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Modification of ASTM E 2187 for Measuring the Ignition Propensity of Conventional Cigarettes

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Abstract. Current existing and proposed US flammability standards for soft furnishings such as mattresses and upholstered furniture specify a "standard" cigarette as the ignition source in smoldering resistance performance tests. With the increasing prevalence of reduced ignition propensity cigarettes in the marketplace, the conventional cigarette that has been most widely used in smolder resistance testing is no longer in production. To support manufacturers and testing organizations in product design and testing, and to assist regulators in the compliance evaluation process, a continuing supply of standard conventional cigarettes is required. A key first step in establishing such a supply is the development of a measurement method for quantifying the ignition propensity of a standard cigarette similar to the one currently used for testing soft furnishings. This article describes such a measurement method. It also reports performance data for the conventional test cigarette and other contemporary cigarettes.

Keywords: ASTM E2187, Cigarette, Cigarette ignition propensity, Cigarette ignition resistance, Fire, Fire safety, Fire test, Mattresses, Upholstered furniture

1. Introduction

Cigarette ignition of upholstered furniture and mattresses has been and continues to be the largest single cause of fire deaths in the United States [1]. To mitigate these losses, both the US Consumer Product Safety Commission (CPSC) and the State of California have promulgated, or are in the process of promulgating, regulations that limit the susceptibility of these soft furnishings to ignition by a lit cigarette [2–4]. There are also standard tests for cigarette ignition resistance that are used by the upholstered furniture industries [5, 6].

The ignition tests for both mattresses and upholstered furniture involve placing a lit cigarette on a substrate that is either the finished product or an assembly meant to be indicative of the finished product. The hot coal of the cigarette moves

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along the substrate, transferring heat to the substrate materials, which themselves are transferring heat away from the point of contact. Should the thermal environment and the material chemistry combine appropriately, ignition to smoldering combustion occurs. The process is depicted in Figure 1. A potential threat to life and property results if the smoldering continues to propagate outward from the ignition venue, possibly transitioning to flaming combustion.

In all these tests, the current test cigarette (CTC) is a commercial product, specified by its length (85 mm ± 2 mm), a tobacco packing density (0.270 g/cm^3 ± 0.020 g/cm^3), mass (1.1 g ± 0.1 g), and the absence of a filter tip. This particular cigarette had been selected because early data indicated that it had the highest ignition propensity of any of the cigarettes examined [7, 8]. Over the more than three decades that these ignition susceptibility protocols have been in place, it is likely that the CTC has changed in formulation due to variations in the tobacco crop, changes in smoker preferences, etc. The CTC ignition strength has not been fully quantified at any time and is not specified in any of the test methods.

As furnishing items resisting ignition by the CTC have replaced older pieces, there has been a measurable reduction in the number of furnishing-related fires and casualties [1]. (Other factors, such as the concurrent rise in the installation of residential smoke detectors and a decrease in the number of smokers have also contributed to the increased fire safety [1].) However, as noted earlier, cigarette ignition of upholstered furniture and mattresses continues to be the largest single cause of fire deaths in the United States.

It has long been realized that reduced ignition propensity cigarettes (also referred to as "less fire-prone," "fire-safer," and "fire-safe" cigarettes) could decrease

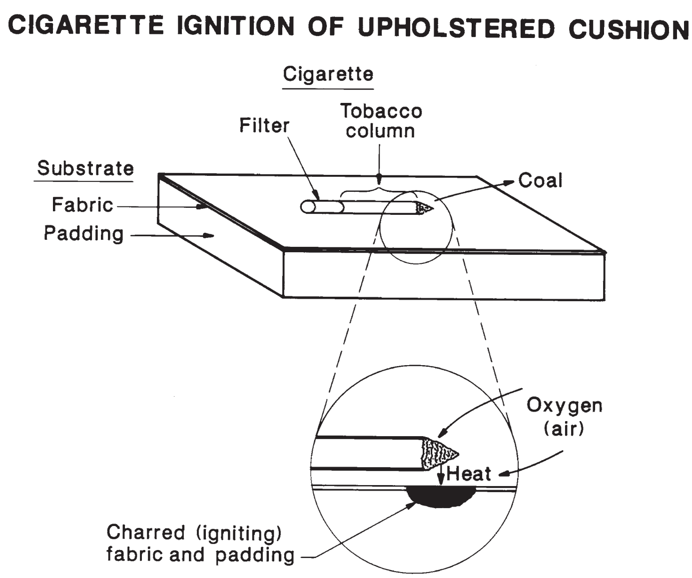

Figure 1. Cigarette ignition of soft furnishings.

the frequency of cigarette-initiated fires. Two Federally sponsored studies developed public understanding of the ignition of furnishings by cigarettes and developed the information infrastructure and basic measurement technology to enable effective regulation of the cigarette as an ignition source [9, 10]. In 2001, New York State issued a rule requiring that all cigarettes sold in the State be of reduced ignition propensity. The rule went into effect in 2004. Since then, 48 other states and the District of Columbia have enacted similar legislation, all with implementation dates no later than January 2011. A similar regulation went into effect throughout Canada in 2005.

It thus appears that within a year, cigarettes with a decidedly lower propensity to ignite soft furnishings will occupy much, if not all, of the North American marketplace. This should result in a reduction in the number of cigarette-initiated fires and, presumably, an accordant reduction in the number of related fire deaths and injuries. Of course, not all such fires will be eliminated since (a) the new cigarette standards do not require perfect performance, and (b) experience with fire standards in general has shown that even compliant products do not always manifest perfect fire safety performance.

This projection of improved fire safety assumes *both* the ignition source becoming less potent and the fuel (i.e., the furnishings) not becoming easier to ignite. Thus, it is necessary that soft furnishings continue to be tested with a cigarette whose ignition strength is comparable to that of the CTC and not with one of the new, reduced ignition propensity cigarettes.

By February 2008, the manufacturer of the CTC had converted production of the cigarette to a reduced ignition propensity version. This has led to demand for some type of successor to the CTC.

To ensure continuation of the same degree of cigarette ignition resistance shown by today's soft furnishings, the replacement standard ignition source (SIS) must be at least as potent as the CTC, i.e., "safety-neutral." Testing using the SIS should generally fail all furnishing materials and composites that fail presently and pass all that pass presently. A weaker SIS would allow more susceptible furnishing composites to enter the market, effectively weakening the existing and proposed flammability rules, lessening the potential gains from the new reduced ignition propensity cigarettes. Were the SIS to be stronger than the CTC, some additional degree of fire safety could be achieved. This would occur if some of the current furnishing materials or composites no longer passed the appropriate test using the SIS.

Regardless of the intended ignition propensity of the SIS, a measurement method is needed to quantify the ignition propensity of both the CTC and candidates for the SIS. The methodology presented here is directly applicable to cigarettes with ignition propensities comparable to the CTC.

2. Options for a Replacement Standard Ignition Source

Arriving at a truly equivalent ignition source requires careful replication of the properties of the CTC and/or enhanced knowledge of the physics of the ignition process. In an incipient fire, the heating of the composite substrate to the point of ignition is a function of:

- the temperature of the burning cigarette coal,
- the area of the burning coal,
- the quality and area of the contact between the coal and the substrate surface,
- the accessibility of air to this contact area,
- the rate of movement of the cigarette coal, and
- the susceptibility of the substrate to ignition (which includes such factors as the ignition temperature, thermal diffusivity, heat capacity, and density).

This list suggests that a replacement for the CTC as the ignition source in a test method needs to have mass and dimensions similar to the CTC (for similar substrate contact) and a hot zone that is similar in size and temperature to the CTC coal. If the hot zone of the SIS did not move in a manner similar to that of the CTC, experimentation would be needed to determine the effect of a faster or slower speed on substrate ignition probability.

Practically, there are two approaches for replacing the CTC:

1. Ensure continuing production of the current test cigarette (or equivalent) in perpetuity. This requires establishing a performance standard for the CTC ignition strength. It also presumes that a vendor will be always available to manufacture a product for which the demand is steady, but modest relative to a mainstream commercial cigarette. Identifying the quantities needed and developing an equitable distribution network are logistical problems.
   a. If the product were tobacco-based, some batch-to-batch variation would continue as a result of annual variation in the tobacco crop, so it would be necessary to certify successive batches of cigarettes.
   b. Developing a non-tobacco-based product would entail demonstrating equivalency on a wide range of substrates.
2. Develop a durable thermal surrogate for the CTC. This requires establishing the ignition performance of the CTC, followed by development of an ignition device. This heating device would preferably be invariant over time. It is likely that it would be more complex to use than a cigarette. Possible approaches to such a device include:
   a. Hot spot. The simplest source is a heated disk of diameter about that of a cigarette. Inexpensively and repeatably, this could capture all the thermal properties of the cigarette, including cooling by the substrate. However, it would not replicate the movement of the cigarette coal over the upholstery fabric and the resulting lengthening of the heated zone. Should lateral transfer of heat be as important as in-depth heat transfer, this could give erroneous results.
   b. Hot rod. A heatable rod of the same dimensions as the test cigarette would be almost as simple to construct and use as the heated disk. It too would replicate most of the features of the cigarette ignition process. However, heating would occur continuously along the full length of the rod, and the rod would be hottest near its middle. This steady heating of the full burn

path might result in too high a frequency of ignitions for an appropriate rod temperature.

c. Traveling hot spot 1. This would be similar to concept a, but the disk would be moved mechanically over the surface of the substrate. This is potentially realistic, but means for preserving thermal contact during the movement would need to be worked.
d. Traveling hot spot 2. The most sophisticated approach would be to develop a cylindrical host or channel within which a hot spot is moved mechanically or electronically. If the cylinder were of proper heat capacity and thermal conductivity, it would be possible to replicate the moving coal of the cigarette without moving the igniter itself.

These approaches introduce increased cost of the hardware, need for research to identify the effects of thermal physics that differ from that of the CTC, and complexity of operation, especially when multiple tests are conducted simultaneously.

If possible, then, the pursuit of replacement cigarettes appears to be the most expedient approach. The subject of this paper is the first step in providing for future supplies of test cigarettes that are equivalent to the CTC.

3. Ignition Propensity Measurement

The measurement method used to quantify the low ignition propensity of cigarettes in all the current regulations is ASTM E 2187, Standard Test Method for the Ignition Strength of Cigarettes [11]. This method is derived from the Cigarette Extinction Method, which was developed under the Fire Safe Cigarette Act of 1990 [12]. The current version of the ASTM Standard is ASTM E 2187-04.

In this method, a cigarette is lit, allowed to burn long enough to ‘‘forget’’ the lighting process (ca. 15 mm), and placed on a set number of layers of filter paper. The filter papers act as a heat sink, absorbing energy from the cigarette. A cigarette of high ignition strength continues burning its full length, despite the heat loss to the paper. The coal in a weaker burning cigarette cannot endure the heat loss and continue burning. The result of a single determination is whether the cigarette burns its full length or not. Typical results are shown in Figure 2.

To provide for measurement of a range of ignition strengths, the Standard includes three different heat sinks, manifested by 3, 10, or 15 layers of filter paper. To obtain a measure of the ignition strength, 40 of these determinations are performed for each cigarette type. The fraction of the 40 determinations that resulted in full-length burns is recorded. Conventionally, this fraction is converted to a percentage of full-length burns (PFLB) by multiplying by 100%.

The performance of cigarettes in the Cigarette Extinction Method has been correlated with the actual ignition propensity of cigarettes on furniture mockups [12]. Ignition performance on furniture mockups has been shown to relate well to performance of the cigarettes on upholstered chairs made of the same materials as the mockups [13]. Thus, there is a high degree of confidence of a good relationship between the measured PFLB value and the likelihood of an ignition in real life.

Figure 2. Photograph of typical results of determinations using ASTM E2187-04. *Top* full-length burn of the CTC (a non-filter cigarette); *Left* full-length burn of a filter tip cigarette; *Right* ceased burning of a low ignition strength cigarette.

To measure the low ignition propensity of the new, reduced ignition propensity cigarettes, a small heat sink is used. All the current regulations require testing on ten layers of filter paper and require that no more than 10 of the 40 determinations result in a full-length burn; i.e., only cigarettes with measured 25 PFLB or lower can be sold.

When the best selling conventional commercial cigarettes were tested on the larger heat sink presented by 15 layers of filter paper, all tests resulted in 100 PFLB [12]. NIST also found that increasing the number of layers beyond 15 resulted in the same 100 PFLB test result [14]. Therefore, to quantify the performance of the CTC, an alternative approach is needed, in which the measured value is significantly different from 0 PFLB and 100 PFLB.

4. Modification of ASTM E 2187

4.1. Alternative Test Substrates

The effectiveness of a heat sink is dependent on its thermal conductivity, heat capacity and density. Filter paper has relatively low values of all three of these, so it was expected that there should be substrate products with considerably higher values of one or all of these properties. Additional important considerations in selecting candidate heat sinks were that the candidates be readily available and of reproducible composition.

The performance of CTCs purchased in 1992 (and stored in a freezer since then) was evaluated on several candidate alternative substrates. The test results are summarized in Table 1.

Table 1
Test Results for the Current Test Cigarette (CTC) on Alternative Substrates

Substrate	Determinations	PFLB	Comments
30 layers of filter paper	16	100	
Gypsum wall board	8	100	
Aluminum plate	10	0	Soggy cigarettes
Brass plate (260/360 alloy)	8	0	Soggy cigarettes
Brass plate plus ten layers of filter paper	12	100	RSU (see below)
Brass plate plus three layers of filter paper	12	92	RSU
Brass plate plus one layer of filter paper	12	58	RSU; soggy cigarettes
Brass plate plus two layers of filter paper	40	88	RSU
Brass plate plus two layers of filter paper	36	80	SSU (see below)

The first substrate examined consisted of 30 layers of filter paper. The expectation was for a test result of 100 PFLB, as had been indicated by the unpublished NIST results mentioned earlier. Obtaining the expected results indicated that adding even more layers of filter paper was not likely to be successful.

The second substrate examined was an approximately 200 mm (8 in.) square of 16 mm (5/8 in.) thick gypsum wall board. Exploratory testing indicated that the CTC registered 100 PFLB on this substrate as well.

Gypsum wall board has a far higher density and heat capacity than multiple layers of filter paper. Therefore, the further search of test substrates was for materials that also had high thermal conductivities. Metal plates were known to meet this criterion.

Tests were conducted with nominally 203 mm (8 in.) squares of aluminum and brass. The aluminum plate was 19 mm (0.75 in.) thick, and the brass plate was 6.35 mm (0.25 in.) thick. Preliminary tests of the CTC on each of these plates resulted in 0 PFLB. However, in these determinations, the water generated by the burning tobacco puddled on the top surface of the plate, wetting the bottom of the cigarette. It was not clear whether the cigarette had extinguished due to heat losses to the plate or due to quenching by the water.

In routine testing on ten layers of filter paper, water had not puddled on the paper surface. This led to the thought that putting layers of filter paper on top of the metal plate might wick the water away from the cigarette. Accordingly, tests were conducted on substrates consisting of one to ten layers of filter paper on top of the brass plate.[1] Testing on ten layers resulted in the CTC showing 100 PFLB. This indicated that this many layers of paper were insulating the cigarette from the high thermal conductivity of the brass plate. The result for 3 layers was not much more encouraging. On one layer of filter paper, the cigarettes were still somewhat soggy. However, the result from two layers of filter paper was in the

[1]Examination of earlier tests of 15 layer substrates had shown that discoloration of the paper occurred as deep as about ten layers; i.e., the bottom four or five layers showed no brown marks in the area below the cigarette coal.

numerically desired range, and the cigarettes were not visibly wet. Hence, further testing was performed using two layers of filter paper.

In a current interlaboratory evaluation of a possible variation in ASTM E 2187 within ASTM E05, Fire Standards, data have indicated that for some cigarette designs, slightly different PFLB values could be obtained depending on whether the rough side or the smooth side of the filter paper was facing upward (A report on this activity is in preparation.). The PFLB value was typically higher for the rough side up (RSU) than for the smooth side up (SSU). It has been suggested that this is due to poorer thermal contact between the cigarette and the paper in the RSU configuration. The preliminary data in Table 1 indicated the possibility of a small difference in this direction. The testing reported in the next section was performed with the rough side up.

4.2. Modified Test Procedure

Following these preliminary results, a standardized procedure for further testing was developed. Figure 3 shows the original apparatus and the new substrate. The apparatus description and the test procedure follow ASTM E 2187-04, except for the following modifications. Additions are shown in boldface, and deletions are shown in strikeout.[2] The changes reflect the replacement of the standard filter paper holder with a brass plate, the use of two layers of filter paper, and the fact that this modified method is (at present) for use with non-filter tip cigarettes only.

Modifications to ASTM E2187-04:

1. Replace Sect. 3.2.1 with the following:
   Full-length burn, n—the outcome of a determination in which the cigarette burns to or past the tips of the metal pins (see 7.5).

2. Modify Sect. 4.1, Summary of Test Method, as follows:
   "This test method measures the probability that a cigarette, placed on a substrate, will generate sufficient heat to maintain burning of the tobacco column. Each determination consists of placing a lit cigarette on the horizontal surface consisting of a *brass plate upon which are two* ~~set number of~~ layers of filter paper. Observation is made of whether or not the cigarette continues to burn to *or past the tips of the metal pins in the metal rim.* ~~the beginning of the tipping paper~~. Forty determinations (comprising a test) are performed to obtain the relative probability that the cigarette will continue burning despite heat abstraction by the substrate."

3. Replace Sect. 7.4, Filter Paper Holder, with the following:
   "*Test Substrate*—A square support for the layers of filter paper, shall be made of 260 or 360 alloy brass.[3] The flat brass plate shall have dimensions

[2]The entire text of the ASTM Standard is not included here due to copyright provisions. Copies of the Standard can be purchased at www.astm.org/Standard/index.shtml.

[3]According to the *Metals Handbook*, 8th edn., vol 1, pp 1011–1021 (American Society for Metals, Metals Park, OH, 1961), the thermal conductivity of copper/zinc alloys is (120 ± 3) W/m K for zinc mass percentages between 28% and 36%, the composition range that includes 260 brass and 360 brass.

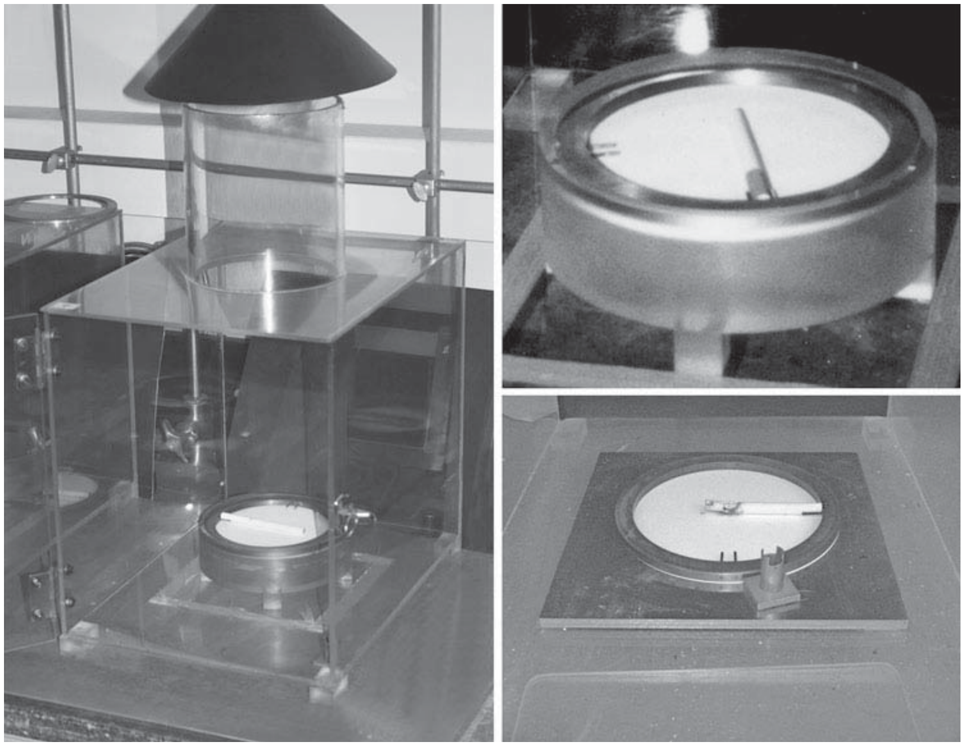

Figure 3. Photographs of ASTM E 2187 test chamber and substrates for measuring the ignition propensity of conventional cigarettes. *Left* complete test chamber; *Right top* standard substrate and solder; *Right bottom* replacement substrate.

within a range of 203 mm ± 3 mm (8.0 in. ± 0.1 in.) on a side and 6.35 mm ± 0.05 mm (0.25 in. ± 0.002 in.) in thickness. The brass plate is nominally centered on the bottom of the test chamber.''

4. Modify Sect. 8.1.2 as follows:
   ''Stability of air inside the test chamber shall be determined daily by placing a lit cigarette in the test position on *two* ~~three or more~~ layers of filter paper, *which have been placed on the brass plate,* then closing the chamber door. Air movement in the chamber shall be observed to ensure that smoke being emitted by the cigarette is rising vertically and is not showing turbulence within nominally 150 mm (ca. 6 in.) above the lit end of the cigarette. If turbulence is noted, then (*a*) the test chamber shall be checked for leaks, (*b*) the test chamber locations shall be evaluated for excess air flow in the laboratory, and (*c*) the air flow of the exhaust system shall be evaluated as the source of the disturbance.''

5. Modify Sect. 9.3 as follows:
   "The substrates consist of nominal 150 mm (6 in.) diameter circles of Whatman #2 ash-free cellulosic filter paper. Substrates are formed by *nominally centering* ~~placing~~ *two* ~~multiple~~ layers of filter paper *on the brass plate* ~~into the holder assembly~~, then placing the metal rim on top to ensure good contact between the layers. *The determinations are performed with the rough side of the filter papers facing upward*."

6. Modify Sect. 11.2 as follows:
   "Ensure that the *brass plate* ~~filter paper holder~~ is in the test chamber at the geometric center of its bottom. Cover the chimney on the test chamber."

7. Replace the text in Sect. 11.3 with the following.
   "Within a test, 20 of the determinations shall be conducted with the rough sides of the filter papers facing up and 20 determinations shall be conducted with the smooth sides of the filter papers facing up."

8. Modify Sect. 11.3.2 as follows:
   "Immediately before testing, place *two* ~~the proper number of~~ filter papers on the *brass plate* ~~filter paper holder~~, *noting the orientation of the rough surface*, and place the metal test rim on top. Discard filter papers that will not lay flat."

9. Modify Sect. 11.3.3 as follows:
   "Place the cigarette holder on the floor of the chamber, just forward of the center of the *brass plate* ~~filter paper holder~~."

10. Add a new Sect. 11.11:
    "At least once per day or per 100 determinations, whichever comes first, the surface of the brass plate shall be cleaned with a medium nylon/aluminum oxide hand pad. Emery paper or sandpaper shall not be used for this cleaning."

11. Eliminate Sect. 12.2.5.

12. Modify Sect. 12.2.6 as follows:
    "The fraction of determination in which the cigarette burned to or past the tips of the metal pins."

13. Sect. 13, Annex A1, and Appendix X1 do not apply.

5. Cigarette Performance Data

5.1. Current Test Cigarettes

It was recognized that the CTC might have undergone changes since the initiation of ignition susceptibility testing in the 1970s. It was thus valuable to gain some perspective on how that evolution might have affected the ignition propensity of the CTC. This perspective would be brought to bear on the development of an ignition strength specification for a future SIS.

Tests were conducted on samples of the CTC from five vintages:

- About 1992. These dated from the activity of the Technical Advisory Group (1990 to 1993) [12]. These were stored in a freezer since that time. Earlier tests indicated that the measured ignition propensity of other stored cigarettes of this vintage had not varied as of 2001 [15].
- 2001, purchased from the open market
- 2006, purchased from the open market
- 2007, purchased from the open market
- 2008, purchased from the open market

Five tests (i.e., 5 × 40 determinations) were conducted for each of the 2001 and 2008 vintages on two layers of Whatman No. 2 filter paper laid on top of the brass plate. There were fewer of the other three vintages available, so just two or three tests were conducted for each of these. In all tests, half of the determinations were conducted with the rough side up (RSU) and half with the smooth side up (SSU). The results are compiled in Table 2. Table 3 reports the measured values of cigarette length, mass, and circumference for five cigarettes of each vintage. Also included are the approximate packing density values calculated from the measured parameters.

The test results for the 1992, 2001, and 2006 vintage cigarettes are not significantly different, given the standard uncertainties (or ranges of values) and the expected repeatability of the measurement method (For ASTM E 2187, the 95% confidence interval is 0.13 at 90 PFLB, 0.26 at 50 PFLB, and 0.25 at 35 PFLB [11]). The differences in ignition strength between the values for the 2007 and 2008 vintage cigarettes and the values for the earlier vintages are outside the overall uncertainty in the measurements.

Based on the data in Table 3, none of the values of the three properties of the cigarettes (length, mass, and packing density) that are specified in the standards differed significantly from those specifications. As a result, there do not appear to

Table 2
Performance Data for Different Vintages of the Current Test Cigarette

Vintage	PFLB					Mean ± σ[a] or range
1992	84	88	95			89 ± 5
2001	75	78	85	68	73	76 ± 6
2006	75	83				75 to 83
2007	35	35				35
2008	48	45	43	50	50	47 ± 3

[a]Standard uncertainty of each determination

Table 3
Properties of Different Vintages of the Current Test Cigarette

Vintage		Length (mm)	Mass (g)	Circumference (mm)	Calculated packing density (g/cm^3)
1992	Data	83.8, 83.7, 83.8, 83.5, 83.5	1.03, 1.02, 1.06, 1.03, 1.08, 1.04	24.6, 24.6, 24.6, 24.7, 24.7	0.258, 0.257, 0.265, 0.258, 0.271
	Mean $\pm$ σ[a]	83.7 $\pm$ 0.2	1.04 $\pm$ 0.03	24.6 $\pm$ 0.1	0.262 $\pm$ 0.006
2001	Data	83.2, 82.9, 82.9, 83.2, 83.1	1.03, 1.03, 0.97, 1.00, 1.06	24.6, 24.6, 24.6, 24.5, 24.6	0.260, 0.260, 0.246, 0.255, 0.269
	Mean $\pm$ σ	83.0 $\pm$ 0.2	1.02 $\pm$ 0.03	24.6 $\pm$ 0.0	0.258 $\pm$ 0.008
2006	Data	83.6, 83.8, 83.9, 84.0, 83.6	0.99, 1.01, 1.00, 1.02, 1.00	25.0, 24.8, 24.8, 25.0, 25.0	0.242, 0.251, 0.247, 0.249, 0.247
	Mean $\pm$ σ	83.8 $\pm$ 0.2	1.01 $\pm$ 0.01	24.9 $\pm$ 0.1	0.247 $\pm$ 0.004
2007	Data	83.2, 82.9, 83.0, 82.9, 83.0	1.05, 1.06, 1.08, 0.98, 1.07	24.8, 24.8, 24.9, 24.8, 24.8	0.263, 0.265, 0.266, 0.244, 0.267
	Mean $\pm$ σ	83.0 $\pm$ 0.1	1.05 $\pm$ 0.04	24.8 $\pm$ 0.0	0.261 $\pm$ 0.009
2008	Data	82.6, 82.9, 82.7, 82.8, 82.8	1.05, 0.99, 0.99, 1.02, 1.00	25.0, 24.8, 24.8, 24.8, 24.8	0.259, 0.247, 0.248, 0.256, 0.251
	Mean $\pm$ σ	82.8 $\pm$ 0.1	1.02 $\pm$ 0.03	24.8 $\pm$ 0.1	0.252 $\pm$ 0.005

[a] Standard uncertainty of each determination

Table 4
Performance Data for Commercial Cigarettes

Cigarette	Number of determinations	PFLB
A	80	44
B	80	66
C	80	73
D	80	0

be any differences among these properties of the five vintages that account for the pattern of measured ignition strengths.

5.2. Other Cigarettes

As mentioned earlier, the CTC had been selected because it was thought to be the cigarette with the highest ignition propensity at the time. For the current project, it was deemed valuable to gain some indication of the CTC performance relative to other commercial cigarettes.

Packs of three commercial brand styles of cigarettes, purchased in 2007 and not compliant with the new reduced ignition propensity cigarette regulations, were designated A, B, and C. Eighty determinations of each brand style were conducted, half with the rough side of the filter paper up, and the other half with the smooth side up.

In the same manner, the same number of determinations of a single brand style of a compliant cigarette, designated D, were performed. With the large heat sink of the alternative substrate, none of these cigarettes were expected to burn their full length.

The results of these tests are compiled in Table 4.

The measured ignition strengths of cigarettes A, B, and C were no higher than the ignition strengths of the 1992, 2001, and 2006 vintages of the CTC. This limited testing is consistent with the earlier finding that the CTC had a high ignition strength relative to other commercial cigarettes. As expected, none of the cigarette D determinations resulted in a full-length burn.

6. Toward a New Standard Ignition Source

The previous sections of this paper described a measurement method for characterizing the ignition strength of the cigarette that has been used to test soft furnishings for cigarette ignition resistance. The next step is to apply the test results to developing a set of specifications for a replacement test cigarette.

The following specification ranges for a non-filter-tip cigarette are proposed:

- Nominal length: 83 mm ± 2 mm
- Tobacco packing density: 0.270 g/cm^3 ± 0.020 g/cm^3

- Mass: 1.1 g ± 0.1 g
- Ignition strength: 70 PFLB to 95 PFLB using ASTM E 2187, as modified in Sect. 4.2 of this paper.

The first three descriptors are subsumed by those required of the CTC. They should provide for continuity of the critical cigarette-substrate relational properties that affect ignition propensity of soft furnishings, as described in Sect. 2.

The proposed ignition strength range reflects equivalency to the three earlier vintages of the CTC. The CTC was intended to be at least as strong an ignition source as the other commercial cigarettes. The tested 1992, 2001, and 2006 versions of the CTC meet that intent, relative to cigarettes A, B, and C. The tested 2007 and 2008 vintage cigarettes do not. Thus, using an ignition strength range based on cigarettes of these three earlier vintages is likely to be ‘‘safety-neutral.’’

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