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# **Development of an Improved Fire Test Method for Aircraft Ducting Materials**

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Final Report

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16. Abstract <p>A comprehensive fire test program was conducted on aircraft ducting materials in an effort to continue mitigating the threat of in-flight fires. Previous work at the Federal Aviation Administration (FAA) William J. Hughes Technical Center has indicated that the current FAA vertical Bunsen burner test requirement could not adequately discriminate between materials that performed poorly and materials that performed well under realistic fire scenarios. From this effort, an alternative radiant heat panel test method was developed. It was demonstrated that this method was effective in evaluating the in-flight fire resistance qualities of aircraft ducting.</p>					
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## LIST OF ACRONYMS

12-VBB	12-second vertical Bunsen burner
CFR	Code of Federal Regulations
FAA	Federal Aviation Administration
ISF	Intermediate-scale fire
MSCC	Microscale combustion calorimeter
NRHP	New radiant heat panel
RHP	Radiant heat panel

## EXECUTIVE SUMMARY

In its current effort to improve in-flight fire safety, the Federal Aviation Administration (FAA) developed an improved flammability test standard for aircraft ducting materials. The current test requirements used to certify these materials is the 12-second vertical Bunsen burner (12-VBB) test (Title 14 Code of Federal Regulations (CFR), Part 25, Appendix F Part I(b)(4)). Previously, the FAA had demonstrated that the 12-VBB test was unable to properly discriminate materials that will or will not prevent fire propagation when exposed to a standard fire threat. The standard fire threat is a urethane foam block used during the development of the improved thermal acoustic insulation fire test method found in 14 CFR 25.856.

The research path selected to develop this standard was largely based on the approach used during the development of the thermal acoustic insulation fire test standard. Five small-scale tests were used to characterize the flammability properties of the aircraft ducting materials and to determine if any of these small-scale tests could be used to predict the fire behavior of ducting materials during intermediate-scale hidden fire tests. The five tests used were (1) the 12-VBB test, (2) radiant heat panel (RHP) test, (3) heat release fire test, (4) smoke test, and (5) microscale combustion calorimeter (MSCC) test. All ducting material tested in this program met the current 12-VBB certification fire test, yet some performed poorly in the intermediate-scale fire (ISF) test. A modified version of the RHP was able to predict the behavior of ducting materials in the ISF tests.

The test equipment for the improved test method was exactly the same as the one specified in 14 CFR 25.856. The differences between the improved test method and 14 CFR 25.856 are related to (1) specimen size, (2) radiant heat flux, (3) heat-soak time, and (4) acceptance criteria. The specimen size was reduced from 31.8-cm wide by 58.4-cm long to 21.59 by 27.94 cm (letter-size office paper). The need to have larger specimens was not necessary because of the rigidity of most aircraft ducting materials. The radiant heat flux was reduced from 1.7 W/cm<sup>2</sup> to 1.13 W/cm<sup>2</sup>. This reduction was necessary because, with the higher radiant heat flux, materials were failing even when their performances were acceptable when exposed to the standard fire threat. The addition of the 1-minute exposure time (heat soak) to the radiant heat was implemented to properly assess thicker ducting materials. The acceptance criteria in this test require the consideration of two parameters: (1) the burn length and (2) the afterflame time. The burn length was retained ( $l < 5.08$  cm), but the afterflame time was increased to 45 seconds because thicker and heavier ducting materials tend to create small flames, which persist for a period of time but do not appear to be hazardous.

The microscale combustion calorimeter, which employs very small test specimen (5 mg), was a useful tool for screening candidate ducting materials. In most cases, materials that exhibit the following attributes will meet the improved RHP fire test criteria: onset temperature greater than 256°C, combustion temperature greater than 322°C, specific heat release rate less than 205 W/g, and specific heat release less than 15 kJ/g.



Briefly, the test method is as follows: the electric RHP is calibrated to emit  $1.13 \text{ W/cm}^2$  on the zero position of the specimen tray. The fire ignition source (the pilot flame) is adjusted to have a flame (blue inner cone) length of 19 mm. After the equipment is calibrated, the 21.59 by 27.94 cm specimen material is exposed (soaked) to the radiant heat for only 1 minute. After the 1-minute heat soak, the pilot flame is impinged on the specimen for 15 seconds. The burn length must be less than 5.08 cm, and the afterflame time must be less than 45 seconds.

## 1. INTRODUCTION.

It was recommended in a previous Federal Aviation Administration (FAA) report [1], that an improved fire test method and criteria be developed for aircraft ducting to improve in-flight fire safety. This recommendation was based on the fact that the current flammability test method requirement, the 12-second vertical Bunsen burner (12-VBB) test, did not adequately predict the fire propagation behavior of aircraft ducting under realistic hidden fire conditions. The work described in this report was conducted with the objective of developing an improved fire test methodology that could be used as an acceptable means to certify aircraft ducting and ducting joints.

The purpose of this report is to present the test results and analysis used to develop the improved fire test method for aircraft ducting materials. The proposed new radiant heat panel (NRHP) fire test protocol is included in appendix B.

## 2. EVALUATION APPROACH.

The approach used to evaluate the flammability properties of aircraft ducting materials was similar to the approach used during the development of the aircraft thermal acoustic insulation fire test method, but with some modifications. The 12-VBB test, the intermediate-scale fire (ISF) test, and radiant heat panel (RHP) test were the only test methods used during the previous approach, because of their applicability to the program's objective. The smoke, heat release rate, and microscale combustion calorimeter (MSCC) tests were also employed to expand the knowledge of the flammability properties of these materials and to support some decisions that were made during the development of the new test method (NRHP).

The current FAA federal regulations require that aircraft ducting materials meet the 12-VBB test. Most materials tested in this program were retested and found to be compliant, although not all specimens could be tested because some suppliers did not provide specimens for the 12-VBB tests. Fifty-five different specimens were tested with the test methods mentioned above, which was composed of different materials (thermoplastics and thermosettings) and different materials combinations and configurations (rigid and flexible). The results of only 23 materials will be described in this report, since they were the only ones tested in the ISF tests. Specimen thicknesses (2 ply versus 4 ply) were identified using different identification letters. Some of the material names were not used because of proprietary considerations. The materials tested are tabulated in table 1. From these tests, the NRHP test method was developed, which gave the best correlation with realistic ISF test results. The following sections will describe the test methods used in this development program and the results.

### 2.1 12-SECOND VERTICAL BUNSEN BURNER TEST AND RESULTS.

This test was conducted according to Chapter 1, Vertical Bunsen Burner Test for Cabin and Cargo Compartment Materials, of report DOT/FAA/AR-00/12, "Aircraft Materials Fire Test Handbook" [2]. This test method requires exposing a 7.62- by 30.48-cm specimen of ducting material to a 3.81-cm methane flame for 12 seconds. The pass/fail criteria are as follows: the burn length shall be less than 20.32 cm, afterflame time shall be less than 15 seconds, and flaming drippings shall self-extinguish within 5 seconds. Tables 2, 3, and 4 show the results of

the tested material specimens. Materials AD, AE, AW, and BC were not retested, but the manufacturer indicated that they met the criteria of the test.

Table 1. Aircraft Ducting Materials Tested

Key	Material	Thickness (mm)	Weight (g/cm <sup>2</sup> )
AD	Flexible duct (Nondisclosure agreement)	Skin: 0.40 Helix: 4.55 Film: 0.08 Blanket: 10.85	0.1634
AE	Metallized tedlar tape on nylon 12	2.8	0.2857
AW	Flexible duct (Nondisclosure agreement)	Skin: 0.14 Helix: 1.81	0.0616
B	Fiberglass/epoxy	0.6	0.0896
C	Fiberglass/epoxy/polyurethane (rigid duct)	13.04	0.1182
D	Rigid duct (Nondisclosure agreement)	0.52	0.0576
F	Fiberglass/phenolic C (rigid duct)	0.35	0.0488
G	Rigid duct (Nondisclosure agreement)	1.1	0.1744
H	Fiberglass/polyester	0.91	0.1331
K	Kevlar/epoxy	1.02	0.1132
M	Kevlar/polyetherimide	0.74	0.0980
N	Nylon 12	1.49	0.1427
O	Rigid duct (Nondisclosure agreement)	0.62	0.0830
P	Rigid duct (Nondisclosure agreement)	0.66	0.0549
Q	Rigid duct (Nondisclosure agreement)	4.39	0.0641
R	Rigid duct (Polyphenylsulfone-based material)	1.45	0.1866
T	Flexible duct (Nondisclosure agreement)	Skin: 0.25 Helix: 0.77	0.0796
U	Flexible duct (Nondisclosure agreement)	Outer skin: 0.25 Outer helix: 0.77 Fabric (x2): 0.05 Blanket: 27.5 Inner skin: 0.34 Inner helix: 1.01	0.1926
V	Flexible duct (Nondisclosure agreement)	Skin: 0.17 Helix: 2	0.0706
W	Polyetherimide-based material	0.73	0.0870
X	Flexible duct (Nondisclosure agreement)	Skin: 0.48 Helix: 4.55	0.1619
Y	Flexible duct (Nondisclosure agreement)	Skin: 0.40 Helix: 4.55	0.1472
BC	Rigid duct (Nondisclosure agreement)	1.91	0.1950

Table 2. 12-Second Vertical Bunsen Burner Test Results (Burn Length)

Material	12-VBB Length (cm)	FAA Acceptance Criteria (cm)	Pass/Fail
R	0.2, 0.4, 0.4	20.32	Pass
X	0.8, 1.3, 1.6	20.32	Pass
K	1.8	20.32	Pass
U	2.4, 1.5, 2.2	20.32	Pass
Y	2.2, 2.5, 2.6	20.32	Pass
P	2.9, 2.2, 3.4	20.32	Pass
H	3.4	20.32	Pass
T	3.8, 3.8, 3.6	20.32	Pass
Q	4.0, 4.0, 4.1	20.32	Pass
O	2.4, 5.1, 5.3	20.32	Pass
N	4.8	20.32	Pass
M	4.9	20.32	Pass
W	5.9	20.32	Pass
B	6	20.32	Pass
V	6.9, 6.8, 6.9	20.32	Pass
C	6.99, 6.99, 7.62	20.32	Pass
F	7.9, 8.1	20.32	Pass
D	14.0, 13.5	20.32	Pass
G	13.5, 14.7, 13.5	20.32	Pass
AD	Not retested. Sample not available	20.32	N/A
AE	Not retested. Sample not available	20.32	N/A
AW	Not retested. Sample not available	20.32	N/A
BC	Not retested. Sample not available	20.32	N/A

N/A = Not applicable

Table 3. 12-Second Vertical Bunsen Burner Test Results (Flame Time)

Material	12-VBB Flame Time (Seconds)	FAA Acceptance Criteria (Seconds)	Pass/Fail
F	0.0	15	Pass
G	0.0	15	Pass
O	0.0	15	Pass
R	0.0	15	Pass
U	0.0	15	Pass
Y	1, 0, 0	15	Pass
B	1.0	15	Pass
D	1.0	15	Pass
H	1.0	15	Pass
N	1.0	15	Pass
P	1.2	15	Pass
X	2, 2.2, 0	15	Pass
T	2.3, 1.6, 1	15	Pass
Q	1.8, 2.1, 2	15	Pass
M	2.3	15	Pass
C	0, 0, 8	15	Pass
W	3.0	15	Pass
V	3.9, 4.4, 4.2	15	Pass
K	5.0	15	Pass
AD	Not retested. Sample not available	15	N/A
AE	Not retested. Sample not available	15	N/A
AW	Not retested. Sample not available	15	N/A
BC	Not retested. Sample not available	15	N/A

N/A = Not applicable

Table 4. 12-Second Vertical Bunsen Burner Test Results (Drip Flame Time)

Material	12-VBB Drip Flame Time (Seconds)	FAA Acceptance Criteria (Seconds)	Pass/Fail
B	0.0	5	Pass
C	0.0	5	Pass
D	0.0	5	Pass
F	0.0	5	Pass
G	0.0	5	Pass
H	0.0	5	Pass
K	0.0	5	Pass
M	0.0	5	Pass
N	0.0	5	Pass
O	0.0	5	Pass
P	0.0	5	Pass
Q	0.0	5	Pass
R	0.0	5	Pass
T	0.0	5	Pass
U	0.0	5	Pass
V	0.0	5	Pass
W	0.0	5	Pass
X	0.0	5	Pass
Y	0.0	5	Pass
AD	Not retested. Sample not available	5	N/A
AE	Not retested. Sample not available	5	N/A
AW	Not retested. Sample not available	5	N/A
BC	Not re-tested. Sample not available	5	N/A

N/A = Not applicable

## 2.2 INTERMEDIATE-SCALE FIRE TEST AND RESULTS.

Actual specimens of aircraft ducting were tested using the ISF test setup to determine their flammability performance while exposed to the standard fire threat. The specimens that were evaluated with the 12-VBB test met the certification test criteria.

The upper half of a narrow-body fuselage section was used to conduct the ISF tests, as shown in figure 1 [3]. This section was insulated with thermal acoustic insulation blankets fabricated with polyimide film (Facile Insulfab<sup>®</sup> film 200C) and fiberglass (Johns Manville Microlite<sup>®</sup> AA Blanket 0.34 PCF Fiberglass). These fire-resistant materials were selected to minimize their potential contribution to the fire behavior of ducting materials. To simulate the cabin ceiling and

create the attic space, a steel frame was installed to hold the composite ceiling panels in place. The 0.635-cm ceiling panels, constructed of fiberglass/phenolic faces and a DuPont™ Nomex® honeycomb core, were installed 30.48 cm below the crown of the fuselage section. The attic space, formed by the ceiling panels and fuselage crown, was instrumented with thermocouples and calorimeters to measure the temperature and heat flux above the ignition source and at each end of the fuselage section. The duct specimen was placed in the attic directly on the centerline of the fuselage; the upper surface of the duct sample was 15.24 cm below the ceiling. Five thermocouples were located above the duct, 30.5 cm apart and centered, to measure the temperature as the fire propagated across the air duct. The thermocouples and calorimeters were connected to a portable data acquisition system, and their signal outputs were collected at a sampling rate of 1 Hz. At least two cameras were set up to record the fire event. Photographs were also taken before and after each test to record the event and damage. The ignition source for the ISF tests was a 101.6- by 101.6- by 228.6-mm urethane foam block spiked with 10 cc of heptane. The block had a foam density of 16.02 kg/m<sup>3</sup> and produced an average peak heat flux of 65 kW/m<sup>2</sup>. It was placed against the ducting specimen 147.32 cm from the forward edge and 11.43 cm from the fuselage center line (to the starboard side). The test was initiated by starting the data acquisition system and activating the video cameras. Thirty seconds after collecting the ambient temperature data, the foam block was ignited and allowed to burn until the foam was consumed and the flames were out.

Two main parameters were studied: fire propagation and afterflame time. After each test, measurements were taken of the burned length, burned area, and material burning time (video analysis). Table 5 includes the measurements along with the peak temperature and peak heat flux readings. Appendix A contains the temperature and heat flux history charts. Results showed that most aircraft ducts self-extinguished within 3 minutes (all tests median: 1.43 minutes) and had a median surface area damage of 649 cm<sup>2</sup>. Since not all aircraft ducting specimens had the same dimensions, in terms of diameter or length, a global comparison could not be made. The largest surface area damage was from material C with an area of 32,583 cm<sup>2</sup> and the smallest area measured was from material AD, 92 cm<sup>2</sup> (see figure 2). There were a few specimens that burned for a long period of time, which included materials N (30 minutes), AW (8.6 minutes), AE (10 minutes), and BC (40.3 minutes); see figure 3. These thermoplastic specimens melted and created a pool fire. Other materials, such as materials C and D, burned within a short period of time, but burned significantly (quick fire propagation), 32,583 cm<sup>2</sup> and 10,423 cm<sup>2</sup>, respectively. The foam block, the ignition source, burns for about 9 to 10 minutes. Some materials produced a significant amount of smoke inside the air duct, even though there was no fire penetration. These smoky materials were B, C, and K. Material N experienced fire penetration and produced a significant amount of smoke as well. The results, based on afterflame time and burned area, showed that there were six poor performers: materials AW, C, BC, D, N, and AE. Materials C and D burned significantly (more than 50% of their surface area), while materials AW, BC, N, and AE burned for a longer period of time.

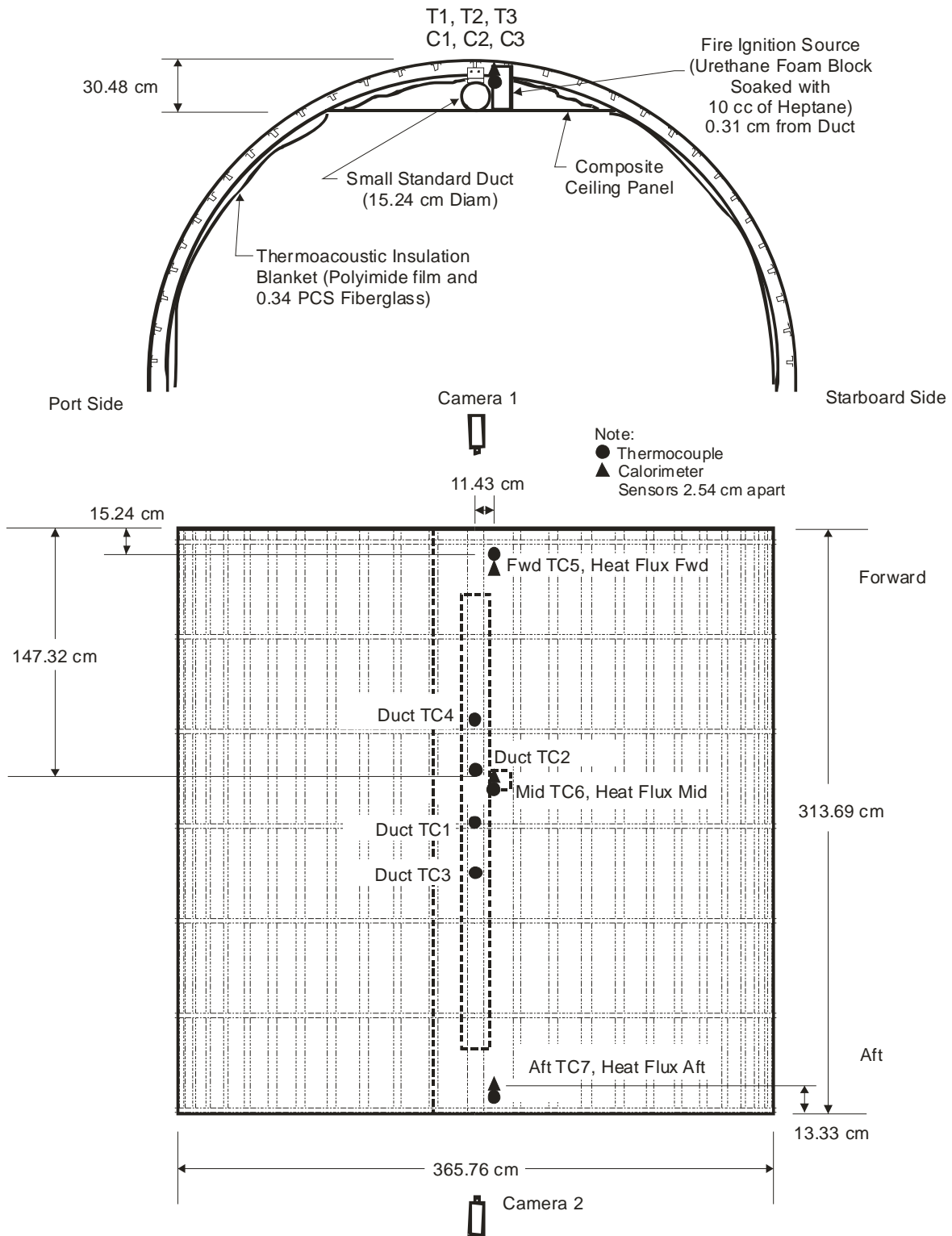


Figure 1. Intermediate-Scale Fire Test Mockup



Table 5. Intermediate-Scale Fire Test Results

Duct Material	Test Number	Burned Area (cm <sup>2</sup> )	Maximum Burn Length (cm)	Peak Temperature (°C)	Peak Heat Flux (kW/m <sup>2</sup> )	Burning Time (Minutes)
AD	080905T3	92	19	834	70	1
AE	021506T1	111	47	810	64	10.0
AW	101206T2	1040	55	765	64	8.6
B	050305T2	1112	74	655	77	1.5
BC Test 1	031506T1	4985	152	766	59	40.3
BC Test 2	031506T2	336	30	698	39	2.2
C	092104T14	32583	305	825	92	5.6
D	090205T4	10423	150	831	25	7
F	081605T1	113	49	697	50	0.5
G	051705T1	1190	150	641	74	1.2
H	050305T1	632	83	562	70	1.4
K	012705T2	750	53	896	81	1.1
M	012705T1	374	51	816	58	0.9
N	050305T4	1752	29	708	59	30.0
O	083105T4	510	53	825	66	1.3
P	083105T3	347	43	797	66	1.3
Q	083105T1	690	35	758	54	2.0
R	080205T1	761	36	756	65	1.5
T	083105T5	653	36	777	58	1.2
U	090105T1	1081	18	779	65	1.2
V	083105T2	610	47	816	58	1.2
W	042205T1	593	52	512	56	1.3
X	080905T1	302	35	787	59	2.7
Y	080905T2	644	54	804	62	1.4

**INTERMEDIATE-SCALE FIRE TEST RESULTS**  
**Burned Area of Aircraft Ducting Materials**

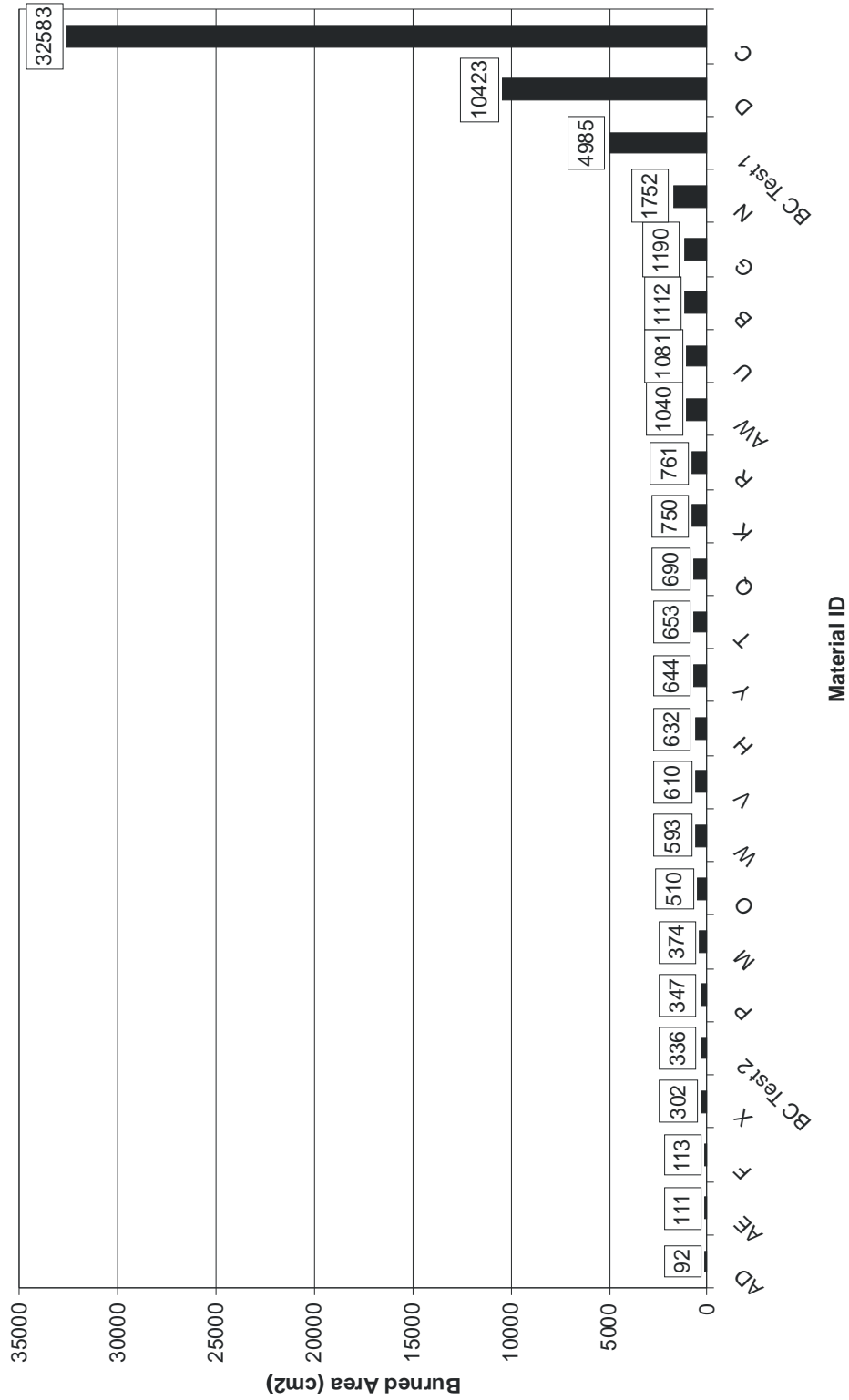


Figure 2. Intermediate-Scale Fire Test Results: Burned Area

**INTERMEDIATE-SCALE FIRE TEST RESULTS**  
**Burning Time (min)**

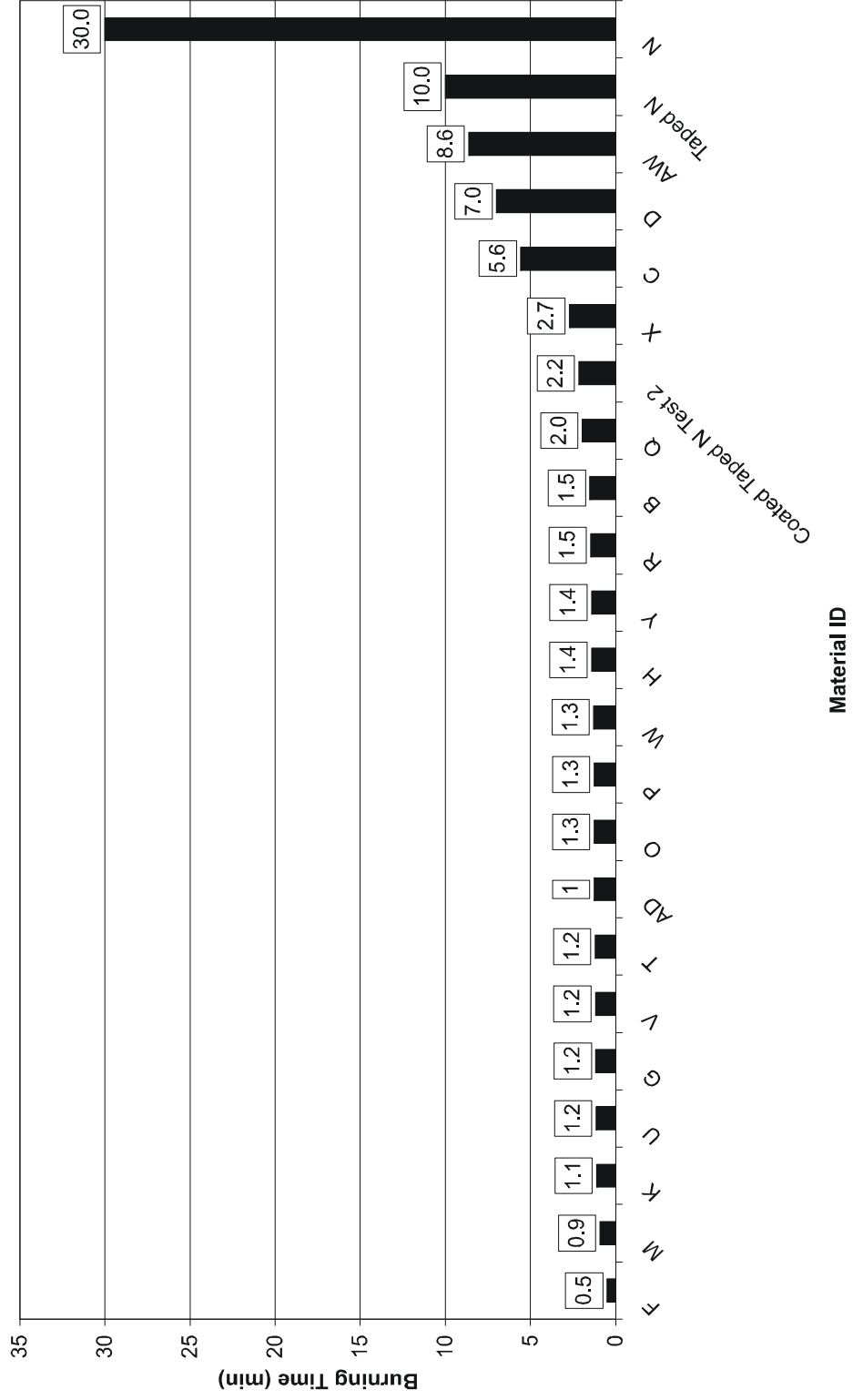


Figure 3. Intermediate-Scale Fire Test Results: Burning Time

## 2.3 RADIANT HEAT PANEL TEST AND RESULTS.

The RHP test method was used to evaluate the fire propagation and flaming characteristics. Initially, the test method dictated in Title 14 Code of Federal Regulations (CFR) 25.856, which is used for the certification of thermal acoustic insulation, was used “as is.” Ideally, the existing test method would apply with no change. However, because this specific test method and acceptance criteria were designed for the evaluation of very thin insulation film materials, the test method had to be modified to allow for the evaluation of thicker, heavier materials such as aircraft ducting.

Three variations of the test method were evaluated and are herein referred to as protocol versions 1, 2, and 3. Protocol version 3 gave the best correlation with ISF test results. The following sections will explain the modification made to the original 14 CFR 25.856.

### 2.3.1 Radiant Heat Panel Test per 14 CFR 25.856.

The original 14 CFR 25.856 RHP test is the current FAA fire test requirement for aircraft thermal acoustic insulation. This test was used “as is” to determine the fire propagation characteristics of aircraft ducting. It is described in Part VI of Appendix F to Part 25, “Test Method to Determine the Flammability and Flame Propagation Characteristics of Thermal Acoustic Insulation Materials.” It uses an RHP with an ignition source to measure the tendency of thermal acoustic insulation to propagate a fire. The electric RHP mounted in the chamber at 30° from the horizontal specimen plane, had a radiation surface of 327 by 470 mm and calibrated to emit 1.7 W/cm<sup>2</sup> on the zero position. The fire ignition source was a propane pilot burner that was approximately 127-mm long with a flame (blue inner cone) length of 19 mm. The test specimens were 318-mm wide by 584-mm long and secured on the sliding platform holder, which allowed the specimen to be 191 mm below the RHP. The sliding platform was then inserted into the chamber and its door was closed. Immediately after this, the pilot burner flame was impinged on the specimen for 15 seconds. The test required consideration of two parameters as pass/fail criteria: flame propagation and flame time after removal of the ignition source. To pass this test, no flame propagation was allowed beyond 5.08 cm to the left of the centerline of the pilot flame application, and the afterflame time must not exceed 3 seconds on any specimen [4]. In this project, the flame propagation was reported as burn length for consistency with the 12-VBB test. The results of the 20 materials evaluated are found in tables 6 and 7.

Results showed that the majority of the specimens that did well in the ISF test failed the RHP test because of the afterflame time acceptance criteria ( $t < 3$  seconds). Sixteen of the 20 materials tested in the RHP test failed because of afterflame time, and only 4 failed because of the propagation criteria ( $l < 5.08$  cm). Therefore, this test method, as prescribed in the current regulation, could not be used “as is” for the aircraft ducting application.

Table 6. Radiant Heat Panel Test: Per CFR 25.856 Results (Burn Length)

Material	Thickness (mm)	RPH Burn Length (cm)	FAA Acceptance Criteria (cm)	Pass/Fail
Y	0.87 skin (5.14 rib)	1.0, 1.8	5.08	Pass
AE	2.12	1.9	5.08	Pass
X	0.83 skin (5.14 rib)	1.1, 2.8	5.08	Pass
U	1.66	2.3, 2.3	5.08	Pass
V	0.78 skin (2 rib)	2.0, 3.2, 2.2	5.08	Pass
G	1.10	2.5	5.08	Pass
O	0.66	2.8, 2.8, 2.5	5.08	Pass
R	1.59	2.8	5.08	Pass
Q	4.45	2.8, 3.0, 2.6	5.08	Pass
W	0.85	2.9	5.08	Pass
F	0.76	2.9	5.08	Pass
BC	2.13	3.3, 2.0, 4.3	5.08	Pass
P	0.53	3.2, 3.2, 3.1	5.08	Pass
M	1.18	3.9	5.08	Pass
K	1.25	4.3	5.08	Pass
T	0.25 skin (1.59 rib)	3.5, 2.5, (8.2)	5.08	Pass
H	0.6	6.3	5.08	Fail
C	13.29	>16	5.08	Fail
D	1.25	>16	5.08	Fail
N	2.17	>16	5.08	Fail
AD	Not tested. Sample not available	N/A	5.08	N/A
AW	Not tested. Sample not available	N/A	5.08	N/A
B	Not tested. Sample not available	N/A	5.08	N/A

N/A = Not applicable

### 2.3.2 Radiant Heat Panel Test per Protocol Version 1.

The protocol version 1 change included (1) the addition of a preheating period (2) changes to the specimen size, (3) pilot exposure time, and (4) acceptance criteria.

The first change to the 14 CFR test method was the addition of the preheating period. While conducting the 14 CFR 25.856 RHP test method, it was noticed—and expected—that when different thicknesses of materials were tested, inconsistent results were achieved. When material K was tested as 2- and 4-ply samples, results indicated that the thinner sample failed both the flame propagation and the afterflame time, and the thicker sample failed only the afterflame

time. To obtain the same failure modes on both samples, the materials were conditioned by subjecting them to a heat-soak period of 1 minute; this allowed the samples to achieve temperature equilibrium throughout their thickness. The test was run again, and results showed that both samples had the same failure modes. This conditioning period was added to the test method. Still, all specimens failed the test, which did not match the results found in the ISF test.

Table 7. Radiant Heat Panel Test: Per FAR 25.856 Results (Afterflame Time)

Material	RHP Afterflame Time (Seconds)	FAA Acceptance Criteria (Seconds)	Pass/Fail
F	0.0	3	Pass
R	0.3	3	Pass
H	1.0	3	Pass
O	2.7, 1.7, 2.08	3	Pass
P	4.5, 3.6, 3.4	3	Fail
M	6.0	3	Fail
BC	10.0, 3.0, 9.0	3	Fail
W	7.5	3	Fail
Q	7.2, 6.2, 11.9	3	Fail
Y	4.0, 15.0	3	Fail
G	13.3	3	Fail
V	12.8, 16.5	3	Fail
U	11.7, 19.6	3	Fail
K	21.0	3	Fail
T	8.1, 39.7	3	Fail
C	>40	3	Fail
D	>40	3	Fail
N	>40	3	Fail
AE	>40	3	Fail
X	>40	3	Fail
AD	Not tested. Sample not available	3	N/A
AW	Not tested. Sample not available	3	N/A
B	Not tested. Sample not available	3	N/A

N/A = Not applicable

Note: According to 14 CFR 25.856, the RHP was heated to 1.7 W/cm<sup>2</sup>. The specimen was exposed to this heat and the propane pilot flame for 15 seconds.

The second change was to reduce the size of the specimen. The need to have larger specimens, as in the original 14 CFR test protocol (318-mm wide by 584-mm long), was not necessary because of the rigidity of most of the aircraft ducting materials. The second change to the

original 14 CFR protocol was the reduction of the test specimen size to 21.59 by 27.94 cm. Most of the time, the specimens were laid on the sliding platform holder without a holding fixture. There were a few materials that shrunk or significantly warped during the preheating period; in these cases, they were clamped down to keep them in place (see figure 4).

The third change was the decrease of the pilot flame impingement time. Instead of impinging the pilot flame to 15 seconds, it was impinged for 10 seconds. The justification for using 10 seconds was based on the time it took to achieve the same peak temperature (863°C) as in the 12-VBB test.



Figure 4. Example of Clamped Radiant Heat Panel Test Specimen

Unfortunately, this impingement time did not change the results of material K vis-à-vis what was seen during the ISF test.

The fourth and last modification made in this first protocol change was the change of acceptance criteria. The allowable burn length was kept the same (5.08 cm), but the allowable afterflame time was increased to 20 seconds. This increase in afterflame time was required because none of the recognized fire-worthy materials met the stringent 3-second criteria dictated in the FAA rule for thin insulation film materials. The greater ducting material thickness provided extra fuel to the afterflame, increasing the self-extinguishing time. This change allowed the passing of additional test specimens that were found acceptable during the ISF tests.

Protocol version 1 of the RHP test did not provide an acceptable correlation with the ISF test results. Tables 8 and 9 contain the results for the RHP test, protocol version 1.

Table 8. Radiant Heat Panel Test: Experimental Protocol Version 1 Results (Burn Length)

Material	Thickness (mm)	RHP Burn Length (cm)	Potential Acceptance Criteria (cm)	Pass/Fail
Q	4.45	0.0	5.08	Pass
AE	2.12	1.3, 1.3, 1.9	5.08	Pass
Y	0.87 skin (5.14 rib)	2.2, 1.3	5.08	Pass
F	0.76	2.1	5.08	Pass
V	0.78 skin (2 rib)	2.0, 2.0, 2.3	5.08	Pass
X	0.83 skin (5.14 rib)	2.3, 2.1	5.08	Pass
U	1.66	2.3	5.08	Pass
O	0.66	2.4, 2.5, 2.0	5.08	Pass
P	0.53	2.9, 2.5, 2.9	5.08	Pass
R	1.59	3.0	5.08	Pass
T	0.25 skin (1.59 rib)	4.7, 4.3, 2.5	5.08	N/A, material shrunk, not clamped
BC	2.13	7.0, 12.3	5.08	Fail
C	13.29	>16	5.08	Fail
D	1.25	>16	5.08	Fail
K	1.25	>16	5.08	Fail
N	2.17	>16	5.08	Fail
AD	Not tested	N/A	5.08	N/A
AW	Not tested	N/A	5.08	N/A
B	Not tested	N/A	5.08	N/A
G	Not tested	N/A	5.08	N/A
H	Not tested	N/A	5.08	N/A
M	Not tested	N/A	5.08	N/A
W	Not tested	N/A	5.08	N/A

N/A = Not applicable

Note: According to experimental test protocol version 1, the RHP was heated to  $1.7 \text{ W/cm}^2$ , the specimen was exposed to this heat for 1 minute, and then the propane pilot flame was impinged on it for 10 seconds.



Table 9. Radiant Panel Test: Experimental Protocol Version 1 Results (Afterflame Time)

Material	RHP Afterflame Time (Seconds)	Potential Acceptance Criteria (Seconds)	Pass/Fail
F	0.0	20	Pass
R	0.0	20	Pass
X	1.0	20	Pass
O	13.77, 12.74, 12.16	20	Pass
P	13.9, 13.5, 15.3	20	Pass
AE	4.0, 3.0, 6.2	20	Pass
V	17.4, 15.4, 17.1	20	Pass
U	15.3	20	Pass
Y	31.0, 21.0	20	Fail
T	38.9, 49.1, 52.3	20	Fail
C	>40	20	Fail
BC	>40	20	Fail
D	>40	20	Fail
K	>40	20	Fail
N	>40	20	Fail
Q	>40	20	Fail
AD	Not tested	20	N/A
AW	Not tested	20	N/A
B	Not tested	20	N/A
G	Not tested	20	N/A
H	Not tested	20	N/A
M	Not tested	20	N/A
W	Not tested	20	N/A

N/A = Not applicable

Note: According to experimental test protocol version 1, the RHP was heated to 1.7 W/cm<sup>2</sup>, the specimen was exposed to this heat for 1 minute, and then the propane pilot flame was impinged on it for 10 seconds.

### 2.3.3 Radiant Heat Panel Test per Protocol Version 2.

Protocol version 2 included changes in the pilot flame impingement time and the afterflame time of the acceptance criteria. But other than these changes, the same test protocol was used as before.

The pilot flame impingement time was increased back to 15 seconds since it had no impact on the results of material K, which was a good performer in the ISF test. The intent was also to provide additional ignition energy for material N to burn and better mimic the performance observed during the ISF fire test. Material N melted and created a pool fire for a long period of time during the ISF test.

Materials X, Y, T, U, and V had acceptable propagation behaviors in the ISF test, but failed the RHP test, protocol version 1, because their afterflame times exceeded the 20-second threshold. These materials burned in place, consuming the material through their thickness, but did not propagate because of their high ignition temperatures. For this reason, the afterflame time component of the acceptance criteria was increased to 45 seconds.

#### 2.3.4 Radiant Heat Panel Test per Protocol Version 3.

Protocol version 3 changes included a decrease of the radiant heat emitted by the panel and the way the burn length was determined.

Test results with the previous protocol versions indicated that the radiant heat flux may have been too high for this application. To derive the new radiant heat flux, the MSCC data, described in section 2.6, was analyzed to identify the onset temperatures of material K and others. The results of the MSCC tests showed that the onset temperature of this material (301°C) was below the RHP temperature at the 5.08-cm mark (324°C). The RHP was then calibrated to 1.13 W/cm<sup>2</sup>, which allowed this material to pass this test but still failed the materials that did not perform well during the ISF test (for example: AW, C, D, N, and AE). At this setting, the temperature of the RHP at the 5.08-cm mark was recorded to be 256°C. Results are presented in tables 10 and 11.

Table 10. Radiant Heat Panel Test: Experimental Protocol Version 3 Results (Burn Length)

Material	Thickness (mm)	RPH Burn Length (cm)	Potential Acceptance Criteria (cm)	Pass/Fail
AE With Fire-Protection Blanket	>25.4	2.9	5.08	Pass
AW	0.12 skin (1.73 rib)	7.50	5.08	Fail
B	1.07	3.9, 3.8	5.08	Pass
BC	2.13	6.00	5.08	Fail
C	13.29	14.50	5.08	Fail
D	1.25	9.70	5.08	Fail
H	0.60	3.5, 3.4	5.08	Pass
K	1.25	3.8, 3.7	5.08	Pass
N	2.17	17.00	5.08	Fail
U	1.66	3.20	5.08	Pass
X	0.83 skin (5.14 rib)	3.00	5.08	Pass
Y	0.87 skin (5.14 rib)	4.00	5.08	Pass
AD	Not tested	N/A	5.08	N/A
F	Not tested	N/A	5.08	N/A
G	Not tested	N/A	5.08	N/A
M	Not tested	N/A	5.08	N/A
O	Not tested	N/A	5.08	N/A
P	Not tested	N/A	5.08	N/A
Q	Not tested	N/A	5.08	N/A
R	Not tested	N/A	5.08	N/A
T	Not tested	N/A	5.08	N/A
V	Not tested	N/A	5.08	N/A
W	Not tested	N/A	5.08	N/A

N/A = Not applicable

Table 11. Radiant Heat Panel Test: Experimental Protocol Version 3 Results (Afterflame Time)

Material	Afterflame Time (Seconds)	Potential Acceptance Criteria (Seconds)	Pass/Fail
AE With Fire-Protection Blanket	2.0	45	Pass
AW	>50	45	Fail
B	12.0 4.0	45	Pass
BC	>60	45	Fail
C	>50	45	Fail
D	>50	45	Fail
H	0.0	45	Pass
K	5.0, 14.0	45	Pass
N	>50	45	Fail
U	10.0	45	Pass
X	13.0	45	Pass
Y	14.0	45	Pass
AD	Not tested	N/A	N/A
F	Not tested	N/A	N/A
G	Not tested	N/A	N/A
M	Not tested	N/A	N/A
O	Not tested	N/A	N/A
P	Not tested	N/A	N/A
Q	Not tested	N/A	N/A
R	Not tested	N/A	N/A
T	Not tested	N/A	N/A
V	Not tested	N/A	N/A
W	Not tested	N/A	N/A

N/A = Not applicable

Note: According to experimental test protocol version 3, the RHP was heated to 1.13 W/cm<sup>2</sup>, the specimen was exposed to this heat for 1 minute, and then the propane pilot flame was impinged on it for 15 seconds.

The temperature of the pilot propane flame (963°C) is much higher than the ignition temperature of most of the composite materials used to manufacture aircraft ducting. Normally, the pilot flame leaves a footprint that is oval in shape and measures about 8.5 cm by 4.5 cm (see figure 5). The centerline of this oval is where the zero position is located. Usually, a fire-worthy material will track the pilot flame footprint during the pilot flame impingement period and then have a laminar diffusion flame after the removal of the pilot flame. This flame will usually not move to the left (propagate) beyond the 5.08-cm mark and will extinguish within 45 seconds. In the case of non-fire-worthy materials, the burning flames will clearly move to the left, exceed the 5.08-cm mark, and/or will burn for more than 45 seconds.

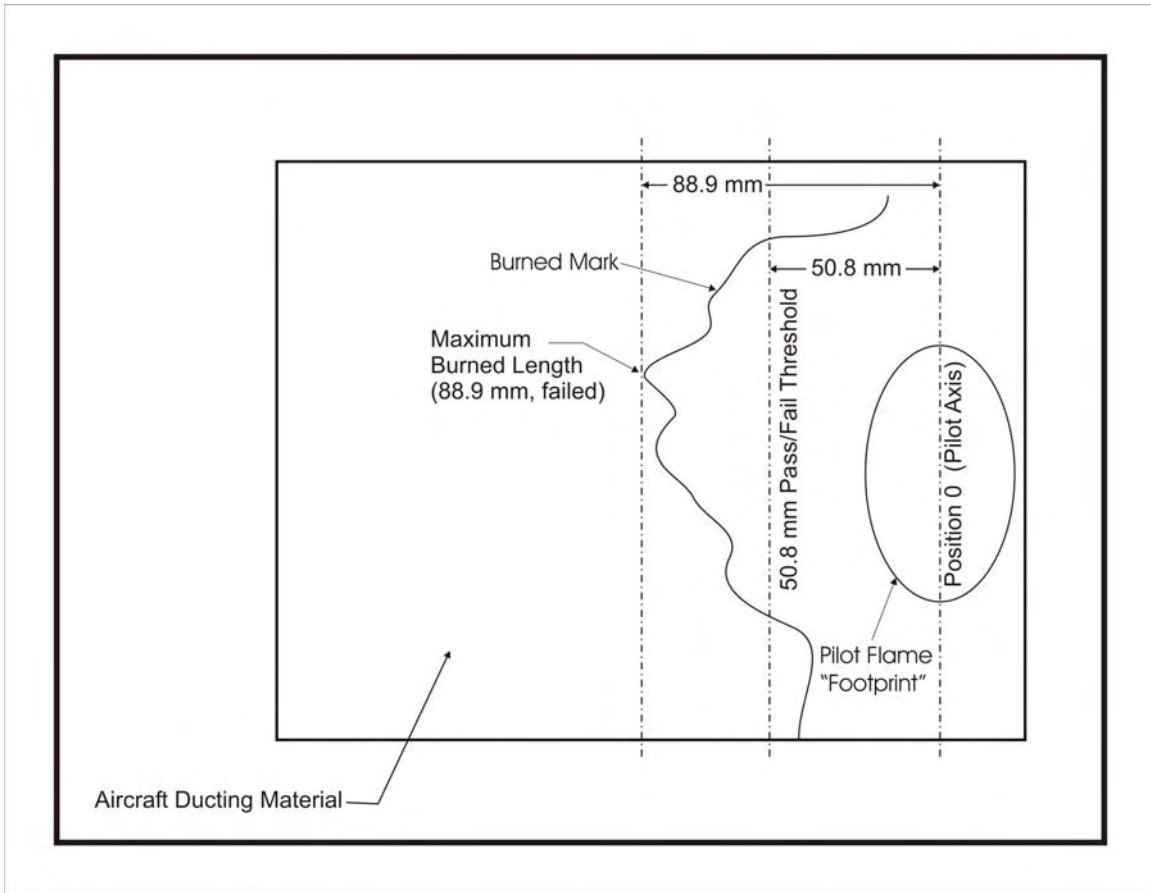


Figure 5. Example of Burn Length Measurement of a Radiant Heat Panel Test Specimen

In some cases, flexible ducts are manufactured with stiffening ribs. If the ribs are placed perpendicular to the pilot flame while testing, the flames (due to their velocity) may travel along the rib and exceed the 5.08-cm mark. It was noticed during RHP testing that the afterflame of ribbed fire-worthy materials retracted behind the 5.08-cm mark after the pilot flame was removed and met the test method acceptance criteria. The slight burn mark created by the pilot flame was ignored when the burn length was measured after the test.

The concept of using a fire-protection jacket was also evaluated using this test method. Material AE was covered with a fire-protection jacket composed of polyimide film, fiberglass insulation (2 layers), and PPS hook and loop. This fire-protection jacket previously met the 14 CFR 25.856 RHP test for thermal acoustic insulation. This protective jacket also successfully passed the acceptance criteria of the RHP (protocol version 3) test and prevented material AE from becoming exposed to the fire threat; the burn length was 2.86 cm and the afterflame time was 2 seconds. The fire-protection jacket maintained its structural integrity and was able to secure the non-fire-worthy material inside it.

This version of the RHP test method was found acceptable for the evaluation of aircraft ducting and ducting joints materials; the detailed version is presented in appendix B.

## 2.4 SMOKE TEST FOR CABIN MATERIALS AND RESULTS.

The smoke-specific optical densities emitted by some aircraft ducting materials were measured by using the fire test method described in Chapter 6 of DOT/FAA/AR-00/12, “Aircraft Materials Fire Test Handbook.” This test is currently not an FAA requirement for aircraft ducting materials. During this test, material specimens measuring 73 by 73 mm were exposed, individually, to a heat flux density of 2.50 W/cm<sup>2</sup> and ignited with several pilot burners for a minimum of 4 minutes. All materials tested met the current FAA maximum-specific optical density of 200, as required by 14 CFR 25.853 for large surface area cabin materials (sidewalls, ceilings, etc.) [5].

The test results are found in table 12. Figure 6 shows an example of the amount of smoke produced by a material having a specific optical density of 190. Smoke was emitted from both sides of the aircraft ducting although fire burnthrough had not occurred.

Table 12. Smoke Test Results

Material	Smoke (Specific Optical Density)	FAA Acceptance Criteria	Pass/Fail
R	0.1	200	Pass
M	0.5	200	Pass
P	0.97, 0.31	200	Pass
O	0.73, 1.27	200	Pass
W	1.9	200	Pass
D	4.0, 5.04	200	Pass
T	6.79, 10.35	200	Pass
V	12.75, 11.21	200	Pass
G	9.99, 12.45, 14.18	200	Pass
U	17.15, 18.05	200	Pass
X	28.17, 15.47	200	Pass
F	23.2	200	Pass
Q	20.13, 29.32	200	Pass
H	36.42, 43.62, 41.56	200	Pass
Y	48.03, 37.46	200	Pass
C	145.02, 119.12, 127.94	200	Pass
N	175.8	200	Pass
K	195.09, 182.84	200	Pass
B	199.58, 179.72	200	Pass
AD	Not tested. Sample not available	200	N/A
AE	Not tested. Sample not available	200	N/A
AW	Not tested. Sample not available	200	N/A
BC	Not tested. Sample not available	200	N/A

N/A = Not applicable

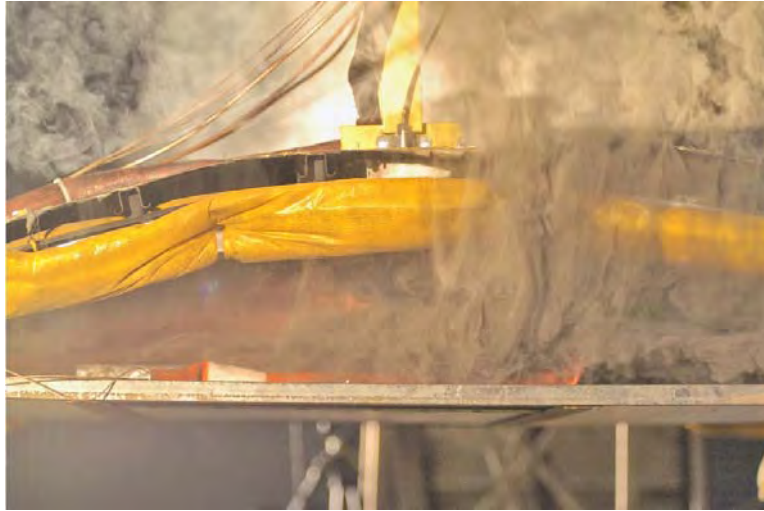


Figure 6. Example of Smoke Produced During Intermediate-Scale Fire Test

## 2.5 HEAT RELEASE RATE TEST FOR CABIN MATERIALS AND RESULTS.

The heat release rate and total heat release of some aircraft ducting materials was measured using the “Heat Release Rate Test for Cabin Materials” described in Chapter 6 of DOT/FAA/AR-00/12, “Aircraft Materials Fire Test Handbook.” This test is currently not an FAA requirement for ducting materials. During this test, a 150- by 150-mm material specimen was exposed to a heat flux of  $3.50 \text{ W/cm}^2$  and ignited with pilot burners [6].

As shown in tables 13 and 14, about half the materials failed this test, including material samples that performed well during the ISF test.

Table 13. Peak Heat Release Rate Test Results

Material	Heat Release Rate Peak (kW/m <sup>2</sup> )	FAA Acceptance Criteria (kW/m <sup>2</sup> )	Pass/Fail
F	30.2	65	Pass
R	27.53, 31.74, 37.14, 25.78	65	Pass
T	30.47, 36.54	65	Pass
W	40.6	65	Pass
O	39.77, 41.55	65	Pass
U	42.21, 41.79	65	Pass
P	41.13, 47.31	65	Pass
M	51.75, 55.05	65	Pass
H	64.99, 50.79, 56.76	65	Pass
D	60.59, 67.36, 70.85	65	Fail
B	66.6	65	Fail
G	68.7	65	Fail
K	76.32, 70.17, 65.14	65	Fail
Q	69.02, 75.35	65	Fail
V	83.8, 78.13	65	Fail
C	74.34, 87.86, 86.23	65	Fail
Y	115.3	65	Fail
X	165.75, 128.08	65	Fail
N	179.3	65	Fail
AD	Not tested. Sample not available	65	N/A
AE	Not tested. Sample not available	65	N/A
AW	Not tested. Sample not available	65	N/A
BC	Not tested. Sample not available	65	N/A

N/A = Not applicable



Table 14. Total Heat Release Test Results

Material	Total Heat Release (kW*min/m <sup>2</sup> )	FAA Acceptance Criteria (kW*min/m <sup>2</sup> )	Pass/Fail
R	1.05, 15.79, 7.37, 11.51	65	Pass
T	23.02, 25.8	65	Pass
O	22.74, 28.69	65	Pass
F	25.9	65	Pass
D	31.4, 28.32, 29.17	65	Pass
G	32.8	65	Pass
U	35.45, 33.84	65	Pass
B	35.7	65	Pass
P	39.33, 40.28	65	Pass
W	40.4	65	Pass
H	36.43, 43.62, 41.56	65	Pass
V	47.82, 48.13	65	Pass
Q	65.08, 65.69	65	Fail
M	68.49, 64.73	65	Fail
K	75.82, 68.76, 74.25	65	Fail
C	105.11, 110.83, 119.56	65	Fail
N	114.2	65	Fail
Y	120.4	65	Fail
X	149.89, 115.58	65	Fail
AD	Not tested. Sample not available	65	N/A
AE	Not tested. Sample not available	65	N/A
AW	Not tested. Sample not available	65	N/A
BC	Not tested. Sample not available	65	N/A

N/A = Not applicable

## 2.6 MICROSCALE COMBUSTION CALORIMETER TEST AND RESULTS.

ASTM D 7309-07, “Standard Test Method for Determining Flammability Characteristics of Plastics and Other Solid Materials Using Micro-Scale Combustion Calorimetry,” was used to determine additional flammability characteristics of the aircraft ducting materials. This standard test provided data on the specimens regarding specific heat release, specific heat release rate, and combustion and onset temperatures. During this test, a very small weighted specimen of the aircraft ducting material (about 5 mg) was placed inside the MSCC and heated at a constant rate of 1°C per second, starting from room temperature or a bit higher, to a selected final temperature (usually 900°C). After the test, the cooled specimen was removed and weighed to determine the residual mass of the specimen. The specific heat release and specific heat release rates were

computed by the software, based on the oxygen consumption and the combustion and onset temperatures were determined using the collected data [7]. Tables 15, 16, and 17 show the flammability characteristics of the aircraft ducting materials obtained during this test.

This test demonstrated that material thickness was a significant parameter to consider during the development of the new test protocol for aircraft ducting materials. Identical materials, with the exception of one being slightly thicker than the other, were tested using the MSCC, where the specimen is heated from all directions, and the RHP test, where the specimen is heated in one direction, as specified in 14 CFR 25.856. Both specimens performed almost identical in the MSCC. However, the RHP test showed that the slightly thicker material performed better than the thinner material; i.e., the fire spread less on the thicker material. Because thick materials will tend to heat up slower than thin materials, the 1-minute heat soak was added to the RHP test. After adding this preheat period, both specimens behaved similarly.

The MSCC data was useful in changing the RHP heat flux to produce results more consistent with the ISF test; e.g., for material K. The RHP heat flux was reduced from  $1.7 \text{ W/cm}^2$  to  $1.13 \text{ W/cm}^2$ , lowering the temperature in the area located 5.08 cm left of the pilot location from  $324^\circ\text{C}$  to  $256^\circ\text{C}$ . The lower temperature,  $256^\circ\text{C}$ , was selected because the onset temperature of material K was  $301^\circ\text{C}$ .

After characterizing the flammability properties of the aircraft ducting materials, it was observed (with a few exceptions outside the box) that if the ducting material had the following flammability characteristics, it will pass the NRHP test method: onset temperature greater than  $256^\circ\text{C}$ , combustion temperature greater than  $320^\circ\text{C}$ , specific heat release lower than  $15 \text{ kJ/g}$ , and specific heat release rate lower than  $205 \text{ W/g}$ . The MSCC test equipment can be used to screen new aircraft ducting materials and allow manufacturers to evaluate their flammability properties without the need of producing large quantities of them. Refer to figures 7 and 8 for a definition of these parameters and their acceptance values.

Table 15. Microscale Combustion Calorimeter Results (Combustion Temperature)

Material	Onset Temperature (°C)	1st Combustion Temperature (°C)	2nd Combustion Temperature (°C)	3rd Combustion Temperature (°C)	4th Combustion Temperature (°C)	Minimum Combustion Temperature (°C)
C	243	239	-	-	-	239
K	301	322	610	-	-	322
H	314	343	-	-	-	343
AE	310	353, 350, 352	413, 412, 413	415, 426, 416	481, 480, 487	350
N	318	360, 357, 358	477	-	-	357
Y	303	359	491	-	-	359
B	304	361, 364, 372	-	-	-	361
X	300	366	492	616	713	366
G	184	426, 455, 466, 417	-	-	-	417
Q	384	449, 448	461	604, 597, 602	-	448
D	253	488, 491, 489, 475	-	-	-	475
AW	269	488				488
M	520	554	614	-	-	554
F	308	563, 561, 560	645, 653, 648	-	-	560
W	502	562	-	-	-	562
U	436	579, 584, 569	626, 624, 632	-	-	569
T	517	567, 582, 592	599, 601, 598	-	-	567
V	547	591, 596, 594	628, 629, 627	-	-	591
P	519	611, 617, 616	-	-	-	611
O	562	611, 617, 616	-	-	-	611
R	448	632	-	-	-	632
AD	Sample not tested	N/A	-	-	-	-
BC	Sample not tested	N/A	-	-	-	-

N/A = Not applicable

Table 16. Microscale Combustion Calorimeter Results (Specific Heat Release Rate)

Material	1st Specific Heat Release Rate Peak (w/g)	2nd Specific Heat Release Rate Peak (w/g)	3rd Specific Heat Release Rate Peak (w/g)	4th Specific Heat Release Rate Peak (w/g)	Maximum Specific Heat Release Rate Peak (w/g)
D	21, 20, 21, 24	-	-	-	24
G	23	-	-	-	23
F	17, 15, 20	26, 26, 30	-	-	30
U	19, 21, 20	40, 39, 42	-	-	42
T	18, 19, 17	44, 45, 53	-	-	53
B	63, 63, 64	-	-	-	64
O	65, 66, 64	-	-	-	66
H	77, 76, 74	-	-	-	77
V	25, 29, 30	147, 151, 145	-	-	151
R	150		-	-	150
K	120	164	-	-	164
W	165	-	-	-	165
P	173, 202, 202	-	-	-	202
M	106	195	-	-	195
AE	116, 112, 125	242, 218, 233	106, 106, 106	288, 352, 329	352
Q	43, 104, 109	355	65, 40, 46	-	355
AW	427				427
C	436	-	-	-	436
Y	20	466	-	-	466
X	25	473	15	26	473
N	79, 77, 73	587, 583, 626	-	-	626
AD	Sample not tested	N/A	-	-	-
BC	Sample not tested	N/A	-	-	-

N/A = Not applicable

Table 17. Microscale Combustion Calorimeter Results (Specific Heat Release)

Material	MSCC Specific Heat Release (kJ/g)
G	2
T	3, 3, 3
D	3, 3, 3, 4
O	4, 4, 4
H	5, 4, 4
F	6, 6, 6
B	6, 7, 7
R	7
P	8, 8, 9
Q	7, 10, 11
W	10
U	10
V	11, 10, 10
M	11
K	14
AW	24
C	25
Y	26
X	27
AE	30, 32, 32
N	32
AD	Sample not tested
BC	Sample not tested

MICRO-SCALE COMBUSTION CALORIMETER TEST

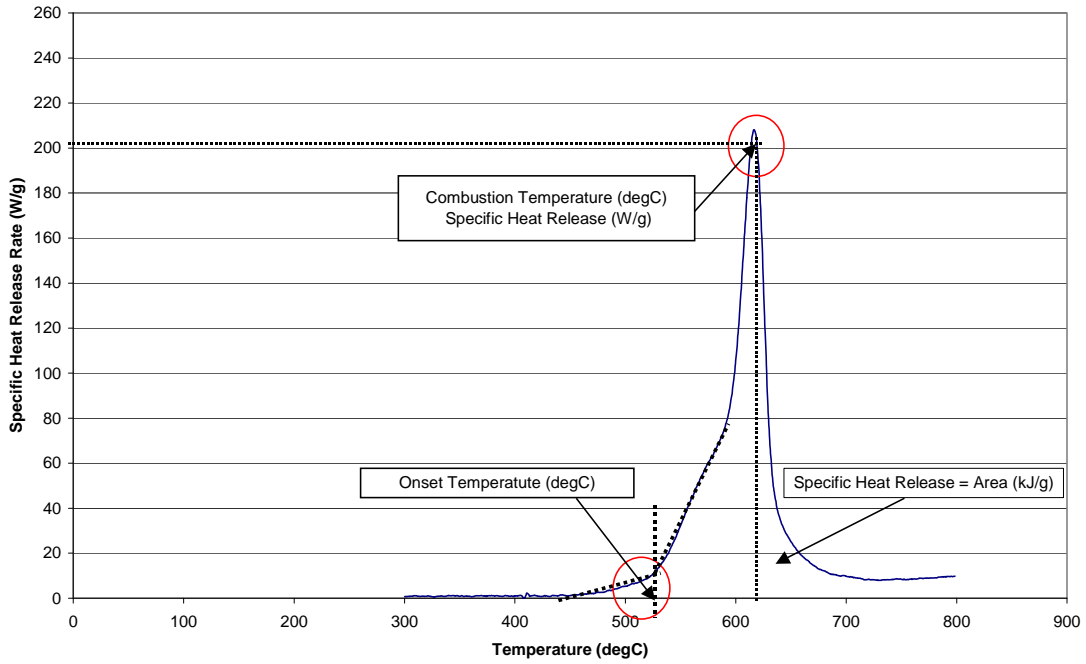


Figure 7. Microscale Combustion Calorimeter Plot Example

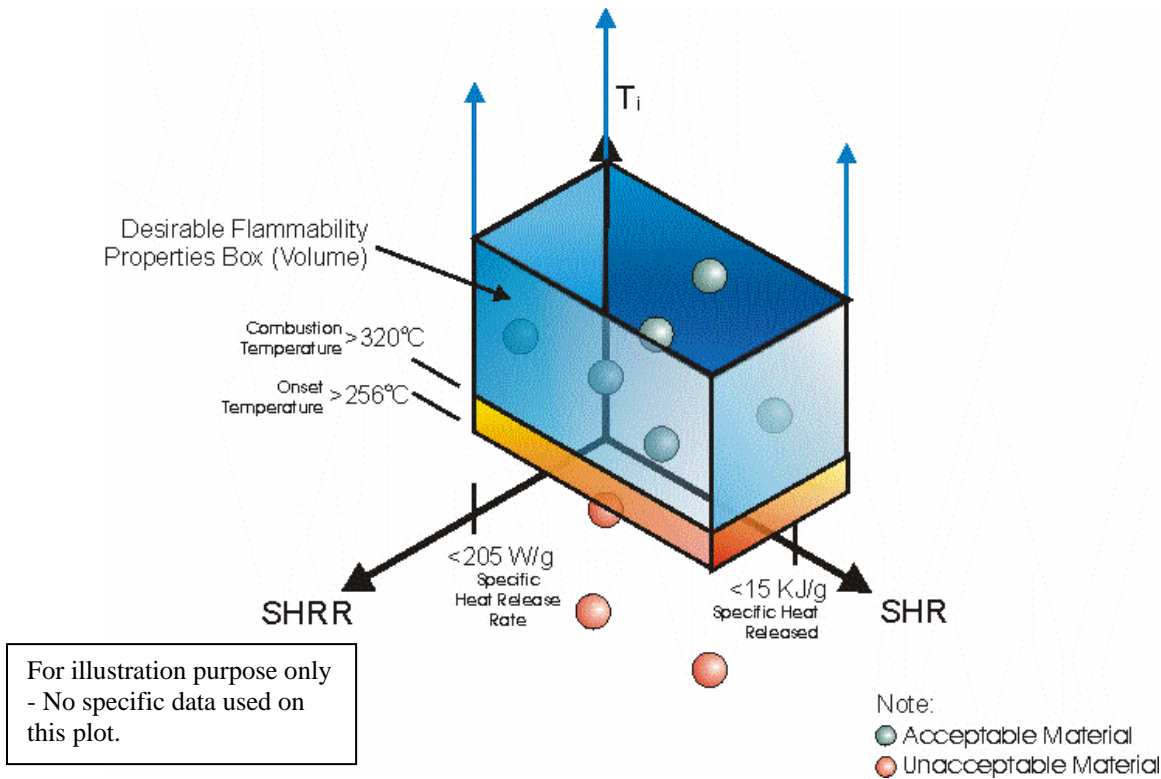


Figure 8. Microscale Combustion Calorimeter Required Parameters to Meet New Radiant Heat Panel Test

### 3. NEW RADIANT HEAT PANEL TEST VERIFICATION.

The objective of this project was to develop an improved fire test procedure (NRHP) that could replace the currently used method to determine the flammability and fire propagation characteristics of aircraft ducting materials. The details of the NRHP are found in appendix B. To verify this new test procedure, the results of two small-scale fire tests, (the baseline and the NRHP), were compared against the results of an ISF test simulating a fire in the attic of an aircraft cabin. The two small-scale tests were the 12-VBB test (baseline) and the new RHP test (NRHP, new procedure).

Table 18 shows a comparison between the results of the 12-VBB, the NRHP, and the ISF tests. This table clearly shows that every material tested passed the 12-VBB test, which was not what was observed during the ISF test. The ISF test showed that six materials did not perform well because they either burned significantly, burned for a long period of time, or both, when subjected to the standardized fire threat. In contrast, the NRHP test was able to predict the behavior encountered during the ISF testing; it matched the failed ducting material and most of the failure modes.

As seen in table 18, material samples AW, BC, N, and AE burned for a long period of time, 9 minutes or longer (sometimes as high as 40 minutes), during the ISF test. The main failure mode for these thermoplastics was that they melted and created a pool of the material on the ceiling panel (attic side) that caused the fire to burn for a long period of time. This same failure mode was observed when these material samples were tested using the NRHP test; the materials melted and created a pool fire. Their afterflame time, which is one of the acceptance criteria of this test, was greater than 45 seconds. These samples also failed the NRHP test burn length criteria, i.e., the burn length was longer than 5.08 cm. During the ISF test, these materials also had serious burned areas (with the exception of material AE). Now, material samples C, BC, and D had significant fire propagation damage during the ISF test; samples C and BC were completely consumed. Again, the NRHP test was also able to fail these materials on this mode; when tested, their burn length exceeded the acceptance criteria threshold. These samples also failed the NRHP afterflame time acceptance criteria; i.e., they did not self-extinguish within 45 seconds. During the ISF test, they had longer burning times than the materials that passed the NRHP test.

From this comparative analysis, it can be concluded that the NRHP test is a better discriminating test than the 12-VBB test at predicting the flammability and fire propagation of aircraft ducting materials when exposed to the standard fire threat in a narrow-body aircraft cabin attic.

Table 18. Comparison Between the Results of the 12-Second Vertical Bunsen Burner Test, New Radiant Heat Panel Test, and Intermediate-Scale Fire Test

Duct Material	ISF Test	12-VBB Test	NRHP Test
AD	Self-extinguished within 3 minutes without significant duct damage (<15%)	Not retested, but expected to pass	Passed
AW	Burned for a long period of time (9 minutes)	Not retested, but expected to pass	Failed
B	Self-extinguished within 3 minutes without significant duct damage (<15%)	Passed	Passed
C	Burned Completely (100%)	Passed	Failed
D	Burned a significantly portion of the duct (~90%)	Passed	Failed
BC Test 1	Burned Completely and for a long period of time (40 minutes)	Not retested, but expected to pass	Failed
BC Test 2	Self-extinguished within 3 minutes without significant duct damage (<15%)	Not retested, but expected to pass	Failed
F	Self-extinguished within 3 minutes without significant duct damage (<15%)	Passed	Passed
G	Self-extinguished within 3 minutes without significant duct damage (<15%)	Passed	Passed
H	Self-extinguished within 3 minutes without significant duct damage (<15%)	Passed	Passed
K	Self-extinguished within 3 minutes without significant duct damage (<15%)	Passed	Passed
M	Self-extinguished within 3 minutes without significant duct damage (<15%)	Passed	Passed
N	Burned for a long period of time (30 min)	Passed	Failed
O	Self-extinguished within 3 minutes without significant duct damage (<15%)	Passed	Passed
P	Self-extinguished within 3 minutes without significant duct damage (<15%)	Passed	Passed
Q	Self-extinguished within 3 minutes without significant duct damage (<15%)	Passed	Passed
R	Self-extinguished within 3 minutes without significant duct damage (<15%)	Passed	Passed
T	Self-extinguished within 3 minutes without significant duct damage (<15%)	Passed	Passed
AE	Burned for a long period of time (10 minutes)	Not retested, but expected to pass	Failed
U	Self-extinguished within 3 minutes without significant duct damage (<15%)	Passed	Passed
V	Self-extinguished within 3 minutes without significant duct damage (<15%)	Passed	Passed
W	Self-extinguished within 3 minutes without significant duct damage (<15%)	Passed	Passed
X	Self-extinguished within 3 minutes without significant duct damage (<15%)	Passed	Passed
Y	Self-extinguished within 3 minutes without significant duct damage (<15%)	Passed	Passed



#### 4. CONCLUSIONS.

After evaluating several fire test methods, it was found that the optimal test to evaluate the fire propagation characteristics of aircraft ducting and ducting joints was a modified version of the radiant heat panel test (version 3) used to evaluate thermal acoustic insulation (Title 14 Code of Federal Regulations Part 25.856). This proposed test was able to replicate the results of the intermediate-scale fire test consistently and was able to discriminate between fire-worthy and non-fire-worthy materials.

#### 5. REFERENCES.

1. Reinhardt, J.W., "Evaluation of the 12-Second Vertical Bunsen Burner Test Used to Determine the Fireworthiness of Aircraft Duct Materials," DOT/FAA/AR-TN05/36, October 2005.
2. "Vertical Bunsen Burner Test for Cabin and Cargo Materials," *Aircraft Material Fire Test Handbook*, DOT/FAA/AR-00/12, Chapter 1, April 2000.
3. Marker, Timothy, "Development of Improved Flammability Criteria for Aircraft Thermal Acoustic Insulation," FAA report DOT/FAA/AR-99/44, September 2000.
4. "The Test Method to Determine the Flammability and Flame Propagation Characteristics of Thermal Acoustic Insulation Materials," *Aircraft Materials Fire Test Handbook*, DOT/FAA/AR-00/12, 1990.
5. "Smoke Test for Cabin Materials," *Aircraft Materials Fire Test Handbook*, DOT/FAA/AR-00/12, Chapter 6, 1990.
6. "Heat Release Rate Test for Cabin Materials," *Aircraft Materials Fire Test Handbook*, DOT/FAA/AR-00/12, Chapter 5, 1990.
7. ASTM D 7309-07, "Standard Test Method for Determining Flammability Characteristics of Plastics and Other Solid Materials Using Micro-Scale Combustion Calorimetry," ASTM International, April 2007.

## APPENDIX A—INTERMEDIATE-SCALE FIRE TEST TEMPERATURE AND HEAT FLUX HISTORY CHARTS

Figures A-1 through A-39 show the intermediate-scale fire (ISF) test temperatures and heat flux history charts for aircraft ducting materials.

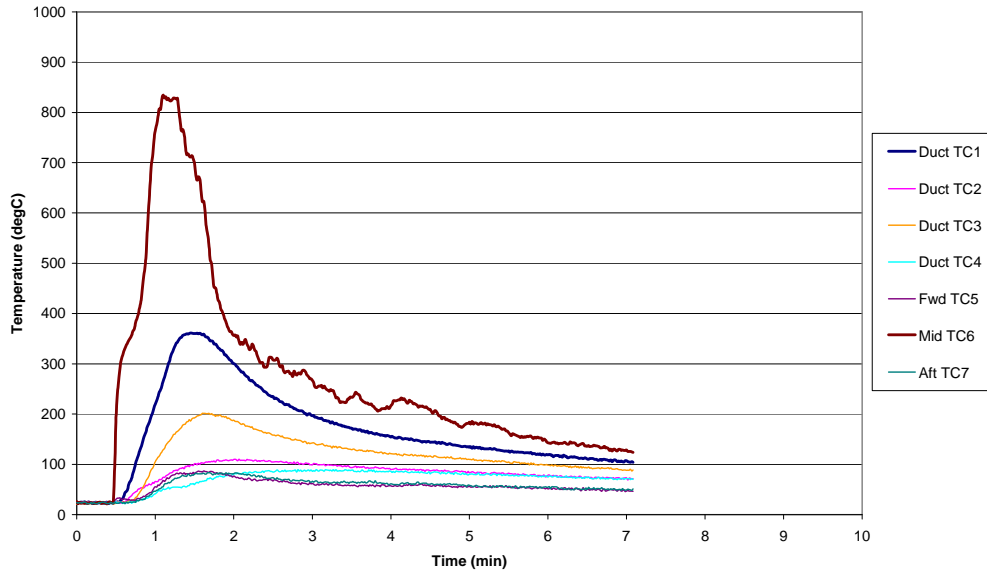


Figure A-1. Intermediate-Scale Fire Test Temperature History of Material AD

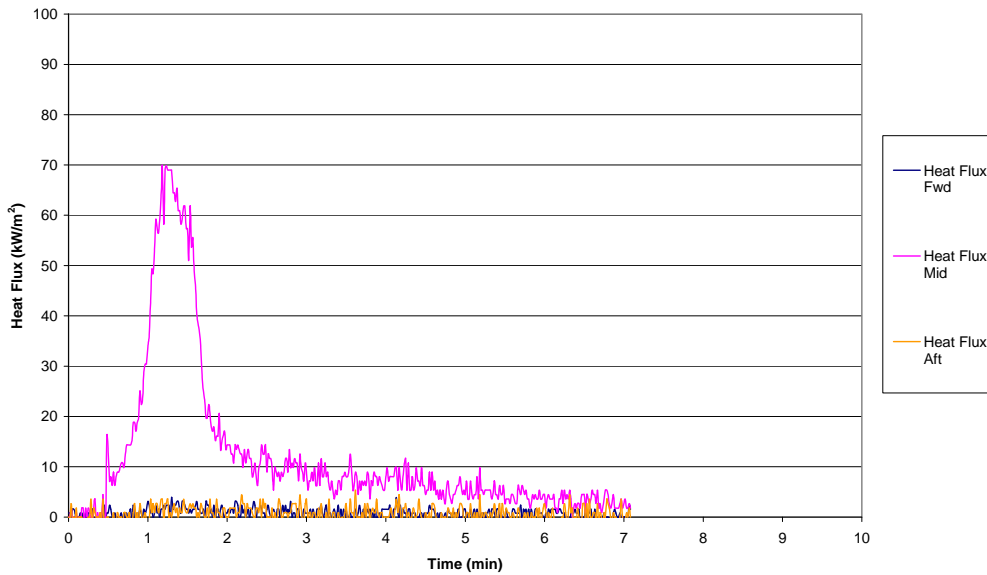


Figure A-2. Intermediate-Scale Fire Test Heat Flux History of Material AD

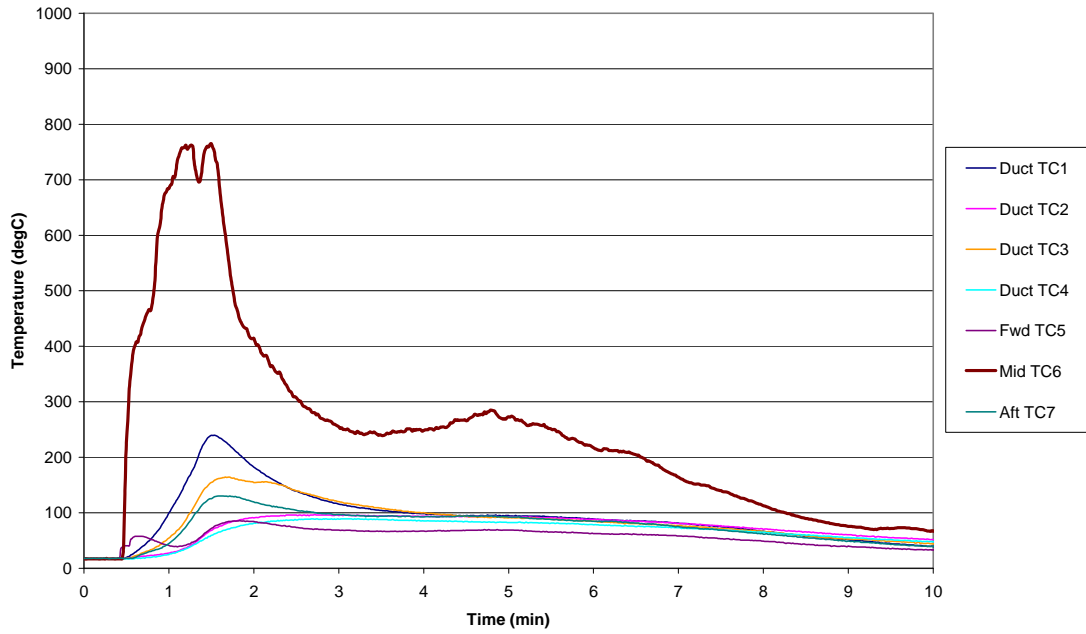


Figure A-3. Intermediate-Scale Fire Test Temperature History of Material AW

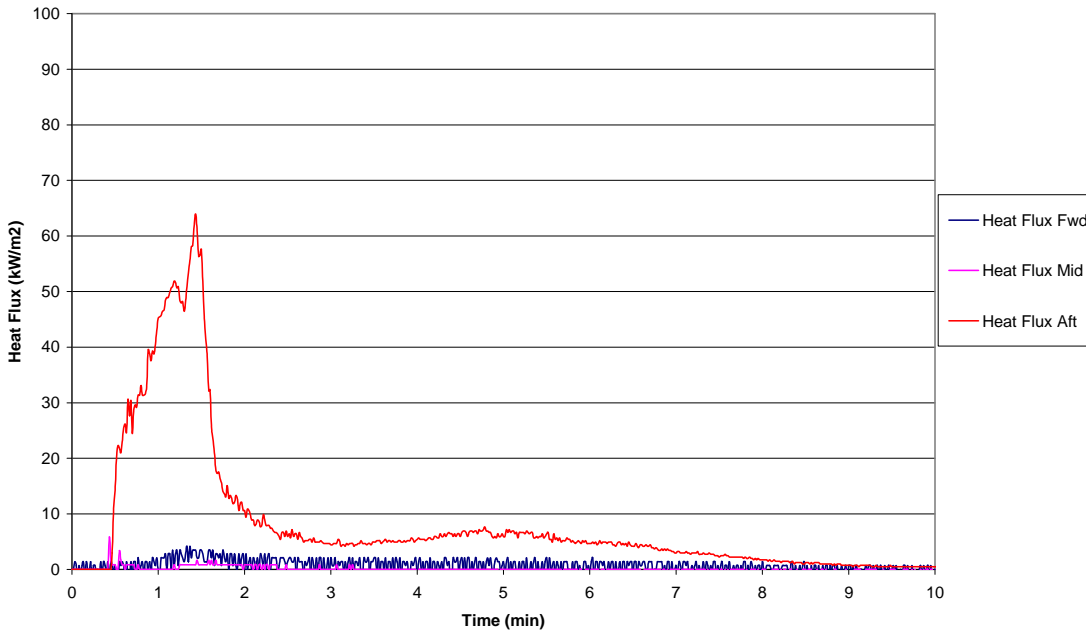


Figure A-4. Intermediate-Scale Fire Test Heat Flux History of Material AW

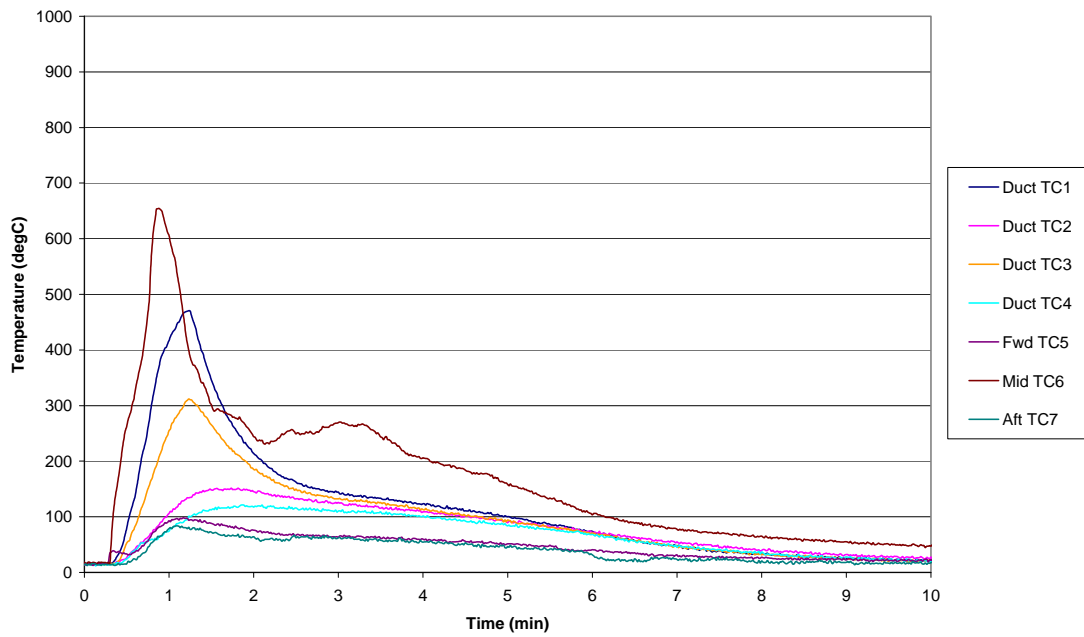


Figure A-5. Intermediate-Scale Fire Test Temperature History of Material B

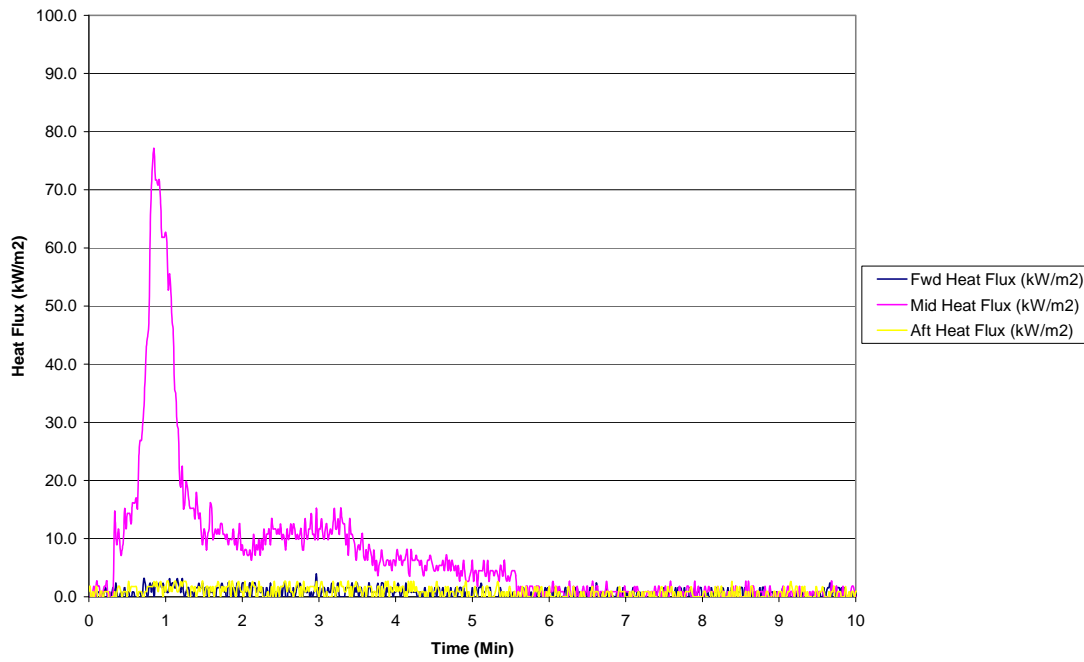


Figure A-6. Intermediate-Scale Fire Test Heat Flux History of Material B

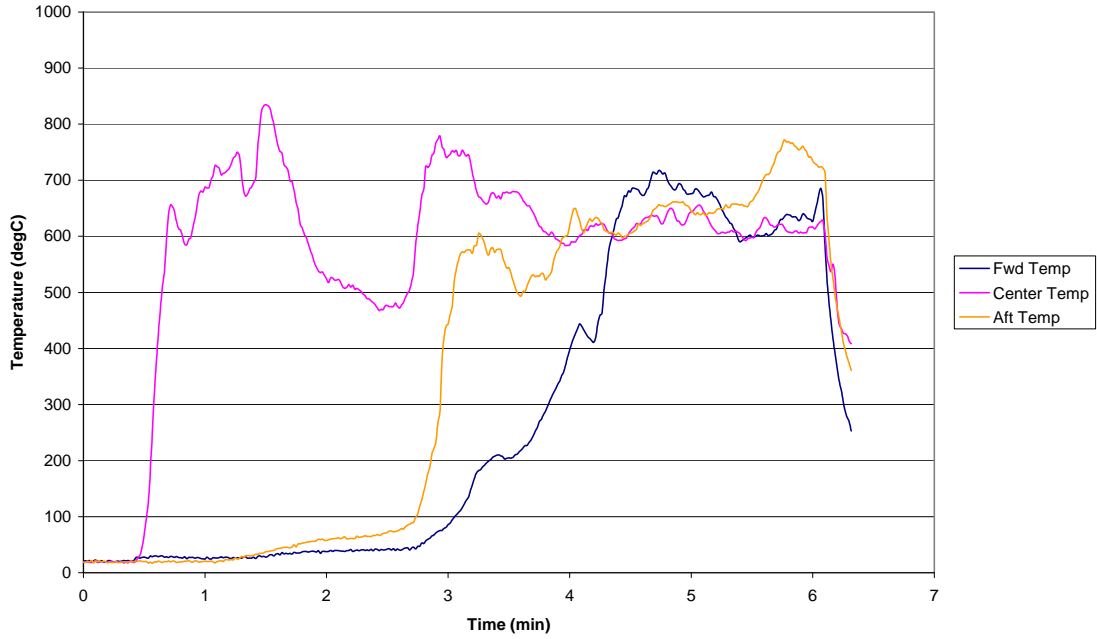


Figure A-7. Intermediate-Scale Fire Test Temperature History of Material C

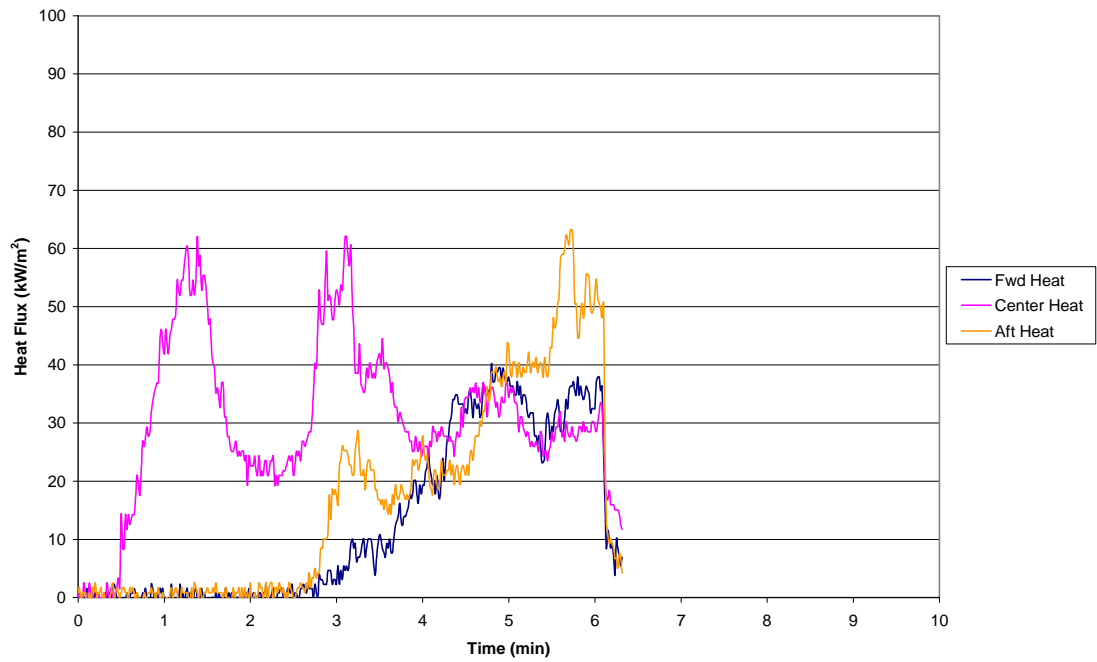


Figure A-8. Intermediate-Scale Fire Test Heat Flux History of Material C

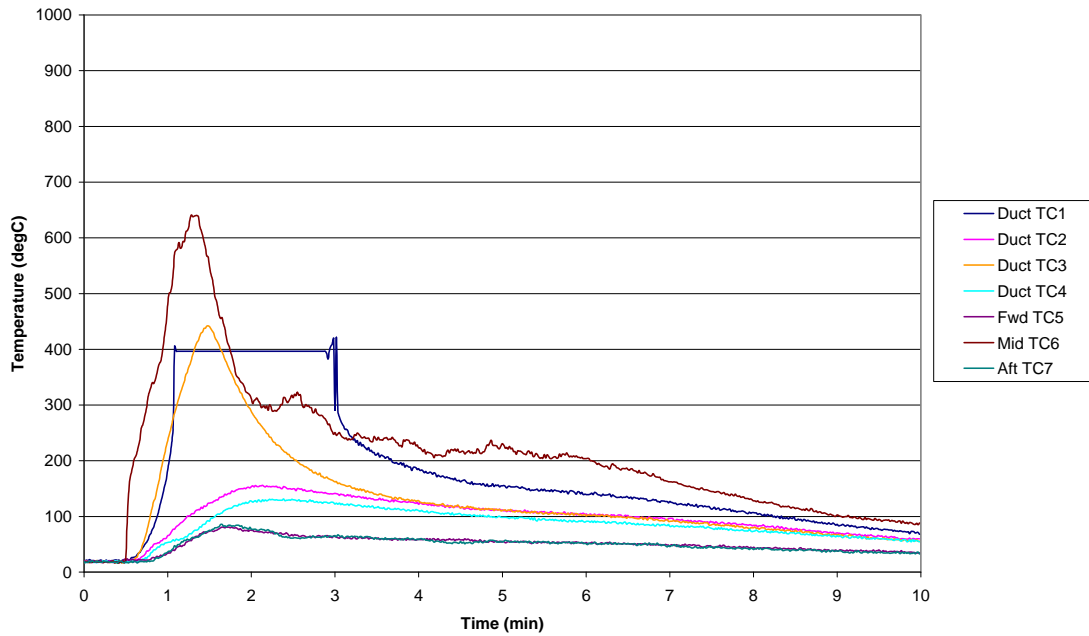


Figure A-9. Intermediate-Scale Fire Test Temperature History of Materials D and E

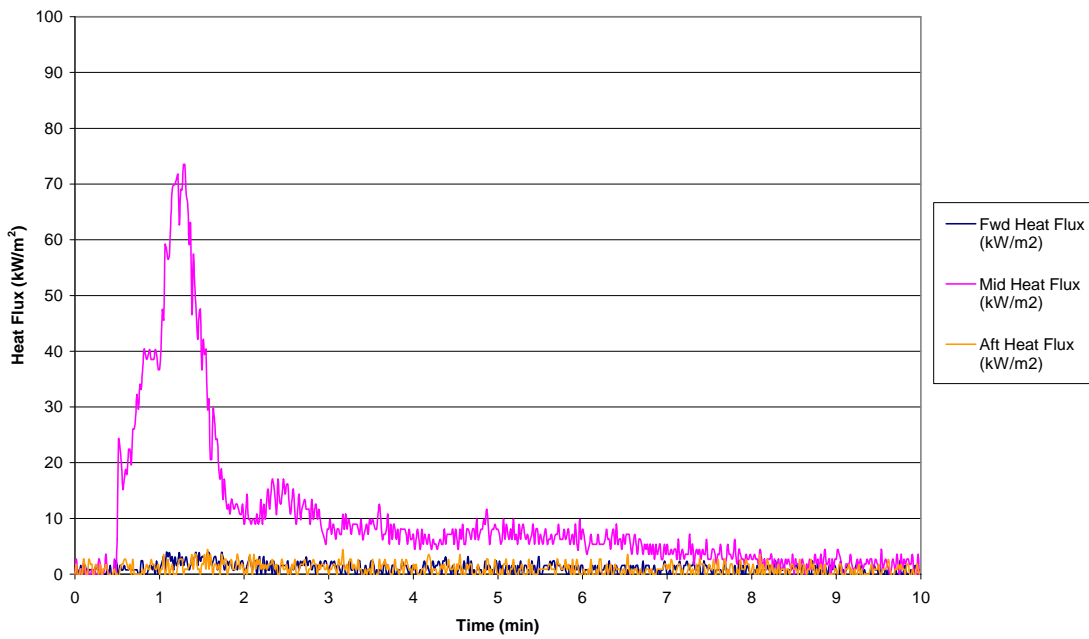


Figure A-10. Intermediate-Scale Fire Test Heat Flux History of Materials D and E

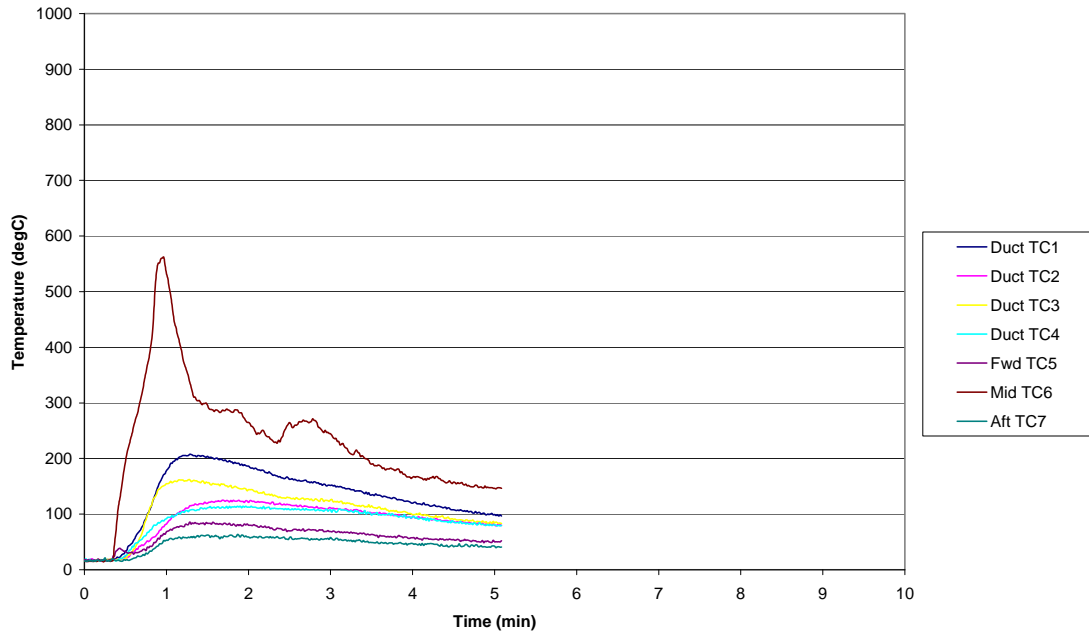


Figure A-11. Intermediate-Scale Fire Test Temperature History of Material H

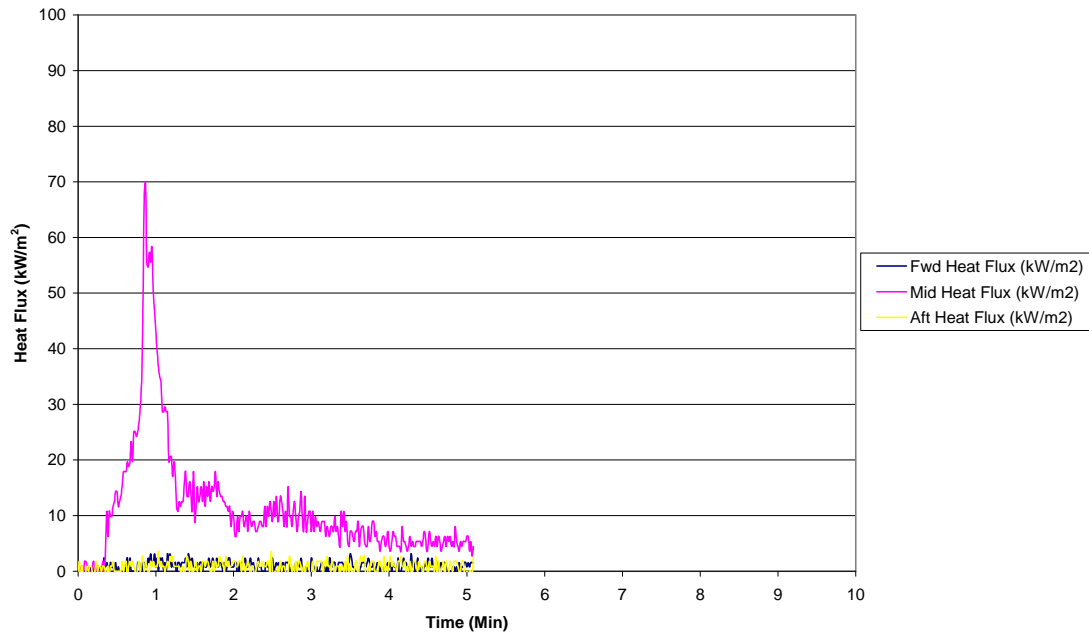


Figure A-12. Intermediate-Scale Fire Test Heat Flux History of Material H

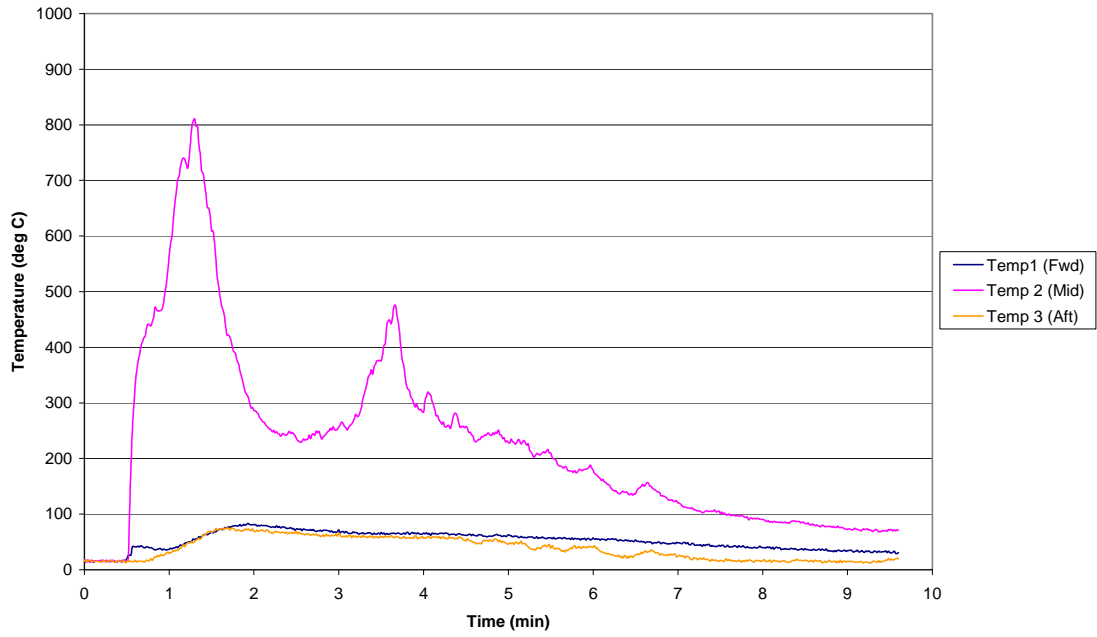


Figure A-13. Intermediate-Scale Fire Test Temperature History of Material K

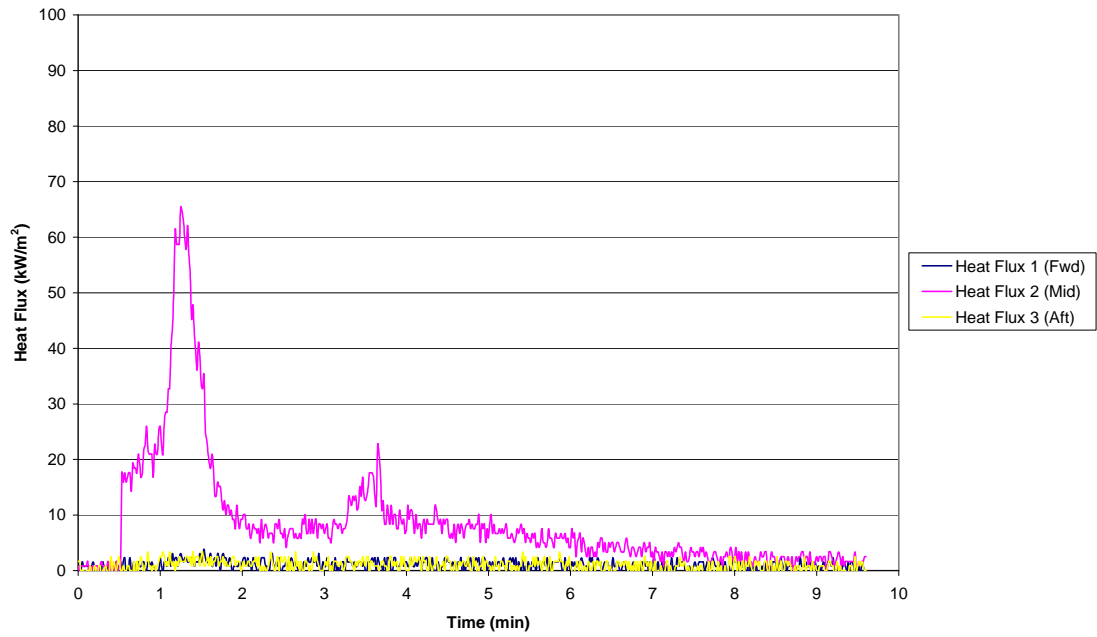


Figure A-14. Intermediate-Scale Fire Test Heat Flux History of Material K



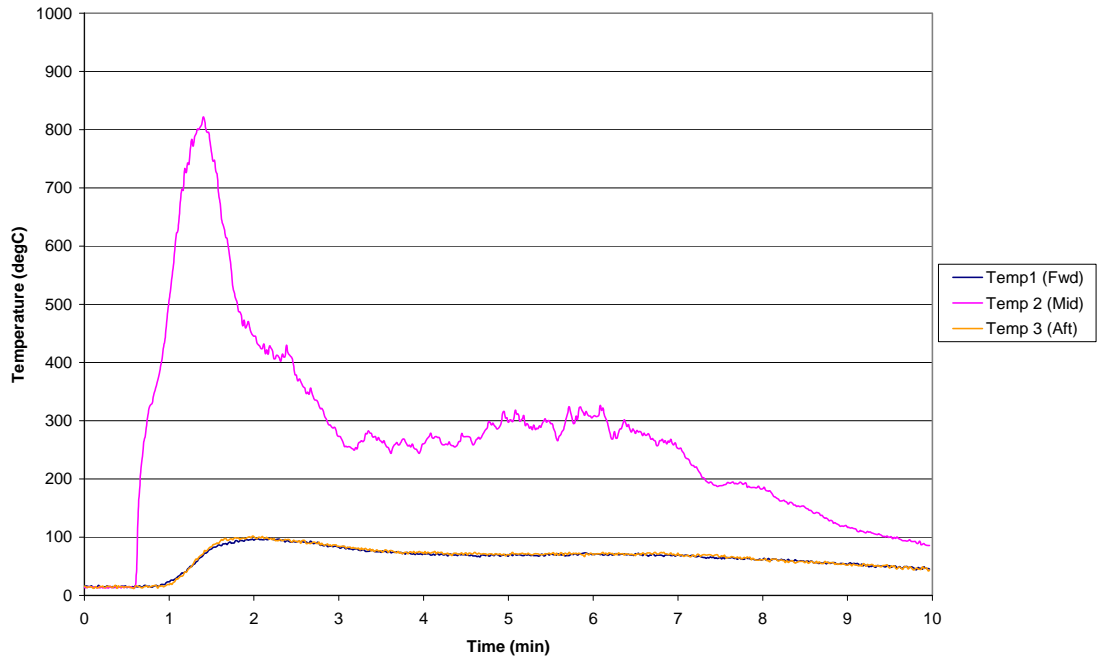


Figure A-15. Intermediate-Scale Fire Test Temperature History of Material M

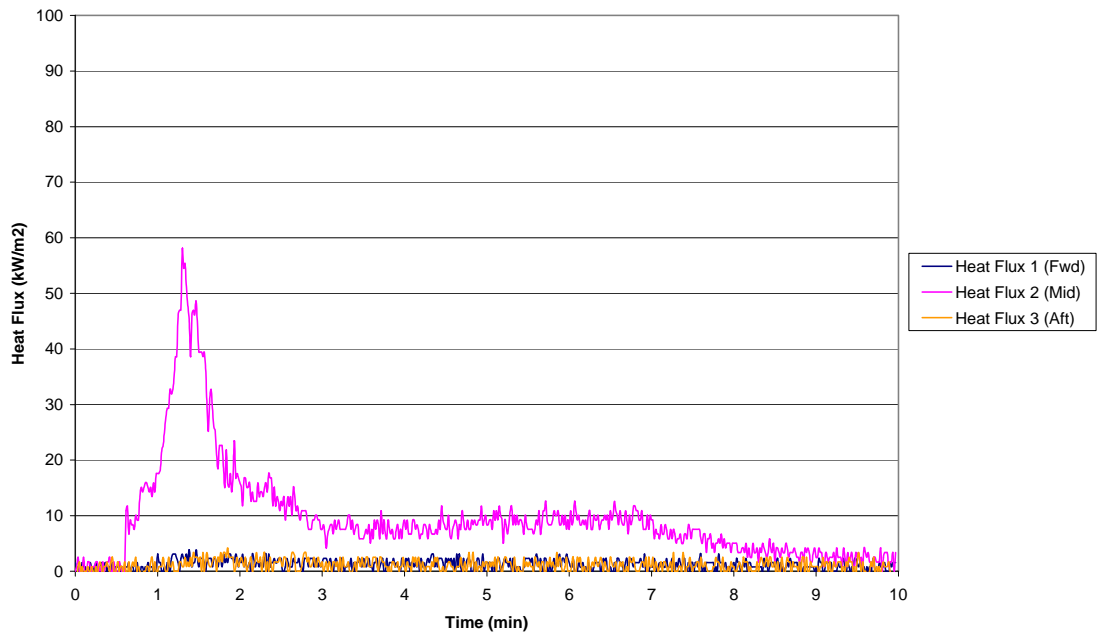


Figure A-16. Intermediate-Scale Fire Test Heat Flux History of Material M

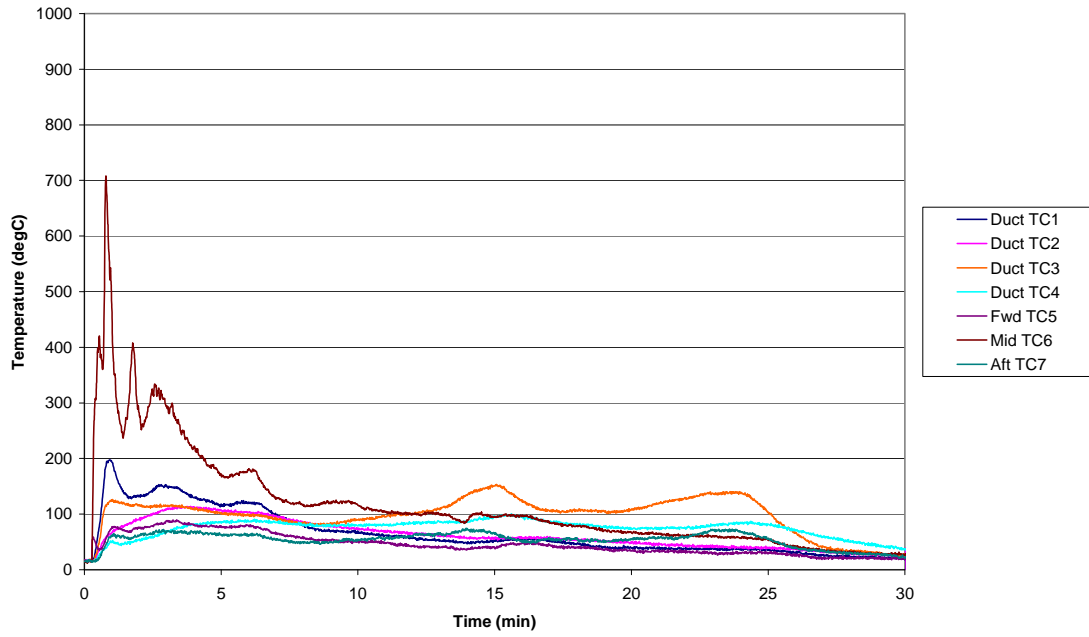


Figure A-17. Intermediate-Scale Fire Test Temperature History of Material N

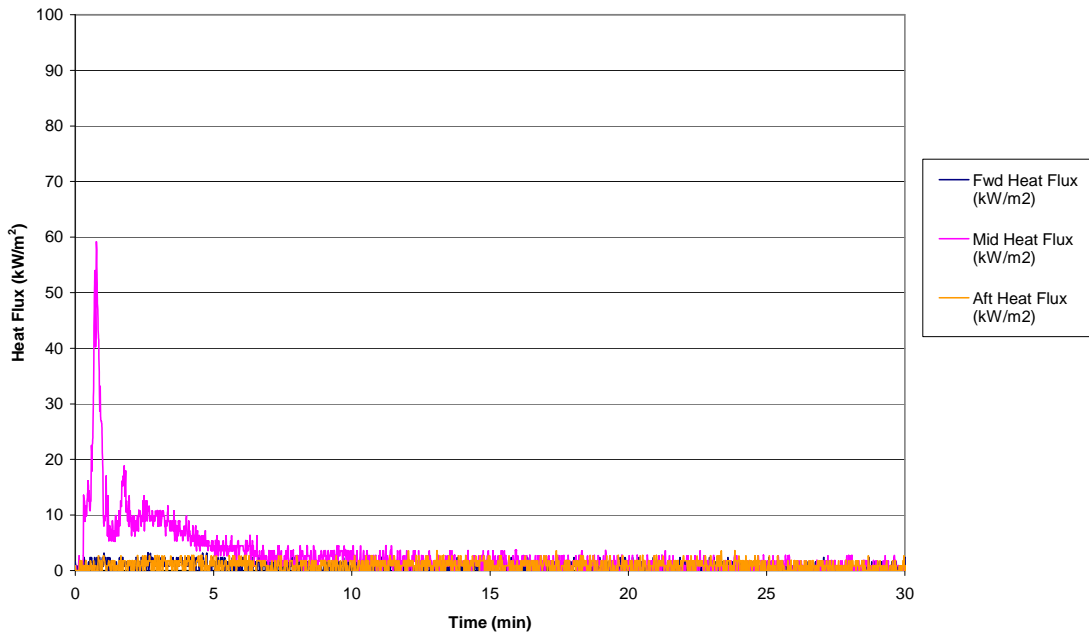


Figure A-18. Intermediate-Scale Fire Test Heat Flux History of Material N

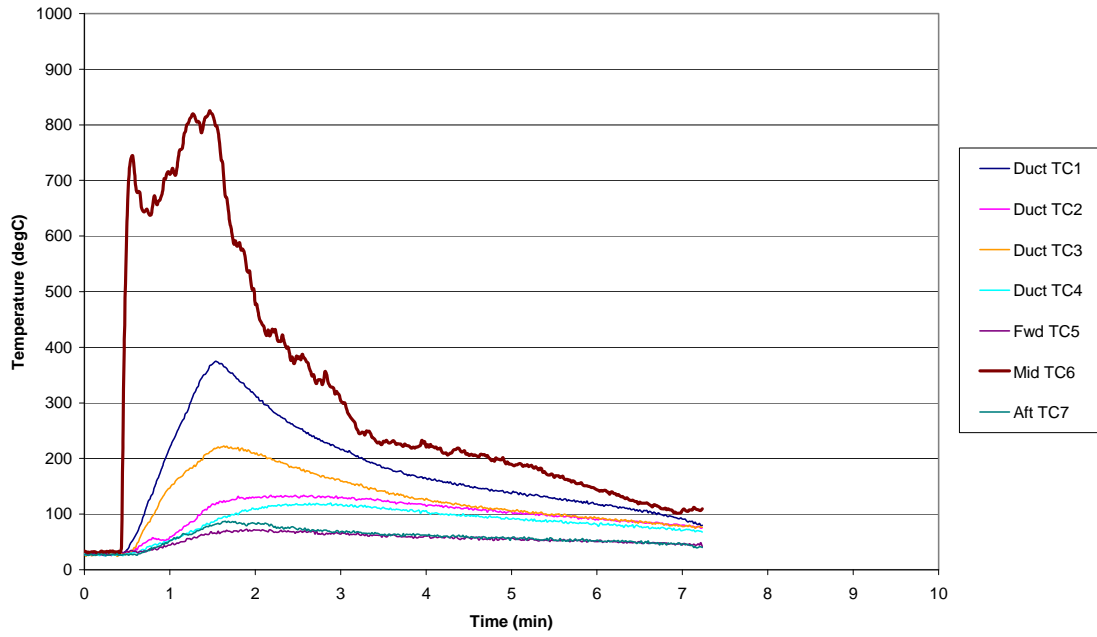


Figure A-19. Intermediate-Scale Fire Test Temperature History of Material O

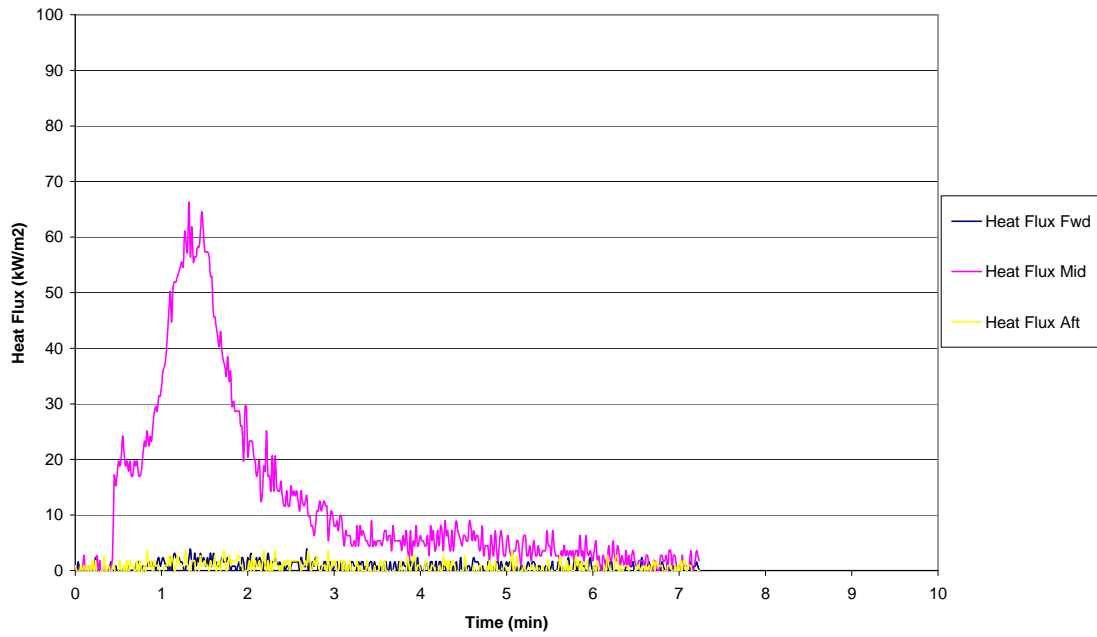


Figure A-20. Intermediate-Scale Fire Test Heat Flux History of Material O

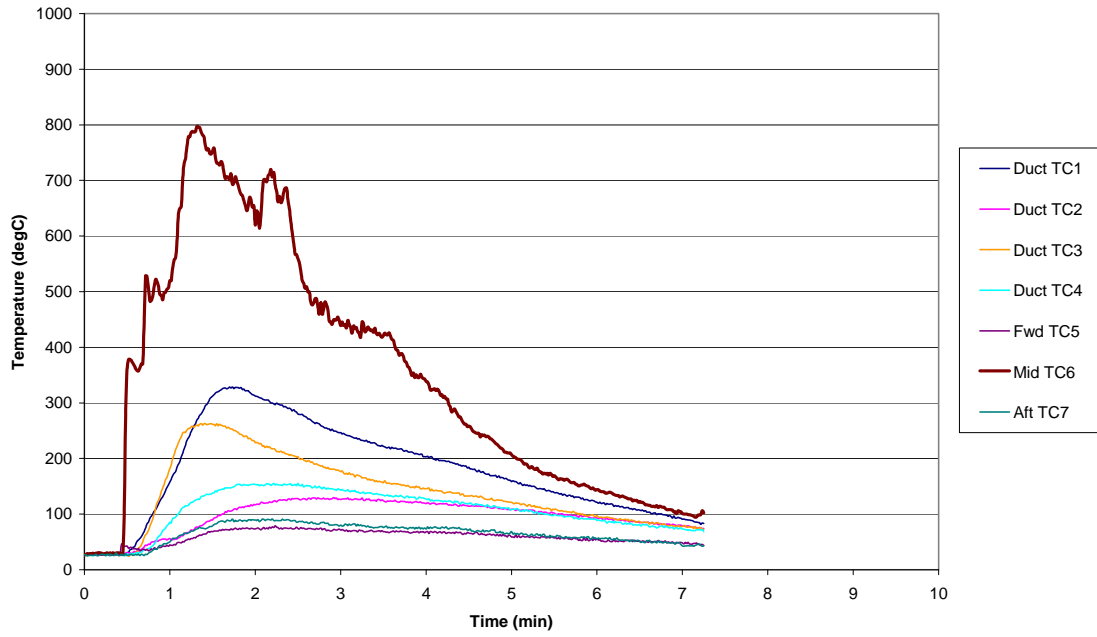


Figure A-21. Intermediate-Scale Fire Test Temperature History of Material P

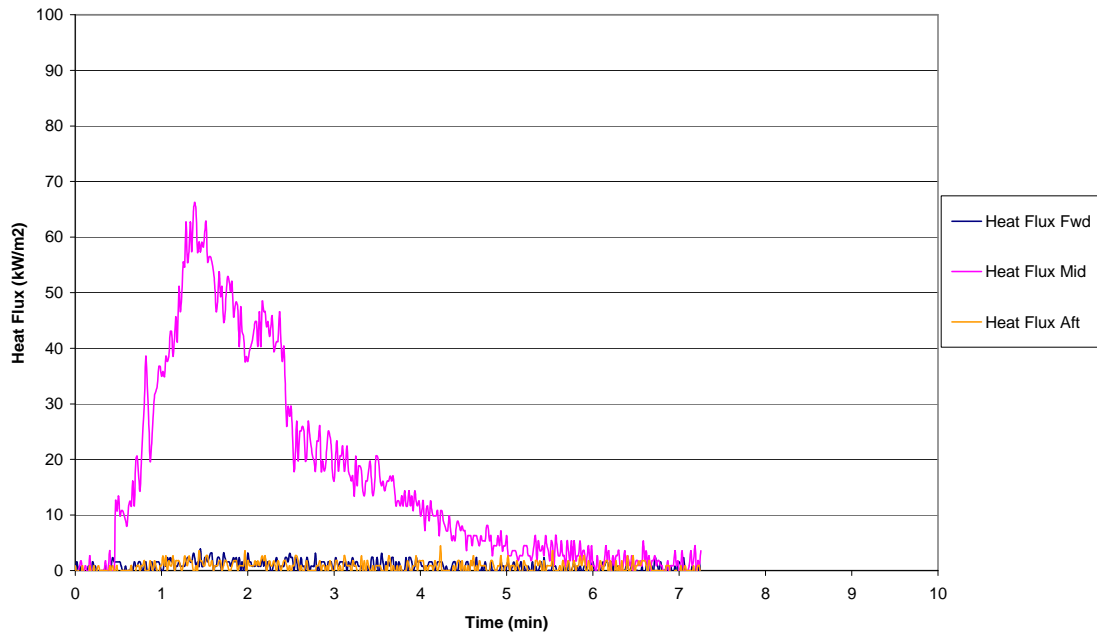


Figure A-22. Intermediate-Scale Fire Test Heat Flux History of Material P

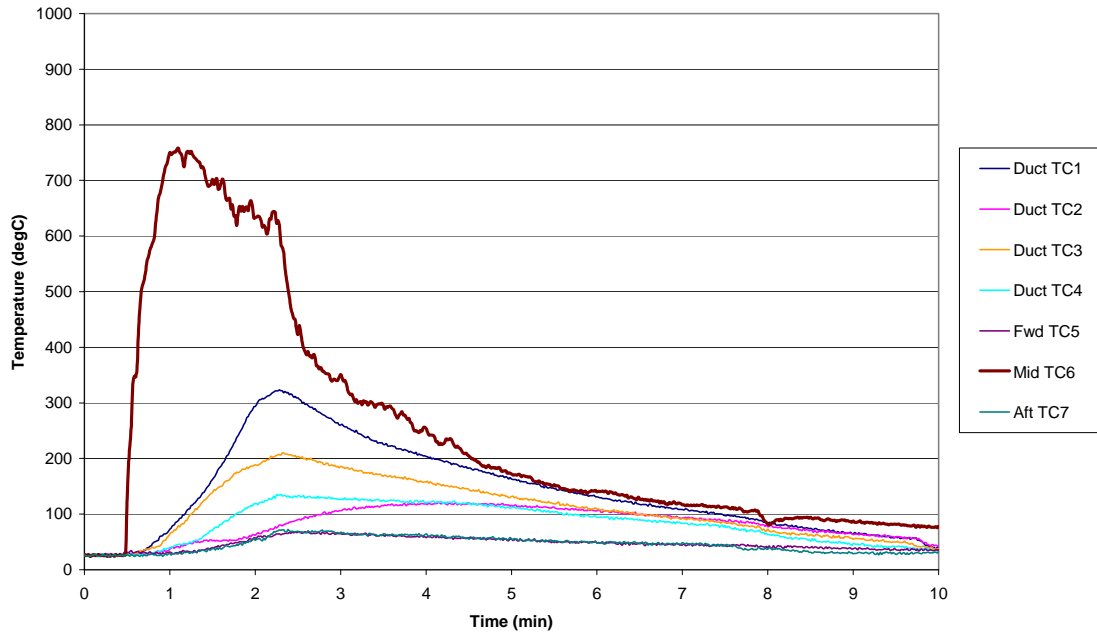


Figure A-23. Intermediate-Scale Fire Test Temperature History of Material Q

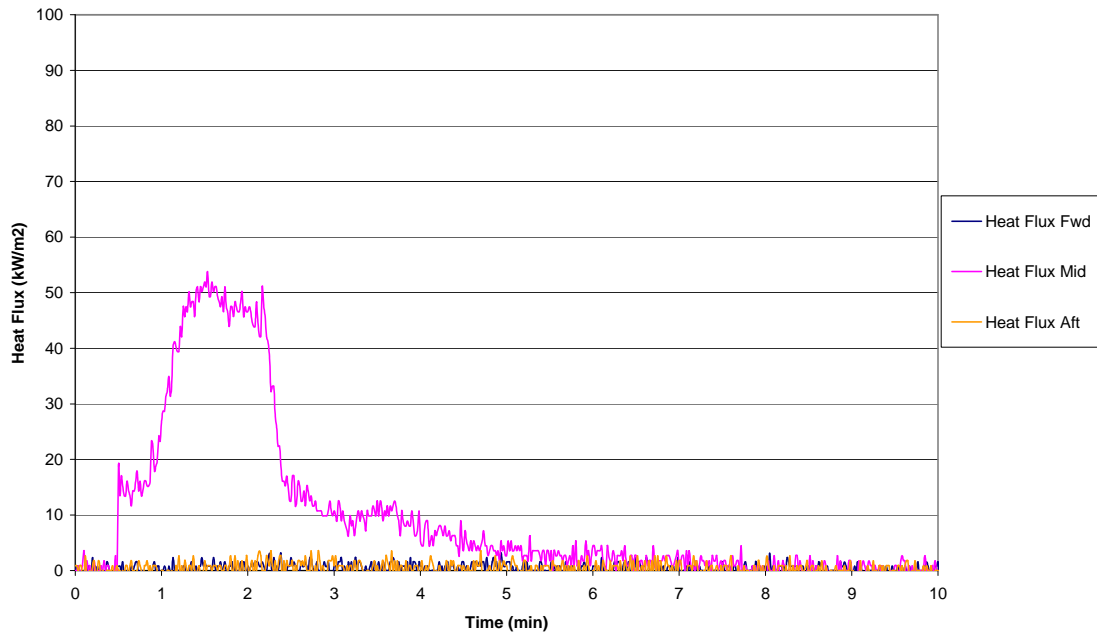


Figure A-24. Intermediate-Scale Fire Test Heat Flux History of Material Q

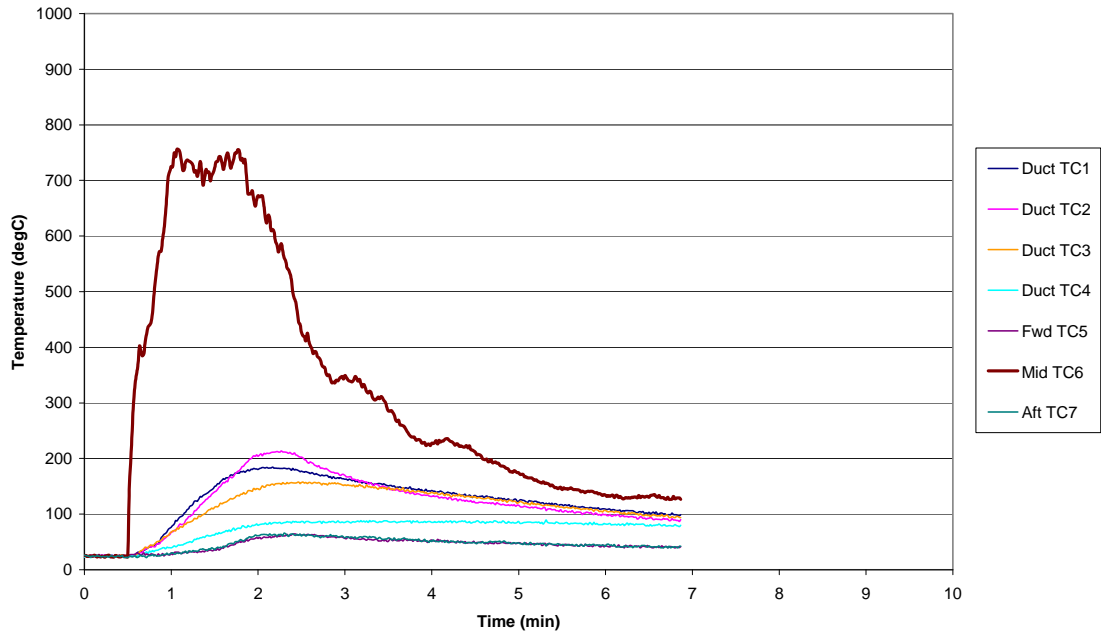


Figure A-25. Intermediate-Scale Fire Test Temperature History of Material R

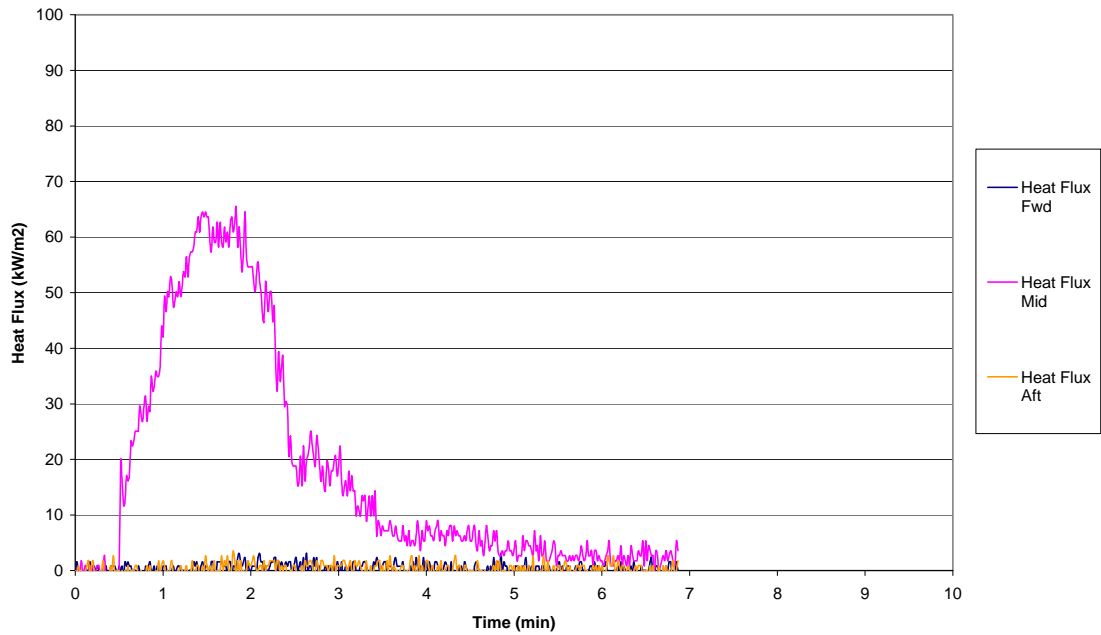


Figure A-26. Intermediate-Scale Fire Test Heat Flux History of Material R

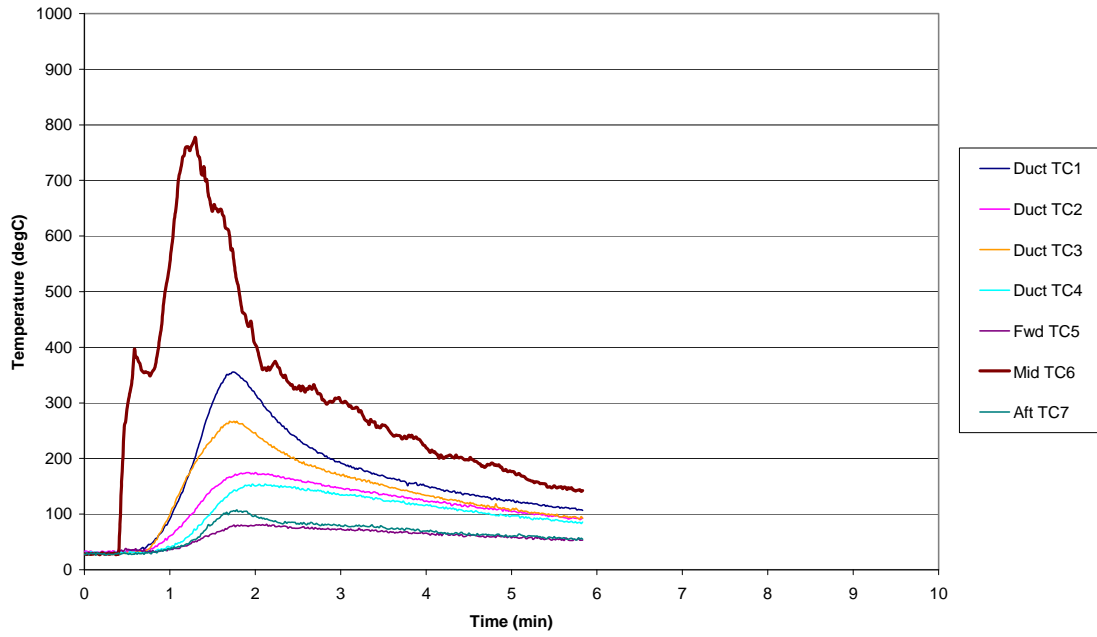


Figure A-27. Intermediate-Scale Fire Test Temperature History of Material T

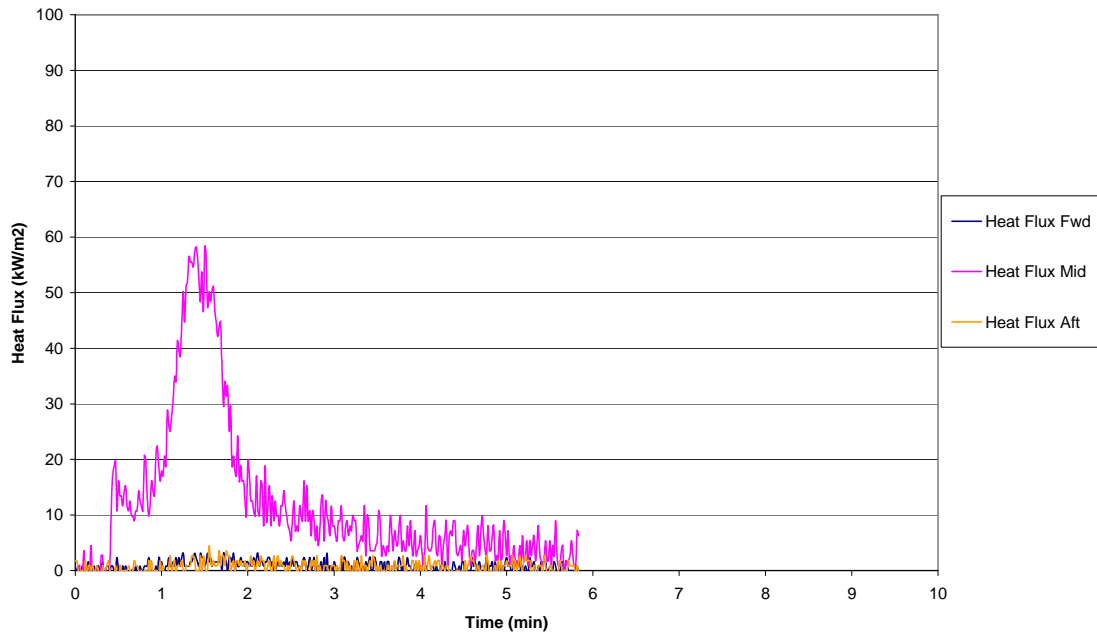


Figure A-28. Intermediate-Scale Fire Test Heat Flux History of Material T

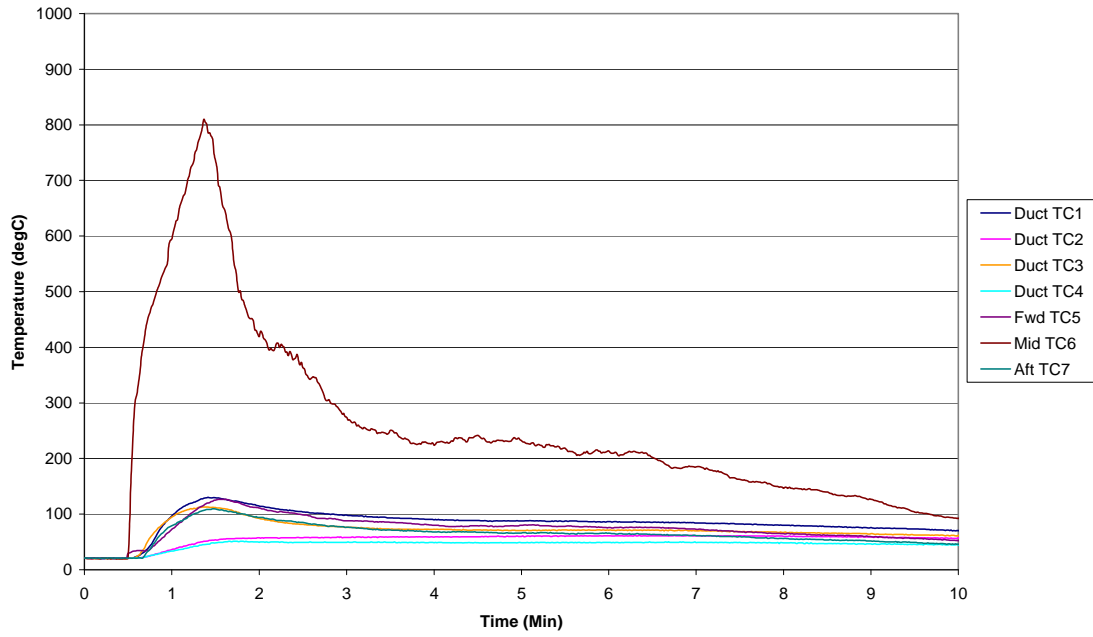


Figure A-29. Intermediate-Scale Fire Test Temperature History of Material Taped N

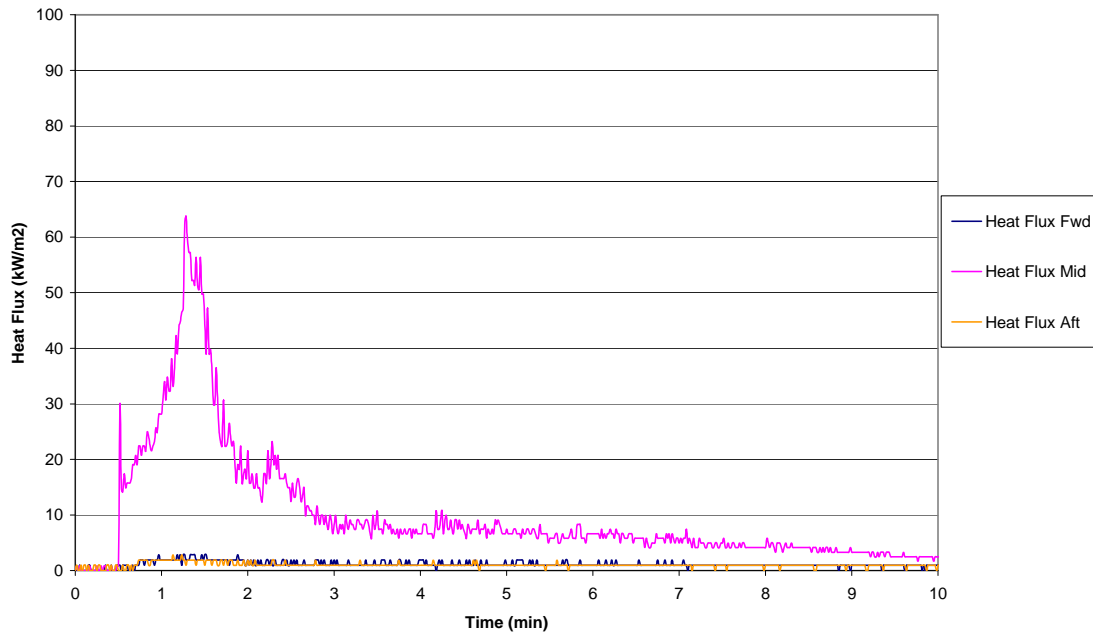


Figure A-30. Intermediate-Scale Fire Test Heat Flux History of Material Taped N



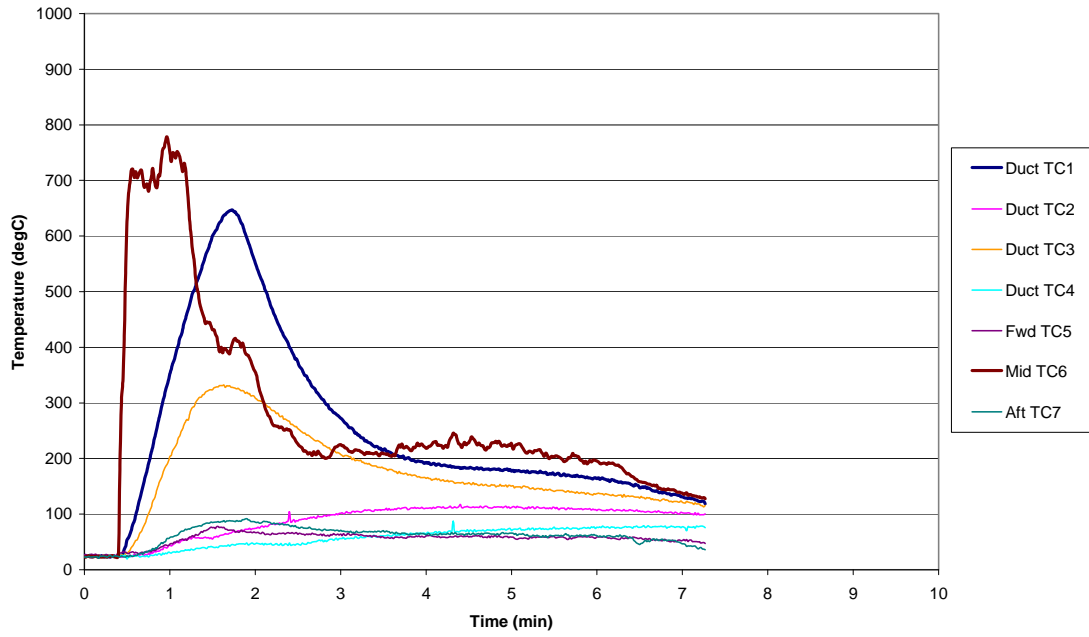


Figure A-31. Intermediate-Scale Fire Test Temperature History of Material U

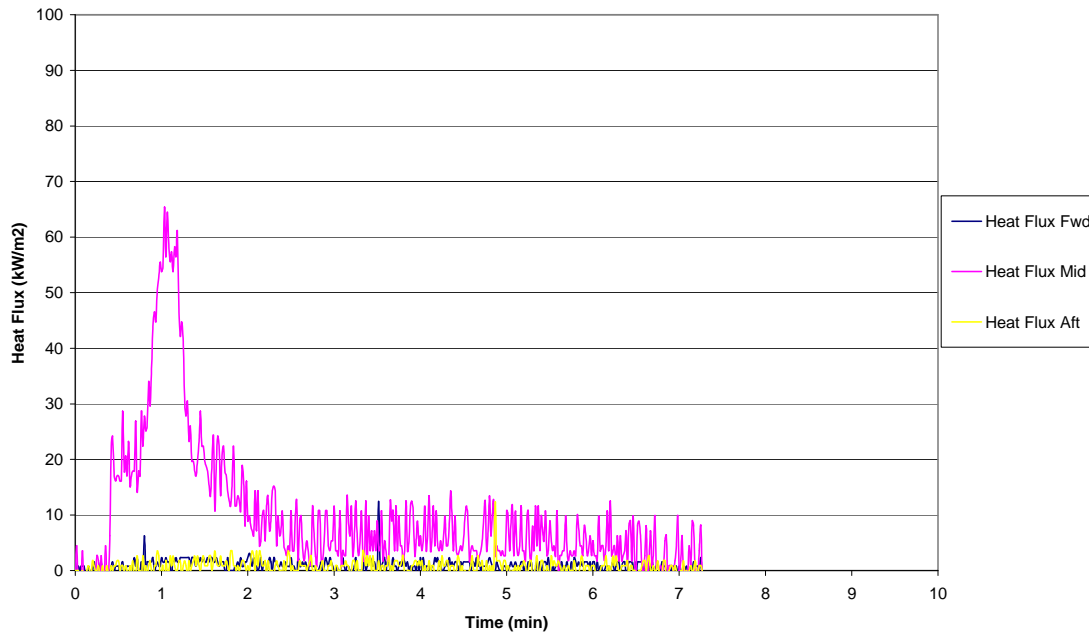


Figure A-32. Intermediate-Scale Fire Test Heat Flux History of Material U

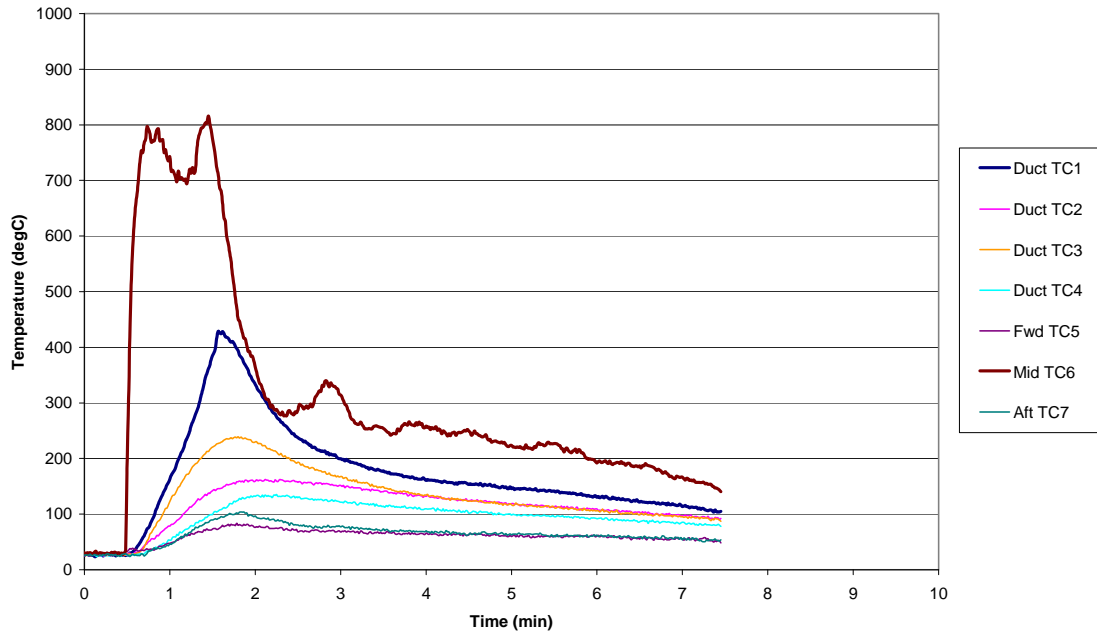


Figure A-33. Intermediate-Scale Fire Test Temperature History of Material V

Material V Heat Flux History not Available

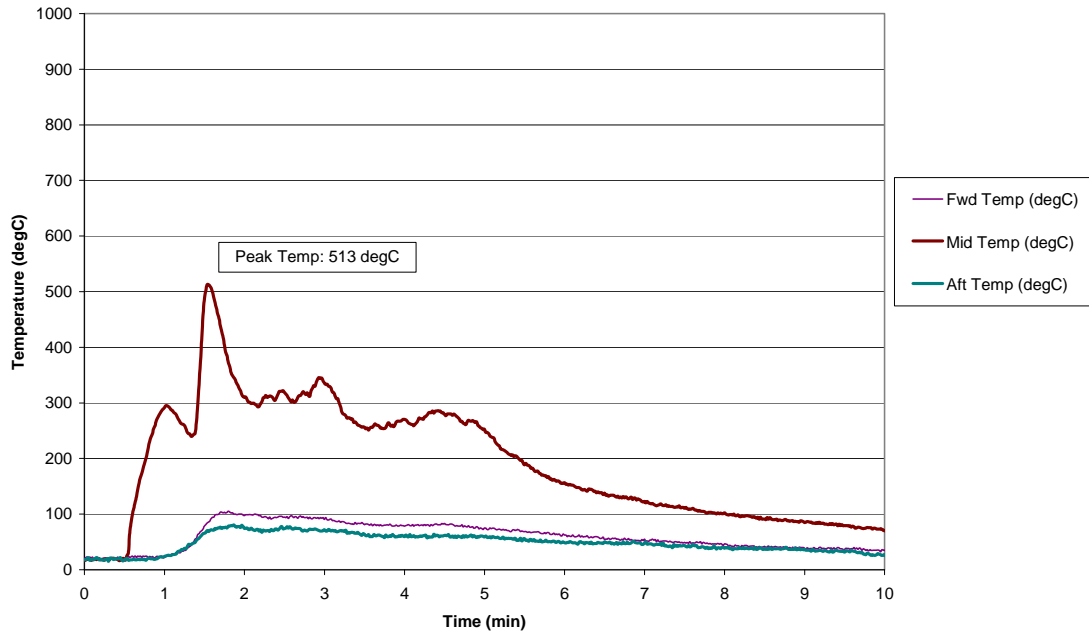


Figure A-34. Intermediate-Scale Fire Test Temperature History of Material W

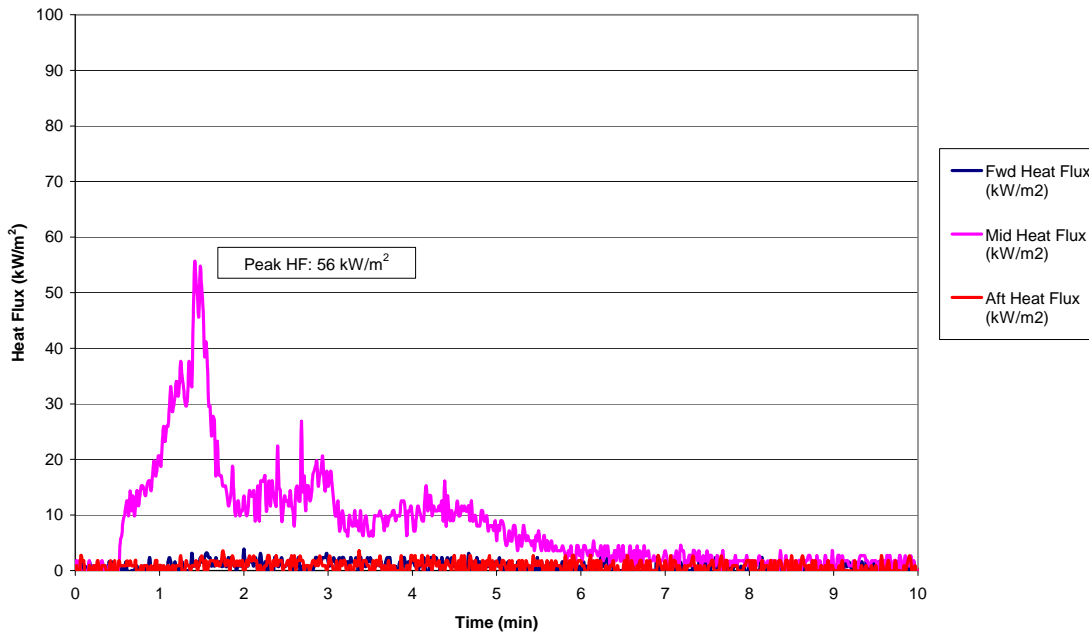


Figure A-35. Intermediate-Scale Fire Test Heat Flux History of Material W

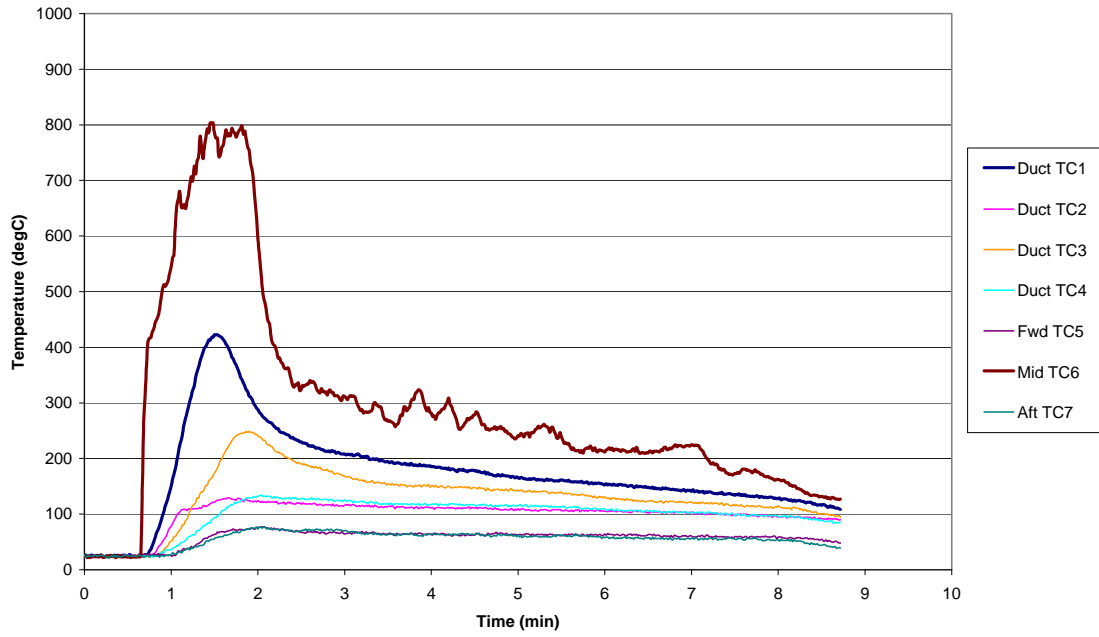


Figure A-36. Intermediate-Scale Fire Test Temperature History of Material X

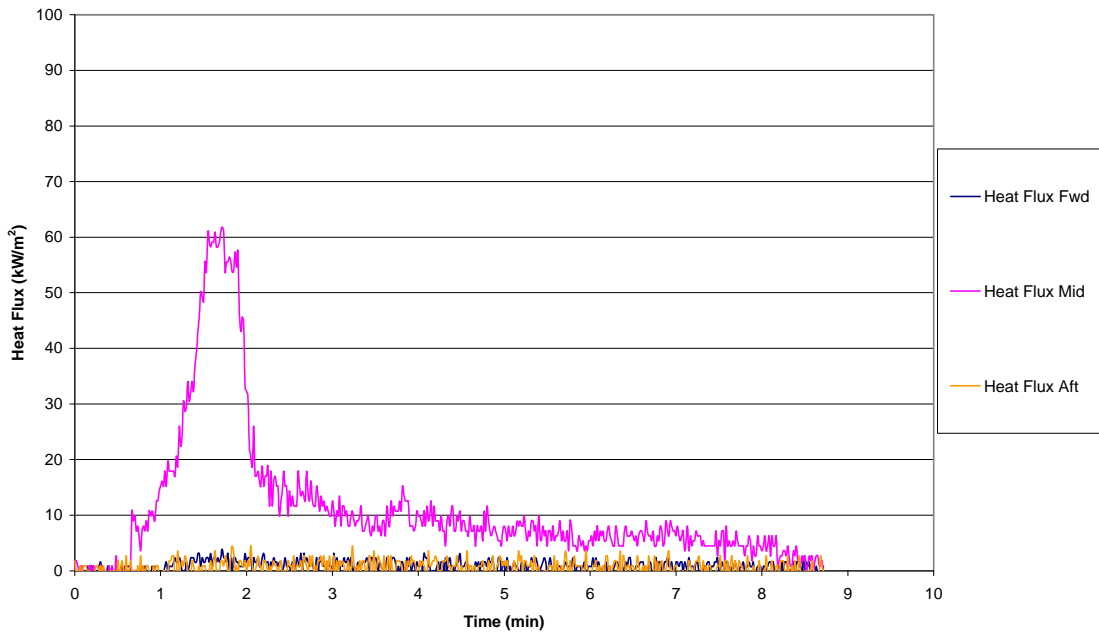


Figure A-37. Intermediate-Scale Fire Test Heat Flux History of Material X

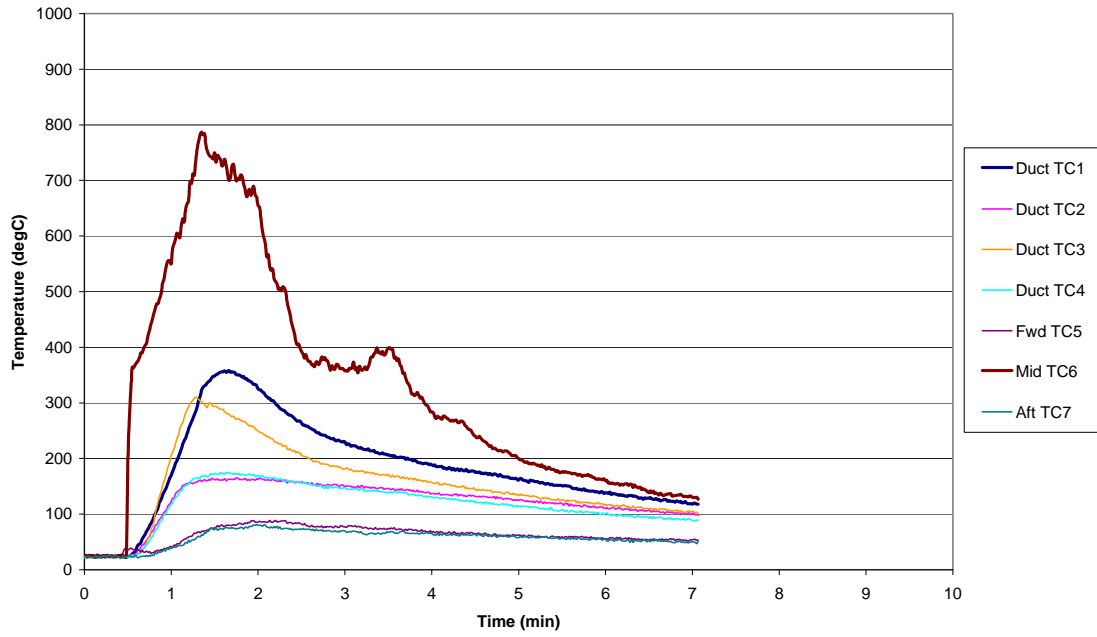


Figure A-38. Intermediate-Scale Fire Test Temperature History of Material Y

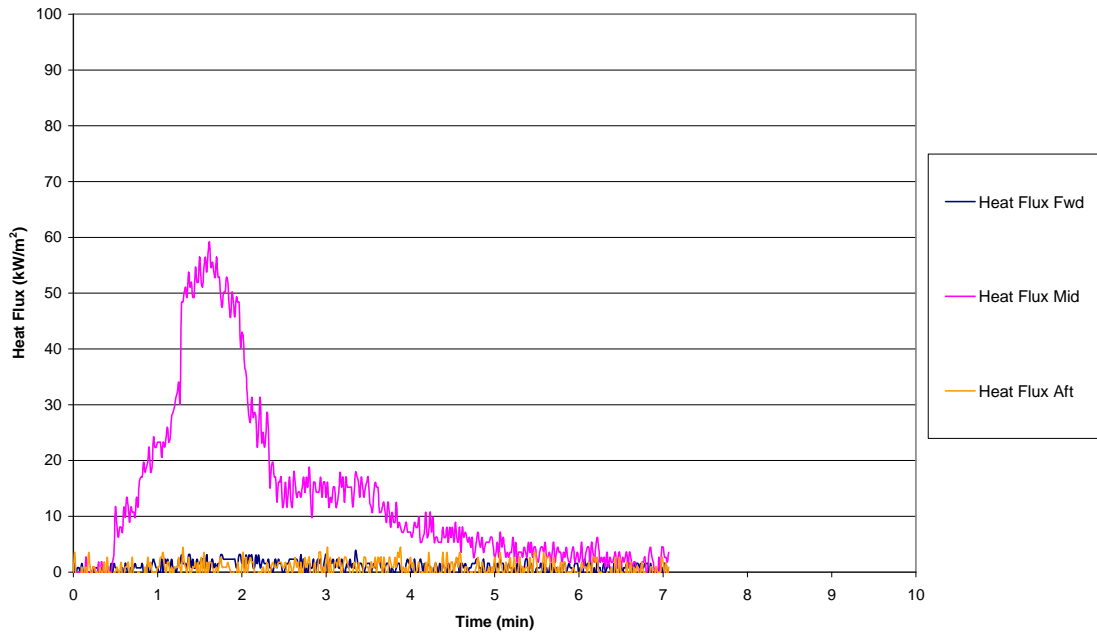


Figure A-39. Intermediate-Scale Fire Test Heat Flux History of Material Y

## APPENDIX B—TEST METHOD USED TO DETERMINE THE FLAMMABILITY AND FIRE PROPAGATION CHARACTERISTICS OF AIRCRAFT DUCTING MATERIALS

### B.1 SCOPE.

This test method is intended for use in determining the flammability and fire propagation characteristics of aircraft ducting materials.

### B.2 DEFINITIONS.

Aircraft ducting: The pipes and tubing (including connection fittings like unions, elbows, T's, manifolds, etc.) used in the heating, ventilation, and air conditioning; plumbing that is used for heating, ventilation, cooling, moving fluids; and electrical distribution system for protecting wires onboard the aircraft.

Fire-blocking jacket: A material or system of materials used to cover aircraft ducting to improve its flammability and fire propagation characteristics. Examples include a blanket composed of polyimide film and fiberglass batting material, which is fastened with a hook and loop system.

Burn length: The distance from the midpoint of the ignition source flame to the farthest evidence of damage to the test specimen due to the area's combustion, including areas of partial consumption, charring, or embrittlement, but not including sooted, stained, warped or discolored areas, nor areas where material has shrunk or melted away from the heat. Measure this distance after applying the ignition source and after all flame on the test specimen is extinguished. Normally, the longest burn length is found at the end of the test because of the involvement of the aircraft ducting material with the flames and radiant heat; but in certain occasions, the longest burn length may occur during the first 15 seconds (during the ignition source flame impingement) because of the material's configuration. In this case, this initial burn length may be discarded if the flames retract back towards the zero position after the ignition source flame is removed from the material and the material has acceptable flammability characteristics. An acceptable flammability characteristic is when a specimen has an onset temperature greater than 256°C, a combustion temperature greater than 322°C, a specific heat release rate lower than 205 W/g, and a specific heat release lower than 15 kJ/g (as determined by ASTM D 7309-07). Radiant heat source: An electric or air propane (gas) panel.

Zero point: The point of application of the pilot burner to the test specimen.

### B.3 TEST APPARATUS.

#### B.3.1 RADIANT PANEL TEST CHAMBER.

Tests should be conducted in a radiant panel test chamber (see figure B-1). The test chamber should be placed under an exhaust hood to clear the chamber of smoke after each test. The radiant panel test chamber must be an enclosure 55 inches (1397 mm) long by 19.5 inches (495 mm) deep by 28 (710 mm) to 30 inches (762 mm) (maximum) above the test specimen. The

sides, ends, and top must be insulated with a fibrous ceramic insulation, such as Kaowool M™ board. On the front side, 52- by 12-inch (1321- by 305-mm), draft-free, high-temperature glass window should be provided for viewing the sample during testing. A door must be placed below the window to provide access to the movable specimen platform holder. The bottom of the test chamber must be a sliding steel platform that will secure the test specimen holder in a fixed and level position.

The chamber must have an internal chimney with exterior dimensions of 5.1 inches (129 mm) wide, by 16.2 inches (411 mm) deep, by 13 inches (330 mm) high at the opposite end of the chamber from the radiant energy source. The interior dimensions must be 4.5 inches (114 mm) wide by 15.6 inches (395 mm) deep. The chimney must extend to the top of the chamber (see figure B-2).

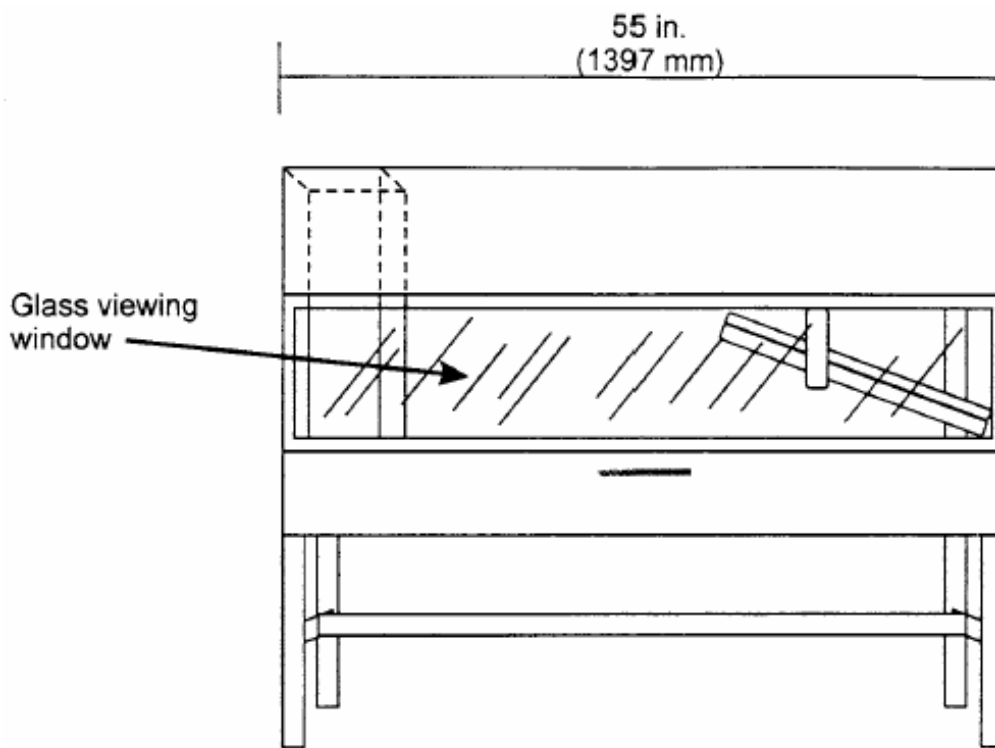


Figure B-1. Radiant Panel Test Chamber

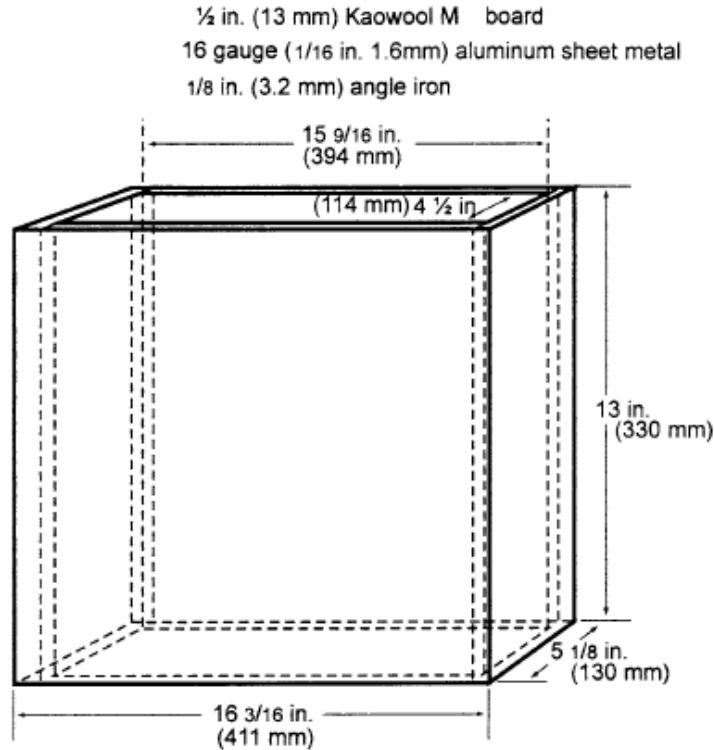


Figure B-2. Internal Chimney

### B.3.1.1 Radiant Heat Source.

Mount the radiant heat energy source in a cast iron frame or equivalent. An electric radiant heat panel (RHP) must have six 3-inch (7.62-cm)-wide emitter strips. The emitter strips must be perpendicular to the length of the electric RHP. The panel must have a radiation surface of  $12 \frac{7}{8}$  by  $18 \frac{1}{2}$  inches (327 by 470 mm). The electric RHP must be capable of operating at temperatures up to  $1300^{\circ}\text{F}$  ( $704^{\circ}\text{C}$ ).

An air propane RHP must be made of a porous refractory material and have a radiation surface of 12 by 18 inches (305 by 457 mm). The air propane RHP must be capable of operating at temperatures up to  $1500^{\circ}\text{F}$  ( $816^{\circ}\text{C}$ ). See figures B-3a and B-3b.

#### B.3.1.1.1 Electric Radiant Heat Panel.

The electric RHP must be three-phase and operate at 208 volts. A single-phase, 240-volt panel is also acceptable. A solid-state power controller and microprocessor-based controller must be used to set the electric RHP operating parameters.



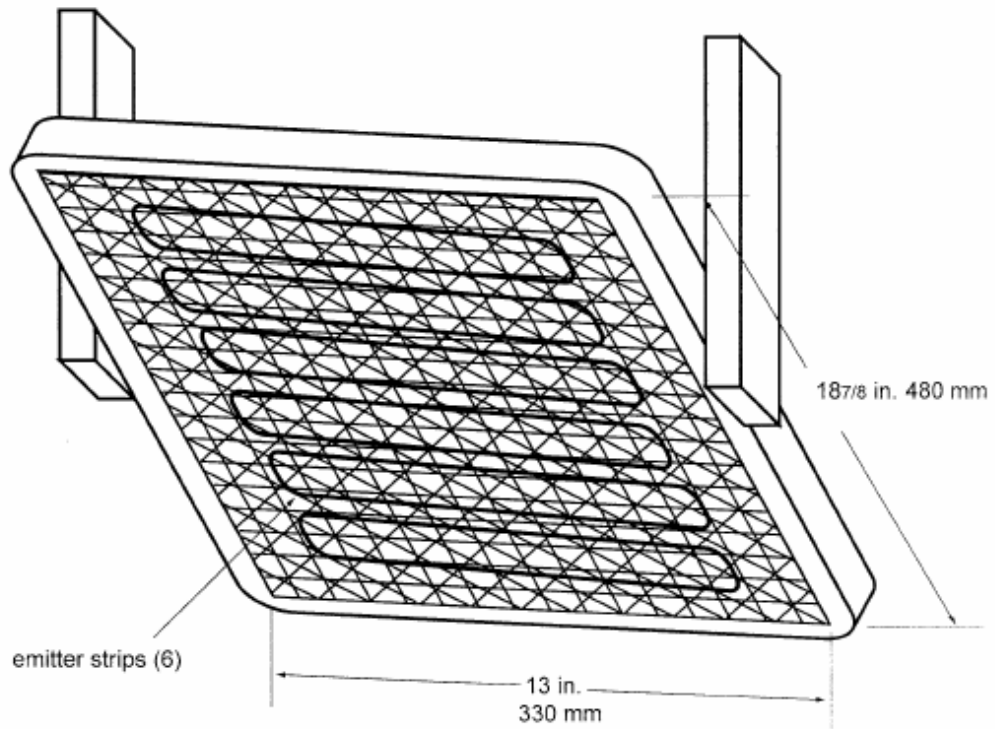


Figure B-3a. Electric Radiant Heat Panel

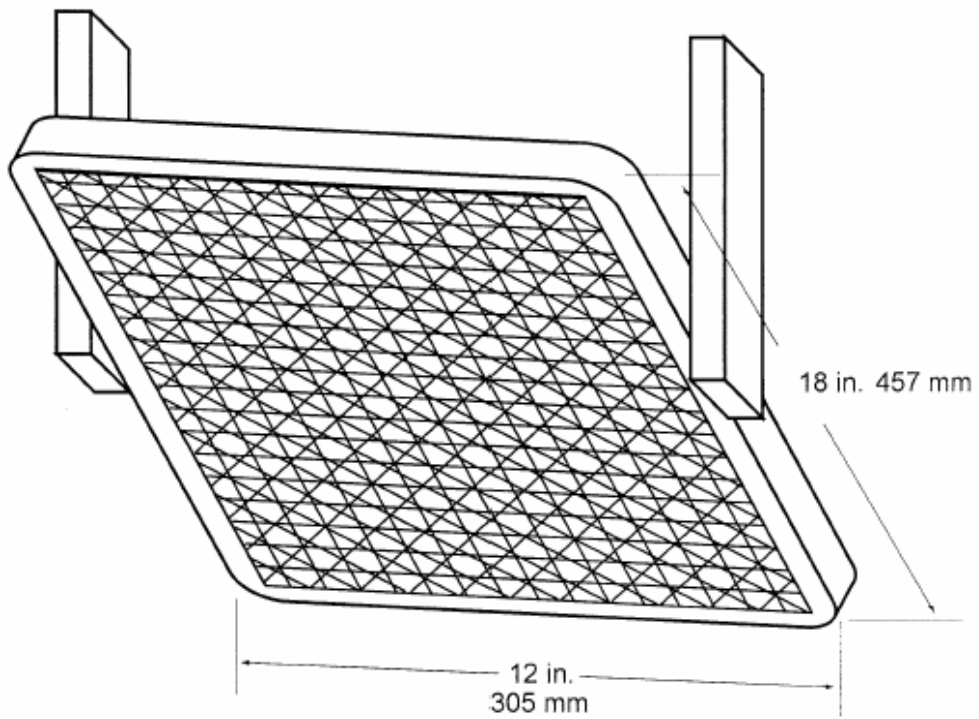


Figure B-3b. Air Propane Radiant Heat Panel

### B.3.1.1.2 Gas Radiant Heat Panel.

Use propane (liquid petroleum gas—2.1 UN 1075) for the gas RHP fuel. The panel fuel system must consist of a venturi-type aspirator for mixing gas and air at approximately atmospheric pressure. Suitable instrumentation should be provided for monitoring and controlling the flow of fuel and air to the panel. An airflow gauge, an airflow regulator, and a gas pressure gauge should be included.

### B.3.1.2 Radiant Heat Panel Placement.

Mount the RHP in the chamber at 30° to the horizontal specimen plane, and 7.5 inches (19.05 cm) above the zero point of the specimen.

### B.3.2 SPECIMEN HOLDING SYSTEM.

The sliding platform serves as the housing for test specimen placement. Brackets may be attached (using wing nuts) to the top lip of the platform to accommodate various thicknesses of test specimens. The test specimens must be placed on a sheet of Kaowool M™ board or 1260 Standard Board (manufactured by Thermal Ceramics and available in Europe), or equivalent, either resting on the bottom lip of the sliding platform or on the base of the brackets. It may be necessary to use multiple sheets of material, based on the thickness of the test specimen, to meet the sample height requirement. Typically, these noncombustible sheets of material are available in 1/4 inch (6-mm) thicknesses. See figure B-4. A sliding platform that is deeper than the 2-inch (50.8mm) platform shown in figure B-4 is also acceptable as long as the sample height requirement is met.

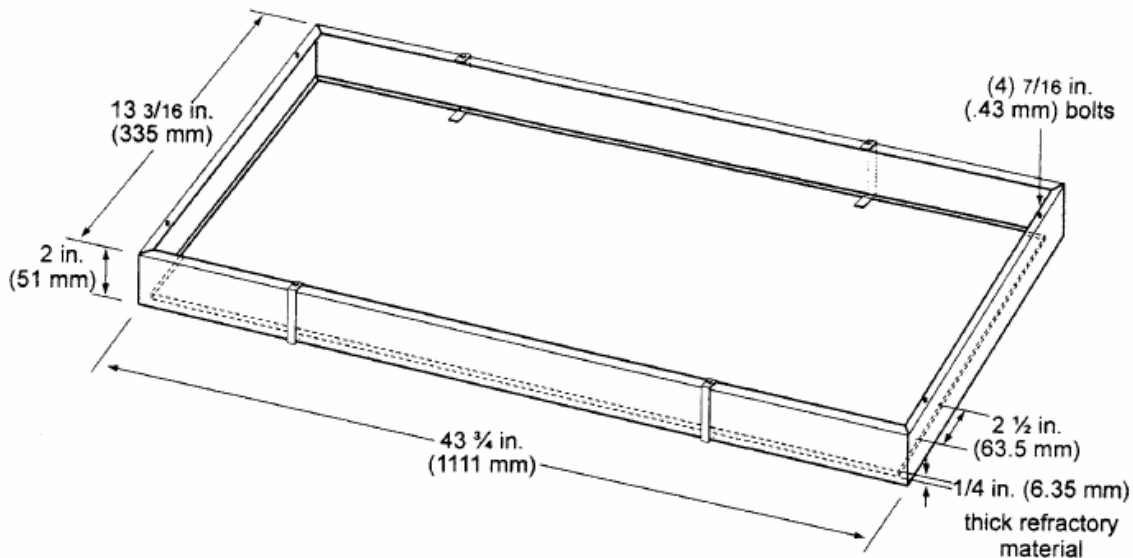


Figure B-4. Sliding Platform

Attach a 1/2-inch (13-mm) piece of Kaowool M™ board or other high-temperature material measuring 41 1/2 by 8 1/4 inches (1054 by 210 mm) to the back of the platform. This board serves as a heat retainer and protects the test specimen from excessive preheating. The height of this board must not impede the sliding platform movement (in and out of the test chamber). If the platform has been fabricated such that the backside of the platform is high enough to prevent excess preheating of the specimen when the sliding platform is out, a retainer board is not necessary.

### B.3.2.1 Specimen Holder.

If the specimen is expected to shrink or warp while being tested, it should be clamped to a noncombustible board measuring 8 by 11 by 1/2 inches (20.32 by 27.94 by 1.27 cm) with large hardened steel binder clips (remove wire handles). See figure B-5.

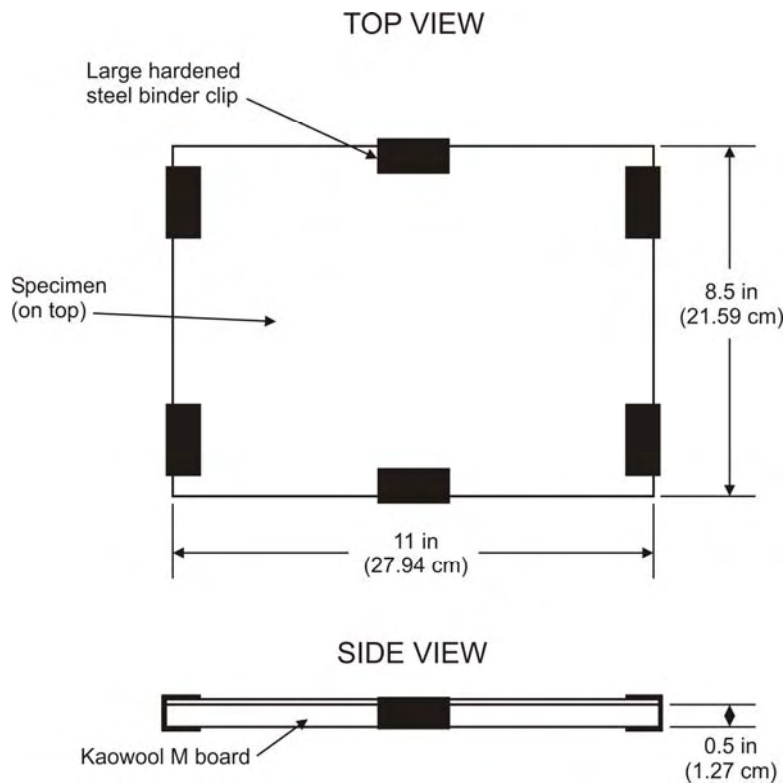


Figure B-5. Specimen Holder

### B.3.3 PILOT BURNER.

The pilot burner used to ignite the specimen must be a Bernzomatic™ commercial propane venturi torch with an axially symmetric burner tip and a propane supply tube with an orifice diameter of 0.006 inch (0.15 mm). The length of the burner tube must be 2 7/8 inches (71 mm). The propane flow must be adjusted using gas pressure through an in-line regulator to produce a blue inner cone length of 3/4 inch (19 mm). A 3/4 inch (19 mm) guide (such as a thin strip of metal) may be soldered to the top of the pilot burner to aid in setting the flame height. The

overall flame length must be approximately 5 inches long (127 mm). A way to move the burner out of the ignition position must be provided so that the flame is horizontal and at least 2 inches (50.8 mm) above the specimen plane. See figure B-6.

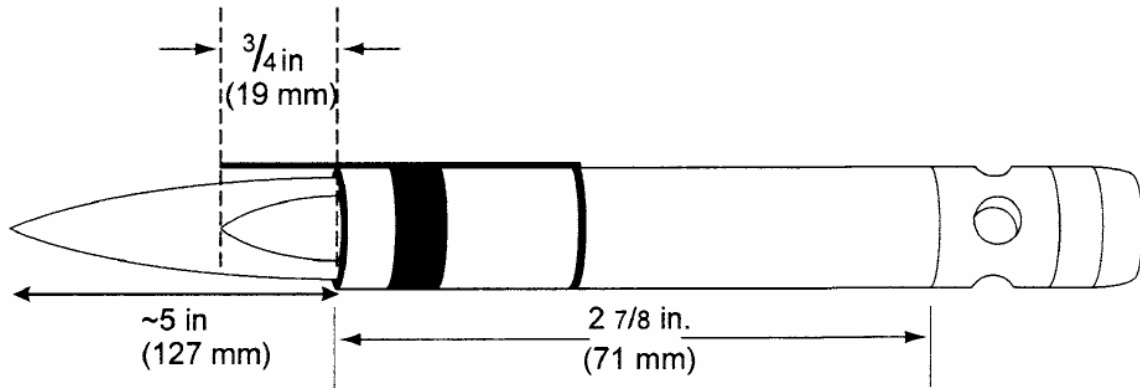


Figure B-6. Propane Pilot Burner

### B.3.4 THERMOCOUPLES.

Install a 24 American Wire Gauge Type K (Chromel-Alumel) thermocouple in the test chamber for temperature monitoring. Insert it into the chamber through a small hole drilled through the back of the chamber. Place the thermocouple so that it extends 11 inches (279 mm) from the back of the chamber wall, 11.5 inches (292 mm) from the right side of the chamber wall, and 2 inches (50.8 mm) below the RHP. The use of other thermocouples is optional.

### B.3.5 CALORIMETER.

The calorimeter must be a 1-inch cylindrical, water-cooled, total heat flux density, foil-type Gardon gage that has a range of 0 to 5 Btu/ft<sup>2</sup>-second (0 to 5.7 Watts/cm<sup>2</sup>).

#### B.3.5.1 Calorimeter Calibration Specification And Procedure.

##### B.3.5.1.1 Calorimeter Specification.

- Foil diameter must be 0.25 ±0.005 inch (6.35 ±0.13 mm).
- Foil thickness must be 0.0005 ±0.0001 inch (0.013 ±0.0025 mm).
- Foil material must be thermocouple grade constantan.
- Temperature measurement must be a copper constantan thermocouple.
- The copper center wire diameter must be 0.0005 inch (0.013 mm).

- The entire face of the calorimeter must be lightly coated with Black Velvet™ paint, having an emissivity of 96 or greater.

#### B.3.5.1.2 Calorimeter Calibration.

- a. The calibration method must be in comparison to a like-standardized transducer.
- b. The standardized transducer must meet the specifications given in section B.3.5.1.1.
- c. The standard transducer must be calibrated against a primary standard traceable to the National Institute of Standards and Technology.
- d. The method of transfer must be a heated graphite plate.
- e. The graphite plate must be electrically heated, have a clear surface area on each side of the plate of at least 2 by 2 inches (51 by 50.8 mm), and be 1/8 inch  $\pm$  1/16 inch thick (3.2  $\pm$  1.6 mm).
- f. The two transducers must be centered on opposite sides of the plates at equal distances from the plate.
- g. The distance of the calorimeter to the plate must be no less than 0.0625 inch (1.6 mm), and no greater than 0.375 inch (9.5 mm).
- h. The range used in calibration must be at least 0–3.5 Btu/ft<sup>2</sup>-second (0–3.9 Watts/cm<sup>2</sup>) and no greater than 0–5.7 Btus/ft<sup>2</sup>-second (0–6.4 Watts/cm<sup>2</sup>).
- i. The recording device used must record the two transducers simultaneously or at least within 1/10 of each other.

#### B.3.5.1.3 Calorimeter Fixture.

With the sliding platform pulled out of the chamber, the calorimeter-holding frame must be installed and a sheet of noncombustible material must be placed in the bottom of the sliding platform adjacent to the holding frame. This will prevent heat losses during calibration. The frame must be 13 1/8 inches (333 mm) deep (front to back) by 8 inches (203 mm) wide and must rest on the top of the sliding platform. It must be fabricated of 1/8 inch (3.2 mm) flat stock steel and have an opening that accommodates a 1/2-inch (12.7 mm)-thick piece of refractory board, which is level with the top of the sliding platform. The board must have three 1-inch (25.4 mm)-diameter holes drilled through the board for calorimeter insertion. The distance to the RHP surface from the centerline of the first hole (zero position) must be 7 1/2  $\pm$  1/8 inches (191  $\pm$  3 mm). The distance between the centerline of the first hole to the centerline of the second hole must be 2 inches (50.8 mm). It must also be the same distance from the centerline of the second hole to the centerline of the third hole, (see figure B-7). A calorimeter holding frame that differs in construction is acceptable as long as the height from the centerline of the first hole to the RHP and the distance between holes is the same as described in this paragraph.

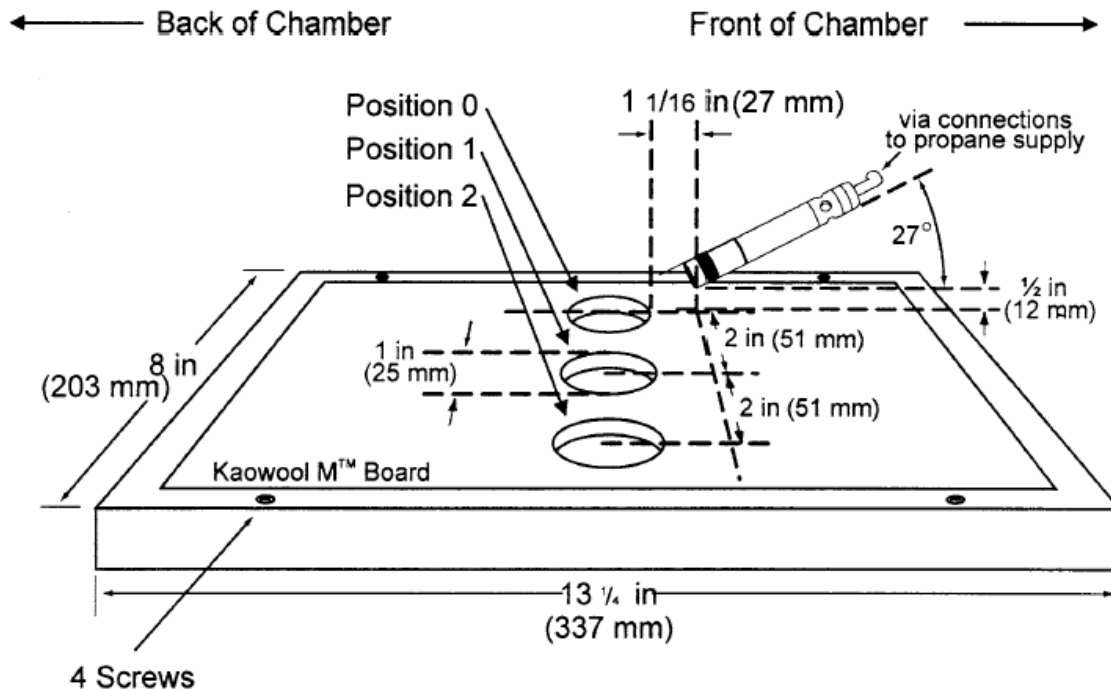


Figure B-7. Calorimeter Holding Frame

### B.3.6 INSTRUMENTATION.

Provide a calibrated recording device with an appropriate range or a computerized data acquisition system to measure and record the outputs of the calorimeter and the thermocouple. The data acquisition system must be capable of recording the calorimeter output every second during calibration.

### B.3.7 TIMING DEVICE.

Provide a stopwatch or other device, accurate to  $\pm 1$  second/hour, to measure the time of application of the pilot burner flame and the afterflame time.

### B.3.8 RULER.

A ruler or scale calibrated and graduated to the nearest 0.125 in. (3.2 mm) shall be provided to measure the burn length.

## B.4 TEST SPECIMENS.

### B.4.1 SPECIMEN SELECTION.

The test specimens are made to include all materials used in the construction of the aircraft duct. Materials must be tested either as section cut from a fabricated part as installed in the airplane or as a specimen simulating a cut section, such as a specimen cut from a flat sheet of the material or a model of the fabricated part. Fabricated units, such as sandwich panels, may not be separated.

#### B.4.1.1 Bonded Fire-Blocking Jackets.

This type of material must first meet the requirements of Title 14 Code of Federal Regulations (CFR) Part 25.856(a) and then the requirements of this document. Fire-blocking jackets that will be bonded to an aircraft duct must be prepared as follows:

- a. Prepare the specimen as indicated in section B.4, including the fire-blocking jacket, the actual ducting material to protect, the adhesive, and any other material to be included in the part.
- b. On the centerline of the specimen, include the seam (as designed) that will be present when the two ends of the fire-blocking jacket meet (see figure B-8).
- c. Test this specimen on its warp and fill directions.

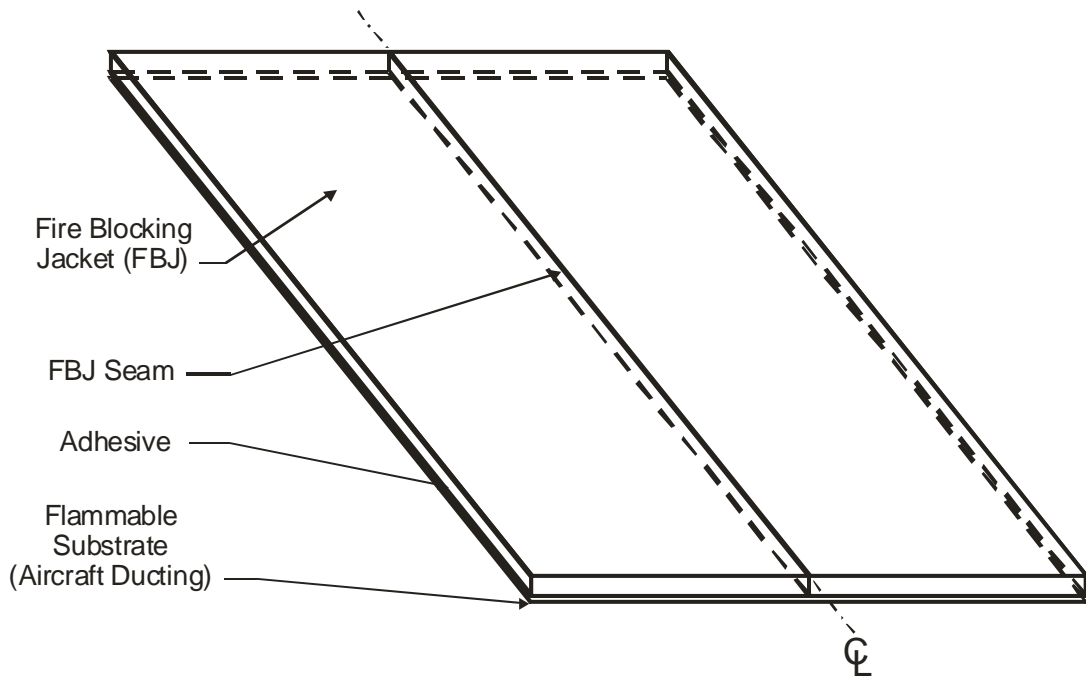


Figure B-8. Bonded Fire-Blocking Jacket Specimen

#### B.4.2 SPECIMEN NUMBER.

Prepare and test a minimum of three test specimens. If an oriented material is used (such as stiffeners on a flexible duct), prepare and test both the warp and fill directions (three times each direction).

#### B.4.3 SPECIMEN SIZE.

The specimen shall be a rectangle at least 8.5 by 11 in. (21.59 by 27.94 cm), unless the actual size used in the aircraft is smaller.

#### B.4.4 SPECIMEN THICKNESS.

The specimen thickness shall be the same as that in the part qualified for use in the airplane, except for the following:

- If the part construction is used in several thicknesses, the minimum thicknesses shall be tested;
- Foam parts that are thicker than 1/2 in. (13 mm), such as the duct core, shall be tested in 1/2-in. (13-mm) thicknesses;
- Parts that are smaller than the size of the specimen, which cannot have specimens cut from them, may be tested using a flat sheet of the material used to fabricate the part, in the actual thickness used in the airplane, as long as the thickness is not greater than 1/8 in. (3 mm). If the part thickness is greater than 1/8 in. (3 mm), the thickness used for the test specimen shall not exceed 1/8 in. (3 mm).

#### B.5 CONDITIONING.

Specimens must be conditioned at  $70^{\circ} \pm 5^{\circ}\text{F}$  ( $21^{\circ} \pm 3^{\circ}\text{C}$ ) and  $50\% \pm 5\%$  relative humidity for 24 hours minimum. Only one specimen should be removed at a time from the conditioning environment immediately before testing.

#### B.6 PROCEDURE.

##### B.6.1 APPARATUS CALIBRATION.

- a. With the sliding platform out of the chamber, install the calorimeter holding frame. Push the platform back into the chamber and insert the calorimeter into the first hole (zero position, (see figure B-7). Close the bottom door located below the sliding platform. The distance from the centerline of the calorimeter to the RHP surface at this point must be 7 1/2 inches  $\pm 1/8$  inch (191 mm  $\pm 3$  mm). Prior to igniting the RHP, ensure that the calorimeter face is clean and water is running through the calorimeter.
- b. Ignite the RHP. Adjust the fuel/air mixture to achieve 1.0 Btu/ft<sup>2</sup>-second  $\pm 5\%$  (1.13 Watts/cm<sup>2</sup>  $\pm 5\%$ ) at the zero position. If using an electric RHP, set the power controller to achieve the proper heat flux. Allow the unit to reach steady state (this may take up to 1 hour). The pilot burner must be off and in the down position during this time.
- c. After steady-state conditions are reached, move the calorimeter 2 inches (50.8 mm) from the zero position (first hole) to position 1 and record the heat flux. Then, move the calorimeter to position 2 and record that heat flux. Allow enough time at each position for the calorimeter to stabilize. Table B-1 depicts typical calibration values at the three positions.



Table B-1. Calibration Table

Position	Btu/ft <sup>2</sup> sec	Watts/cm <sup>2</sup>
Zero Position	1.0 ±0.05	1.13 ±0.06
Position 1	1.0 ±0.05	1.13 ±0.06
Position 2	0.99 ±0.05	1.12 ±0.06

- d. Open the bottom door and remove the calorimeter and holding frame. Use caution, as the fixture is very hot.

**B.6.2 TEST PROCEDURE.**

- a. Ignite the pilot burner. Ensure that it is at least 2 inches (50.8 mm) above the top of the platform. The pilot burner must not contact the specimen until the test begins.
- b. Place the test specimen in the sliding platform. Ensure that the test sample surface is level with the top of the platform. At zero point, the specimen surface must be 7 1/2 inches ±1/8 inch (191 mm ±3 mm) below the RHP.
- c. If a fire-blocking jacket material is being tested and it uses film or fiberglass assemblies, it is critical to make a slit in the film cover to purge any air inside. This allows the operator to maintain the proper test specimen position (level with the top of the platform) and allows ventilation of gases during the tests. A longitudinal slit, approximately 2 inches (50.8 mm) in length, must be centered 3 inches ±1/2 inch (76 mm ±13 mm) from the left flange of the securing frame. A utility knife is acceptable for slitting the film cover.
- d. Immediately push the sliding platform into the chamber and close the bottom door.
- e. Heat soak the sample for 1 minute.
- f. After the 1-minute heat soak, bring the pilot burner flame into contact with the center of the specimen at the zero point and simultaneously start the timer. The pilot burner must be at a 27° angle with the sample and be approximately 1/2 inch (12 mm) above the sample. See figure B-7. A stop, as shown in figure B-9, allows the operator to position the pilot burner correctly each time.
- g. Leave the pilot burner in position for 15 seconds and then remove it to a position at least 2 inches (50.8 mm) above the specimen.

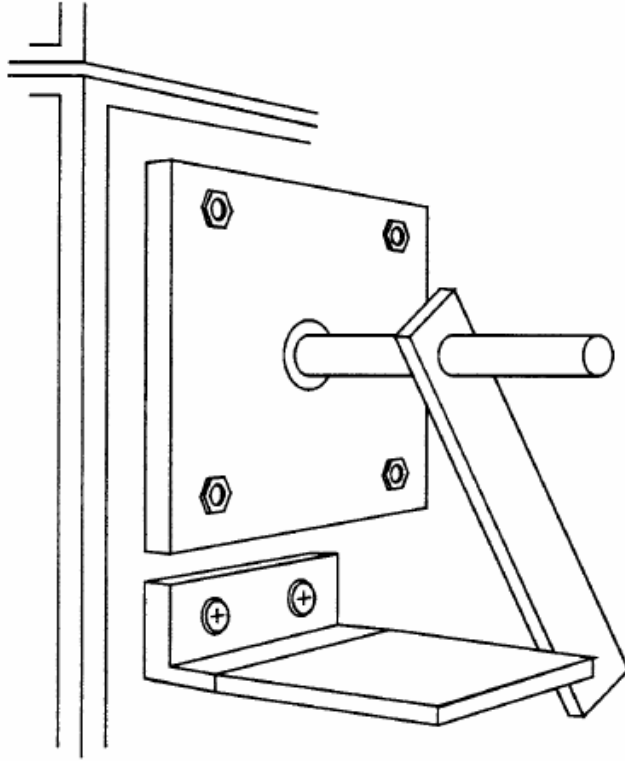


Figure B-9. Propane Burner Stop

B.7 REPORT.

B.7.1 MATERIAL IDENTIFICATION.

- a. Fully identify the material tested, including thickness.
- b. Report any shrinkage or melting of the test specimen.

B.7.2 TEST RESULTS.

B.7.2.1 Afterflame Time.

Report the afterflame time for each specimen tested.

B.7.2.2 Burn Length.

Report the burn length for each specimen tested. If the burn length distance is less than 2 inches (50.8 mm), report this as a pass (no measurement required).

B.7.2.3 Posttest Specimen Condition.

Report any shrinkage or melting of any of the tested specimens.

## B.8 REQUIREMENTS.

### B.8.1 AFTERFLAME TIME.

The flame time after removal of the pilot burner may not exceed 45 seconds on any specimen.

### B.8.2 BURN LENGTH.

There must be no burn length beyond 2 inches (50.8 mm) to the left of the centerline of the pilot flame application on any specimen.

### B.8.3 FIRE-BLOCKING JACKETS.

The fire-blocking jackets not only must meet 14 CFR 25.856(a) and requirements B.8.1 and B.8.2, but they also need to demonstrate that they have maintained their protective and structural integrity to prevent exposing the flammable substrate (aircraft ducting specimen).