting test

1. Set up in the hood as described below and shown Figure 7a-b.
 - a. Place a metal tray measuring $(17 \times 20 \times 3) \text{ in.}^3$ ($(432 \times 508 \times 76) \text{ mm}^3$) (W×L×H) in the enclosure for the dismantling step. Lay a piece of aluminum foil measuring $(18 \times 26) \text{ in.}^2$ ($(46 \times 66) \text{ cm}^2$) (W×L) per test on the bottom of the tray for quick removal and wrapping of the leftover extinguished fabrics and charred foam cores between each test.
 - b. Place a mass balance in the enclosure. Level and plug it in an outlet outside of the enclosure. Check and record the balance accuracy using calibration weights. Place a tray measuring $(10 \times 10 \times 0.5) \text{ in.}^3$ ($(254 \times 254 \times 13) \text{ mm}^3$) (W×L×H) made of heavy duty aluminum foil onto the balance.
 - c. Place an adjustable laboratory platform in the enclosure for each test to be conducted.
 - d. Place the test assemblies (test specimen in the holder and aluminum tray as shown in Figure 8) onto the platforms. Adjust the assemblies to the same height so that they will be exposed to the same airflow.
 - e. Place a timer in front of each test assembly.
 - f. For real-time measurements, place the test assembly on a balance (Figure 7b).



a) Arrangement for three off-line mass loss tests. A: adjustable platforms; B: balance; C: outlet; D: stopwatches; E: metal tray; F: cigarette igniter apparatus's conic nut. The numbers indicate the order of ignition at the beginning.



b) Arrangement for a real time (#1) and two off-line (#2 and #3) mass loss tests. A: adjustable platforms; B: balance; C: outlet; D: stopwatches; E: metal tray; F: cigarette igniter apparatus's conic nut. The numbers indicate the order of ignition at the beginning.

Figure 7. Experimental setup in the test enclosure

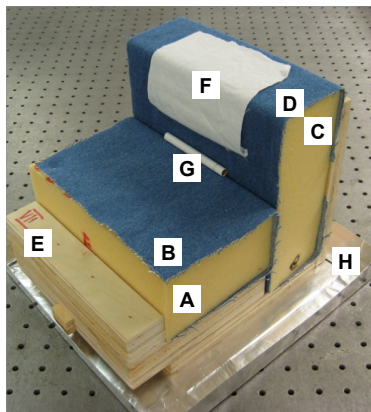
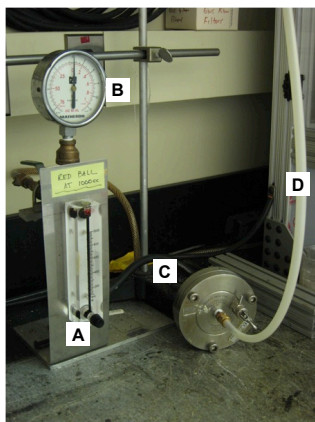
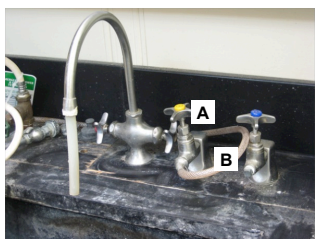


Figure 8. Fully constructed test assembly before cigarette ignition. A&B: "front" foam and fabric specimens; C&D: "back" foam and fabric specimens; E: sample holder; F: cigarette cover sheeting; G: cigarette; H: aluminum foil tray

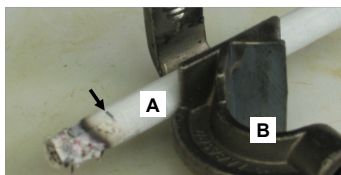
2. Ignite the cigarette with the cigarette igniter apparatus (Figure 9a), as follows:
 - a. Mark the cigarette with a pencil 0.2 in. (5 mm) and 0.6 in. (15 mm) away from one end on the strip where the cigarette paper overlaps with itself.
 - b. Open the vacuum valve (Figure 9b).
 - c. Set the pressure to $(20 \pm 2) \text{ lb in.}^{-2}$ ($(50 \pm 5) \text{ kg cm}^{-2}$) on the manometer of the apparatus by using the adjusting knob. Different pressure values will change the rate at which the cigarette burns down to the mark, but has no difference on the test performance. Therefore, this value is provided only for clarification of the test procedure.
 - d. Place tightly the unmarked end of the cigarette to the conic nut either in the vertical or horizontal position and ignite the cigarette by holding a cigarette lighter to its marked end. After removing the lighter keep holding the cigarette to the nut until the smoldering front reaches the mark at 0.2 in.
 - e. Place the cigarette in a metal holder in the horizontal position next to the mock-up (Fig. Figure 9c). If more than one test is to be run at the same time, a 7 to 8 minute delay should be applied between the cigarette ignitions.
 - f. Close the vacuum valve.
 - g. Keep the cigarette in the horizontal position in the holder until the smoldering front reaches the second mark at 0.6 in. (Figure 9c).



a) Cigarette igniter apparatus. A: adjusting knob; B: manometer; C: rubber tubing; D: vacuum tubing.



b) Vacuum valve. A: vacuum valve; B: vacuum tubing.



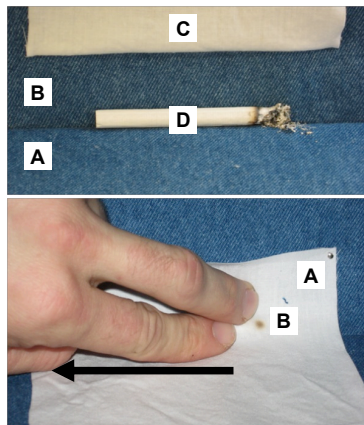
c) Cigarette placement in the metal holder. A: cigarette; B: metal holder. The black arrow indicates the second mark at 0.6 in.

Figure 9. Setup for cigarette ignition

3. Place the cigarette in the center of the test assembly where the "back" and "front" specimens meet. Ensure the whole cigarette is center across the width of the assembly (Figure 10a).
4. Cover the cigarette with the cover sheeting. Pull your fingers on the sheeting along the cigarette so that the sheeting touches the cigarette and there remain no air pockets between the cigarette and sheeting (Figure 10b). Heat resistant gloves or leather gloves are used for this step.
5. Start timer.
6. Clamp front of the enclosure.
7. After 40 minutes, don respirators for the removal of the specimen. Move all of the items/tools needed at the end of the test (e.g., spray and squirt bottles, leather gloves, metal spatulas) to within reach.

8. At 45 minutes, remove the front panel and dismantle the mock-ups in the metal tray. First, remove the cover sheeting from the "back" specimen and place in the metal tray. Remove the "back" specimen from the frame. Since this is the bigger specimen it smolders more intensely. Remove the fabric, weigh it on the balance and extinguish it with a spray bottle in the metal tray. Weigh the still-smoldering foam specimen on the balance with char. To prevent the smoldering core from accidental separation from the specimen, lay it down on the balance so that the core is on top (Figure 11). A wide metal spatula may be used to keep the core in place while handling between the platform and balance and then between the balance and metal tray. After weighing, carve the smoldering core off into the metal tray with a spatula and extinguish it with the spray bottle and/or squirt bottle. Weigh the foam piece without the core. Do the same process for the "front" specimen. After extinguishing wrap the charred fabrics and charred cores with the aluminum foil that was placed in the metal tray earlier. Move this package to under the storage hood.
9. After extinguishing all of the items, and recording the data, wait for 10 to 15 minutes before taking off your respirator.

After the test, check the specimens 3 times in 10 minute intervals for visible smoke and also flip them over with a spatula to check both the bottom and top to make sure that the smoldering was extinguished properly. Unassemble the sample holders and check to see if the smoldering cigarette butt has fallen onto the bottom of the frame. If so, drop it into the metal tray.

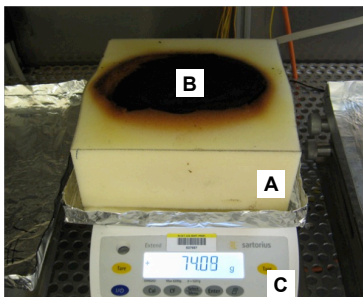


a) Cigarette positioning. A: "front"; B: "back" specimen; C: cigarette cover sheeting; D: cigarette.

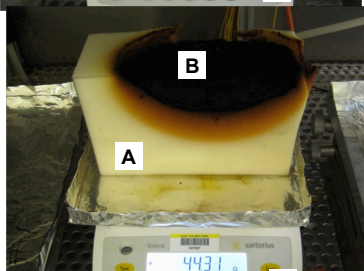


b) Cigarette cover sheeting arrangement. A: cigarette cover sheeting; B: charred spot burned by the cigarette's smoldering tip.

Figure 10. Cigarette placement on the top of the mock-up assembly.



a) Weighing the "back" foam specimen. A: "back" specimen; B: charred core; C: balance.



b) Weighing the "front" foam specimen. A: "front" specimen; B: charred core; C: balance.

Figure 11. Placement of “back” and “front” charred foam specimens onto the balance.

8.5 *Clean up*

All housekeeping (e.g., dust-off of the wooden frames from remaining soot/ash and disposal of charred foams and fabrics) is performed in a well ventilated hood. Researchers wear nitrile gloves during clean-up. All waste is disposed of as solid chemical waste.

9 References

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- [1] Consumer Product Safety Commission 16 CFR 1634 Standard for the Flammability of Residential Upholstered Furniture (Proposed Rule), Section 1634.12, 2008: pg 11746.
 - [2] *IST/SEMATECH e-Handbook of Statistical Methods*, 2012, §7.3.1,
<http://www.itl.nist.gov/div898/handbook/prc/section3/prc31.htm>