Cleanroom Materials Flammability Test Protocol

Class Number 4910

June 2009

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1 INTRODUCTION

1.1 Purpose

1.1.1 This test standard states FM Approvals test requirements and procedures for the evaluation of materials used in cleanroom occupancies mainly, but not restricted, for use in the semiconductor industry. The test evaluates the materials' fire propagation behavior and potential for smoke contamination using two indices: Fire Propagation Index (FPI) and Smoke Development Index (SDI).

1.1.2 This test standard does not qualify products for Approval based solely on these test results, as the end use of the product will determine the applicable Approval Standard requirements, if available, which will also have to be met to achieve Approval.

1.1.3 Approval criteria may include, but are not limited to, performance requirements, marking requirements, examination of manufacturing facility(ies), audit of quality assurance procedures, and a follow-up program.

1.2 Scope

1.2.1 This test standard describes minimum performance requirements for materials which are intended for use in cleanroom facilities. This standard evaluates the ability of the components to limit fire spread and smoke damage. All requirements in the standard must be met for materials to be acceptable in cleanrooms.

1.2.2 This standard is intended to verify that the product as described will meet minimum specific stated conditions of performance, safety, and quality, useful in determining the potential suitability for end-use conditions of these products.

1.3 Basis for Requirements

1.3.1 The requirements of this test standard are based on experience, research and testing, and/or the standards of other organizations. The advice of manufacturers, users, trade associations, jurisdictions and/or loss control specialists was also considered.

1.3.2 Meeting these requirements does not qualify a product for Approval. Additional testing and requirements for Approval are specified in the Approval Standards which are based on the end use of the product.

1.4 Basis for Specification Testing

1.4.1 Examination and tests on production samples shall be performed to evaluate:

- the suitability of the product;
- the performance of the product as specified by the manufacturer and required by FM Approvals; and as far as practical;
- the durability and reliability of the product.

1.4.2 An examination of the manufacturing facilities and audit of quality control procedures is made to evaluate the manufacturer's ability to consistently produce the product which is examined and tested, and the marking procedures used to identify the product. These examinations may be repeated as part of FM Approvals' product follow-up program.

1.5 Basis for Continued Listing

Continued Listing is based upon:

- production or availability of the product as currently tested;
- the continued use of acceptable quality assurance procedures;
- satisfactory field experience;
- compliance with the terms stipulated in the Specification Tested report;
- satisfactory re-examination of production samples for continued conformity to requirements; and
- satisfactory Facilities and Procedures Audits (F&PAs) conducted as part of FM Approvals' product follow-up program.

Also, as a condition of retaining Specification Tested Listing, manufacturers may not change a product or service without prior authorization by FM Approvals.

1.6 Effective Date

The effective date of a test standard mandates that all products tested for evaluation after the effective date shall satisfy the requirements of that standard.

The effective date of this Standard is June 30, 2009.

1.7 System of units

Units of measurement used in this Standard are International System (SI) units. These are followed, where applicable, by their arithmetic equivalents in United States (U.S.) customary units, enclosed in parentheses. The first value stated shall be regarded as the requirement. The converted equivalent value may be approximate. Appendix A lists the selected units and conversions to U.S. Customary units for measures appearing in this standard. Conversion of SI units is in accordance with SI10-02 IEEE/ASTM SI 10 American National Standard for Use of the International System of Units (SI): The Modern Metric System

1.8 Applicable Documents

The following standards, test methods, and practices are referenced in this standard:

1. Tewarson, A., ''Generation of Heat and Chemical Compounds in Fires'', Chapter 4, Section 3, pp. 3-53 to 3-124. The SFPE Handbook of Fire Protection Engineering, 2nd Edition. The National Fire Protection Association Press, Quincy, MA, June 1995.

2. Tewarson, A., ''Flammability'', Chapter 42, pp. 577-604. Physical Properties of Polymers Handbook (J.E. Mark, Editor). American Institute of Physics, Woodbury, NY, 1996.

3. Wu, P.K.S. ''PVDF Flame Propagation Test'', Interoffice Correspondence December 27, 1995.

4. Tewarson, A., and Khan, M.M., ''Electrical Cables-Evaluation of Fire Propagation Behavior and Development of Small Scale Test Protocol'', Technical Report FM Global Research J.I. OM2E1.RC, FM Global Research, Norwood, MA, January 1989.

5. Specification Test Standard, Cable Fire Propagation, Class Number 3972, FM Approvals, Norwood, MA, March 2009.

6. Khan, M.M. ''Classification of Conveyor Belts Using a Fire Propagation Index'', Technical Report FM

Global Research J.I. OT1E2.RC, FM Global Research, Norwood, MA, June 1991.

7. FM Approval Standard, Class 1 Conveyor Belting, Class Number 4998, FM Approvals, Norwood, MA, August 1995.

8. FM Approval Standard, Fume Exhaust Ducts or Fume and Smoke Exhaust Ducts, Class Number 4922, FM Approvals, Norwood, MA, June 1994.

9. Newman, J.S. and Steciak, J., ''Characterization of Particulates from Diffusion Flames'', *Combustion and Flame*, 67, 55-64, 1987.

10. Newman, J.S. and Steciak, J., ''Particulate Generation from Diffusion Flames'', *Proceedings of the 1987 ASME/JSME Thermal Engineering Joint Conference*, March 22-27, 1987. The American Society of Mechanical Engineers, NY.

11. ASTM E2058 "Standard Test Method for Measurement of Synthetic Polymer Material Flammability Using a Fire Propagation Apparatus (FPA)"

1.9 Definitions

For purposes of this test standard, the following terms apply:

Critical Heat Flux (CHF)	maximum heat flux at or below which there is no ignition.
Fire Propagation Index (FPI)	An index representing the propensity of -the material to support fire propagation.
Ignition Zone	area of the surface of a material heated by an outside source resulting in ignition.
Smoke Damage Index	smoke yield multiplied by FPI. It is an indicator of the extent of smoke contamination of the environment during fire propagation.
Smoke yield (y_s)	ratio of the total mass of smoke released to the total mass of the material vaporized.
Thermal Response Parameter (TRP)	indicator of the ignition resistance of a material.

2 GENERAL INFORMATION

2.1 Product Information

Specification Tested materials or systems for use in semiconductor clean room occupancies are usually supplied in sheet form or as resins that are either powders or pellets. They are tested as sheets in either the Fire Propagation Apparatus for materials with thicknesses greater than, or equal to, 0.25 in (6 mm) or the FM Approvals 8 ft. (2.4 m) parallel panel test for materials with thicknesses less than 0.25 in (6 mm) or other thicknesses as appropriate for which Specification Tested Listing is sought.

2.2 Specification Testing Application Requirements

To apply for Specification Tested examination, the manufacturer or its authorized representative, should submit a request to

Materials Director
FM Approvals
1151 Boston-Providence Turnpike
PO Box 9102
Norwood, MA 02062
U.S.A.

The manufacturer shall provide the following preliminary information with any request for Specification Tested consideration:

- a complete list of all the formulations for the products or services being submitted for Specification Tested consideration;
- brochures, sales literature, spec. sheets, process flow diagrams, quality controls; and
- the number and location of manufacturing facilities.
- all documents shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level. All documents shall be provided with English translation.

2.3 Requirements for Samples for Examination

2.3.1 Following authorization of a Specification Tested examination, the manufacturer shall submit samples for examination and testing based on the following:

- Sample requirements to be determined by FM Approvals following review of the preliminary information.

- A representative of FM Approvals shall inspect the manufacturing facility for, witness the production of, and place their mark on, each sample material to be evaluated.

- If a resin material is being submitted, the production of the resin as well as production of sheet for testing from the resin shall be witnessed by a representative of FM Approvals.

2.3.2 Requirements for samples may vary depending on results of prior or similar testing, and results of any foregoing tests.

2.3.3 The manufacturer shall submit samples representative of production. Any decision to use data generated using prototypes is at the discretion of FM Approvals.

3 PERFORMANCE REQUIREMENTS

3.1 Test Criteria

Test criteria for the selection of materials for cleanrooms are presented. The criteria deal with limiting fire propagation and limiting contamination of the cleanroom environment by smoke. The criteria are represented by the following two indices[1]:

*1) *Fire Propagation Index (FPI)* ≤ 6 $(m/s^{1/2})/(kW/m)^{2/3}$ is used as a criterion for non fire propagation beyond the ignition zone. The FPI value is the maximum value for 15 second running average of the data

*2) *Smoke Damage Index (SDI)* ≤ 0.40 $[(m/s^{1/2})/(kW/m)^{2/3}]$ [g/g] is used as a criterion for significantly limiting smoke concentration for non propagating fires beyond the ignition zone.

The cleanroom materials shall satisfy both criteria. The FPI and SDI values are quantified in the Fire Propagation Apparatus following the test methodology of ASTM E2058 and *Cleanroom Material Flammability Test Protocol*. Three types of tests are performed: 1) ignition test; 2) fire propagation test; and 3) combustion test.

The ignition test is performed in accordance with ASTM E2058 to quantify the ignition resistance of the material, expressed as the *Thermal Response Parameter (TRP).* The fire propagation test is performed in accordance with ASTM E2058 to quantify the chemical heat release rate during fire propagation. The chemical heat release rate and the TRP value are combined to calculate the FPI value. The combustion test is performed in accordance with ASTM E2058 to quantify the yield of smoke. The yield of smoke is multiplied by the FPI value to calculate the SDI value.

The materials examined by the protocol have been found to have the following ranges of values: 1) FPI: 2 to 36; and 2) SDI: 0.06 to 4.10.

The reported test data will be rounded as follows: FPI-rounded to the nearest whole number (1.0, 2.0) and SDI rounded to the nearest tenth (0.1, 0.2)

3.2 Calibration

All examinations and tests performed in evaluation to this standard shall use calibrated measuring instruments traceable and certified to acceptable national standards.

3.3 Re-Testing of Materials

A retest of materials shall be called for when a fifth formulation modification has been requested via Product Revision Report (Form 797) and the previous four have been accepted without additional testing.

[1] *FPI and SDI are dimensional numbers. The dimensions indicated are used throughout the standard for these indices.

4 TEST PROTOCOL

Tests on samples with thicknesses greater than, or equal to, (0.25 in.) 6 mm are performed in the Fire Propagation Apparatus (ASTM E2058) in accordance with the test methodology of ASTM E2058. Materials whose thickness is less than (0.25 in.) 6 mm cannot be tested in accordance with ASTM E2058 on the FPA for this Specification Tested Standard. Samples with FPI and SDI values that are greater than the acceptance criteria are tested using the 8 ft. (2.4 m) Parallel Panel Test procedure. The Fire Propagation Apparatus as configured for ignition and combustion tests is shown in Figure 1 and for fire propagation in Figure 2. The Parallel Panel Test is shown in Figure 5. Pertinent test information is given below:

4.1 Sample Requirements

Ignition and Combustion Tests

Ten, 4 in (100 mm) square samples from ¼ to 1 in. (6 to 25 mm) in thickness are needed. Cables are tested in their end-use size and construction; 15 ft (5 m) of 12 to 24 AWG cables and 10 ft (3 m) of 11 to 4/0 AWG and up to 400 MCM (thousand circular mils) cables are needed.

Fire Propagation Test

Two, 12 in (300 mm) long, 4 in (100 mm) wide and 0.25 to 1 in. (6 to 25 mm) thick samples are needed. There are no additional sample requirements for cables.

4.2 Sample Preparation and Placement in the Fire Propagation Apparatus

Ignition and Combustion Tests

The sample is wrapped in heavy duty aluminum sheet to tightly cover the edges and back of the sample. For the ignition test, the sample surface is coated with a thin layer of fine graphite powder or Thermo-lux Solar-Collective black paint to compensate for surface absorptivity differences.

The wrapped sample is placed horizontally, exposed surface up, in the Fire Propagation Apparatus (Figure 1) as indicated in Figure 2. For the ignition test, the quartz tube is not used. For the combustion test, the sample is located inside the quartz tube.

Fire Propagation Test

The sides of the sample are covered with 0.25 in. (13 mm) wide ceramic paper and the sides and back of sample are wrapped tightly with heavy duty aluminum sheet. The sample is attached to a 12 in. (300 mm) long and 4 in (100 mm) wide vertical steel ladder by three #24 gage nichrome wires and placed inside the quartz tube in the Fire Propagation Apparatus. The sample configuration for fire propagation test is shown in Figure 3.

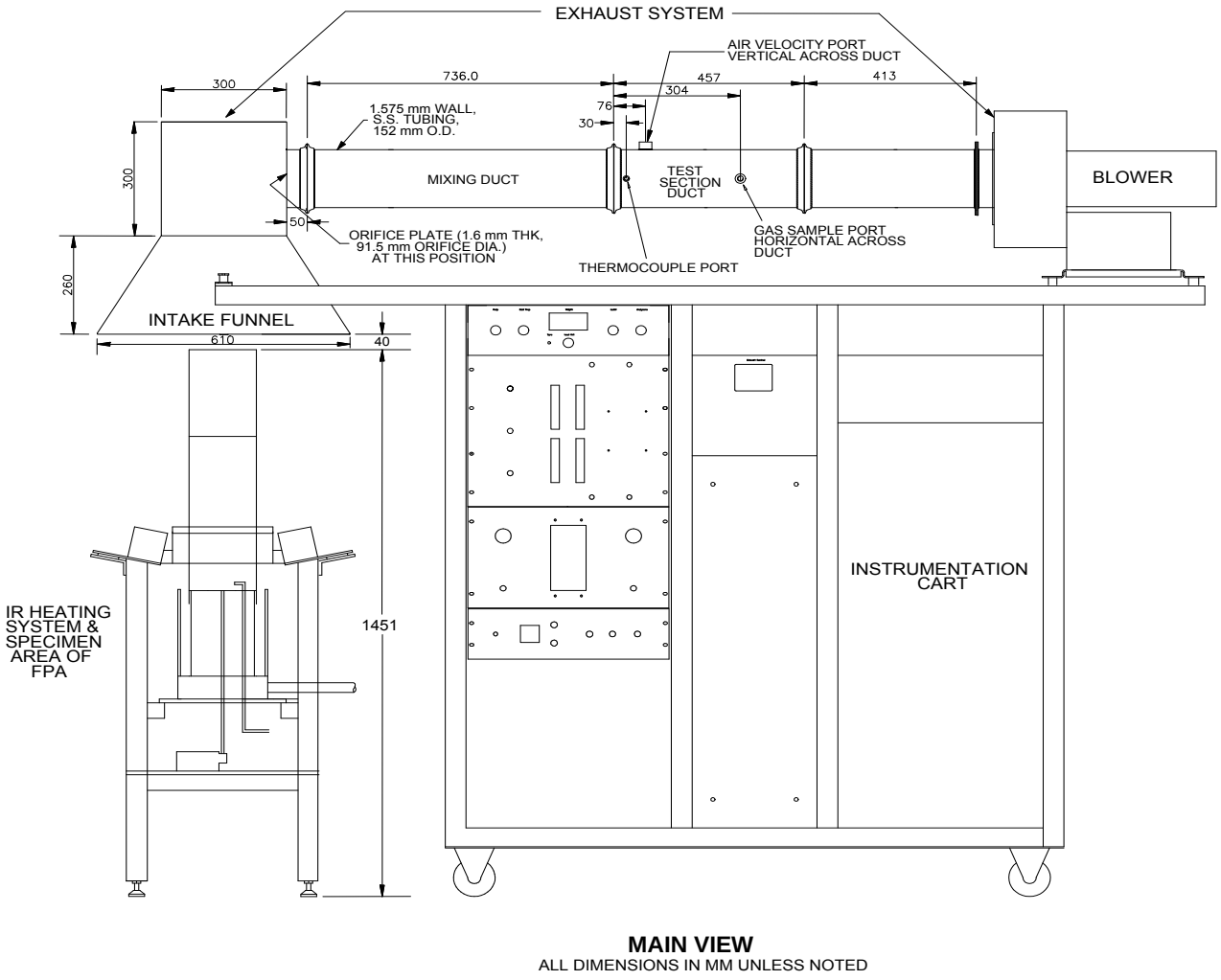

Figure 1: The ASTM E2058 Fire Propagation Apparatus

4.3 Test Conditions and Quantification of FPI and SDI

Ignition Test

The ignition test is performed in accordance with ASTM E2058 in the open under natural air flow (no quartz tube in Fig.1) in the Fire Propagation Apparatus. The pilot consists of a vertical 0.25 in (6 mm) diameter copper tube with perforated ceramic tip bent at right angle near the sample surface. In the ignition tests, sample surfaces are exposed to various external heat flux values. The heat flux value is fixed in each test. The sample set up is shown in Figure 2.

Both time to vapor formation and time to sustained-ignition are measured visually with a stop watch. Four to five tests are performed. The data are used to calculate the *Critical Heat Flux (CHF)* and *Thermal Response Parameter (TRP),* using the *Ignition Test Data Calculation Procedure* described in Section 5.1.

Combustion Test

The combustion test is performed in co-flowing normal air in the Fire Propagation Apparatus (Figure 1) in accordance with ASTM E2058. Air enters the apparatus at the bottom and flows through a series of inlet tubes and screens such that the air velocity across the quartz tube, near the sample, is uniform.

In the combustion test, the sample surface is exposed to 50 kW/m^2 of external heat flux. The measurements are made for: 1) times to vaporization and sustained ignition, total test time, 2) flame height, 3) release rates of material vapors, heat CO, CO_2, hydrocarbons, and smoke. The data are used to calculate the heat of combustion, yields of CO, CO_2, hydrocarbons and smoke using the Combustion Test Data Calculation Procedure outlined in Section 5.3. The test sample set up is shown in Figure 3.

Fire Propagation Test

The fire propagation test is performed in the Fire Propagation Apparatus in accordance with ASTM E2058 as shown in Figure 2, with a co-flowing oxygen-air mixture having 40% oxygen concentration. The mixture enters the apparatus at the bottom and flows through a series of inlet tubes and screens such that the mixture velocity across the quartz tube, near the sample, is uniform within 5%.

In the test, the bottom 4 in (100 mm) of the 12 in. (300 mm) long and 4 in. (100 mm) wide vertical sample is exposed to 50 kW/m^2 of external heat flux in the presence of a pilot flame. This zone is defined as the ignition zone. All samples burn in the ignition zone[2].

The fire propagation test is continued until there are no visible flames and no material vapors are issuing from the front, side, or back of the sample.

In the fire propagation test external heat flux is negligible beyond the ignition zone. Thus fire has to propagate by itself, supported by the heat flux from its own flame. Four types of fire propagation behavior beyond the ignition zone are observed: 1) no fire propagation, 2) decelerating fire propagation (fire does not propagate to the end of the material surface), 3) steady fire propagation, and 4) accelerating fire propagation. The propagation sample set up is shown in Figure 4.

[2] The test is aborted if the sample starts melting rapidly and/or burns very intensely such that flames enter the sampling duct. (For these materials, FPI > 6)

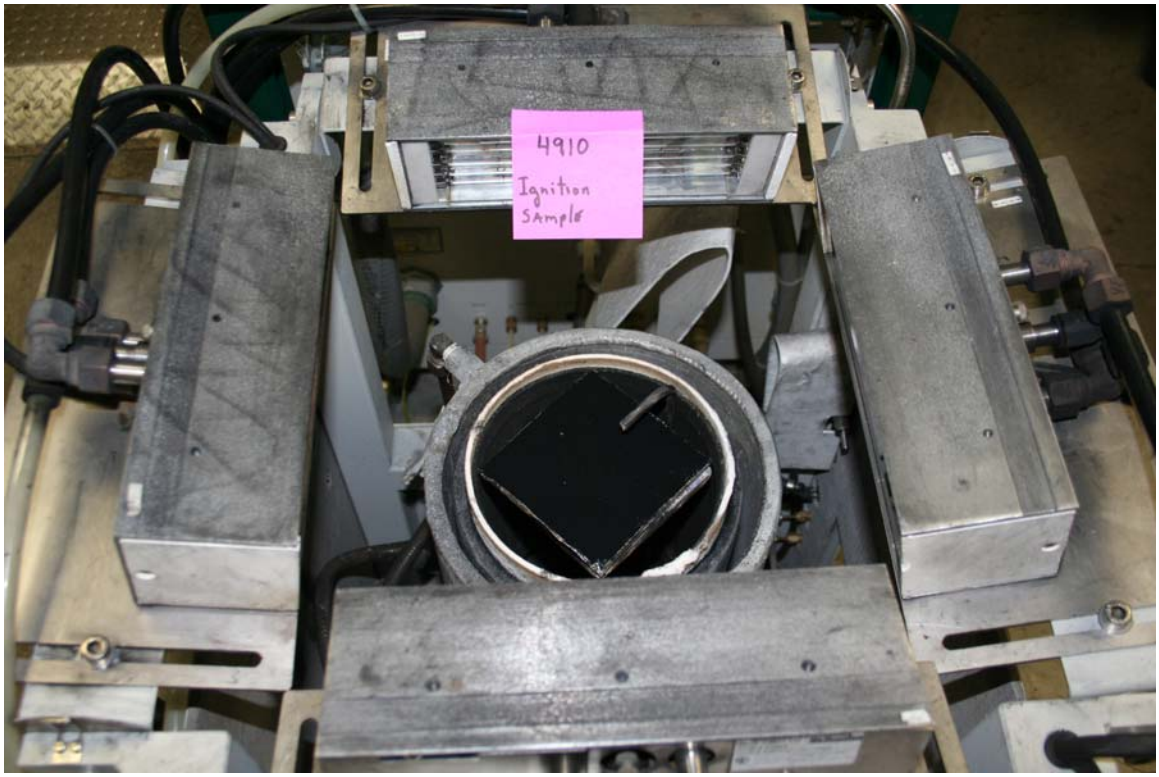

Figure 2: Ignition Test Sample set up on the FPA

Figure 3: Combustion Test Sample set up on the FPA

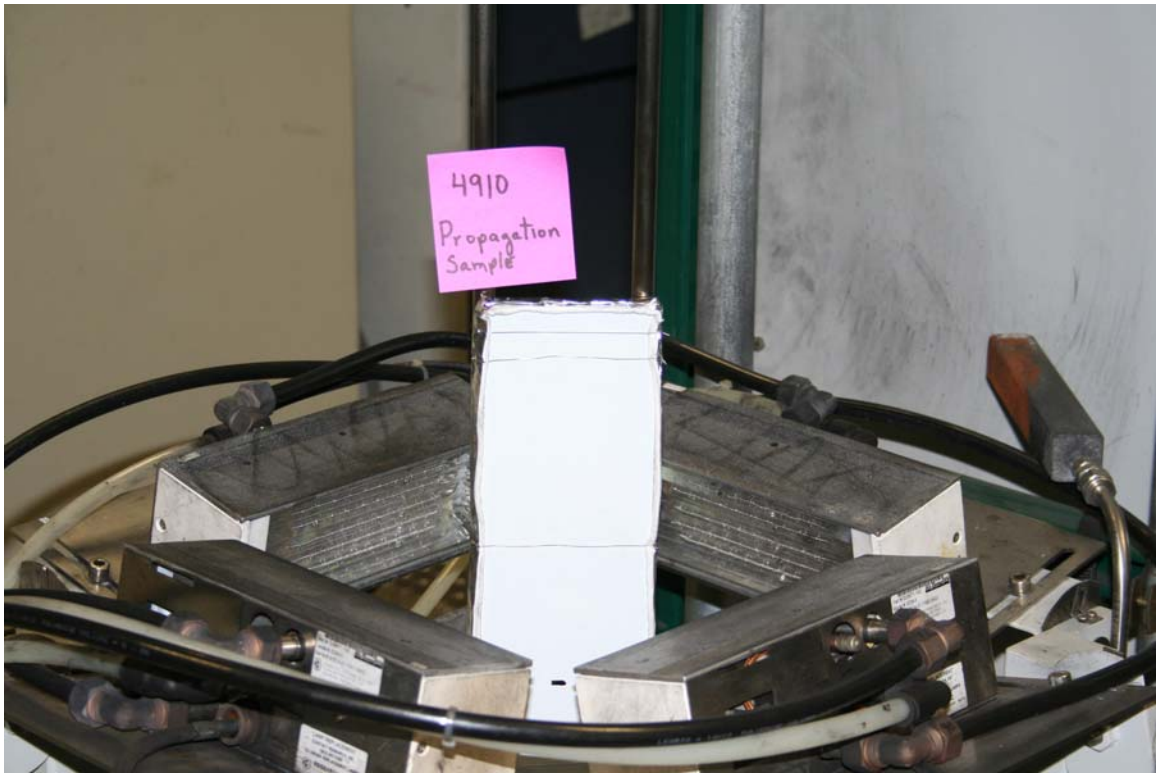

Figure 4: Sample set up on the FPA for Fire Propagation Tests

In the test, measurements are made for: release rates of heat, CO, CO_2 and smoke. The data are used to calculate heat of combustion, yields of CO, CO_2, hydrocarbons, and smoke using the Combustion Test Data Calculation Procedure described in Section 5.3.

The data for the release rate of heat and TRP are used to calculate the Fire Propagation Index (FPI) following the Fire Propagation Test Data Calculation Procedure outlined in Section 5.2.

4.4 Testing Samples Less than 6 mm (0.25 inches) thick and Resolution of Uncertain Ranges of FPI

The 8 ft. (2.4 m) Parallel Panel test is performed in accordance with the FM Approvals 8 ft. (2.4 m) Parallel Panel Test Procedure when samples are less than 6 mm (0.25 inches) thick or the FPI values measured in the Fire Propagation Apparatus are within the uncertain range (between 6 & 7). The test is performed under the 5 MW Fire Products Collector (FPC). The Parallel Panel Apparatus is shown in Figures 5 and 6.

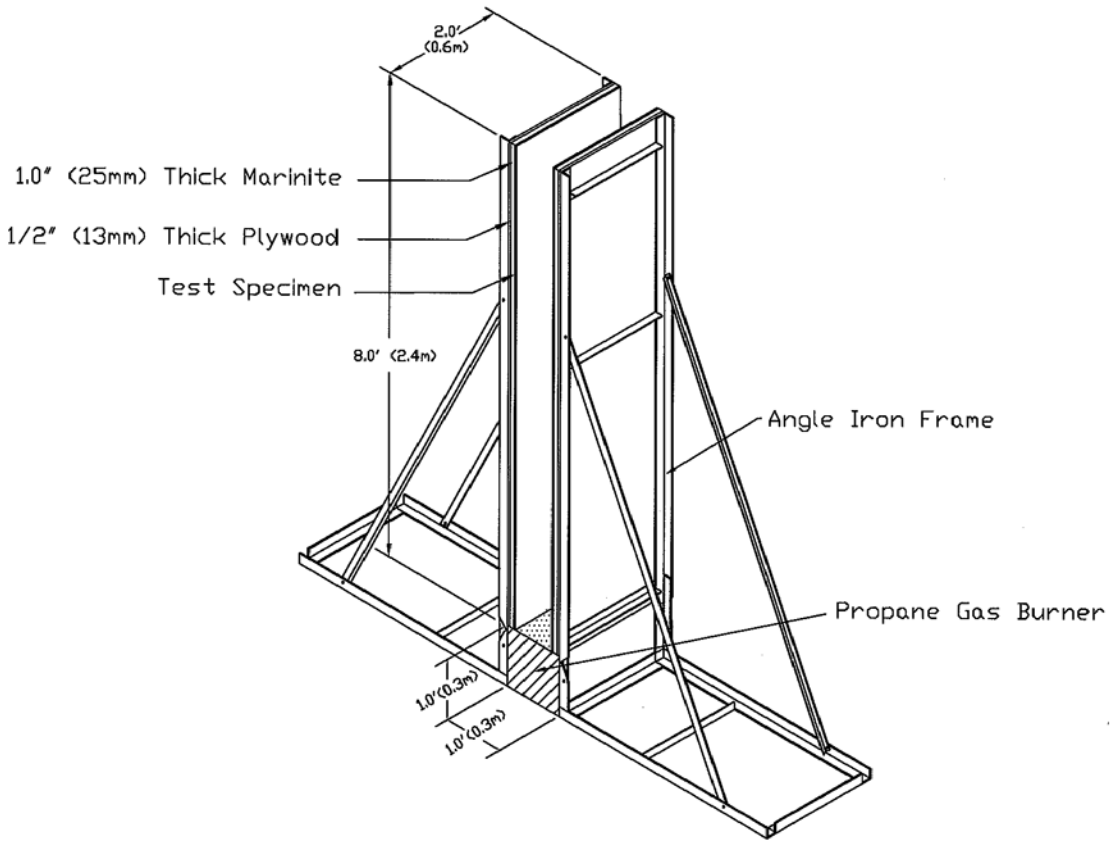

Figure 5: Parallel Panel under the 5 MW Fire Products Collector

In the test, two vertical parallel panels separated by 1 ft (0.31 m) are used as shown in Figure 5. The ignition source is located at the bottom between the panels. Each panel is 8 ft (2.4 m) long, 2 ft (0.61 m) wide, and 1 in. (25 mm) maximum thickness. The ignition source consists of a 2 ft (0.61 m) long, 1 ft (0.31 m) wide and 1 ft (0.31 m) high propane sand burner. The propane gas flow is adjusted to provide a heat release rate of 60 kW.

The panels and the ignition source are placed on top of a load cell. During the test, measurements are made for: 1) release rates of material vapors (mass loss rate), chemical and convective heats, and smoke, 2) heat fluxes to the panel, and 3) flame height.

Visual observations for fire propagation, flame heights, and heat flux data are used to assess propagating versus non-propagating behavior in order to resolve the acceptance of a material with FPI value greater than 6 but ≤ 7.

The acceptance criteria for the Parallel Panel test are that 1) Visual flame height does not exceed 6 feet, 2) heat flux measured at 4 ft (1.2 m) above the sand burner does not exceed 40 kW/m^2, 3) heat release rate 2 minutes after the burner is shut off falls to or below 25% of that maximum heat release rate observed 10 seconds before the burner is shut down, 4) smoke generation rate is less than, or equal to, 0.23 g/s (0.0005 lb/s), 5) smoke generation at 12 min. less than, or equal to, 0.07 g/s (0.0002 lb/s) and 6) total smoke is less than, or equal to, 60 g (0.13 lb).

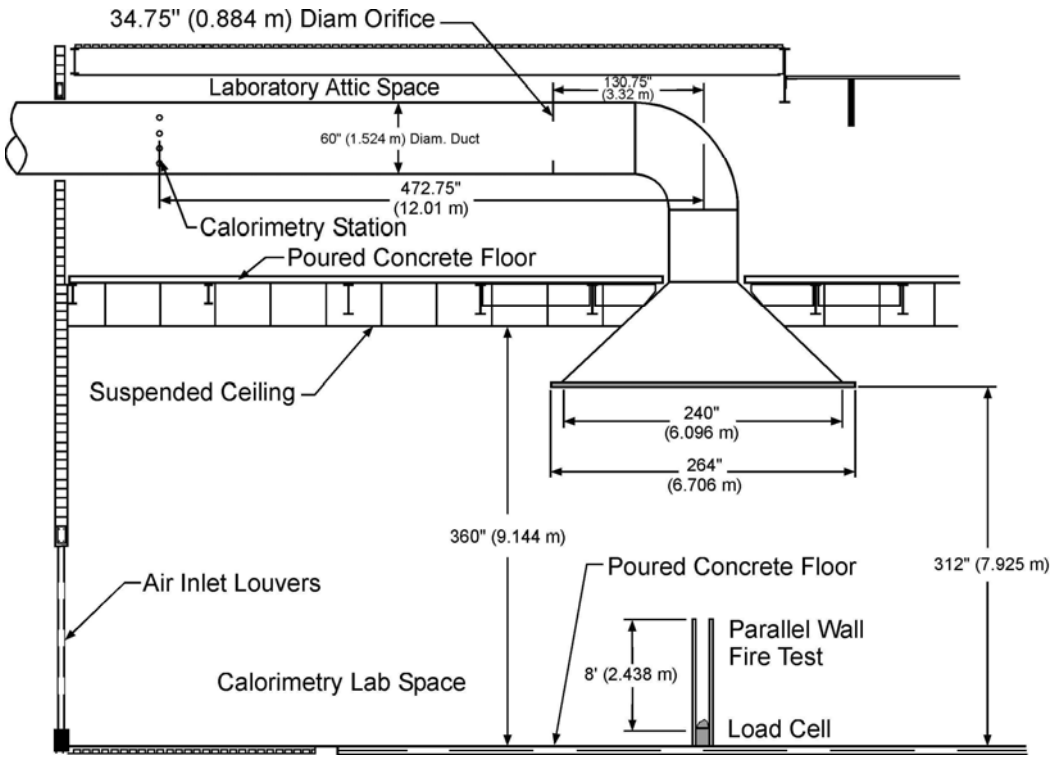

Figure 6: Parallel Panel Products Collector

5 PROCEDURES TO CALCULATE FLAMMABILITY DATA

5.1 Ignition Test Data Calculation

In the ignition tests, time-to-ignition is measured at various external heat flux values. The time-to-ignition follows the following relationship:

1. Thermally Thick Material Relationship at Higher External Heat Flux Values

$$\sqrt{\frac{1}{t_{ig}}} \propto \sqrt{\frac{4}{\pi}\frac{\dot{q}''_e}{TRP_{thick}}} \qquad (1)$$

where t_{ig} is time-to-ignition (s), $\dot{q}''_e$ is the external heat flux (kW/m^2), TRP_{thick} is the *Thermal Response Parameter (TRP) for thermally thick material* (kW-s/$^{1/2}$m^2). TRP is a constant and is expressed as $\Delta T_{ig} (k\rho c_p)^{1/2}$, where ΔT_{ig} is the ignition temperature above ambient (K), k is the thermal conductivity of the material (kW/m-K), ρ is the density of the material (g/m^3), and c_p is the specific heat of the material (kJ/g-K).

Maximum heat flux at, or below, which there is no ignition, defined as *Critical Heat Flux (CHF)* is determined from the intercept on the x-axis of the line obtained from the inverse of measured times-to-ignition versus external heat flux values.

5.2 Fire Propagation Test Data Calculation

In the fire propagation test, release rates of CO, CO_2 and smoke are measured as functions of time for a vertical, 4 in (100 mm) wide by -12 in (305 mm) long sheet, with edges covered with ceramic paper and by aluminum foil wrapped around the edges and back of the sample. The sample is contained inside a quartz tube. Co-flowing air with an oxygen concentration of 40%[3] enters the quartz tube at the bottom. The bottom 5in (127mm) of the sample is exposed to 50 kW/m^2 of external heat in the presence of a pilot flame. Beyond the ignition zone, flame propagates by itself, supported by its own radiation dominated flame heat flux.

The chemical heat release rate is calculated from the release rates of CO_2 and CO [1,2] and used in the following expression to calculate the Fire Propagation Index (FPI) as a function of time:

$$FPI = \frac{750\left(\dot{Q}_{ch} / w\right)^{1/3}}{TRP} \qquad (2)$$

where FPI is the *Fire Propagation Index*, $\dot{Q}'_{ch}$ is the chemical heat release rate per unit width (w in meters) for sheet materials or circumference (c in meters) for cables (kW/m) and TRP is the Thermal Response Parameter for the material (kW-s/$^{1/2}$m^2) (Equation 1).

[3] 40% oxygen is used to simulate flame radiation typical of large-scale fires [1,2].

5.3 Combustion Test Data Calculation

In the combustion test, a 4 in (100 mm) square sample is exposed to 50 kW/m^2 of external heat flux in normal air. Measurements are made for release rates of material vapors, CO, CO_2 and smoke, consumption rate of O_2, gas temperature, and volumetric flow rate of the fire products air mixture as functions of time. Flame height as a function of time and test duration are also measured.

The chemical heat release rate is calculated from the release rates of CO_2 with a correction for the release rate of CO. All the release rates are integrated to calculate the release of total amounts of material vapors, CO, CO_2, smoke, and chemical energy. These data are used to calculate:

1) average chemical heat of combustion: calculated from the ratio of the total chemical energy to the total amount of material vapors released.

2) average yield of each product: calculated from the ratio of the total amount of the product released to the total amount of material vapors released.

5.4 Smoke Damage Index (SDI)

Smoke Damage Index (SDI) is defined as the yield of smoke multiplied by the Fire Propagation Index (FPI). The FPI values from small and large-scale tests provide very similar information for the fire propagation behaviors of materials, especially the non-propagating behavior beyond the ignition zone for FPI $\leq$ 6. The smoke yields for various materials from small and large-scale tests show good agreement. Thus SDI values from small and large-scale tests are in agreement. In the fire propagation tests, visual observations are made for the amount of smoke released and its blackness.

5.5 FPI and SDI for Specification Tested Product Listed Material

For the purpose of obtaining a Specification Tested Product Listing, the reported FPI shall be determined as the average from three individual propagation tests and one ignition series test.

The SDI shall be determined as the average from three individual combustion tests.

6 OPERATIONS REQUIREMENTS

A quality assurance program is required to assure that subsequent specimens of wall and ceiling materials or systems produced by the manufacturer shall present the same quality and reliability as the specific interior wall and ceiling materials or systems examined. Design quality, conformance to design, and performance are the areas of primary concern.

- Design quality is determined during the examination and tests, and is documented in the Specification Tested Report.
- Continued conformance to this standard is verified by the Facilities and Procedures Audit (F&PA).
- Quality of performance is determined by field performance and by periodic re-examination and testing.

6.1 Demonstrated Quality Control Program

6.1.1 The manufacturer shall demonstrate a quality assurance program which specifies controls for at least the following areas:

- existence of corporate quality assurance guidelines;
- incoming quality assurance, including testing;
- in-process quality assurance, including testing;
- final inspection and tests;
- equipment calibration;
- drawing and change control;
- packaging and shipping; and
- handling and disposition of non-conforming materials.

6.1.2 Documentation/Manual

There should be an authoritative collection of procedures/policies. It should provide an accurate description of the quality management system while serving as a permanent reference for implementation and maintenance of that system. The system should require that sufficient records are maintained to demonstrate achievement of the required quality and verify operation of the quality system.

6.1.3 Records

To assure adequate traceability of materials and products, the manufacturer shall maintain a record of all quality assurance tests performed, for a minimum period of two years from the date of manufacture.

6.1.4 Drawing and Change Control

- The manufacturer shall establish a system of product configuration control that shall allow no unauthorized changes to the product. Changes must be reported to, and authorized by, FM Approvals prior to implementation for production.

- The manufacturer shall assign an appropriate person or group to be responsible for, and require that, proposed changes to Specification Tested products be reported to FM Approvals before implementation. The manufacturer shall notify FM Approvals of changes in the product or of persons responsible for keeping FM Approvals advised by means of FM Approvals' Form 797, *FM Approved Product/Specification-Tested Revision Report or Address/Main Contact Change Report*.

- Records of all revisions to all Specification Tested products shall be maintained.

6.2 Facilities And Procedures Audit (F&PA)

6.2.1 An audit of the manufacturing facility is part of the investigation to verify implementation of the quality assurance program. Its purpose is to determine that the manufacturer's equipment, procedures, and quality program are maintained to insure a uniform product consistent with that which was Specification Tested.

6.2.2 These audits shall be conducted periodically but at least annually by FM Approvals or its representatives.

6.2.3 Specification Tested products or services shall be produced or provided at or from the location(s) audited by FM Approvals and as specified in the Report and/or Audit Manual. Manufacture of products bearing the Specification Tested Wording is not permitted at any other location without prior written authorization by FM Approvals.

6.3 Installation Inspections

Field inspections may be conducted to review an installation. The inspections are conducted to assess ease of application, and conformance to written specifications. When more than one application technique is used, one or all may be inspected at the discretion of FM Approvals.

6.4 Manufacturer's Responsibilities

The manufacturer shall notify FM Approvals of changes in product construction, components, raw materials, physical characteristics, coatings, component formulation or quality assurance procedures prior to implementation.

6.5 Manufacturing and Production Tests

Manufacturing and production tests shall be as indicated in the Audit Manual prepared by FM Approvals for each manufacturing location.

APPENDIX A: UNITS OF MEASUREMENT

LENGTH:	mm - "millimeters"; (in. - "inches") in. = mm / 25.4 mm - "millimeters"; (ft - "feet") ft = mm / 304.8 m - “meters”; (ft - “feet”) ft = m / 0.3048
MASS:	kg - "kilograms"; (lb - "pounds") lb = kg / 0.454
DENSITY:	kg/m^3 - kilograms per cubic meter”; (lb/ft^3 -“pounds per square foot”) $lb/ft^3 = 16.02 \times kg/m^3$
HEAT OF COMBUSTION:	kJ/g - “kilojoules/gram”; (BTU/lb -“British Thermal Units per pound”) BTU/lb = kJ/g / 0.002326
TEMPERATURE:	(°C - "degrees Celsius" (°F - "degrees Fahrenheit) °F = (°C x 1.8) + 32