Development of a New Flammability Test for Aircraft Ducting & Wiring

Federal Aviation Administration

Presented to: The International Aircraft Materials Fire Testing Working Group

By: John Reinhardt, presented by Pat Cahill

Date: March 3-4, 2010

BACKGROUND

• The FAA initiated efforts to improve the fireworthiness of hidden areas in the aircraft (T/A Insulation) in 1995 after several incidents involving the thermal-acoustic insulation.

• The FAA's goal was to raise the level of safety for the airplane such that fires in inaccessible areas would not spread and create catastrophic conditions.

•Systems of interest in the hidden area includes thermal-acoustic insulation, aircraft ducting, wiring, etc.

• Aircraft ducting is currently certified using “12-second Vertical Bunsen Burner test (12VBB, Title 14 Code of Federal Regulations Part 25, Appendix F Part I (a)(ii))

SwissAir MD-11 Accident Investigation Reconstruction, 1998

BACKGROUND

• The current test for aircraft ducts does not predict the behavior of the part in actual conditions and therefore suggests the need for a new standard.

• In 2004, in conjunction with the IAMFTWG, the FAA chartered a project to develop a new fire test procedure to evaluate the fire-worthiness of aircraft ducting.

• In 2004, as part of the project baseline, several aircraft ducting materials were re-tested with the 12VBB test. They all passed the test.

OBJECTIVE

Develop an improved fire test method for aircraft ducting that could adequately discriminate between poorly performing ducting materials and fire worthy ones when exposed to a realistic fire scenario.

METHODOLOGY

Conduct realistic, intermediate-scale tests on various shapes and sizes of ducting using a flaming foam block as the fire source. The results would be used as the basis for the development of a laboratory-scale test.

Intermediate-Scale Test

Radiant Heat Panel Test

(Small-Scale Test)

Equipment Selection

COMPARISON OF EQUIPMENT:

Vertical Bunsen Burner Test Apparatus

(FAR 25.853 or Handbook)

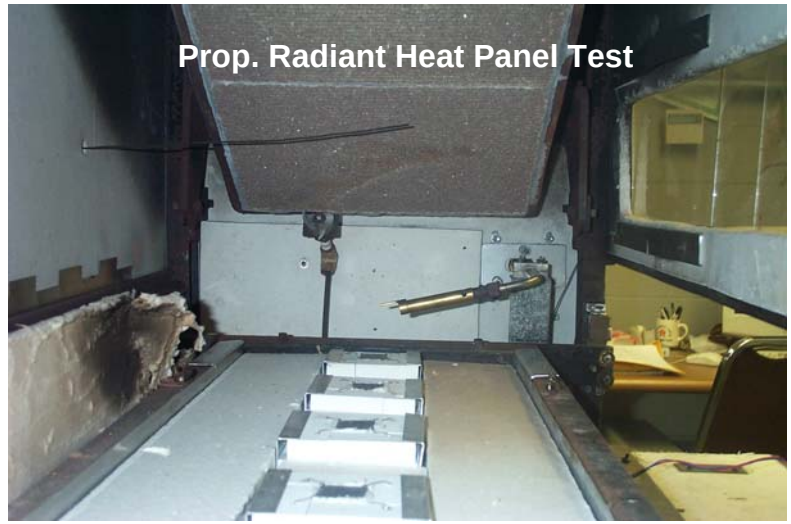
Radiant Heat Panel Test Apparatus

(FAR 25.856)

Radiant Heat Panel Test Protocol

FIRE THREAT:

• Methane Pilot Flame (Inner cone = 7/8” & tip of flame = 1.5 in)



• 1 BTU/ft^{2}-sec Radiant Heat (1 min Exposure)

• Propane Pilot Flame (blue inner cone = ¾”, overall flame length = 5” long)

Radiant Heat Panel Test Protocol

TEST PROCEDURE:

Vertical Bunsen Burner Test

- Impinge the pilot burner flame on the sample for 12 seconds
- Maintain sample in chamber until flames are self-extinguished or after flame time > 15 seconds
- Record after flame time, burn length, and drip flame time

- Expose sample to 1 BTU/ft2 radiant heat for 1 minute
- After the 1 minute exposure, impinge the pilot burner flame on the sample for 15 seconds
- Maintain sample in chamber until flames are self-extinguished or after flame time > 45 seconds
- Record after flame time and burn length

Radiant Heat Panel Test Protocol

ACCEPTANCE CRITERIA

Vertical Bunsen Burner Test

- Burn Length ≤ 8”
- Flame Time ≤ 15 sec
- Drip Flame Time ≤ 3 sec

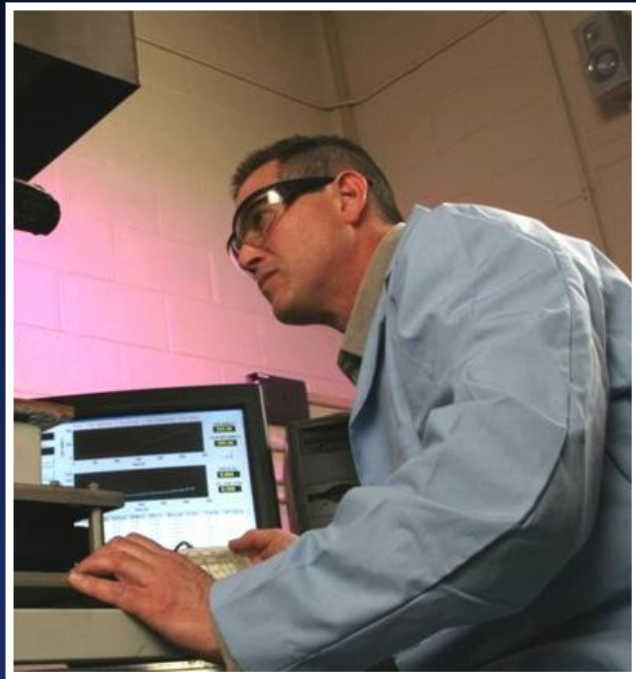
Radiant Heat Panel Test

- Burn Length ≤ 2”
- After Flame Time ≤ 45 sec
- Fire Blocking Jacket, tapes or hook and loop shall not shrink away

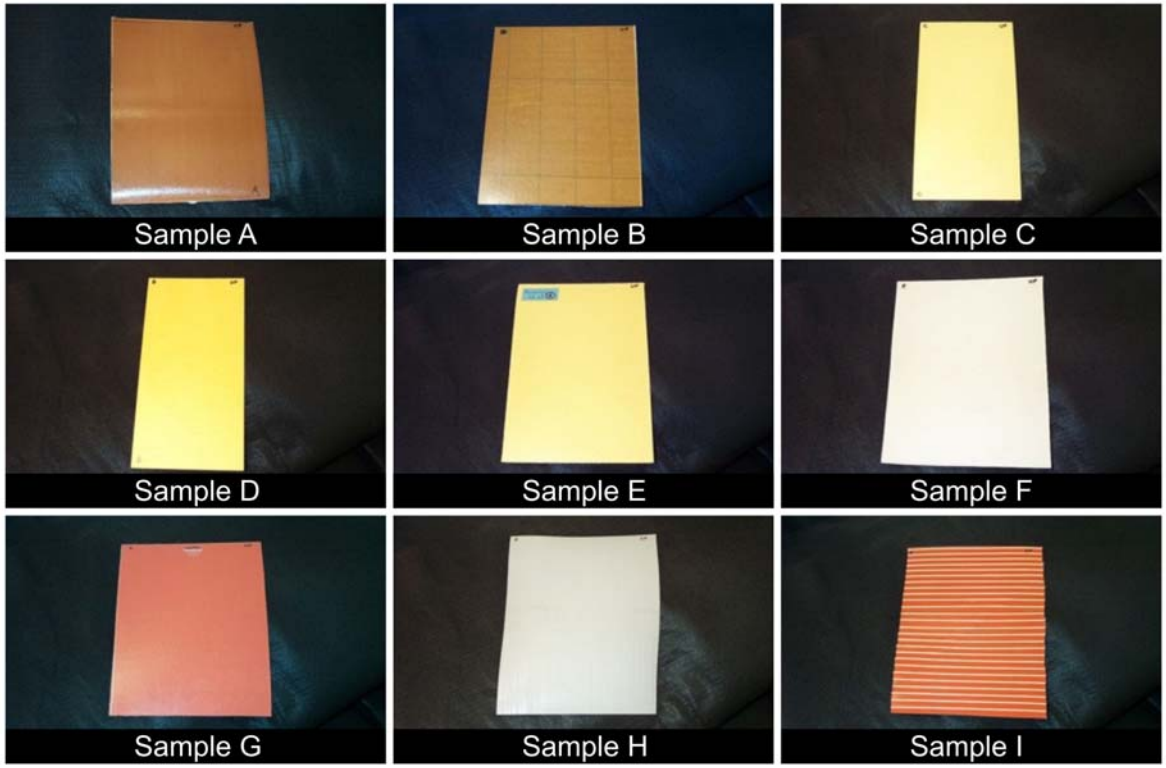
Round Robin Testing

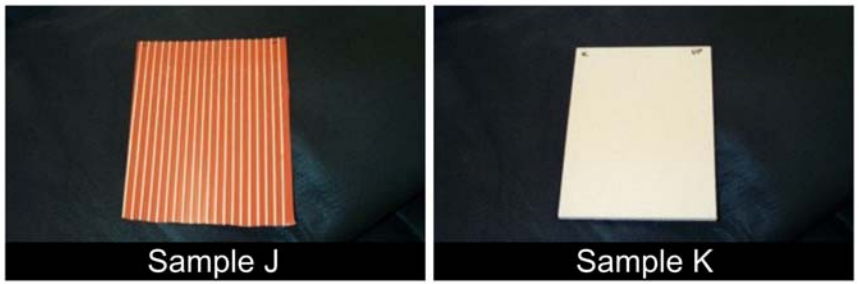
Round Robin Participants:

- ✓ Participants included 6 working group members.
- ✓ Participating laboratories included aircraft manufacturers, national and international government labs, testing equipment manufacturers, material manufacturers, and other aviation component suppliers.
- ✓ Participants wanted to remain anonymous



Tested Samples





Preliminary Results

Round Robin Average Results

Sample ID	Average of All Labs								Pass/Fail Criteria
	Burn Length (cm)	*Std Dev (cm)	After Flame Extinguishing Time (sec)	*Std Dev (sec)	Glow Time (sec)	*Std Dev (sec)	% Mass Loss	*Std Dev (%)	
A	3	0.65	0.6	0.58	0.6	0.66	1.2	0.72	Passed
B	2.9	0.45	7.3	4.63	0.4	1.06	2.1	0.44	Passed
C	2.4	0.38	0.4	0.96	1.7	2.14	2.8	1.22	Passed
D	2.7	0.61	1.4	1.38	3.8	5.54	1.6	0.36	Passed
E	3.5	1.24	3.4	1.19	1	2.04	4.1	1.11	Passed
F	4.1	1.02	0.5	0.77	1.1	1.31	1.7	0.38	Passed
G	2.9	0.79	34.5	8.62	6.8	16.7	1.5	1.32	Passed
H	2.9	0.46	12.5	3.91	1.9	4.74	0.7	0.6	Passed
I	+9.6	N/A	+120	N/A	N/A	N/A	+14.8	N/A	Failed
J	+5.7	N/A	+120	N/A	N/A	N/A	+11	N/A	Failed
K	2.7	0.55	0.2	0.44	0	0	1.2	1.17	Passed

Acceptance Criteria: Burn Length =< 5.08 cm and After Flame Extinguishing Time =< 45 seconds
*Note: This is the standard deviation of the average values reported by the laboratories.

Final Comments

Conclusion:

- Lab #4 did not respond to re-testing request or to obtain courtesy equipment examination.
- There is a possibility that the difference in results of Lab #4 could be attributed to sample placement inside RHP.
- Reproducibility std dev (between labs) was greater than the repeatability std dev: (1) AFET – 1:1.5, (2) BL – 1:3.1
- The deviation between labs was greater than the deviation within a lab.

Final Comments

Conclusion (Cont.):

- Without Lab# 4 re-testing, the precision information indicates that:
  - ✓ There is a 95% confidence level that all labs will obtain the same results for 9, out of 11, materials.
  - ✓ For marginal materials (2), there is a 68% chance or less that all labs will have the same results because of the larger standard deviations.

Initiating Process

- Objective:

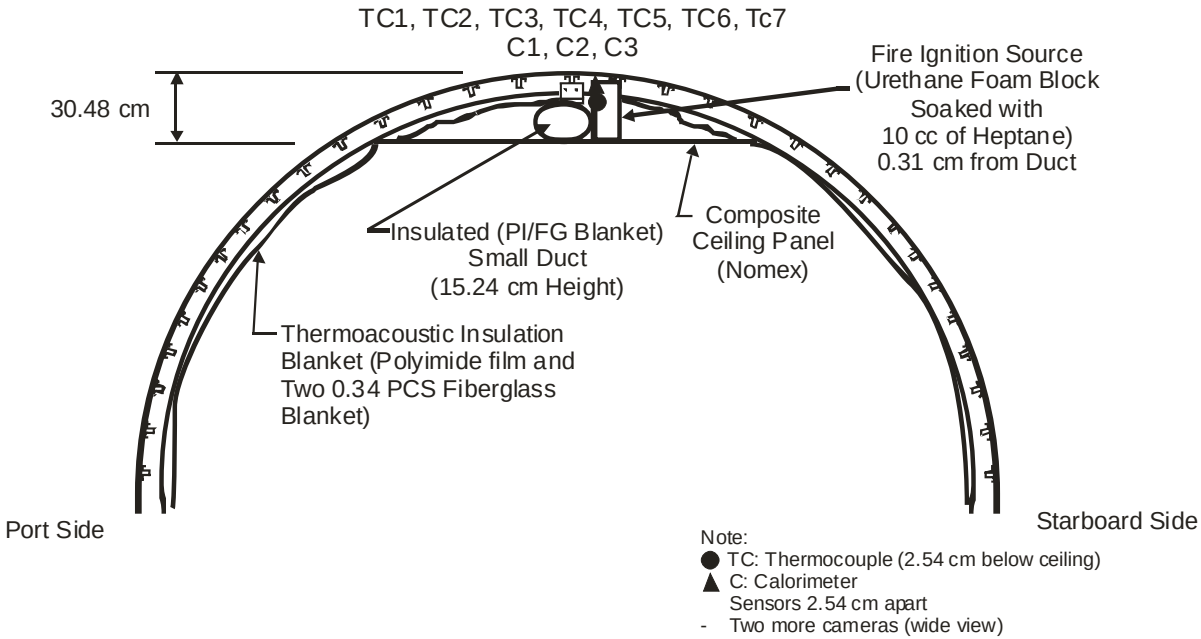
  Develop a fire test method for aircraft electrical wiring that can adequately discriminate between poorly performing wire insulation materials and fire worthy ones when exposed to a realistic fire scenario.

- Methodology:

  Conduct intermediate-scale, realistic tests using various types of wiring to serve as basis for test parameters.

Execution Process

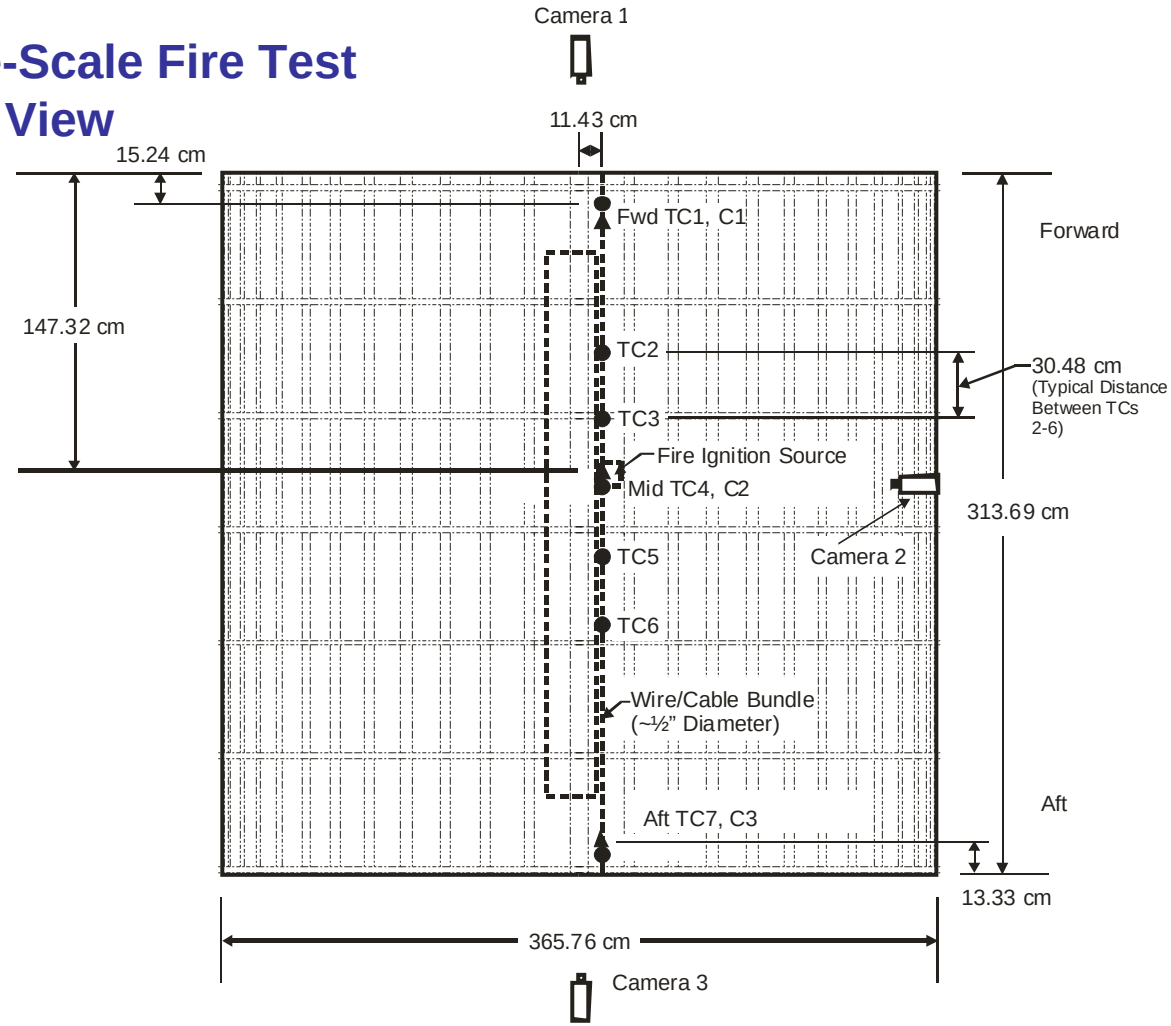
Intermediate-Scale Fire Test Setup – Front View



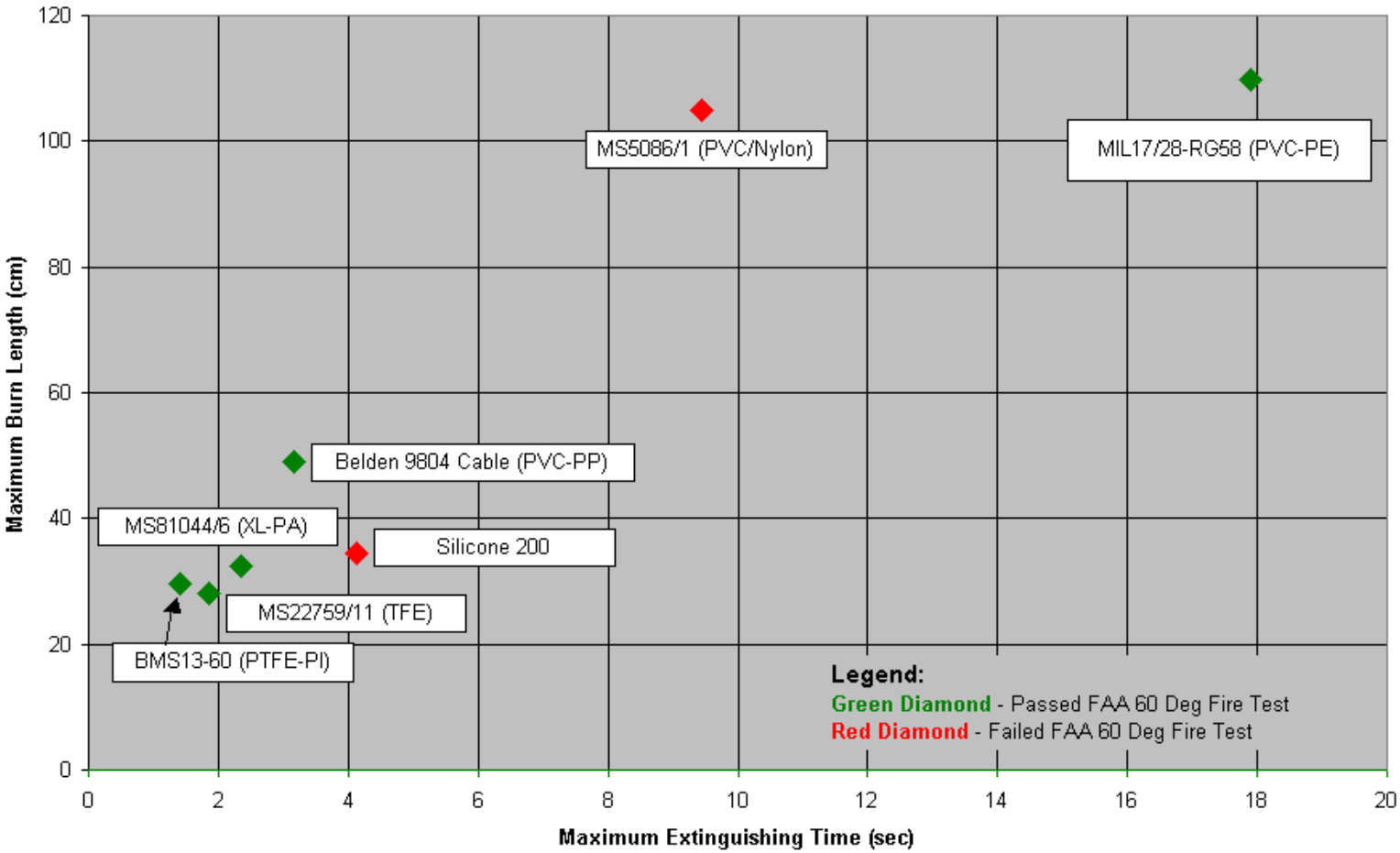
Narrow-body Transport Aircraft Fuselage Section

Execution Process

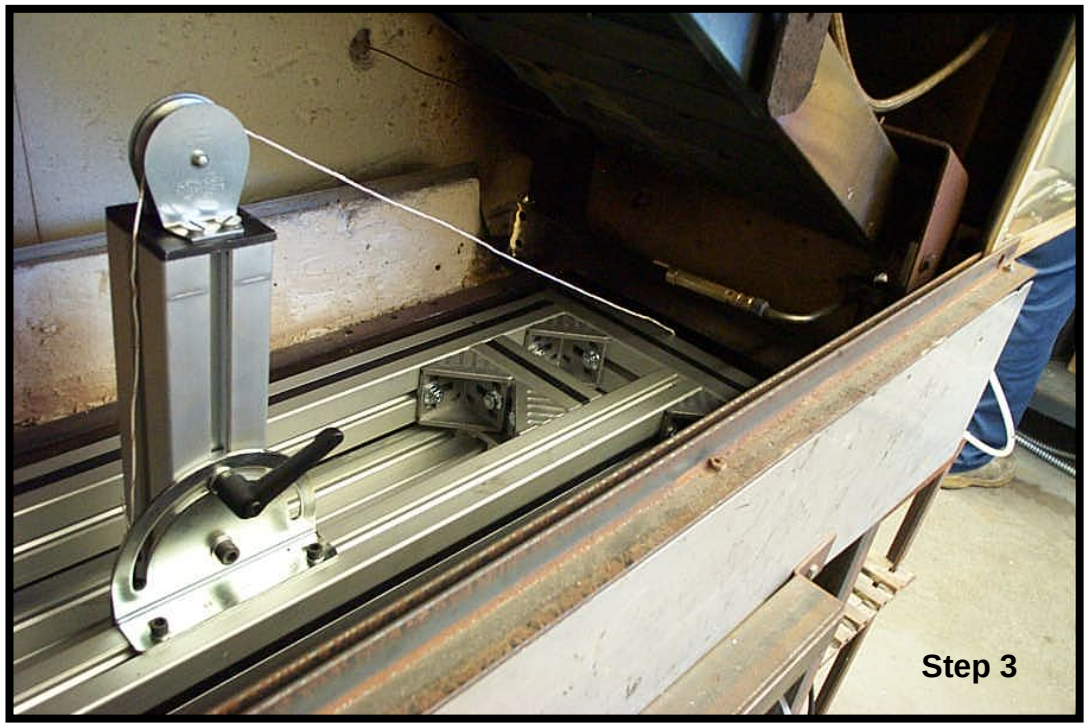
Intermediate-Scale Fire Test Setup – Top View



INTERMEDIATE-SCALE FIRE TEST OF WIRES/CABLES



Description of Selected Test Method



Patent Pending

Execution Process

Select/Modify Selected Test Method

PROCEDURE NO.	RADIANT PANEL HEAT FLUX (Watts/cm2)	DISTANCE TO PANEL (cm)	WIRE LENGTH (cm)	WIRE GAGE SIZE (AWG)	WIRE ANGLE (Degrees)	RADIANT EXPOSURE TIME (min)	PILOT IMPINGEMENT TIME (sec)	RESULT
1	1.7	15.24	76.2	20 or cable	30	1	30	Wire broke
2	1.7	15.24	76.2	20 or cable	30	1	15	No correlation to ISF test
3	1.7	7.62	76.2	20 or cable	30	1	15	Excellent correlation to ISF
4	1.7	N/A	76.2	20 or cable	0	1	15	No correlation to ISF test
5	1.7	7.62	31.75	20 or cable	30	1	15	Excellent correlation to ISF
6	1.7	7.62	76.2	24	30	1	15	Wire broke
7	1.7	7.62	76.2	24, 10 or cable	30	1	3	Excellent correlation to ISF
8	1.7	7.62	76.2	20 or cable	30	0	3	No correlation to ISF test

Selection: Procedure number 7 provided an excellent correlation with the intermediate-scale fire test without breaking the small (24) gage wires.

Execution Process

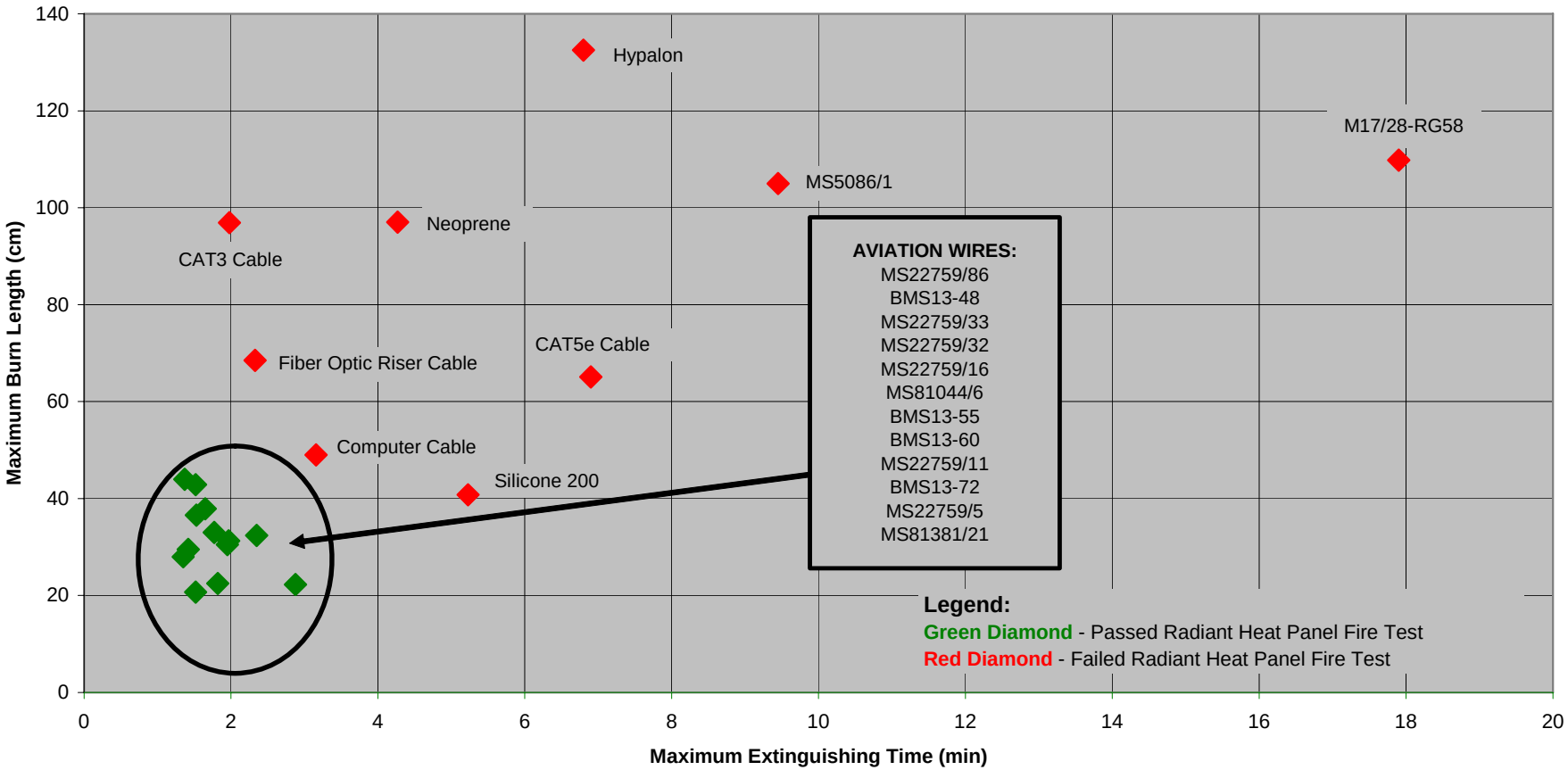
ELECTRICAL WIRES/CABLES FIRE TEST RESULTS

Item No.	Wire ID	Temperature Rating	TEST		
			FAA 60 Degree Flammability Wire Test	Intermediate-Scale Fire Test	30 Degree Radiant Heat Panel Test
1	CAT3 Cable	60	Passed	Failed	Failed
2	CAT5e Cable	60	Passed	Failed	Failed
3	Computer Cable	60	Passed	Failed	Failed
4	M17/28-RG58	80	Passed	Failed	Failed
5	Neoprene	90	Passed	Failed	Failed
6	Fiber Optic Riser Cable	105	Passed	Failed	Failed
7	Hypalon	105	Passed	Failed	Failed
8	MS5086/1	105	Failed	Failed	Failed
9	MS22759/14	135	Passed	Passed	Passed
10	BMS13-48	150	Passed	Passed	Passed
11	BMS13-60	150	Passed	Passed	Passed
12	MS22759/16	150	Passed	Passed	Passed
13	MS22759/32	150	Passed	Passed	Passed
14	MS81044/6	150	Passed	Passed	Passed
15	MS81381/21	150	Passed	Passed	Passed
16	BMS13-55	200	Passed	Passed	Passed
17	BMS13-72	200	Passed	Passed	Passed
18	MS22759/11	200	Passed	Passed	Passed
19	MS22759/33	200	Passed	Passed	Passed
20	MS22759/5	200	Passed	Passed	Passed
21	Silicone 200	200	Failed	Failed	Failed
22	MS22759/86	260	Passed	Passed	Passed

Wire temp rating also based on conductor material and coatings: annealed/high strength copper with tin/silver/nickel coatings

Execution Process

INTERMEDIATE-SCALE FIRE TEST OF WIRES/CABLES
(ISF Data versus RHP 30 Degree Test Data: 7.62 cm Distance, 1 min Exposure, 3 sec Pilot)



Execution Process

30-Degree Radiant Heat Panel Test Setup

– To be recommended as replacement test to Chapter 4 in the *Aircraft Materials Fire Test Handbook* and 14 CFR Part 25 Appendix F, part I (1v) and (3)

– **Sample Size:** 15 inch long x 0.5 inch diameter wire bundle mounted at 30 degrees from horizon.

– **Heat Sources:** Radiant Heat: 1.5Btu/ft^{2}sec, Pilot Flame: Propane (T>2000 F), perpendicular to wire sample

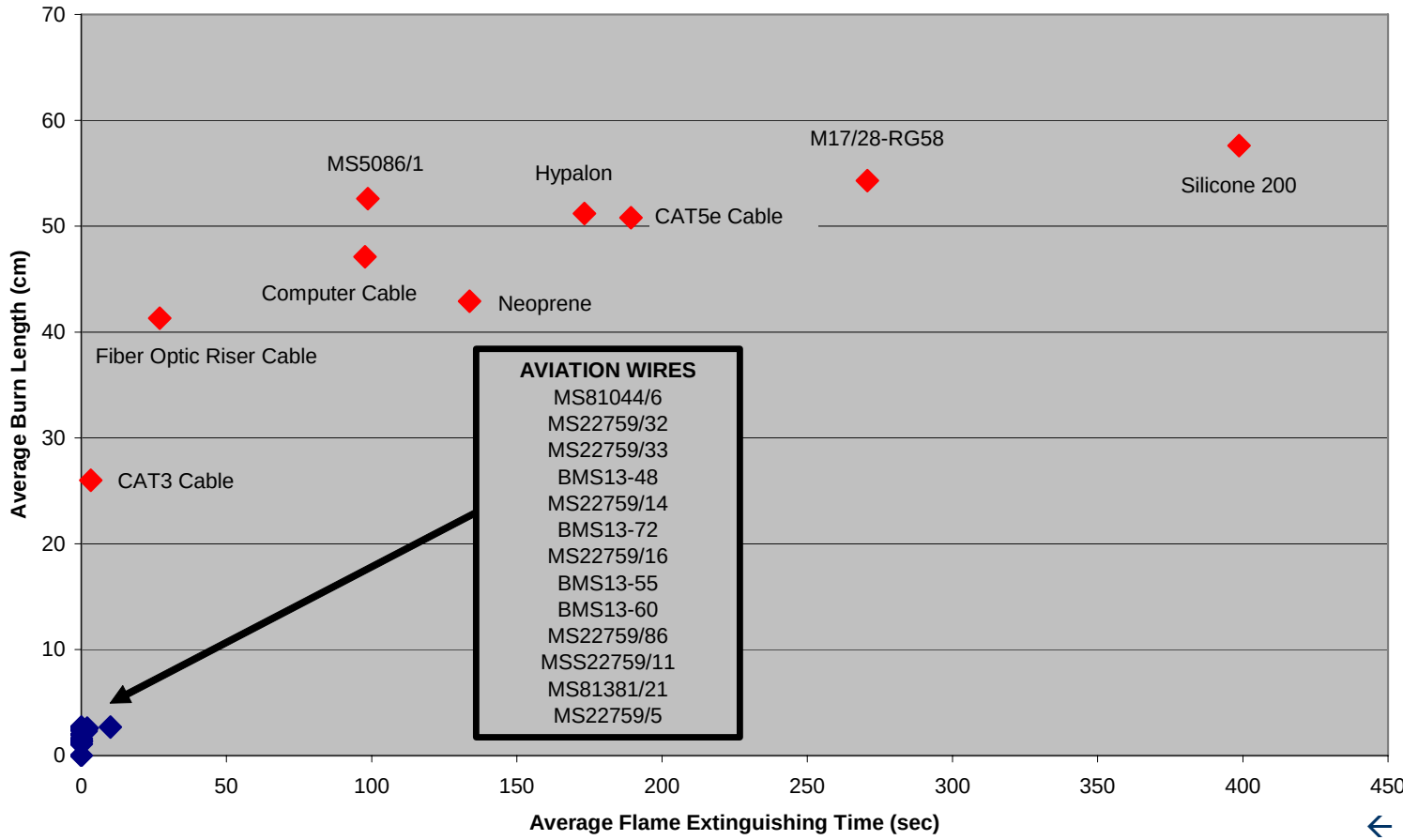
– **Heat Source Exposure:** Radiant Heat: 1 minute, Pilot Flame: 3 seconds

– **Acceptance Criteria:**

- **Flame Extinguishing Time:** <30 seconds
- **Burn Length:** <3 inches
- **Drip Extinguishing Time:** <3 sec

Execution Process

30 DEGREE RADIANT HEAT PANEL TEST FOR ELECTRICAL WIRES & CABLES
(Heat Flux: 1.7 W/cm2, Wires at 7.62 cm from the Panel, 1-minute Exposure, 3-seconds Pilot)



← Back

Alligator Clip Technique to Hold Short Wire

A 12.5 inch short wire was tested in the 30 degrees test configuration to determine if there is a change in the performance of the insulation flammability in this configuration. There was no change in the flammability performance.

Execution Process

Verify Test Method (Cont.)

- Verified procedure with various wire gage sizes: 24 AWG, 20 AWG, and 10 AWG. Also tested jacketed cables.
- Will conduct Round-Robin exercise with other labs to verify procedures.

← Back

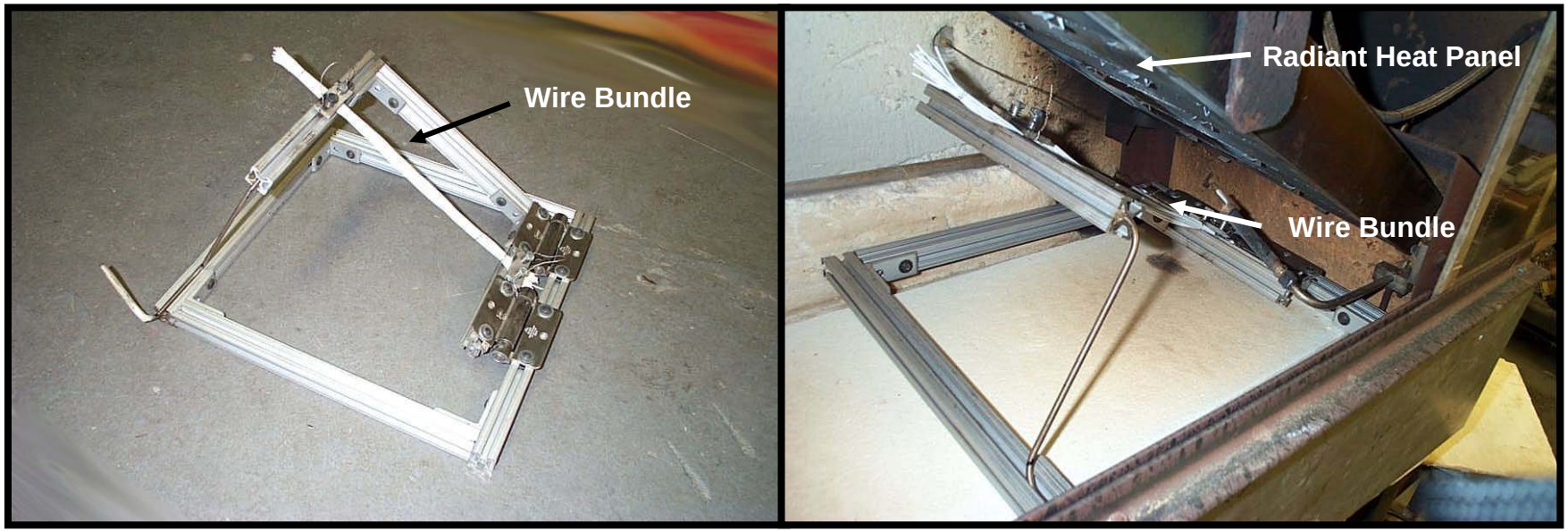
Additional Work

Recommendation

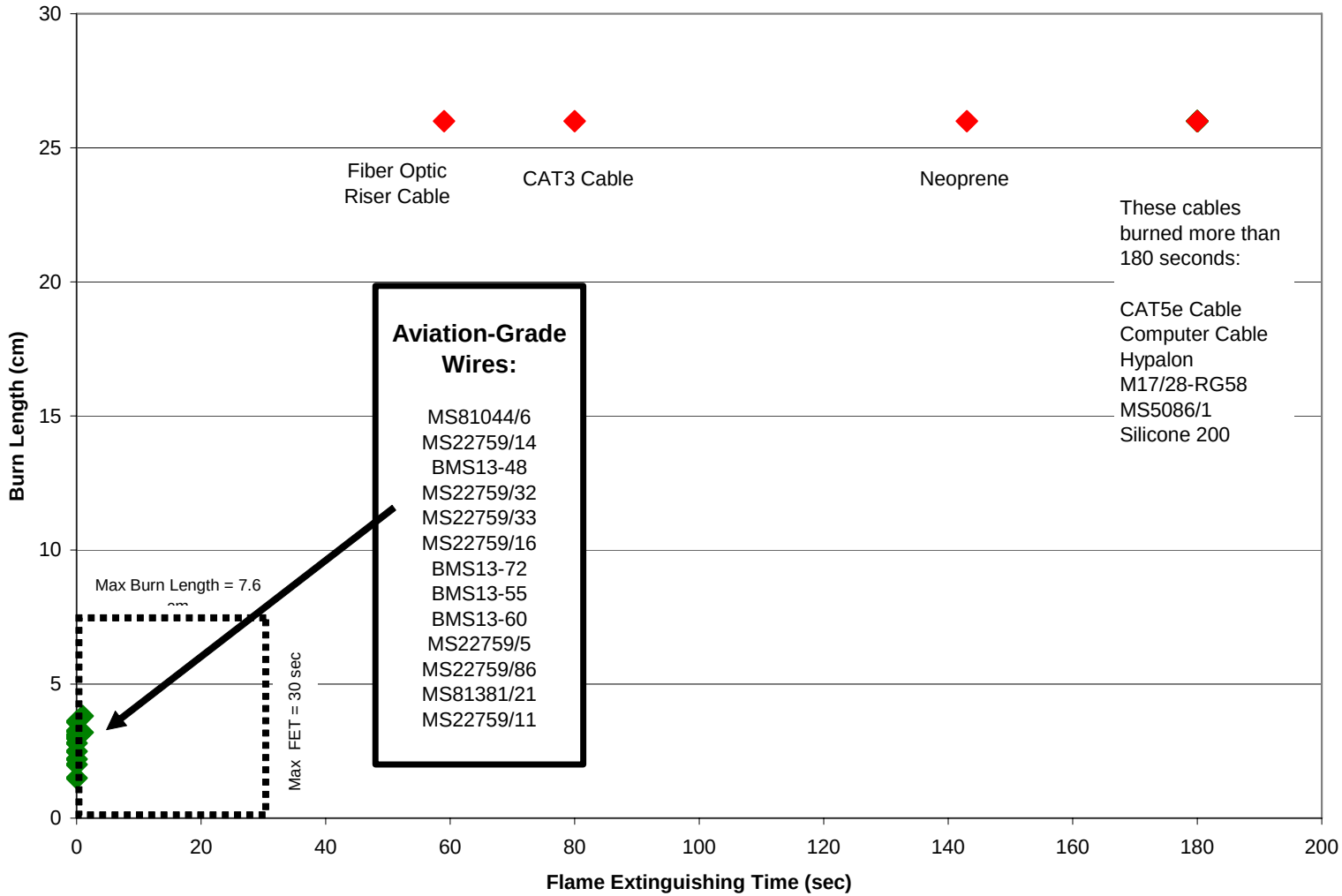
– The National Fire Protection Association and ASTM International concluded and recommended, in their previous research studies, that the flammability of wires should be determined by bundling the wires, instead of testing a single wire. They indicated that different thermodynamics exist when they burn as a group because of the radiation that emanates from each of the wires in the bundle (heat energy to and from the wires).

–In this past quarter, the FAA Technical Center decided to test the wires using bundles to study it and decide which specimen configuration to use.

30-Degree RHP Test Setup



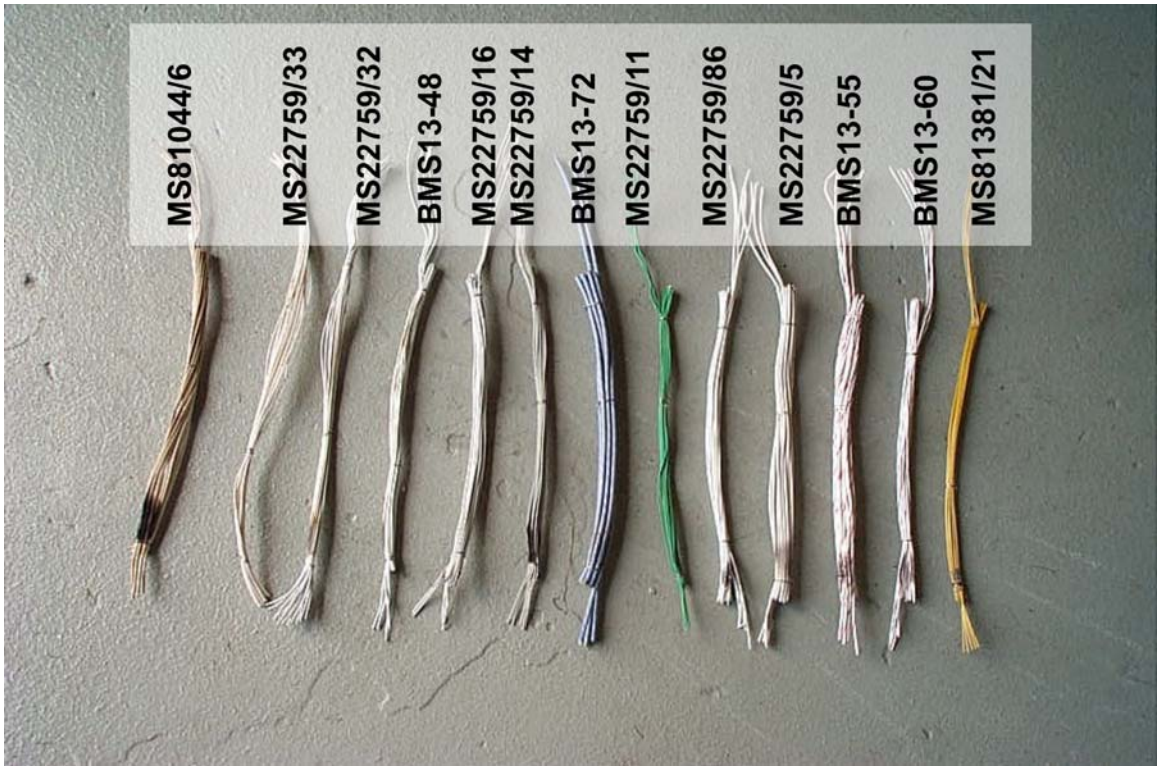
30-Degree RHP Test Results



Item No.	Material ID	Number of Wires/Cables in Bundle	Flame Extinguishing Time, FET (sec)	Burn Length, BL (cm)	Conductors Exposed?	Pass/Fail Criteria	Matched ISF Test?	Comments
1	MS22759/11	25	0	1.5	Yes	Passed	Yes	
2	MS81381/21	25	0	2.0	No	Passed	Yes	
3	MS22759/86	25	0	2.2	No	Passed	Yes	
4	MS22759/5	20	0	2.5	No	Passed	Yes	Light stain on the insulation
5	BMS13-60	25	0	2.8	No	Passed	Yes	
6	BMS13-55	25	0	3.0	No	Passed	Yes	
7	BMS13-72	10	0	3.0	No	Passed	Yes	But, shield exposed
8	MS22759/16	25	0	3.0	No	Passed	Yes	
9	MS22759/33	25	0	3.1	Yes	Passed	Yes	
10	MS22759/32	25	0	3.2	Yes	Passed	Yes	
11	BMS13-48	25	0	3.6	Yes	Passed	Yes	
12	MS22759/14	25	1	3.2	Yes	Passed	Yes	
13	MS81044/6	25	1	3.8	No	Passed	Yes	
14	Fiber Optic Riser Cable	5	59	26.0	Yes	Failed	Yes	
15	CAT3 Cable	6	80	26.0	Yes	Failed	Yes	
16	Neoprene	12	143	26.0	Yes	Failed	Yes	
17	CAT5e Cable	6	180	26.0	Yes	Failed	Yes	Exceeded 180 seconds
18	Computer Cable	4	180	26.0	Yes	Failed	Yes	Exceeded 180 seconds
19	Hypalon	8	180	26.0	Yes	Failed	Yes	Exceeded 180 seconds
20	M17/28-RG58	5	180	26.0	Yes	Failed	Yes	Exceeded 180 seconds
21	MS5086/1	25	180	26.0	Yes	Failed	Yes	Exceeded 180 seconds
22	Silicone 200	16	180	26.0	Yes	Failed	Yes	Exceeded 180 seconds

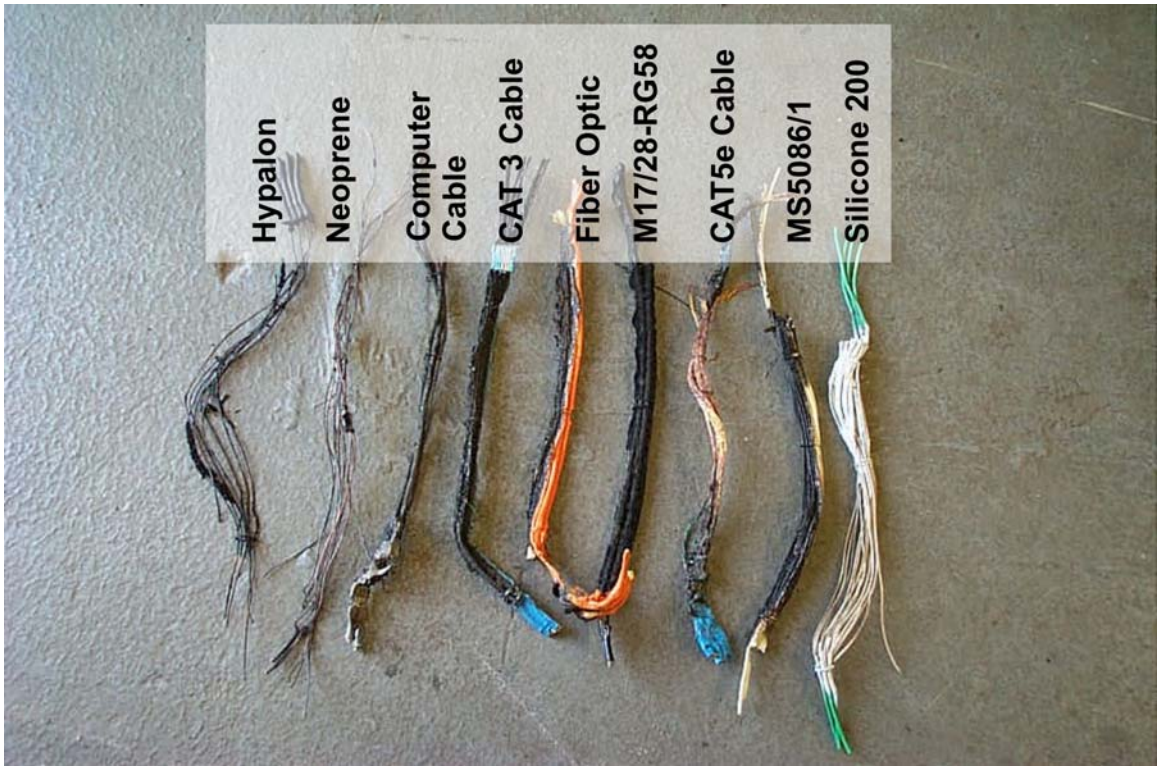
Note: Heat Flux: 1.7 W/cm^2, Wires at 7.62 cm from Panel, 1 min Exposure, 3 seconds Pilot

30-Degree RHP Test Results



Fireworthy Wire Bundles (Aviation-Grade)

30-Degree RHP Test Results



Non-Fireworthy Wire Bundles (Low Temperature Rating =< 105°C)

Final Words

Conclusions:

- ✓ Wire bundling did not affect the results of the aviation-grade wires (current), but it increased the flame extinguishing time and burn length of the low temperature rating wires.
- ✓ Wire bundle specimens amplified the results of the single-wire specimens due to additional fuel (material), and radiant/contact heat interaction between the bundled wires.
- ✓ A wire bundle, instead of a single wire, will be used in the final flammability test method.

Test Method

•The preferred sample is the wire bundle (homogeneous insulation material). By testing it this way, the applicant will be allowed to test only one wire gage size for all of the gage sizes he may have in his inventory - as long as the insulation material is the same material and from the same manufacturer.

•If the applicant tests a single wire, because it was taken from a piece of avionics equipment or is the only sample they could find (or cost, etc.), it will only be applicable to that wire gage size and material. The applicant will have to test other gage sizes of the same material.

•The minimum sample size is 4 inches. An alligator clip may be used to extend it. It could be a single or bundle wire(s).