FLAMMABILITY TEST METHOD AND CRITERIA FOR AIRCRAFT ELECTRICAL WIRING

Federal Aviation Administration

Presented to: Fire Safety Team Management

By: John Reinhardt, Project Manager, PMP

Date: October, 2009

Location: WJH FAA Technical Center

Outline

- Scope
- Definitions
- Test Apparatus
- Test Specimens
- Conditioning
- Test Procedure
- Report
- Requirements

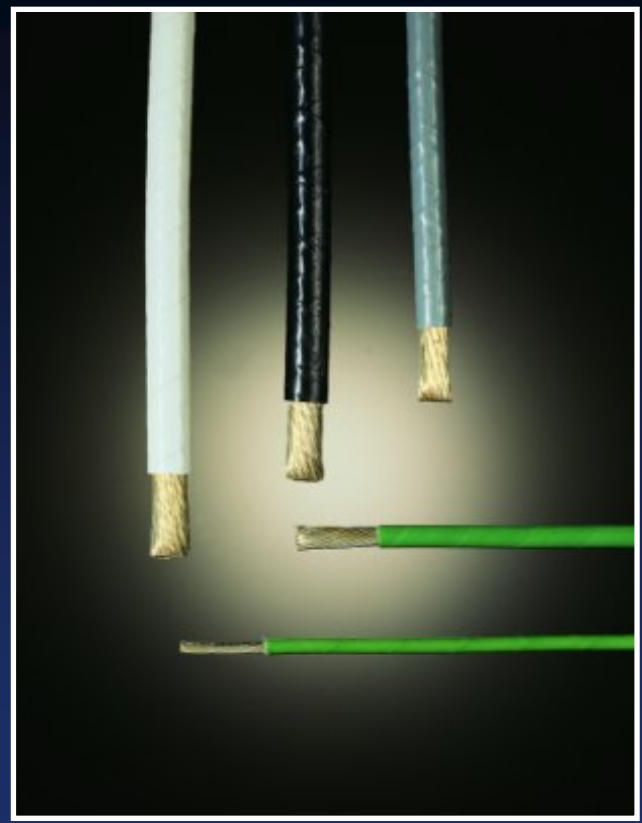
Outline

- Scope
- Definitions
- Test Apparatus
- Test Specimens
- Conditioning
- Test Procedure
- Report
- Requirements

Scope

1. SCOPE

This test method is intended for use in determining the flammability characteristics of aircraft electric wire insulation, and materials used to provide additional protection to wires and cables, and comply with FAR 25.1713.



Outline

- Scope
- Definitions
- Test Apparatus
- Test Specimens
- Conditioning
- Test Procedure
- Report
- Requirements

Definitions

2. DEFINITIONS

2.1 IGNITION TIME.

Ignition time is the length of time the pilot flame is applied to the specimen. The ignition time for this test is 3 seconds.

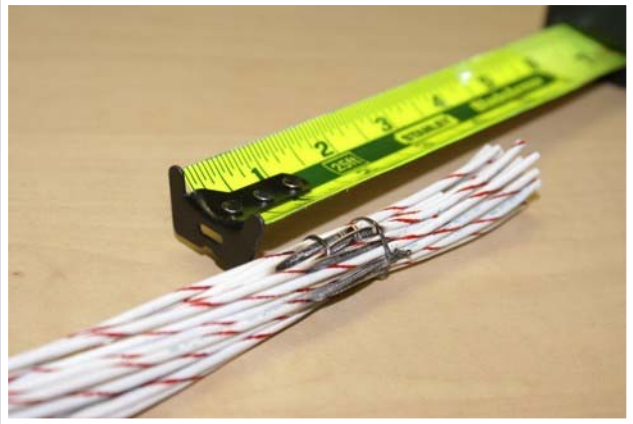
2.2 AFTER FLAME EXTINGUISHING TIME.

The after flame extinguishing time is the time in seconds that the specimen continues to flame after the pilot burner is removed from the specimen. Surface burning that result in a glow, but not in a flame, is not included.

Definitions

2.3 BURN LENGTH.

Burn length is the length of damage along the wire bundle, both above and below the point of pilot burner impingement, due to that area's combustion, including areas of partial consumption, charring, or embrittlement, but not including areas sooted, stained, warped, shrunk, or discolored.



2.4 RADIANT HEAT SOURCE.

It means an electric or air propane radiant heat panel.

Outline

- Scope
- Definitions
- Test Apparatus
- Test Specimens
- Conditioning
- Test Procedure
- Report
- Requirements

Test Apparatus

3. TEST APPARATUS

3.1 RADIANT PANEL TEST CHAMBER.

- Conduct tests in a radiant panel test chamber. Place the test chamber under an exhaust hood to facilitate clearing 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 33 inches (762 mm) (maximum) above the test specimen; the tolerance is +/- 5%.
- Insulate the sides, ends, and top with a fibrous ceramic insulation, such as refractory board Kaowool M™ board or 1260 Standard Board.

Test Apparatus

3.1 RADIANT PANEL TEST CHAMBER (CONT.).

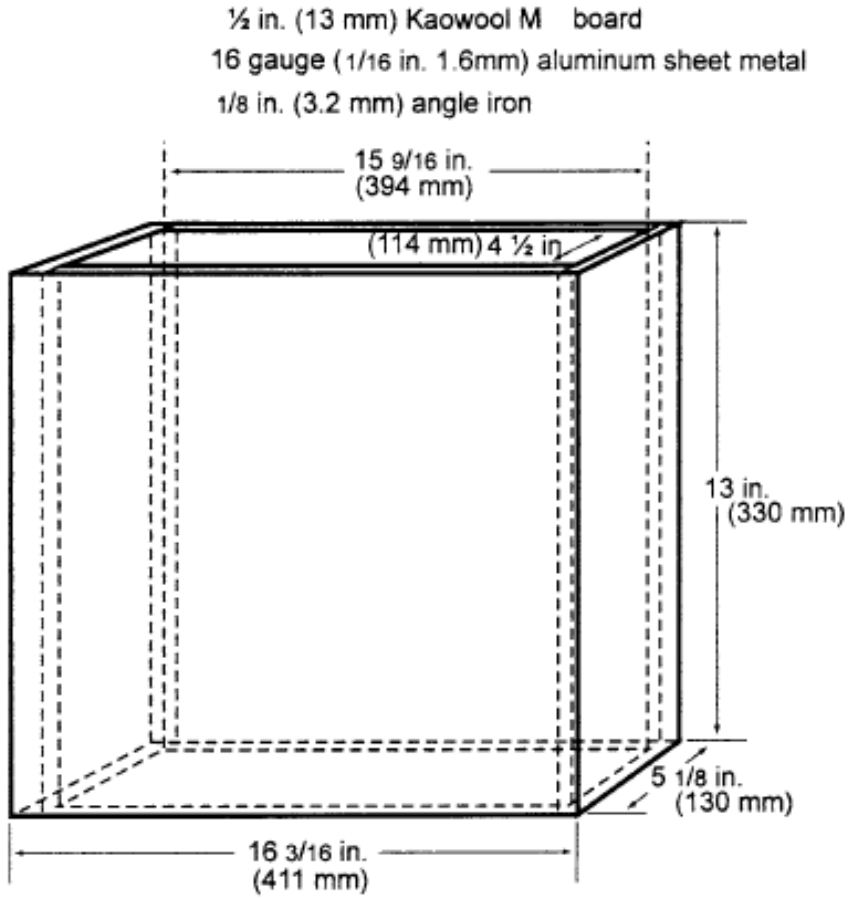
- On the front side, provide a suitable viewing window that is draft-free, high-temperature, glass window for viewing the sample during testing; a 44″x 6″ (111.8 by 15.2 cm) or larger viewing window has been found useful.
- Place a door below the window to provide access to the movable specimen platform holder.
- The bottom of the test chamber must be a sliding steel platform that has provision for securing the test specimen holder in a fixed and level position.

Test Apparatus

3.1 RADIANT PANEL TEST CHAMBER (CONT.).

- 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 chimney interior dimensions must be 4.5 inches (114 mm) wide, by 15.6 inches (395 mm) long, by 13 (330 mm) inches deep; the tolerance of these dimensions is 5%.
- The chimney must extend to the top of the chamber.

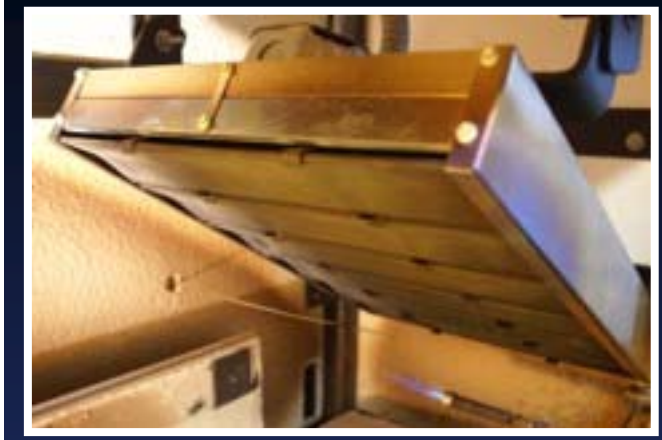
Test Apparatus



Test Apparatus

3.1.1 Radiant Heat Source.

- Mount the radiant heat energy source in a cast iron frame or equivalent.
- An electric panel must have six, 3-inch (7.62-cm) wide emitter strips. The emitter strips must be perpendicular to the length of the panel. The panel must have a radiation surface of 13 by 18-7/8 inches (330 by 480 mm, ±3 mm), ±1/8. The panel must be capable of operating at temperatures up to 1300°F (704°C).
- An air propane panel must be made of a porous refractory material and have a radiation surface of 12 by 18 inches (305 by 457 mm). The panel must be capable of operating at temperatures up to 1,500°F (816°C).



Test Apparatus

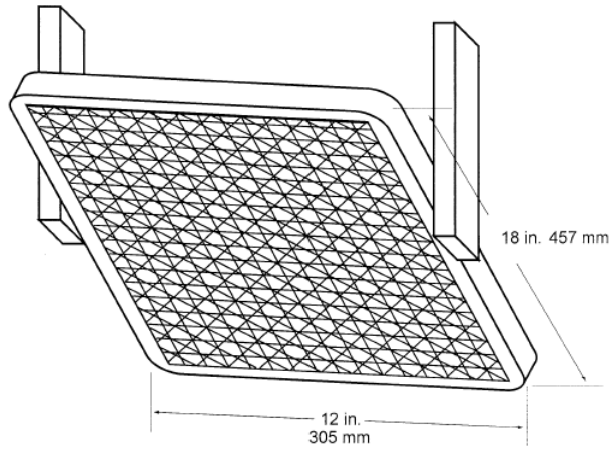
3.1.1.1 Electric Radiant Panel.

- The radiant panel must be 3-phase and operate at 208 volts. A single-phase, 240-volt panel is also acceptable.
- An acceptable unit is assembled by Power Modules Inc. and it is part # 10799-FAA; the radiant heat panels are Raymax™ 1330.
- Use a solid-state power controller and microprocessor-based controller to set the electric panel operating parameters.

Test Apparatus

3.1.1.2 Gas Radiant Panel.

- Use propane (liquid petroleum gas—2.1 UN 1075) for the radiant panel fuel.
- The panel fuel system must consist of a venturi-type aspirator for mixing gas and air at approximately atmospheric pressure.
- Provide suitable instrumentation for monitoring and controlling the flow of fuel and air to the panel.
- Include an airflow gauge, an airflow regulator, and a gas pressure gauge.



Test Apparatus

3.1.2 Radiant Panel Placement.

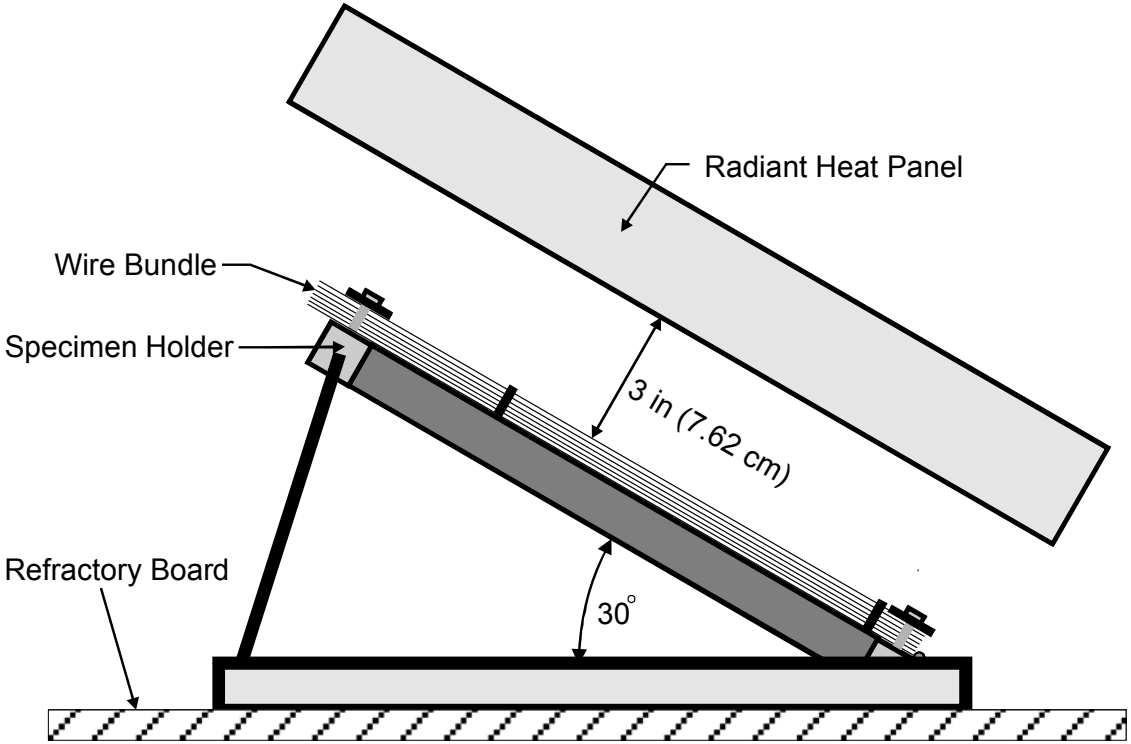
Mount the panel in the chamber at 30° (±0.3°) to the horizontal specimen plane, and 7.5 ±0.062 inches (19.05 ± 0.15 cm) above the zero point of the sliding platform.

Test Apparatus

3.2 SPECIMEN HOLDING SYSTEM.

- The sliding platform serves as the “floor” to place the specimen holding system.
- The sliding platform dimensions may vary depending on the equipment purchased; these dimensions are not critical as long as the internal chamber dimensions (volume) are met.
- Some equipment manufacturers changed these dimensions to mount specimen holders and refractory boards.
- Place the refractory board on the sliding platform to create a horizontal surface.

Test Apparatus



- On this horizontal surface, place the specimen holder so that the wire bundle specimen is 3±1/16 (7.62±0.16 cm) inches away from the radiant heat panel and clears the pilot burner.

Test Apparatus

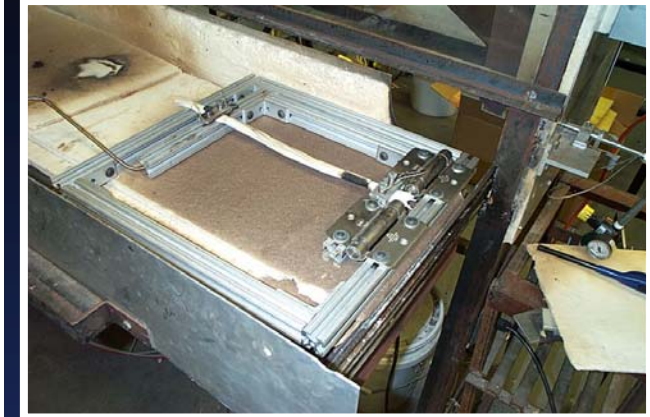
3.2 SPECIMEN HOLDING SYSTEM (CONT.).

- It may be necessary to use multiple sheets of board material based on the test specimen holder used (to meet the sample height requirement). Typically, these non-combustible sheets of material are available in ¼ inch (6 mm) thicknesses.
- A sliding platform that is deeper than the 2-inch (50.8mm) platform is also acceptable as long as the sample height requirement is met.
- Attach a ½ inch (13 mm) piece of refractory board, measuring 41 ½ by 8 ¼ inches (1054 by 210 mm), to the back of the platform.

Test Apparatus

3.2 SPECIMEN HOLDING SYSTEM (CONT.).

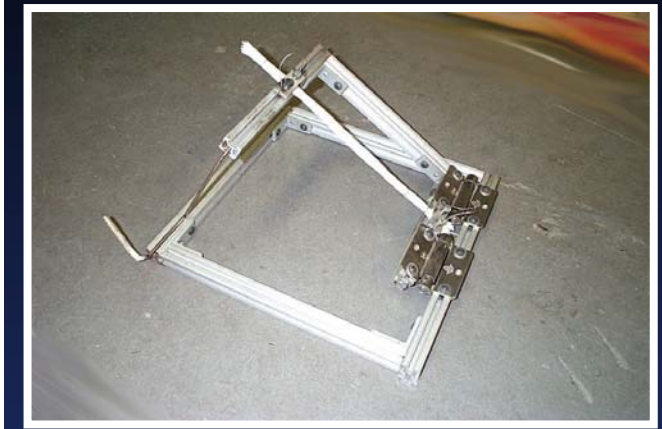
- The height of this board must not impede the sliding platform movement (in and out of the test chamber).
- If the platform has been fabricated such that the backside of the platform is high enough to prevent excess preheating of the specimen when the sliding platform is out, a retainer board is not necessary.



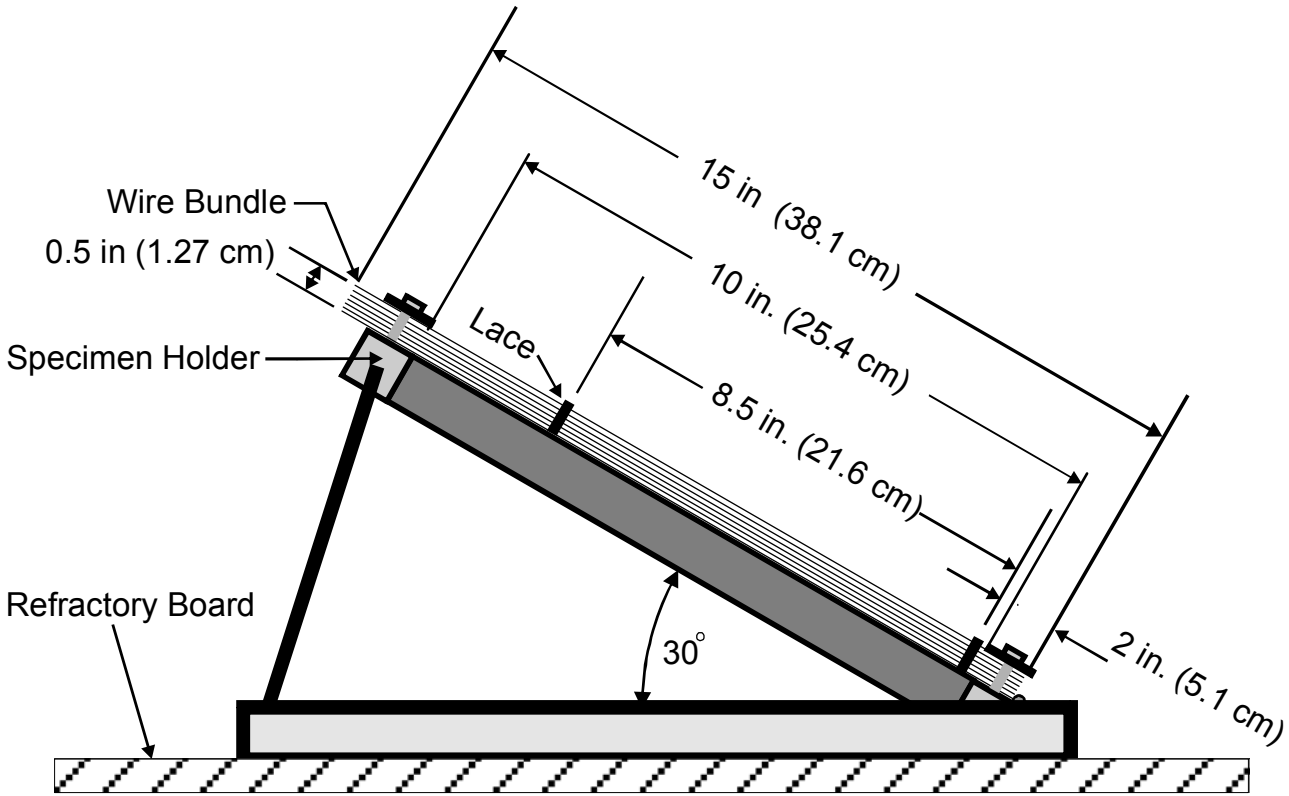
Test Apparatus

3.2.1 Specimen Holder.

- The 15±0.125-inch (38.1±0.3 cm) long wire bundle (specimen) shall be clamped on both ends with a specimen holder that will maintain it tight and at a 30±0.3° angle from the horizon.
- The specimen span between the lower clamp and upper clamp shall be 10 ±0.125 inches (25.4±0.3 cm).
- The specimen holder shall be mounted on the sliding platform so that the perpendicular distance between the radiant heat panel and the upper surface of the specimen is 3±1/16 inches (7.62±0.16 cm).



Test Apparatus



Test Apparatus

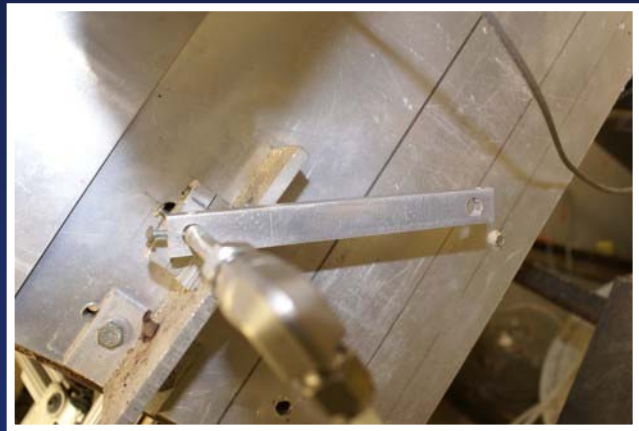
3.3 PILOT BURNER.

- The pilot burner used to ignite the specimen must be a commercial propane venturi torch with an axially symmetric burner tip and a propane supply tube with an orifice diameter of 0.006 inches (0.15 mm).
- The length of the burner tube must be 2-7/8 inches (71 mm).
- The propane flow must be adjusted via gas pressure through an in-line regulator to produce a blue inner cone length of ¾ inch (19 mm).

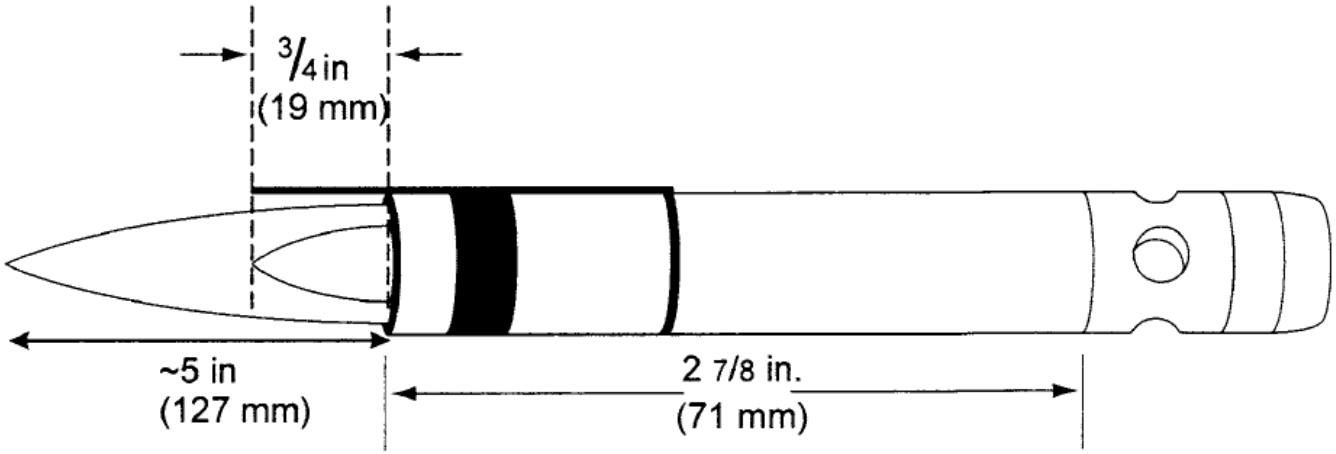
Test Apparatus

3.3 PILOT BURNER (CONT.).

- A ¾ inch (19 mm) guide (such as a thin strip of metal) may be soldered to the top of the burner to aid in setting the flame height.
- The overall flame length must be approximately 5 inches long (127 mm).
- Provide a way to move the burner out of the ignition position so that it is at least 1 inch (25.4 mm) above the wire specimen.



Test Apparatus



Test Apparatus

3.4 THERMOCOUPLES.

- Install a 24 American Wire Gauge (AWG) 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) out from the back of the chamber wall, 11.5 inches (292 mm) from the right side of the chamber wall, and is 2 inches (50.8 mm) below the radiant panel.
- The use of other thermocouples is optional.

Test Apparatus

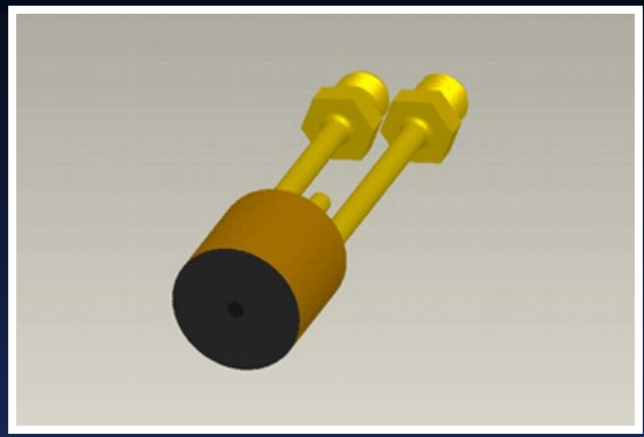
3.5 CALORIMETER.

The calorimeter must be a one-inch cylindrical water-cooled, total heat flux density, foil type Gardon Gage that has a range of 0 to 5 BTU/ft2 –second (0 to 5.7 Watts/cm2).

3.5.1 Calorimeter Calibration Specification And Procedure.

3.5.1.1 Calorimeter Specification.

- Foil diameter must be 0.25 ±0.005 inches (6.35 ±0.13 mm).
- Foil thickness must be 0.0005 ±0.0001 inches (0.013 ±0.0025 mm).



Test Apparatus

3.5.1.1 Calorimeter Specification.

- Foil diameter must be 0.25 ±0.005 inches (6.35 ±0.13 mm).
- Foil thickness must be 0.0005 ±0.0001 inches (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 inches (0.013 mm).
- The entire face of the calorimeter must be lightly coated with “Black Velvet” paint having an emissivity of 96 or greater.

Test Apparatus

3.5.1.2 Calorimeter Calibration.

- The calibration method must be by comparison to a like standardized transducer.
- The standardized transducer must meet the specifications given in paragraph 3.5.1.1 of this appendix.
- Calibrate the standard calorimeter against a primary standard traceable to the National Institute of Standards and Technology (NIST).
- The method of transfer must be a heated graphite plate.

Test Apparatus

3.5.1.2 Calorimeter Calibration (Cont.).

- 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 ± 1/16 inch thick (3.2 ±1.6 mm).
- Center the 2 transducers on opposite sides of the plates at equal distances from the plate.
- The distance of the calorimeter to the plate must be no less than 0.0625 inches (1.6 mm), nor greater than 0.375 inches (9.5 mm).
- The range used in calibration must be at least 0–3.5 BTUs/ft2 second (0–3.9 Watts/cm2) and no greater than 0–5.7 BTUs/ft2 second (0–6.4 Watts/cm2).
- The recording device used must record the 2 transducers simultaneously or at least within 1/10 of each other.

Test Apparatus

3.5.1.3 Calorimeter Fixture.

- With the sliding platform pulled out of the chamber, install the calorimeter-holding frame and place a sheet of non-combustible material (refractory board) in the bottom of the sliding platform adjacent to the holding frame; the calorimeter holding frame may have a single calorimeter or multiple calorimeters.

- The calorimeter holding frame dimensions can be of any size as long as the distance from the upper surface of the calorimeter to the radiant panel surface, from the centerline of the first hole (″zero″ position), is 7 ½ ± 1/8 inches (191 ±3 mm).

Test Apparatus

3.5.1.3 Calorimeter Fixture (Cont.).

• There are two typical frame dimensions currently used by laboratories with this equipment, which are: (1) 13.25 inches (336 mm) (front to back) in length by 8.5 inches (216 mm) in width; (2) 14 inches (356 mm) (front to back) in length by 7 inches (178 mm) in width.

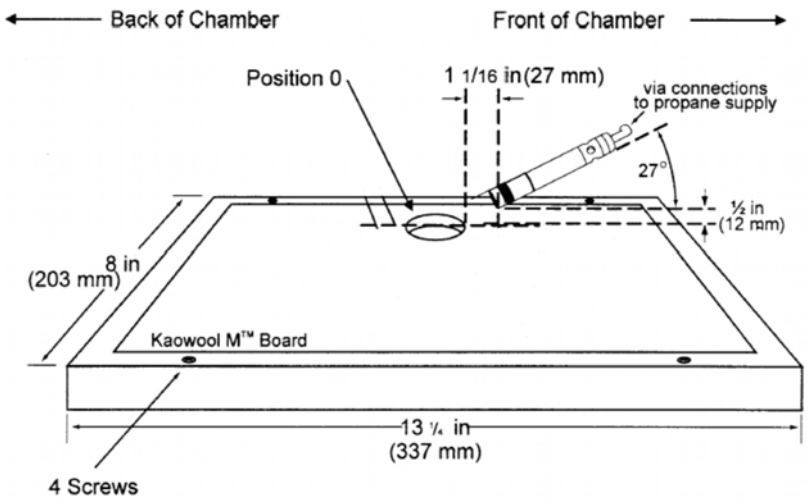
• These frames must rest on the top of the sliding platform, must be fabricated of 0.125 inch (3.2 mm) flat stock steel, and have an opening that accommodates a ½ inch (12.7 mm) thick piece of refractory board, which is level with the top of the sliding platform.

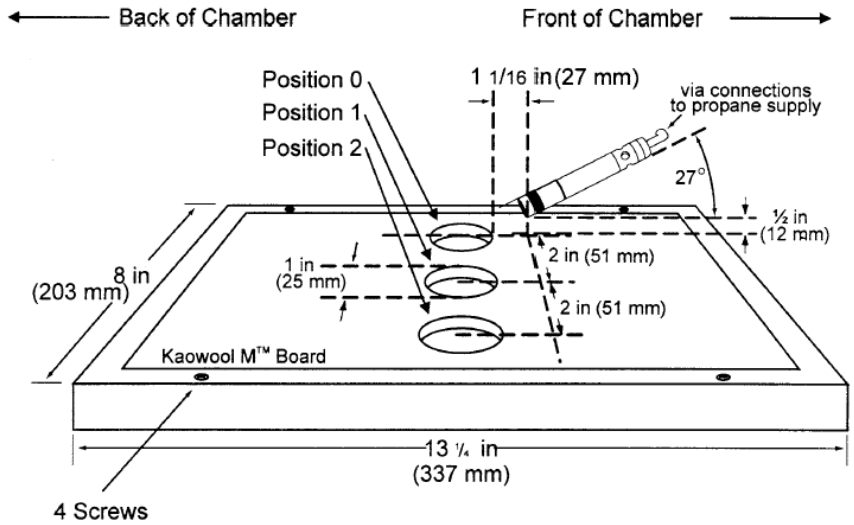
• For the multiple calorimeters holding frame, (1) the board must have three 1-inch (25.4 mm) diameter holes drilled through the board for calorimeter insertion; (2) the distance between the centerline of the first hole to the centerline of the second hole must be 2 inches (50.8 mm); (3) it must also be the same distance from the centerline of the second hole to the centerline of the third hole.

Test Apparatus

3.5.1.3 Calorimeter Fixture (Cont.).

- If the single calorimeter holding frame is used, move the frame in 2-inch (5.1 cm) intervals to verify the required heat fluxes.
- A calorimeter holding frame that differs in construction is acceptable as long as the height from the centerline of the first hole to the radiant panel and the distance between holes is the same as described in this paragraph.





3.5.1.3 Calorimeter Fixture (Cont.).

Table 1. Calibration Values at the the 3 Positions

Position	BTU's/ft^{2}sec	Watts/cm^2
"Zero" Position	1.5 ± 5%	1.7 ± 5%
Position 1	1.5 ± 5%	1.7 ± 5%
Position 2	1.43 ± 5%	1.62 ± 5%

Test Apparatus

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.

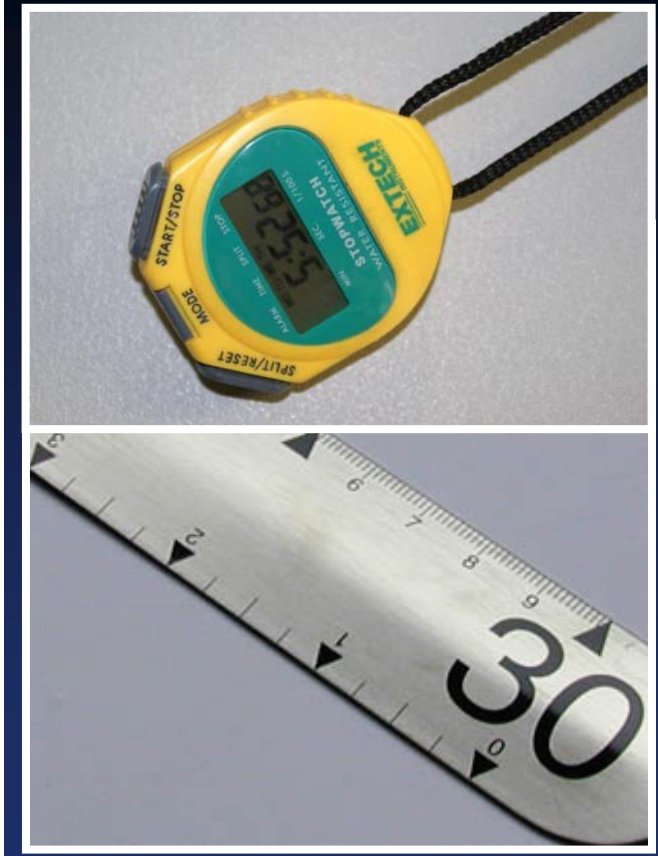
Test Apparatus

3.7 TIMING DEVICE.

• Provide a stopwatch or other device, accurate to ±1 second/hour, to measure the time of application of the pilot burner flame and the after flame time.

3.8 RULER.

• A ruler or scale calibrated and graduated to the nearest 1/16 in (1.58 mm) shall be provided to measure the burn length.



Outline

- Scope
- Definitions
- Test Apparatus
- Test Specimens
- Conditioning
- Test Procedure
- Report
- Requirements

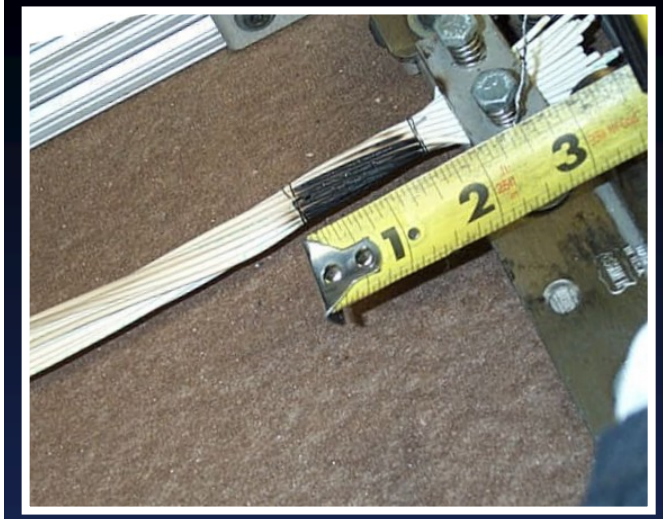
Test Specimens

4. TEST SPECIMENS

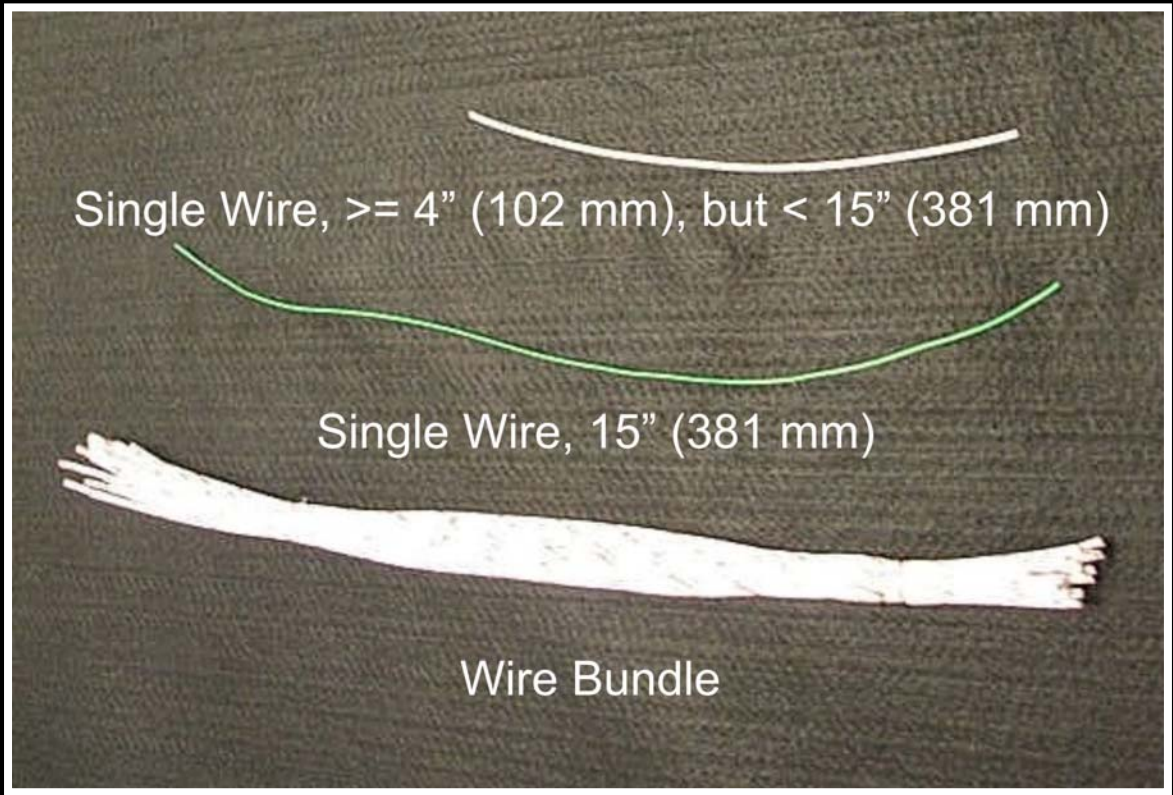
• Wire or cable bundles are the preferred test specimens, but certain situations may exist in were enough samples of the wire or cable are not available or the wire gage size is too large to bundle. In these cases then, single wire or cable testing will be allowed.

• The minimum specimen length, in this test, is 4 inches (10.16 cm).

• Test specimens also include materials use to provide additional protection to wires and cables, such as sleeves.



Test Specimens



Test Specimens

4.1 SPECIMEN NUMBER.

- At least three specimens of each wire insulation and/or jacket type shall be prepared and tested.
- No additional tests are required if the wire gage size is changed as long as the specimen is tested in the wire bundle configuration, the insulation material is the same, and it is from the same manufacturer.

Test Specimens

4.2 SPECIMEN LENGTH.

- The preferred specimen length is 15±0.125-inches (38.1±0.3 cm), but certain situations, like testing the wires that are inside electronic equipment, may exist that will not allow the specimen to be that length.
- In the case that the specimen is 4 inches, 10.16 cm, or greater and the same type of wire is not available in longer lengths, an extension may be used, such as an alligator clip connected to a bare wire, to achieve the preferred length.

Test Specimens

4.2 SPECIMEN LENGTH (CONT.).

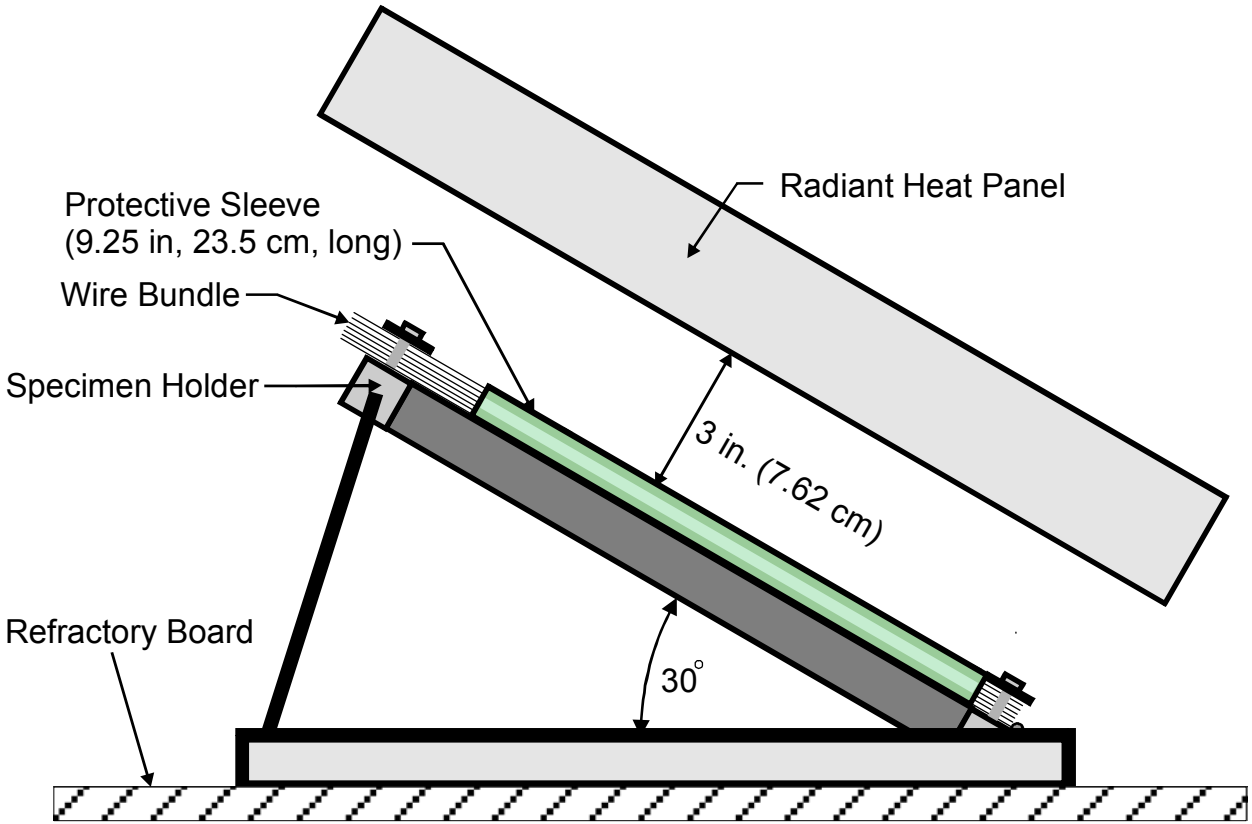
- If a **protective sleeve** is to be tested, cut it to 9.25±0.125 inches (23.5±0.3 cm) long and wrap it around the 15 inch-long wire bundle specimen (1/2” in diameter) or some other ½” diameter non-flammable core;

- The sleeve shall be located between the upper and lower clamp in such a way that covers the wire bundle near the pilot burner area;

- Make sure that the upper surface of the protective sleeve is 3±1/16 inches (7.62±0.16 cm) away (parallel) from the radiant heat panel.

Test Specimens

WIRE PROTECTIVE MATERIALS



Test Specimens

4.2 SPECIMEN LENGTH (CONT.).

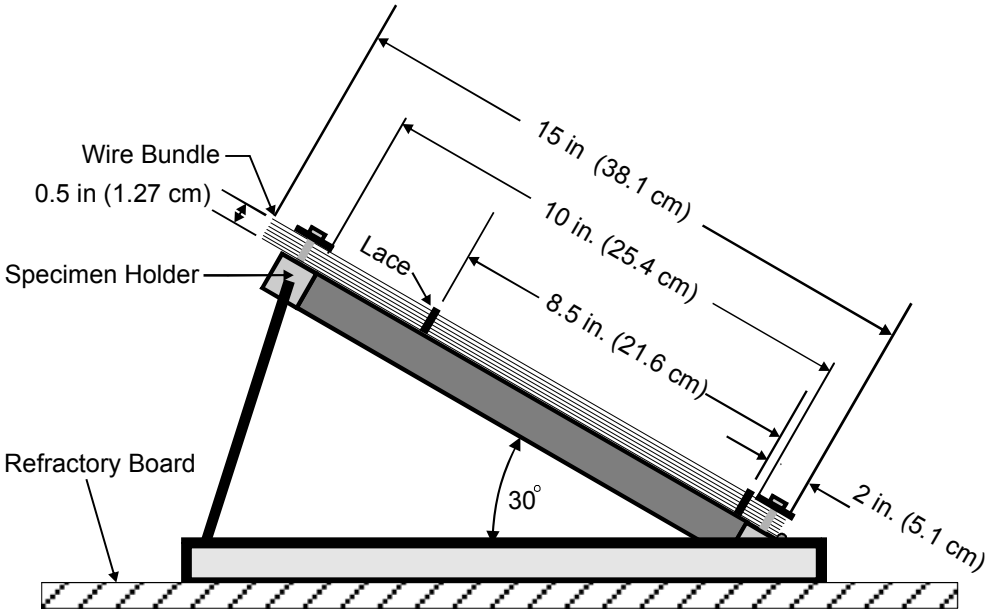
• If heat shrink is to be tested, cut it to the desired length, place it on the 15±0.125-inches (38.1±0.3 cm) long fireworthy wire or cable (at the pilot burner impingement point) and test.

Test Specimens

4.3 SPECIMEN DIAMETER.

- The preferred specimen (wire bundle) diameter shall be approximately 0.5 inch (1.27 cm); bundle as many wires or cables until its diameter is approximately 0.5 inch (1.27 cm) and secure with safety wire or any other lacing material that will not melt or burn away during the test.
- A ½″-hole template is useful to determine the number of wires and cables in the bundle.
- The wire bundle must be homogeneous, that is, built with the same type of wire insulation.
- Two laces (or safety wire) have been found useful (and enough) to secure the wire bundle specimen.

Test Specimens



- Keep the lace (or safety wire) away from the pilot burner impingement point.
- The first lace (or safety wire) shall be placed approximately 2 inches (51 mm) from the lower part of the wire bundle specimen and the second one 8.5 inches (216 mm) from the first one

Test Specimens

4.3 SPECIMEN DIAMETER (CONT.).

- If the gage of the wire or cable is very large, were bundling exceeds 0.5 inch (1.27 cm), use the large diameter single wire or cable as the specimen.
- If the wire gage is larger than 0.5 inch (1.27 cm), then test a single wire.
- If the number of wires is insufficient to create the 0.5 inch (1.27 cm) wire bundle, then test a single wire. The results of this single-wire test will apply only to wires with the same AWG gage size, and by the same manufacturer, as the one tested.

Outline

- Scope
- Definitions
- Test Apparatus
- Test Specimens
- Conditioning
- Test Procedure
- Report
- Requirements

Conditioning

5. CONDITIONING

• Condition specimens at 70° ± 5°F (21° ± 3°C) and 50% ± 5% relative humidity for 24-hours minimum. Remove only one specimen at a time from the conditioning environment immediately before testing.

Outline

- Scope
- Definitions
- Test Apparatus
- Test Specimens
- Conditioning
- Test Procedure
- Report
- Requirements

Test Procedure

6 PROCEDURE

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).

Close the bottom door located below the sliding platform.

The distance from the centerline of the calorimeter to the radiant panel surface at this point must be 7 ½ inches ±1/8 (191 mm ±3).

Test Procedure

6.1 APPARATUS CALIBRATION (CONT.).

Cover the upper and bottom parts of the sliding platform with Kaowool boards to minimize cold air drafts.

Prior to igniting the radiant panel, ensure that the calorimeter face is clean and that there is water running through the calorimeter.

b. Turn on the panel. Adjust its power or fuel/air mixture to achieve 1.5 BTUs/ft2 -second ±5% (1.7 Watts/cm^2 ±5%) at the “zero” position. Allow the unit to reach steady state (this may take up to 1 hour).

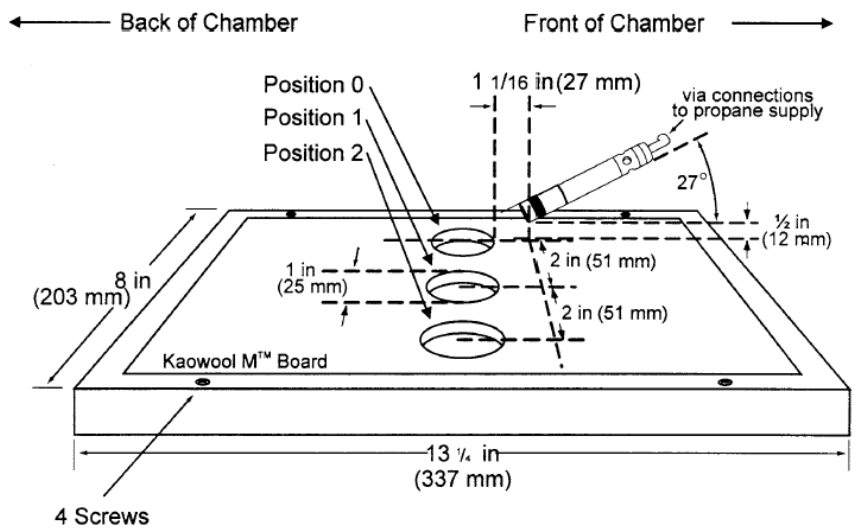
The pilot burner must be off and in the down position during this time.

Test Procedure

6.1 APPARATUS CALIBRATION (CONT.).

c. After steady-state conditions have been reached, move the calorimeter 2 inches (50.8 mm) from the “zero” position (first hole) to position 1 and record the heat flux.

Move the calorimeter to position 2 and record the heat flux. Allow enough time at each position for the calorimeter to stabilize. Table 1 depicts typical calibration values at the three positions.



Test Procedure

Table 1. Calibration Values at the the 3 Positions

Position	BTU's/ft^{2}sec	Watts/cm^2
"Zero" Position	1.5 ± 5%	1.7 ± 5%
Position 1	1.5 ± 5%	1.7 ± 5%
Position 2	1.43 ± 5%	1.62 ± 5%

6.1 APPARATUS CALIBRATION (CONT.).

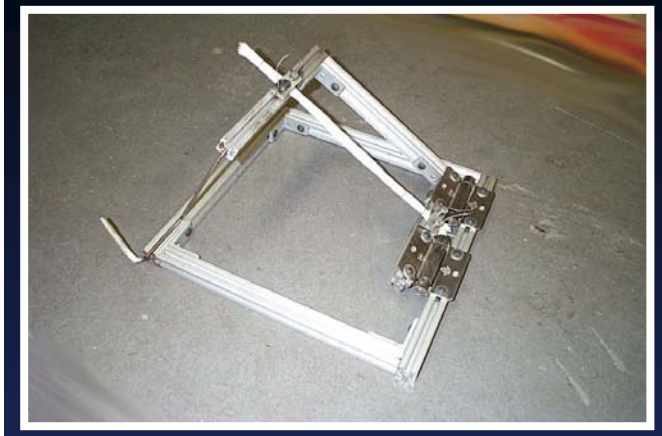
d. Open the bottom door and remove the calorimeter and holder fixture. Use caution, as the fixture is very hot.

Test Procedure

6.2 TEST PROCEDURE.

a. Before calibrating the radiant heat panel, at room temperature, mount the specimen holder on the sliding platform so that the perpendicular distance between the radiant heat panel and the upper surface of the specimen is 3±1/16 inches (7.62±0.16 cm).

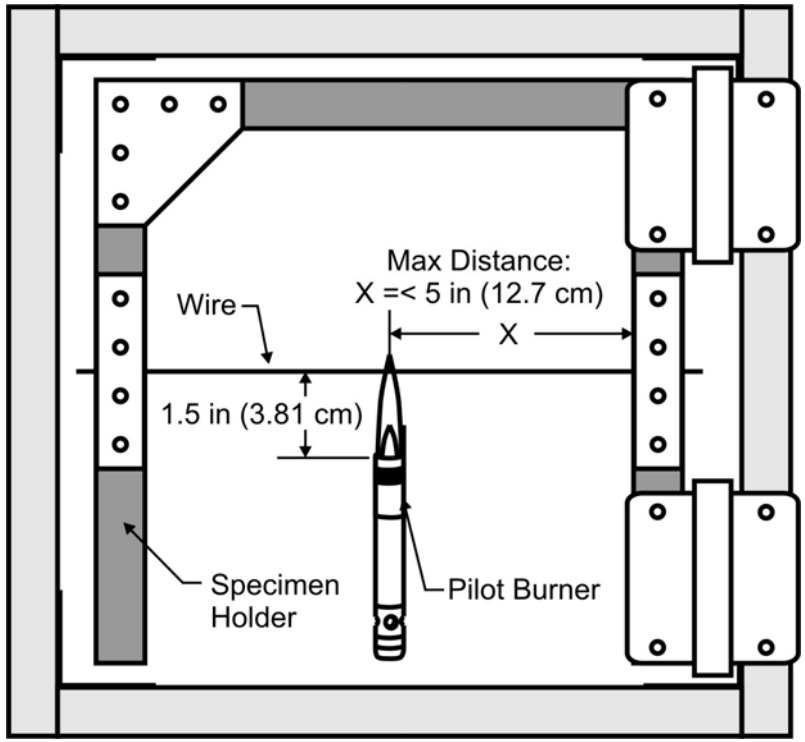
The distance between the base of the pilot burner flame and the specimen shall be approximately 1.5 inches (3.81 cm),



Test Procedure

The center of the pilot burner flame must impinge the wire at a distance of no more than 5 inches (12.7 cm) from the lower clamping point.

Mark or setup guides to identify the correct position of the specimen holder because it will be removed from the sliding platform for test equipment calibration and specimen changes.



Test Procedure

6.2 TEST PROCEDURE (CONT.).

b. Calibrate the radiant heat panel as dictated in section 6.1.

c. Ignite the pilot burner. Ensure that it is at least 1 inch (25.4 mm) above the wire specimen. The pilot burner should be above the wire specimen before the test begins.

d. Place the test specimen, mounted on the specimen holder, on the sliding platform. Ensure that the specimen holder is placed on the pre-marked location and secured.

e. Immediately push the sliding platform into the chamber and close the bottom door.

Test Procedure

6.2 TEST PROCEDURE (CONT.).

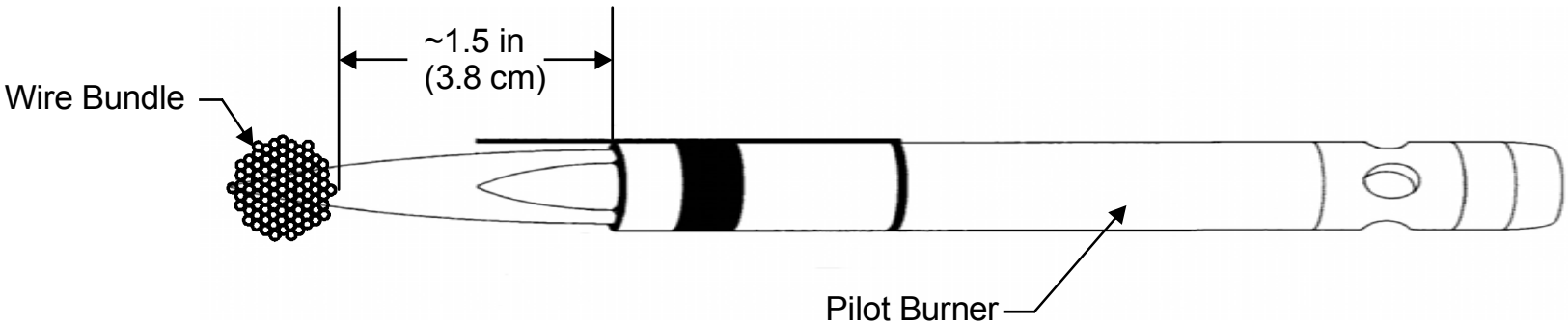
f. Quickly rotate the specimen holder arm, where the wire is mounted, 30 degrees so that the wire specimen is parallel to the radiant panel heater and 3 inches (76.2 mm) from it.

g. Heat-soak the specimen for 1 minute.

h. After the 1-minute heat-soak, impinge the pilot burner flame on the specimen for 3 seconds. Then remove to a position at least 1 inch (25.4 mm) above the specimen.

i. Wait 5 seconds after flames self-extinguished to verify that it will not re-ignite.

Test Procedure



Pilot Burner Placement

Outline

- Scope
- Definitions
- Test Apparatus
- Test Specimens
- Conditioning
- Test Procedure
- Report
- Requirements

Report

7 REPORT

7.1 MATERIAL IDENTIFICATION.

- Fully identify the wire/cable bundle tested.

7.2 TEST RESULTS.

7.2.1 After-Flame Time.

- Report the after-flame time for each specimen tested.
- Determine and record the average value for after flame extinguishing time.

Report

7.2 TEST RESULTS (CONT.).

7.2.2 Burn Length.

- Report the burn length for each specimen tested.
- Determine and record the average value for burn length.

7.2.3 Post-Test Specimen Condition.

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

Outline

- Scope
- Definitions
- Test Apparatus
- Test Specimens
- Conditioning
- Test Procedure
- Report
- Requirements

Requirements

8 REQUIREMENTS

The following requirements apply to wire bundle specimens and protective sleeve specimens.

8.1 AFTER- FLAME EXTINGUISHING TIME.

The average flame extinguishing time for all of the specimens tested shall not exceed 30 seconds.

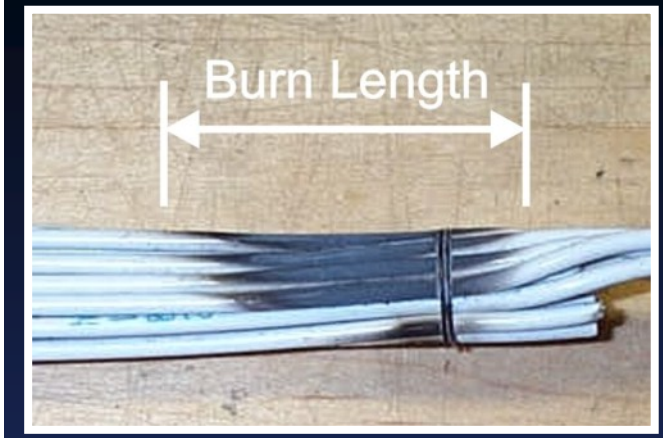
Requirements

8.2 BURN LENGTH.

- The average burn length for all of the specimens tested shall not exceed 3 inches (76 mm).

8.3 WIRE BREAKAGE.

- It shall not be considered a failure if the wire, in the bundle, breaks during the test.



Aircraft Wiring Test Development

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

Q&A

- Questions?
- Looking for laboratories that would like to participate in a Round Robin Exercise

Go Back