Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2, and 3. Further, Appendix A is applicable for identifying the environmental tests performed.
26 Fire, Flammability

26.1 Purpose

This section defines test conditions and procedure for Flammability and Fire resistance.

26.2 Applicability

Flammability and fire tests apply to equipment installed on fixed wing propeller driven aircraft, fixed-wing turbojet aircraft, turbofan aircraft, prop fan aircraft, and helicopters.

These tests are applicable for equipment:

- Mounted in pressurized zones
- Mounted in fire zones
- Mounted in non-pressurized, non fire zones

26.3 Equipment Categories

26.3.1 Category A: Fireproof

Equipment installed in fire zone which must function during the first five minutes of fire and which must keep its safety functions for at least fifteen minutes. For fluid handling components, there shall be no leakage to support a flame after the burner has been removed (wetting or droplet that self extinguishes may be acceptable). For air handling components there shall be no leakage that may additionally feed the fire. Equipment shall remain firmly attached to the mounting.

The fireproof procedure shall be applied.

Test will be performed on equipment in the operating mode

26.3.2 Category B: Fire Resistant

Equipment installed in fire zone, which must function or not cause a hazardous condition during the five first minutes of fire without structural degradation. For fluid handling components there shall be no leakage to support a flame after the burner has been removed (wetting or droplet that self extinguishes may be acceptable). For air handling components there shall be no leakage that may additionally feed the fire. In general any leakage of continued burning of the test article at the end of the five minutes would be considered a test failure unless it can be shown that there is not a significant increase in the overall fire hazard. An example of this would be if the fire extinguishing equipment is capable of extinguishing the residual flame.

The fire resistant procedure shall be applied.

Test will be performed on equipment in the operating mode.
26.3.3 **Category C: Flammability**

Enclosures housing electronics and non-metallic material, component parts, sub-assemblies installed in pressurized or non-pressurized zones and non-fire zones. Test to be performed on equipment in a non-operating mode. The purpose of this test is to check the non-propagation of the flame in the case where ignition would appear inside or outside of the equipment. Tests will be performed on specimens of material.

The *flammability* procedure shall be applied.

*Note: If all materials used in the construction of the equipment can be shown to meet the equivalent vertical and horizontal flammability tests herein, either through composition or previous testing, this test is not required.*

Testing is not necessary on enclosures housing electronic or non-metallic material if the following apply:

1- The enclosures is constructed of metal (metal finish that is non flammable), on all sides, and has no vent holes
2- The enclosures is constructed of metal (metal finish that is non flammable) on five sides and one side is constructed of glass polycarbonate(display) that has met the 12 second vertical test, and has no vent holes.

**Small Parts Exemption:**
Parts/materials which are considered small may be exempt due to their small size and amount because they would not contribute significantly to the propagation of a fire. Examples of small parts could be: knobs, handles, rollers, fasteners, clips, grommets, rubber strips, pulleys, etc. Further definition is offered below:

**Table 26-1 Parts/Material Definitions**

<table>
<thead>
<tr>
<th>Size Relation (Typical Usage)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fits inside a 76.2 mm x 76.2 mm x 12.7 mm (3” x 3” x .5”) or 50.8 mm x 50.8 mm x 50.8 mm (2” x 2” x 2”) Box without bending of the part</td>
<td></td>
</tr>
<tr>
<td>Smaller than 50.8 mm x 76.2 mm x 1.178 mm (label and / or its adhesive) (2” x 3” x .07”)</td>
<td></td>
</tr>
<tr>
<td>Smaller than 6.35 mm (0.25”) Dia. Sphere (drop of thread lock or Nycote)</td>
<td></td>
</tr>
<tr>
<td>Smaller than 101.6 mm x 2.286 mm (4” x .09”) dia (lacing tape)</td>
<td></td>
</tr>
</tbody>
</table>

Consideration must be given when more than one small part is located in the same proximity with the same or other small parts (one part may ignite the other part) as the combined fuel load may contribute to propagation of a flame, in this case the above small parts exemption would not apply.

Small parts exemption does not apply to wire and cable.
26.4  **Fire proof/Resistant Test procedure**

26.4.1  **Apparatus**

Fire proof/resistant test: Burner with a flame standardized of 1100°C ± 80°C. A modified gun type burner with extension tube shall be used with kerosene. Adjustment of fuel flow and air is allowed during the pre-test calibration only to achieve the required characteristics of the flame.

26.4.2  **Burner Calibration**

The following burner calibration steps shall be taken after a five minute warm-up period. Do not expose the heat transfer copper tube to the flame during this warm-up period to avoid carbon build-up on the tube.

26.4.3  **Flame Temperature**

The flame temperature shall be adjusted to provide 1100°C ± 80°C as measured by a thermocouple rake placed 100 mm (nominal) from the burner. The equipment under test must be placed 100 mm (nominal) from the burner during the test. The rake consists of seven thermocouples centered across the torch at a distance of 100 mm (nominal) in front of the nozzle (See Figure 26-2). Temperature data shall be taken at least every 30 seconds for a three-minute period during the pre and post test flame temperature calibration to ensure steady-state conditions.

26.4.4  **Flame Intensity**

The flame heat content is required to provide 4,500 Btu/hr minimum input to a 380 mm exposed length of 127 mm by 0.81 mm (0.5” by 0.032”) refrigeration type copper tubing with a water flow rate of one gallon/minute (500 lb/hr). This measurement is taken at the same location in the flame where the requirements of Flame Temperature are satisfied. The temperature delta multiplied by the water flow rate through the tube (500 lb/hr) = the Btu/hr input into the tube.

1- Clean the copper tubing with fine steel wool before the pre test calibration.
2- The supplied water temperature shall be between 10°C and 21°C.
3- Water flow rate through tube shall be adjusted to 500 lb/hr minimum.
4- Transfer the burner to the heat transfer tube and begin a three-minute warm-up period to ensure stable conditions.
5- Record inlet and outlet water temperature at least every thirty seconds for a three-minute period.
6- Perform calculations to ensure minimum requirements are met. Refer to Figure 26-4 and Figure 26-5 for additional details on the heat flux measurement apparatus.

26.4.5  **Steady State Operating Conditions**

Steady state operating conditions should be chosen to represent the worst case scenario for the unit under test. Considerations shall include the minimal cooling, highest pressures, and maximum working fluid temperatures the product may experience. It is not require for the chamber to simulate the maximum ambient temperature of the equipment, room temperature ambient is sufficient. Ground idle conditions are often chosen to represent a worst case scenario.
26.4.6 Flame Direction and Location(s) Determination

The test flame impingement location(s) on the test article is established via analysis based on most critical location(s) with respect to the fire source and the most susceptible location(s) on the test article considering critical circuitry, fluid flow, wall thickness, seals, etc. The most likely flame direction (i.e. bottom of unit) may also be considered in the impingement location analysis but this may result in limiting future changes/use of unit. The flame must impinge the critical location(s) on the test article determined from the impingement analysis. For equipment determined to have more than one critical location, additional tests may be required if a single, representative impingement location cannot be identified to adequately address all locations. If multiple locations are required, multiple test articles may be used but are not required.

26.4.7 Fire Proof Test

Perform the following tests using the flame adjusted as detailed above. Connect the equipment so that it is both powered on and functional. All connections (electrical, fluid, pneumatic, etc.) to the test article must be of the type design configuration. The use of non-type design cables, bundles, and connectors is permitted at locations not directly interfacing with the test article. All non-type design hardware may be protected during the test as long as the protection provided does not interfere with the test article flame exposure. High temperature ceramic insulation is recommended to protect non type design cables and tubing.

With the equipment operating, apply the normal flame for fifteen minutes.

ONLY DURING THE FIRST FIVE MINUTES OF THE TEST DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

At the completion of the test, without extinguishing the flame, a post test calibration of the flame temperature shall be performed. After the last ten minutes the equipment shall be inspected and shall show no evidence of continued combustion or flame propagation and shall be self extinguishing.

Caution: In particular cases (e.g. systems of fluids), a specific procedure could be specified by the aircraft manufacturer.

26.5 Fire Resistant Test

Perform the following tests using the appropriate test flame of paragraph 26.4.

Connect the equipment so that it is both powered on and functional. The use of non-type design cables, bundles, and connectors is permitted. All non-type design hardware may be protected during the test as long as the protection provided does not interfere with the test article flame exposure. High temperature ceramic sleeving is recommended to protect non-type design cables and tubing.

After the pre-test flame calibration and with the equipment operating, apply the flame for five minutes.

DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS DURING THE TEST OR DEMONSTRATE THAT A NON-HAZARDOUS CONDITION IS MAINTAINED DURING THE FIVE MINUTE PERIOD.
At the completion of the test, without extinguishing the flame, a post test calibration of the flame temperature shall be performed. In addition, the equipment shall be inspected and shall show no structural default or evidence of continued combustion or flame propagation and shall be self-extinguishing. In general any leakage or continued burning of the test article at the end of the five minutes would be considered a test failure unless it can be shown that there is not a significant increase in the overall fire hazard. An example of this would be if the fire extinguishing equipment is capable of extinguishing the residual flame.

**CAUTION:** In particular cases (e.g. systems of fluids), a specific procedure could be specified by the aircraft or engine manufacturer.

26.7.6 Data Recording

a) Data recording of key parameters (T/C’s, flows, pressures, etc) throughout the test is required, including key parameters for calibration determination.

b) The entire test is to be video recorded. Multiple views are recommended. Post test photos are required also.

26.6 Flammability Test

26.6.1 Determination of the Type of Test

The following table defines which test shall be applied to demonstrate that the equipment complies with flammability requirements. Material sample size to be tested is listed in each method section.

<table>
<thead>
<tr>
<th>Components</th>
<th>Method</th>
<th>Paragraph</th>
</tr>
</thead>
<tbody>
<tr>
<td>All materials other than rubber or elastomer parts, wire and cable</td>
<td>Vertical 12 second bunsen burner test</td>
<td>26.6.2</td>
</tr>
<tr>
<td>Rubber or elastomer parts</td>
<td>Horizontal bunsen burner test</td>
<td>26.6.3</td>
</tr>
<tr>
<td>Wire and cable</td>
<td>60 degree bunsen burner test</td>
<td>26.6.4</td>
</tr>
</tbody>
</table>
26.6.2 Vertical Bunsen Burner Test for Cabin and Cargo Compartment Materials

26.6.2.1 Definitions

26.6.2.1.1 Ignition Time

Ignition time is the length of time the burner flame is applied to the specimen.

26.6.2.1.2 Flame Time

Flame time is the time in seconds that the specimen continues to flame after the burner flame is removed from beneath the specimen. Surface burning that results in a glow but not in a flame is not included.

26.6.2.1.3 Drip Flame Time

Drip flame time is the time in seconds that any flaming material continues to flame after falling from the specimen to the floor of the chamber. If no material falls from the specimen, the drip flame time is reported to be 0 seconds, and the notation “No Drip” is also reported. If there is more than one drip, the drip flame time reported is that of the longest flaming drip. If succeeding flaming drips reignite earlier drips that flamed, the drip flame time reported is the total of all flaming drips.

26.6.2.1.4 Burn length

Burn length is the distance from the original specimen edge to the farthest evidence of damage to the test specimen due to that area’s combustion including areas of partial consumption, charring, or embrittlement but not including areas sooted, stained, warped, or discolored nor areas where material has shrunk or melted away from the heat.

26.6.2.2 Test Apparatus

26.6.2.2.1 Test Cabinet

Tests will be conducted in a draft-free cabinet fabricated in accordance with Figure 26-1, Figure 26-2 and Figure 26-3 or equivalent. Other cabinets may be used if they are draft free and have enough air to allow complete combustion. It is suggested that the cabinet be located inside an exhaust hood to facilitate clearing the cabinet of smoke after each test. Stainless steel or other corrosion-resistant metal 0.04 inch (1 mm) thick will be used for the bottom surface of the chamber.

26.6.2.2.2 Specimen Holder

The specimen holder will be fabricated of corrosion-resistant metal in accordance with Figure 26-3 or the equivalent. The holder will be able to accommodate specimens up to 1 inch (25 mm) thick.

26.6.2.2.3 Burner

The burner will be a Bunsen or Tirrill type, have a 3/8-inch (10-mm) inside diameter barrel, and be equipped with a needle valve located at the bottom of the burner barrel to adjust the gas flow rate and, thereby, adjust the flame height. There will be a means provided to move the burner into and out of test position when the cabinet door is closed.
26.6.2.2.3.1 Burner Fuel

Methane gas of 99 percent minimum purity shall be used. It can be used without adding air through the aspirating holes at the bottom of the burner barrel; e.g., a pure diffusion flame may be used.

26.6.2.2.3.2 Plumbing for Gas Supply

The necessary gas connections and the applicable plumbing will be essentially as shown in Figure 26-4. A control valve system with a delivery rate designed to furnish gas to the burner under a pressure of 2 1/2 ± 1/4 psi (17 ± 2 kPa) at the burner inlet will be installed between the gas supply and the burner.

26.6.2.2.3.3 Flame Height Indicator

A flame height indicator may be used to aid in setting the height of the flame. A suitable indicator has a prong extending 1.5 inches (38 mm) above the top of the burner barrel, is attached to the burner barrel, and spaced 1 inch (25 mm) from the burner barrel, as shown in Figure 26-4. If using methane as the burner fuel, it is desirable to have two prongs for measuring the flame height, one prong to indicate the height of the inner cone of the flame and one prong to indicate the height of the tip of the flame. For methane, it has been determined that when the height of the inner cone is 7/8 inch (22 mm) and the tip of the flame is 1.5 inches (38 mm) long, the proper flame profile is achieved.

26.6.2.2.4 Timer

A stopwatch or other device, calibrated to the nearest 0.1 second, will be used to measure the time of application of the burner flame, the flame time, and the drip flame time.

26.6.2.2.5 Ruler

A ruler or scale graduated to the nearest 0.1 inch (2.5 mm) will be provided to measure the burn length.

26.6.2.3 Test Specimens

26.6.2.3.1 Specimen Selection

Specimens tested will be either cut from a fabricated part as installed in the aircraft or cut from a section simulating a fabricated part, e.g., cut from a flat sheet of material or from a model of the fabricated part. The specimen may be cut from any location in the fabricated part. However, the edge to which the burner is applied must not consist of the finished or protected edge of the specimen. Fabricated units, such as sandwich panels, will not be separated into individual component layers for testing.

26.6.2.3.2 Specimen Number

Each separate set of specimens prepared for testing will consist of at least three specimens (multiple places).

26.6.2.3.3 Specimen Size

The specimen will be a rectangle at least 3 by 12 inches (75 by 305 mm), unless the actual size used in the aircraft is smaller and it is not possible to acquire a larger sample of the material. This issue will be addressed at the next working group meeting on October 21-22 in New Jersey.
26.6.2.3.4 Specimen Thickness

The specimen thickness will be the same as that of the part qualified for use in the airplane, with the following exceptions:

1. If the part construction is used in several thicknesses, the minimum thickness will be tested.

2. Foam parts that are thicker than 1/2 inch (13 mm) will be tested in 1/2-inch (13 mm) thicknesses.

3. Parts that are smaller than the size of a specimen and 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 aircraft.

26.6.2.4 Conditioning

Specimens will be conditioned 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.

26.6.2.5 Procedure

26.6.2.5.1 Burner Adjustment

1. If using methane as the burner fuel, ensure that the air supply to the burner is shut off.

2. Open the stopcock in the gas line fully and light the burner.

3. Adjust the needle valve on the burner to achieve the proper 1.5-inch (38-mm) flame height, in accordance with Section 26.6.2.2.3.3.

26.6.2.6 Test Procedure

1. Place the burner at least 3 inches (76 mm) from where the specimen will be located during the test.

2. Insert the specimen with its lower edge 3/4 inch (19 mm) above the level of the top of the burner.

3. Close the cabinet door, and keep it closed during the test.

4. Start the timer immediately upon positioning the burner. Position the burner so that the flame impinges on the midpoint of the lower edge of the front face of the test specimen. This flame position should be used for all specimen thicknesses (See FIGURE 26-5).

5. Apply the flame for 12 seconds and then withdraw it by moving the burner at least 3 inches (76 mm) from the specimen or by turning the gas off.

6. If flaming material falls from the test specimen, determine the drip flame time for the specimen.

7. Determine the flame time for the specimen.

8. After all flaming ceases, open the cabinet door slowly to clear the test cabinet of fumes and smoke. The exhaust fan may be turned on to facilitate clearing smoke and fumes.
9. Remove the specimen and determine the burn length. To aid in determining the burn length, a dry soft cloth or tissue, or a soft cloth or tissue dampened with a moderate solvent, such as methyl, ethyl, or isopropyl alcohol (which does not dissolve or attack the specimen material), may be used to remove soot and stain particles from tested specimens.

10. Remove any material from the bottom of the cabinet that fell from the specimen. If necessary, clean the test cabinet window and/or back face mirror prior to testing the next specimen.

26.6.2.7 **Report**

26.6.2.7.1 **Material Identification**

Fully identify the material tested, including thickness. Also, include the specimen length if a 12-inch specimen is not available.

26.6.2.7.2 **Test Results**

Ignition Time - Report the ignition time applied was 12 seconds.

Flame Time - Report the flame time for each specimen tested. Determine and record the average value for flame time (see Section 26.6.2.1.2).

Drip Flame Time - Report the drip flame time for each specimen tested. Determine and record the average value for the drip flame time (see Section 26.6.2.1.3). For specimens that have no drips, record “0” for the drip flame time and also record “No Drips.”

Burn Length - Report the burn length to the nearest 0.1 inch for each specimen tested. Determine and record the average value for burn length.

26.6.2.8 **Requirements**

26.6.2.8.1 **Flame Time**

The average flame time for all of the specimens tested will not exceed 15 seconds for the 12-second test.

26.6.2.8.2 **Drip Flame Time**

The average drip extinguishing time for all of the specimens tested will not exceed 5 seconds for the 12-second vertical test.

26.6.2.8.3 **Burn Length**

The average burn length for all of the specimens tested will not exceed 8 inches (203 mm) for the 12-second vertical test.
26.6.3 Horizontal Bunsen Burner Test for Miscellaneous Materials

Definitions

26.6.3.1.1 Ignition Time

Ignition time is the length of time the burner flame is applied to the specimen. For this test, the ignition time is 15 seconds.

26.6.3.1.2 Burn Rate

Burn rate is the rate at which a flame front moves over a specified distance on a test specimen, under specified test conditions. In this test, it is the rate with which a flame front moves across a test specimen mounted horizontally.

26.6.3.2 Apparatus

26.6.3.2.1 Test Cabinet

Tests will be conducted in a draft-free cabinet fabricated in accordance with Figure 26-6, Figure 26-7 and Figure 26-8 or other equivalent enclosure. Other cabinets may be used if they are draft free and have enough air to allow complete combustion. It is suggested that the cabinet be located inside an exhaust hood to facilitate clearing the cabinet of smoke after each test. Stainless steel or other corrosion resistant metal, 0.04 inch (1 mm) thick will be used for the bottom surface of the chamber.

26.6.3.2.2 Specimen Holder

A specimen holder fabricated of corrosion-resistant metal in accordance with Figure 26-9 will be used. When performing the tests, the specimen will be mounted in the frame so that the two long edges are held securely. The exposed area of the specimen will be 2 inches (51 mm) in width and 12 inches (305 mm) in length.

26.6.3.2.3 Burner

The burner will be a Bunsen or Tirrill type, have a 3/8-inch (10-mm) inside diameter barrel, and will be equipped with a needle valve located at the bottom of the burner barrel to adjust the gas flow rate and, thereby, adjust the flame height. There will be a means provided to move the burner into and out of test position when the cabinet door is closed.

26.6.3.2.4 Burner Fuel

Methane gas (99 percent minimum purity) will be used. It can be used without adding air through the aspirating holes at the bottom of the burner barrel, i.e., a pure diffusion flame may be used.

26.6.3.2.5 Plumbing for Gas Supply

The necessary gas connections and the applicable plumbing will be essentially as shown in Figure 26-10. A control valve system with a delivery rate designed to furnish gas to the burner under a pressure of 2 1/2 ± 1/4 psi (17 ± 2 kPa) at the burner inlet will be installed between the gas supply and the burner.
26.6.3.2.6 Flame Height Indicator

A flame height indicator may be used to aid in setting the height of the flame. A suitable indicator has a prong extending 1.5 inches (38 mm) above the top of the burner barrel, is attached to the burner barrel, and spaced 1 inch (25 mm) from the burner barrel, as shown in Figure 26-10. When using methane as the burner fuel, it is desirable to have two prongs for measuring the flame height, one prong to indicate the height of the inner cone of the flame and one prong to indicate the height of the tip of the flame. For methane, it has been determined that when the height of the inner cone is 7/8 inch (22 mm) and the tip of the flame is 1.5 inches (38 mm) long, the proper flame profile is achieved.

26.6.3.3 Timer

A stopwatch or other device, calibrated to the nearest 0.1 second, will be used to measure the time of application of the burner flame, the flame time, and the drip flame time.

26.6.3.4 Ruler

A ruler or scale graduated to the nearest 0.1 inch (2.5 mm) will be provided to measure gage marks and flame front position.

26.6.3.5 Test Specimens

26.6.3.5.1 Specimen Selection

Specimens tested will be either cut from a fabricated part as installed in the aircraft or cut from a section simulating a fabricated part, e.g., cut from a flat sheet of material or from a model of the fabricated part. The specimen may be cut from any location in the fabricated part. Fabricated units, such as sandwich panels, will not be separated into individual component layers for testing.

26.6.3.5.2 Specimen Number

Each separate set of specimens prepared for testing will consist of at least three specimens (multiple places where possible).

26.6.3.5.3 Specimen Size

The specimen will be a rectangle at least 3 by 12 inches (76 by 305 mm), unless the actual size used in the aircraft is smaller. This issue will be addressed at the next working group meeting on October 21-22 in New Jersey.

26.6.3.5.4 Specimen Thickness

The specimen thickness will be the same as that of the part qualified for use in the aircraft, with the following exceptions:

1) The specimen thickness must be no thicker than the minimum thickness to be qualified for use in the aircraft. The specimen thickness will not exceed 1/8 inch (3 mm).

2) Parts that are smaller than the size of a specimen and 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 aircraft. The sheet thickness will not exceed 1/8 inch (3 mm) if the test being run is the 4 inches per minute horizontal burn rate test.
26.6.3.5.5 Specimen Preparation

Mark gauge lines on the back surface (opposite the surface to be exposed to the flame) of the specimen 1.5 inches (38 mm) and 11.5 inches (292 mm) from the end of the specimen that will be subjected to the flame.

1) A fine-gauge wire mesh with large openings can be used to support test specimens that sag severely during testing so that the flame propagation may be determined accurately.

26.6.3.6 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 being tested.

26.6.3.7 Procedure

26.6.3.7.1 Burner Adjustment

1) If using methane as the burner fuel, ensure that the air supply to the burner is shut off.

2) Open the stopcock in the gas line fully and light the burner.

3) Adjust the needle valve on the burner to achieve the proper 1.5-inch (38-mm) flame height in accordance with section 26.6.3.2.6.

4) Close the cabinet door, and keep it closed during the test.

5) Start the timer immediately upon positioning the burner. Position the burner so that the centerline of the burner orifice is in line with the edge of the specimen holder and the centerline of the width of the specimen (See Figure 26-11).

6) Apply the flame for 15 seconds and then withdraw it by moving the burner at least 3 inches (76 mm) from the specimen or by turning the gas off.

7) Note the times and/or locations on the specimen at which the following events occur:

   a. If the flame front crosses the 1.5-inch (38-mm) gauge line, note the elapsed time in seconds, t_{e(1 ½)}, at which the crossing occurs.

   b. If the flame front crosses the 11.5-inch (292-mm) gauge line, note the elapsed time in seconds, t_{e(11 ½)}, at which the crossing occurs.

   c. If the specimen burns very slowly so that the flame front does not reach the 11.5-inch (292-mm) gauge line within 4 minutes after it passes the 1.5-inch (38-mm) gauge line, note the position in inches, d_{f}, of the flame front from the ignited end of the specimen and the elapsed time in seconds, t_{e(f)}, and terminate the test.

8) After all flaming ceases, open the cabinet door slowly to clear the test cabinet of fumes and smoke. The exhaust fan may be turned on to facilitate clearing of smoke and fumes. Remove any material from the bottom of the cabinet that fell from the specimen.

9) If necessary, clean the test cabinet window prior to testing the next specimen.
26.6.3.8 Test Results—Burn Rate

Determine the burn rate as follows:

1) If the flame front self-extinguished before crossing the 11.5-inch (292-mm) gauge line, record the burn rate as zero.

2) If the flame crosses the 11.5-inch (292-mm) gauge line, determine and record the burn rate as:

\[
\text{Burn rate (in/min)} = \frac{600}{t_e(10)}, \text{ where } t_e(10) = t_e(11 \frac{1}{2}) - t_e(1 \frac{1}{2}) = \text{time in seconds for the flame front to burn from the 1.5-inch (38-mm) gauge line to the 11.5-inch (292-mm) gauge line.}
\]

3) If the specimen burned very slowly (see Section 26.9.5.8.1, Step 7), the burn rate may be estimated and recorded as:

\[
\text{Burn Rate (in/min)} = 60 \times \frac{(d_f - 1.5)}{t_e(f) - t_e(1 \frac{1}{2})}
\]

26.6.3.9 Report

26.6.3.9.1 Material Identification

Fully identify the material tested, including thickness.

26.6.3.9.2 Test Results

Report the burn rate from Section 26.6.3.1.2 for each specimen tested. Determine and record the average value for burn rate.

26.6.3.10 Requirements

26.6.3.10.1 Burn Rate

The average burn rate for all the specimens tested will not exceed 4 inches/minute
26.6.4 60-Degree Bunsen Burner Test for Electric Wire

26.6.4.1 Definitions

26.6.4.1.1 Ignition Time

Ignition time is the length of time the burner flame is applied to the specimen. The ignition time for this test is 30 seconds.

26.6.4.1.2 Flame Time

Flame time is the time in seconds that the specimen continues to flame after the burner flame is removed from beneath the specimen. Surface burning that results in a glow but not in a flame is not included.

26.6.4.1.3 Drip Flame Time

Drip flame time is the time in seconds that any flaming material continues to flame after falling from the specimen to the floor of the chamber. If there is more than one drip, the drip flame time reported is that of the longest flaming drip. If succeeding flaming drips reignite earlier drips that flamed, the drip flame time reported is the total of all flaming drips.

26.6.4.1.4 Burn Length

Burn length is the length of damage along the wire above and below the point of burner flame impingement and due to that area’s combustion, including areas of partial consumption, charring, or embrittlement, but not including areas sooted, stained, warped, or discolored nor areas where material has shrunk or melted away from the heat.

26.6.4.2 Apparatus

26.6.4.2.1 Test Enclosure and Setup

Tests will be conducted in a cabinet fabricated of sheet metal, approximately 24 inches (610 mm) high by 12 inches (305 mm) wide by 12 inches (305 mm) deep and open at the front and top. External conditions around the cabinet will be such that the cabinet is free of drafts during a test, but sufficient airflow will be available for complete combustion. Other cabinets may be used if they are draft free and have enough air to allow complete combustion. It is suggested that the cabinet be located inside an exhaust hood to facilitate removal of smoke and fumes after each test.
26.6.4.2.2 Specimen Holder

A specimen holder fabricated of corrosion-resistant metal in accordance with Figure 26-12 will be used. The specimen holder will be placed so that the specimen is maintained at an angle of 60 degrees with the horizontal and is positioned parallel to and 6 inches (152 mm) back from the front of the enclosure.

26.6.4.2.2.1 Clamp and Pulley

The specimen will be attached to the specimen holder by a clamp at the lower end and a pulley or rod at the upper end. The span between the clamp and the rod or pulley will be 24 inches (610 mm).

26.6.4.2.2.2 Weight

A weight will be attached to the free end of the specimen to keep the specimen taut during the test (See Figure 26-12). Suggested weights for various wire sizes are shown in Table 26-3.

<table>
<thead>
<tr>
<th>AWG</th>
<th>Pounds</th>
<th>Kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.8</td>
<td>0.4</td>
</tr>
<tr>
<td>14</td>
<td>2.0</td>
<td>0.9</td>
</tr>
<tr>
<td>8</td>
<td>3.0</td>
<td>1.4</td>
</tr>
<tr>
<td>1/0</td>
<td>11.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>

26.6.4.2.3 Burner

The burner will be a Bunsen or Tirrill type, have a 3/8-inch (10-mm) inside diameter barrel and be equipped with a needle valve at the bottom of the burner barrel to adjust the gas flow rate (see Figure 26-13). A means will be provided to move the burner into and out of the test position. Mounting the burner on a fixture that allows it to be rotated in the horizontal plane is suggested.

26.6.4.2.3.1 Burner Fuel

Methane gas of 99 percent minimum purity shall be used. It can be used without adding air through the aspirating holes at the bottom of the burner barrel, i.e., a pure diffusion flame may be used.

26.6.4.2.3.2 Plumbing for Gas Supply

The necessary gas connections and the applicable plumbing will be essentially as shown in Figure 26-13. A control valve system with a delivery rate designed to furnish gas to the burner under a pressure of 2 1/2 ± 1/4 lb/ft² (17 ± 2 kPa) at the burner inlet will be installed in between the gas supply and the burner.
26.6.4.2.3 Flame Height Indicator

A flame height indicator may be used to aid in setting the height of the flame. A suitable indicator has a prong 3 inches (76 mm) above the top of the barrel, is attached to the burner barrel, spaced 1 inch (25 mm) from the burner barrel, and extends above the burner, as shown in Figure 26-2. It is desirable to have two prongs to measure flame height, one prong to indicate the height of the inner cone of the flame and one prong to indicate the height of the tip of the flame. For this test, it has been determined that when the height of the inner cone is 1 inch (25 mm) and the tip of the flame is 3 inches (76 mm), the proper flame profile is achieved.

26.6.4.2.4 Timer

A stopwatch or other device graduated to the nearest 0.1 second will be used to measure the time of application of the burner flame, the flame time, and the drip flame time.

26.6.4.2.5 Ruler

A ruler or scale graduated to the nearest 0.1 inch (2.5 mm) will be provided to measure the burn length.

26.6.4.3 Test Specimens

26.6.4.3.1 Specimen Number

Each separate set of specimens prepared for testing will consist of at least three specimens (multiple places).

26.6.4.3.2 Specimen Length

The specimens will be cut to a length of 30 inches (762 mm). The specimen span between the lower clamp and upper pulley or rod will be 24 inches (610 mm). This issue will be addressed at the next working group meeting on October 21-22 in New Jersey.

26.6.4.3.3 Specimen Preparation

Make a gauge mark 8 inches (203 mm) from one end of each specimen.

26.6.4.4 Conditioning

Condition specimens at 70 ± 5°F (21 ± 3°C) and 50% ± 5% relative humidity for 24 hours minimum unless otherwise specified. Remove only one specimen at a time from the conditioning environment immediately before being tested.
26.6.4.5 Procedure

26.6.4.5.1 Burner Adjustment

1) If using methane as the burner fuel, ensure that the air supply to the burner is shut off.

2) Open the stopcock in the gas line fully and light the burner.

3) Adjust the burner flame to obtain a flame profile so that the outer cone of the flame is 3 inches (76 mm) in length and the inner cone is approximately 1 inch (25 mm) in length. The proper flame length will be obtained by adjusting the needle valve on the burner controlling the gas flow rate.

4) Burner Placement
   For the test, place the burner into position so that the top end of the burner barrel is 1 inch from the mark on the specimen, and the centerline of the burner barrel is perpendicular to the specimen and intersects the specimen at the mark (See Figure 26-12).

26.6.4.5.2 Test Procedure

1) Place the burner at least 3 inches (76 mm) from where the specimen will be located during the test.

2) The timer must be started immediately upon positioning the burner. Position the burner as described in section 26.6.4.2.3.3 so that the tip of the inner cone of the burner flame contacts the gauge mark on the wire.

3) Apply the flame for 30 seconds, and then withdraw it.

4) If flaming material falls from the test specimen, note the drip flame time for the specimen (see Section 26.6.4.1.3).

5) Determine the flame time for the specimen (see Section 26.6.4.1.2).

6) After all flaming ceases, remove the specimen and determine the burn length (see Section 26.6.4.1.4). To facilitate determining the burn length, a dry soft cloth or tissue or a soft cloth or tissue dampened with a moderate solvent that does not dissolve or attack the specimen material, such as alcohol, may be used to remove soot and stain particles from tested specimens.

7) Remove any material from the bottom of the cabinet that fell from the specimen.
26.6.4.6 Report

26.6.4.6.1 Material Identification

Fully identify the wire tested.

26.6.4.6.2 Test Results

1) Report the flame time for each specimen tested. Determine and record the average value for flame time.

2) Report the drip flame time for each specimen tested. Determine and record the average value for drip flame time. For specimens that have no drips, record “0” for the drip flame time and also record “No Drips.”

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

26.6.4.7 Requirements

26.6.4.7.1 Extinguishing Time

The average extinguishing time for all the specimens tested will not exceed 30 seconds.

26.6.4.7.2 Drip Extinguishing Time

The average drip extinguishing time for all the specimens tested will not exceed 3 seconds.

26.6.4.7.3 Burn Length

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

26.6.4.7.4 Wire Breakage

It will not be considered a failure if the wire breaks during the test.
FIGURE 26-1  Vertical Bunsen Burner Test Cabinet

FIGURE 26-2  Front and Top View of Vertical Bunsen Burner Test Cabinet
FIGURE 26-3  Vertical Bunsen Burner Test Specimen Holder

FIGURE 26-4  Burner Plumbing and Burner Flame Height Indicator
FIGURE 26-5  Flame Position on Vertical Specimens
FIGURE 26-6  Horizontal Bunsen Burner Test Cabinet

FIGURE 26-7  Front and Top View of Horizontal Bunsen Burner Test Cabinet
FIGURE 26-8  Side Views of Horizontal Bunsen Burner Test Cabinet

FIGURE 26-9  Horizontal Bunsen Burner Test Specimen Holder
FIGURE 26-10        Burner Plumbing and Burner Flame Height Indicator

FIGURE 26-11        Typical Burner and Specimen location
FIGURE 26-12  60-Degree Electrical Wire Bunsen Burner Test Setup

FIGURE 26-13  Burner Plumbing and Burner Flame Height Indicator
NOTES
1. The diameter of the thermocouple wire shall be between 0.6 mm and 1 mm.
2. If a metal sheath is used, the maximum diameter shall not exceed 3 mm. (1/8 in)
3. The thermocouple shall be unshielded and non-aspirated.

FIGURE 26-14  Details of Thermocouple

FIGURE 26-15  Liquid Fuel Burner – Thermocouple Positions
FIGURE 26-16  Liquid Fuel Burner Nozzle
FIGURE 26-17  Set-Up of Standard Heat Flux Density Measuring Apparatus

FIGURE 26-18  View of Mounting Heat Flux Density Measuring Tube
APPENDIX A

USERS GUIDE (will be adding additional guidance on fireproof and fire resistant methods)
I. Vertical Burner

This supplement contains advisory material pertinent to referenced paragraphs. This test method is intended for use in determining the resistance of materials to flame when tested according to 12-second Vertical Bunsen Burner Tests specified in Federal Aviation Regulation (FAR) 25.853 and FAR 25.855. There is also a 60 second vertical test that is intended to show compliance for interior compartments occupied by crew or passengers. This method was not included because the intent of this 60 second test is for testing interior ceiling panels, interior wall panels, partitions, galley structure, large cabinet walls, structural flooring, and materials used in the construction of stowage compartments. As stated in paragraph 26.3.3, the methods to show compliance to category C are for enclosures housing electronics and non-metallic material, component parts, sub-assemblies installed in pressurized or non-pressurized zones and non-fire zones.

26.6.2.1.1 Ignition time should start only after the flame has stabilized and is properly positioned under the test specimen.

26.6.2.1.4 This definition of burn length is a clarification of that used in FAR 25, Appendix F, Part I, viz.: “Burn length is the distance from the original edge to the farthest evidence of damage to the test specimen due to flame impingement including areas of partial or complete consumption, charring, or embrittlement, but not including areas sooted, stained, warped, or discolored nor areas where material has shrunk or melted away from the heat source.” The main point is that “damage to the test specimen due to flame impingement” is clarified by “damage to the test specimen due to that area’s combustion” because it is a better description of the intent of the rule and is consistent with current test practices.

The burn length definition specified in FAR 25, Appendix F, applies to all materials listed in Part 25.853 and FAR 25.855. Since such a wide variety of materials require vertical Bunsen burner testing, areas that might obviously be included as burn length in some materials may not always be as well defined in others.

For the most part, these materials may be divided into four general categories; they are polymeric materials (such as panels, partitions, transparencies, etc., which may be hybrid or single plastic material), textiles, carpeting, and foams.

The following methods have been suggested for determining burn length:

a. Polymeric Materials. In order to fix the boundary where the flame front was impinging on the specimen surface and damaging the specimen due to that area’s combustion, i.e., below which combustion of the specimen occurred and above which it did not, it is necessary to observe the specimen continuously during the test. Flame impingement on the specimen may lead to outgassing due to thermal decomposition. As these gases burn, radiating heat may cause discoloration, sooting, staining, melting, etc., to areas above the flame front. This type of damage is not a result of thermal decomposition due to flaming and, therefore, would not be included in the burn length.

b. Polyurethane Foams. Polyurethane foams are cellular in nature and, therefore, have low thermal conductivity. Since high surface temperatures are generated on exposure to the burner flame, an almost instantaneous conversion to flammable gases results. This, in turn, produces rapid surface flame spread with complete consumption of the foam immediately above the ignition source. By definition, complete consumption of an area is part of the burn length and should be included.

This issue will be addressed at the next working group meeting on October 21-22 in New Jersey.

26.6.2.2.1 Suitable test cabinets of the type described are manufactured by the U.S. Testing Co., 1415 Park Ave., Hoboken, New Jersey 07030; Atlas Electric Devices Co., 4114 N. Ravenswood Ave., Chicago, Illinois 60613; and The Govmark Organization, Inc., P.O. Box 807, Bellmore, New York 11710.
Draft free implies a condition of no air currents in a closed in space. One way of determining whether the cabinet is draft free is to place a smoldering and smoking material, such as a lighted cigarette, in the test cabinet, then closing the door and observing the behavior of the smoke for signs of drafts. A test cabinet other than one fabricated in accordance with figures 1-1 to 1-3 may be found to be acceptable after review by the FAA.

The entire inside back wall of the chamber may be painted flat black to facilitate viewing of the test specimen, and a mirror may be located on the inside back surface to facilitate observation of the hidden surfaces.

26.6.2.2.3 A suitable burner is available from Rascher & Betzold Inc., 5410 N. Damen Ave., Chicago, Illinois 60625, Catalog No. R3726A.

26.6.2.2.3.3 The tip of the methane flame is blue, transparent, and difficult to see. It is more easily seen if there is no light on the flame, as in a darkened room. The inner cone of the flame is, however, more visible and easily seen and can be used to monitor flame height. When the flame height (blue transparent tip) is set to 1.5 inches, the height of the inner cone has been found to vary slightly from burner to burner, but is generally about 7/8 inch. Therefore, if the inner cone height is used to monitor flame height, the inner cone height needs to be established for that burner.

26.6.2.3.3 By regulation, there must be at least 2 inches of the specimen exposed; however, the text specifies a specimen cut 3 inches in width. This allows enough material to ensure that the specimen is securely held in the holder. From experience, it has been found that materials such as films are difficult to secure in the holder and, therefore, may be cut even greater than 3 inches in width. This allows the operator adequate material to pull or adjust so that the specimen does not buckle or fall out of the holder.

26.6.2.3.4 According to the FAR 25.853, the specimen thickness must be no thicker than the minimum thickness to be qualified for use in the airplane. If the test facility has found from experience or has questions concerning the flammability of a thicker specimen, then vertical testing may be conducted and test data recorded for further review.

26.6.2.4 As stated in the FAR 25.853, only one specimen may be removed at a time from the conditioning chamber prior to being subjected to the flame. Some facilities, however, have conditioning chambers located in areas remote from the testing area. In this case, it is permissible to remove more than one specimen at a time only if each specimen is placed in a closed container (a plastic stowage bag is acceptable) and protected from contamination such as dirty lab tops, soot in the air, etc., until the specimen is subjected to the flame.

26.6.2.6 Item 4 More information is available in DOT/FAA/CT-86/22, “An Investigation of the FAA Vertical Bunsen Burner Flammability Test Method.” Appendix F, FAR 25.853, Part I describes this test and specifies that the flame be placed “along the centerline of the lower edge.” The “centerline of the lower edge” is the line from the front face to the back face of the specimen. For thicker specimens, this is ambiguous since exactly “where” along the “centerline of the lower edge” is not specified.

Historically, test practices regarding burner flame placement have not been uniform or consistent within either the FAA or aircraft manufacturers. The most common placement used in the past was specified in the original issue of this handbook, viz.:

For specimens that are 3/4 inch (19 mm) thick or less, place the burner barrel centerline under the center of the bottom surface of the specimen.
For specimens thicker than 3/4 inch (19 mm), center the burner barrel under the bottom surface of the specimen 3/8 inch (10 mm) in from the surface exposed to the airplane interior, test each surface separately unless the surfaces are of the same materials and construction.

Another placement that has been less commonly used is that specified here, viz., directly under the middle of the lower edge of the face of the specimen that is exposed to the airplane interior. For specimens thinner than the burner barrel thickness (3/8 inch; 10 mm), test results are relatively insensitive to exactly where “along the centerline of the lower edge” the burner flame is placed. For samples of greater thickness, however, burn lengths are typically an inch or so longer if the burner barrel centerline is placed under or near the specimen face, and flame times are sometimes a little longer than if the flame is placed per the original handbook, Report DOT/FAA/CT-89/15, September 1990.

Materials used in contemporary (especially postheat release) designs produce burn lengths and flame times that are considerably less than the acceptance criteria for certification (6 inches and 15 seconds), regardless of where the flame is placed. Although where the burner flame is applied is not of important pass/fail significance in this test, placing it directly under the specimen face generally represents a worst-case situation.

The FAA should accept data for certification using the flame placement described in the original portion of this handbook, or using the flame placed under the exposed face of the test specimen. However, the FAA and aircraft manufacturers have agreed that in the future, the preferred placement of the burner flame is under the middle of the lower edge of the face of the specimen.

26.6.2.6 Item 5 If the burner extinguishes during the ignition time for any reason, rerun the test. From experience, it has been found that this is a necessary requirement when running a 12-second test. The opposite end of the same specimen can be used for the retest if the burn length for the aborted test is less than 3 inches (76 mm). If the burn length for the aborted test is greater than 3 inches (76 mm), a new specimen must be used.

26.6.2.6 Item 8 The operator should refer to the facility’s safety manual for further information on dealing with smoke and flammability by-products.
II. Horizontal Burner

This supplement contains advisory material pertinent to referenced paragraphs.

26.6.3.1.1 Ignition time should start only after the flame has stabilized and is properly positioned under the test specimen.

26.6.3.2.1 Suitable test cabinets of the type described are manufactured by the U.S. Testing Co., 1415 Park Ave., Hoboken, New Jersey 07030; Atlas Electric Devices Co., 4114 N. Ravenswood Ave., Chicago, Illinois 60613; and The Govmark Organization, Inc., P.O. Box 807, Bellmore, New York 11710.

Draft free implies a condition of no air currents in a closed in space. One way of determining whether the cabinet is draft free is to place a smoldering and smoking material, such as a lighted cigarette, in the test cabinet, then closing the door and observing the behavior of the smoke for signs of drafts. A test cabinet other than one fabricated in accordance with figures 3-1 to 3-3 may be found to be acceptable after review by the FAA.

The entire inside back wall of the chamber may be painted flat black to facilitate viewing of the test specimen, and a mirror may be located on the inside back surface to facilitate observation of the hidden surfaces.

26.6.3.2.3 A suitable burner is available from Rascher & Betzold, Inc., 5410 N. Damen Ave., Chicago, Illinois 60625, Catalog No. R3726A.

26.6.3.2.6 The tip of the methane flame is blue, transparent, and difficult to see. It is more easily seen if there is no light on the flame, as in a darkened room. The inner cone of the flame is, however, more visible and easily seen.

26.6.3.5.3 A 3-inch by 13-inch (76- by 330-mm) specimen can be used to secure the specimen at the end of the specimen holder.

26.6.3.5.4 According to the FAR 25.853, the specimen thickness must be no thicker than the minimum thickness to be qualified for use in the aircraft. If the test facility has found from experience or has questions concerning the flammability of a thicker specimen, then vertical testing may be conducted and test data recorded for further review.

26.6.3.6 As stated in the FAR 25.853, only one specimen may be removed at a time from the conditioning chamber prior to being subjected to the flame. Some facilities, however, have conditioning chambers located in areas remote from the testing area. In this case, it is permissible to remove more than one specimen at a time only if each specimen is placed in a closed container (a plastic stowage bag is acceptable) and protected from contamination such as dirty lab tops, soot in the air, etc., until the specimen is subjected to the flame.

26.6.3.7.1 Item 4) It is important to note that the test should be watched carefully while it is being conducted. This applies to all samples.

26.6.3.7.1 Item 6) Some laboratories turn the gas off upon completion of the test; however, the majority of test facilities, including the OEMs, withdraw the flame by moving the burner away from the specimen.

26.6.3.7.1 Item 8) The operator should refer to the facility’s safety manual for further information dealing with smoke and flammability by-products.
III. **60 Degree Burner**

This supplement contains advisory material pertinent to referenced paragraphs.

26.6.4.1.1 Ignition time should start only after the flame has stabilized and is properly positioned under the test specimen.

26.6.4.2.1 Draft free implies a condition of no air currents in a closed in space. One way of determining whether the cabinet is draft free is to place a smoldering and smoking material, such as a lighted cigarette, in the test cabinet, then closing the door and observing the behavior of the smoke for signs of drafts. A test cabinet other than one described in section 4.3.1 may be found to be acceptable after review by the FAA.

The entire inside back wall of the chamber may be painted flat black to facilitate viewing of the test specimen, and a mirror may be located on the inside back surface to facilitate observation of the hidden surfaces.

26.6.4.2.3 A suitable burner is available from Rascher & Betzold, Inc., 5410 N. Damen Ave., Chicago, Illinois 60625, Catalog No. R3726A.

26.6.4.2.3.1 Gases such as natural gas and propane can be used as burner fuel. However, it should be required to show compliance with the 1750°F minimum flame temperature using a 24 AWG thermocouple.

26.7.4.3.2 It is strongly recommended to have samples length of 30 inches. However, in the event that 30 inches of product is not available, actual length of test item may be used and additional non-flammable cable can be attached to item (metal clip or similar) to complete tension using pulley. This issue will be addressed at the next working group meeting on October 21-22 in New Jersey.

26.6.4.4 As stated in FAR 25.853, only one specimen may be removed at a time from the conditioning chamber prior to being subjected to the flame. Some facilities, however, have conditioning chambers located in areas remote from the testing area. In this case, it is permissible to remove more than one specimen at a time only if each specimen is placed in a closed container (a plastic stowage bag is acceptable) and protected from contamination such as dirty lab tops, soot in the air, etc., until the specimen is subjected to the flame.
26.6.4.5.1 Item 4) Alternative Burner Placement
Place the burner into position so that the top end of the burner barrel is 1 inch from the mark on the specimen. Make sure the centerline of the burner barrel is perpendicular to the underside of the mark on the specimen, that the centerline of the burner barrel forms an angle of 30 degrees with the line that is in the vertical plane containing both ends of the specimen, is perpendicular to the specimen, and passes through the mark on the specimen. It has been found convenient to fabricate a fixture to position and hold the location of the burner quickly and repeatably (see figure 26-A-III-1).

Figure 26-A-III-1  Alternative Setup for 60-Degree Electrical Wire Bunsen Burner Test

26.6.4.5.2 Item 6) The operator should refer to the facility's safety manual for further information dealing with smoke and flammability by-products.

NOTE: The Alternative Burner Placement conforms to the 30-second, 60-degree Bunsen burner test described in FAR 25, Appendix F, Part I through Amendment 25-72. The FAA William J. Hughes Technical Center has determined that the Burner Placement in section 4.6.1.4 produces equivalent test results.