American National Standard for Cleanroom Materials Flammability Test Protocol

ANSI/FM Approvals 4910

June 2004

Foreword

NOTE: This foreword is introductory only and is not part of American National Standard FM 4910.

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. It describes minimum performance requirements for materials that are intended for use in cleanroom facilities by evaluating the ability of the materials and, in turn, the system components to limit fire spread, and smoke damage resulting from a fire in the cleanroom environment.

This American National Standard has been developed according to the essential requirements of due process for standards development of the American National Standards Institute (ANSI). FM Approvals is an ANSI-accredited standards developer (ASD).

Approval of an American National Standard requires verification by ANSI that the principles of openness and due process have been followed and that a consensus of those directly and materially affected by the standard has been achieved. Consensus requires that all views and objections be considered, and that a concerted effort be made toward their resolution. Consensus is established when, in the judgment of the ANSI Board of Standards Review, substantial agreement has been reached.

The American National Standards Institute does not develop standards nor will it in any circumstances give an interpretation of any American National Standard. Requests for interpretations of this test standard should be addressed to FM Approvals.

ANSI regulations require that this American National Standard shall be revised, reaffirmed or withdrawn within five years of the date of publication.

FM Approvals
1151 Boston-Providence Turnpike
P. O. Box 9102
Norwood, MA 02062
U. S. A.

Phone: 781-762-4300
Fax: 781-762-9375
E-mail: Approvals@fmglobal.com

TABLE OF CONTENTS

1. INTRODUCTION

1.1 PURPOSE

This Test Standard states test requirements and procedures for the evaluation of materials used in semiconductor cleanroom occupancies mainly for, but not restricted to, use in the semiconductor industry. The test evaluates the materials' fire propagation behavior, expressed as Fire Propagation Index (FPI), and potential for smoke contamination, expressed as Smoke Development Index (SDI).

1.2 SCOPE

1.2.1 This standard describes minimum performance requirements for materials that are intended for use in cleanroom facilities. This standard evaluates the ability of the materials and, in turn, the system components to limit fire spread, and smoke damage resulting from a fire in the cleanroom environment.

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. All requirements (for the particular test method used) in the standard must be met for materials to be acceptable in cleanrooms.

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 has also been considered.

1.4 APPLICABLE DOCUMENTS

The following standards, test method descriptions and practices are related to this standard:

1. Tewarson, A., ''Generation of Heat and Chemical Compounds in Fires'', Chapter 4, Section 3, pp. 3-82 to 3-161. The SFPE Handbook of Fire Protection Engineering, 3rd Edition. The National Fire Protection Association Press, Quincy, MA, June 2002.
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. ASTM E 2058 (2002), ''Standard Test Methods for Measurement of Synthetic Polymer Material Flammability Using a Fire Propagation Apparatus (FPA),'' American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.
4. NFPA 287 (2001) ''Standard Test Methods for Measurement of Flammability of Materials in Cleanrooms Using a Fire Propagation Apparatus (FPA)'', National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269.

1.5 DEFINITIONS

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

Chemical Heat Release Rate ($\dot{Q}_{ch}$)	energy actually released by chemical reactions during a test
Critical Heat Flux (CHF)	the maximum heat flux at or below which there is no ignition.
Fire Propagation Index (FPI)	the ratio of the heat flux from the flame of the burning material to the material's ignition resistance. It is an indicator of the propensity of a material to support fire propagation beyond the ignition zone.
Flame Height	elevation of the tip of the contiguous flame region averaged over a 5-second interval
Ignition Zone	the area of the surface of a material heated by an outside source, resulting in ignition.
PHRR	peak heat release rate.
Smoke Development Index	smoke yield multiplied by FPI. It is an indicator of the potential for smoke contamination during fire propagation.
Smoke yield (y_s)	ratio of the total mass of smoke released to the total mass of the material vaporized.
Thermally Thick Behavior	having negligible temperature rise above ambient on the unexposed face of the material.
Thermally Thin Behavior	having a uniform temperature across the thickness of a material.
Thermal Response Parameter (TRP)	the quantification of the ignition resistance of a material.

2. GENERAL INFORMATION

2.1 CLEANROOMS

Due to the sensitivity of cleanroom environments, the high cost of construction and the high value of equipment and products produced and stored in them, significant damage can be caused by the presence of small amounts of contamination. As a result, it is useful to evaluate the ability of a material to limit fire propagation and restrict emission of particulates in the form of smoke. The criteria for the selection of materials for use in cleanrooms are based on tests conducted using the NFPA 287 Fire Propagation Apparatus (for determining FPI and SDI) or the Parallel Panel Test (when the FPI and SDI results are uncertain). The criteria used to assess cleanroom materials deal with limiting fire propagation beyond the ignition zone and limiting contamination of the cleanroom environment due to smoke.

2.2 FPI AND SDI

Materials examined using the NFPA 287 Fire Propagation Apparatus are evaluated based on the following two criteria:

2.2.1 The Fire Propagation Index (FPI), $(m/s^{1/2})/(kW/m)^{2/3}$, is used as a criterion for limiting fire propagation beyond the ignition zone. The criterion is based on the maximum value of FPI for a 15 second running average of the data during the entire test duration. A value ≤ 6 has been assigned for materials intended for use in cleanrooms.

2.2.2 The Smoke Development Index (SDI), $(m/s^{1/2})(g/g)/(kW/m)^{2/3}$, is used as a criterion for limiting smoke generation for non propagating fires beyond the ignition zone. A value ≤ 0.40 $(m/s^{1/2})(g/g)/(kW/m)^{2/3}$ has been assigned for materials intended for use in cleanrooms.

2.3 REQUIRED TESTS

2.3.1 The FPI and SDI indices shall be quantified in the Fire Propagation Apparatus. In order to do so, three types of tests shall be performed: 1) ignition test; 2) fire propagation test; and 3) combustion test.

2.3.2 The purpose of the ignition test is to determine the Thermal Response Parameter (TRP). The fire propagation test is conducted 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 conducted in order to quantify the yield of smoke. The yield of smoke shall be multiplied by the FPI value to calculate the SDI value.

2.3.3 The reported test data shall be rounded such that the FPI is rounded to the nearest whole number (1, 2). The SDI shall be rounded to the nearest tenth (0.1, 0.2).

2.4 UNCERTAIN RANGES OF FPI AND SDI

2.4.1 Experience has shown that an uncertain range of FPI and SDI exists. These ranges encompass FPI values > 6 and approaching 7 and/or SDI values > 0.4 and approaching 0.5. When the FPI and/or SDI value falls within these ranges, the material can exhibit fire propagation and smoke development characteristics undesirable of materials used in cleanroom environments. In these cases, the large scale Parallel Panel Test shall be conducted in order to determine the material's suitability.

2.4.2 The Parallel Panel Test shall be permitted to be used as an alternate to the Fire Propagation Apparatus regardless of a material's FPI or SDI. In cases where the FPI and SDI have been determined and a Parallel Panel Test has been conducted, the results of the Parallel Panel Test shall govern.

3. FIRE PROPAGATION APPARATUS TESTS

3.1 TEST SAMPLES

3.1.1 Ignition and Combustion Tests — samples of planar materials shall be 4 in x 4 in (± ⅛ in) [100 × 100 mm (± 3 mm)] square with a minimum thickness of ¼ in (6 mm).

3.1.2 Fire Propagation Tests — samples of planar materials shall be 12 in. ± ⅛ in. long × 4 in. ±⅛ in wide [305 mm (± 3 mm) long × 102 mm wide (± 3 mm)] with a minimum thickness of ¼ in. (6 mm) and a maximum thickness of ½ in. (13 mm) thick.

3.2 SAMPLE PREPARATION AND PLACEMENT IN THE APPARATUS

3.2.1 Ignition and Combustion Tests — the samples shall be wrapped in heavy duty aluminum sheet to tightly cover the edges and back of the sample. For the ignition test, the sample surface shall be sprayed with a single coat of flat black paint to compensate for surface absorptivity differences. The wrapped sample shall be placed horizontally, exposed surface up, in the Fire Propagation Apparatus at the location marked sample in Fig. 1. For the ignition test, the quartz tube shall not be used. For the combustion test, the sample shall be located inside the quartz tube.

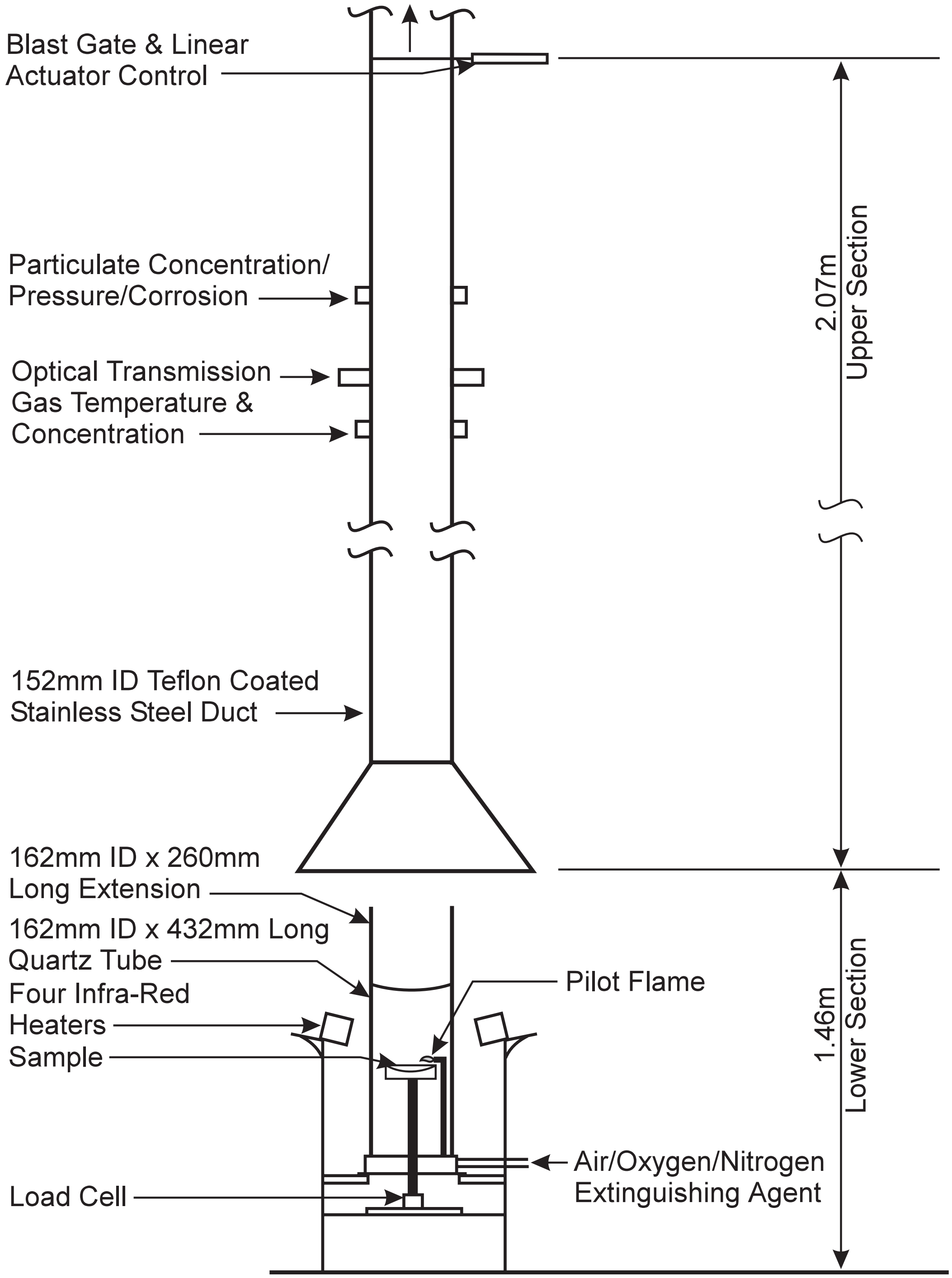

Fig. 1. Fire Propagation Apparatus for Ignition and Combustion Tests
(Quartz Tube Shown But Not Used for Ignition Tests)

3.2.2 Fire Propagation Test — the sides and back surface of the sample shall be covered with 0.125 in. (3.2 mm) thick ceramic paper and the sides and back of the sample shall be wrapped tightly with heavy duty aluminum sheet. The covered and exposed width of the sample shall then be wrapped at three evenly spaced locations with single turns of #24 gage nichrome wire. The sample shall be attached to a 19 in. ± ¼ in. [485 mm ± 6 mm] long and 5 in. ± ¼ in. [133 mm ± 6 mm] wide vertical steel ladder by two #24 gage nichrome wires and placed inside the quartz tube in the Fire Propagation Apparatus. The sample set up for the fire propagation test is shown in Fig. 2.

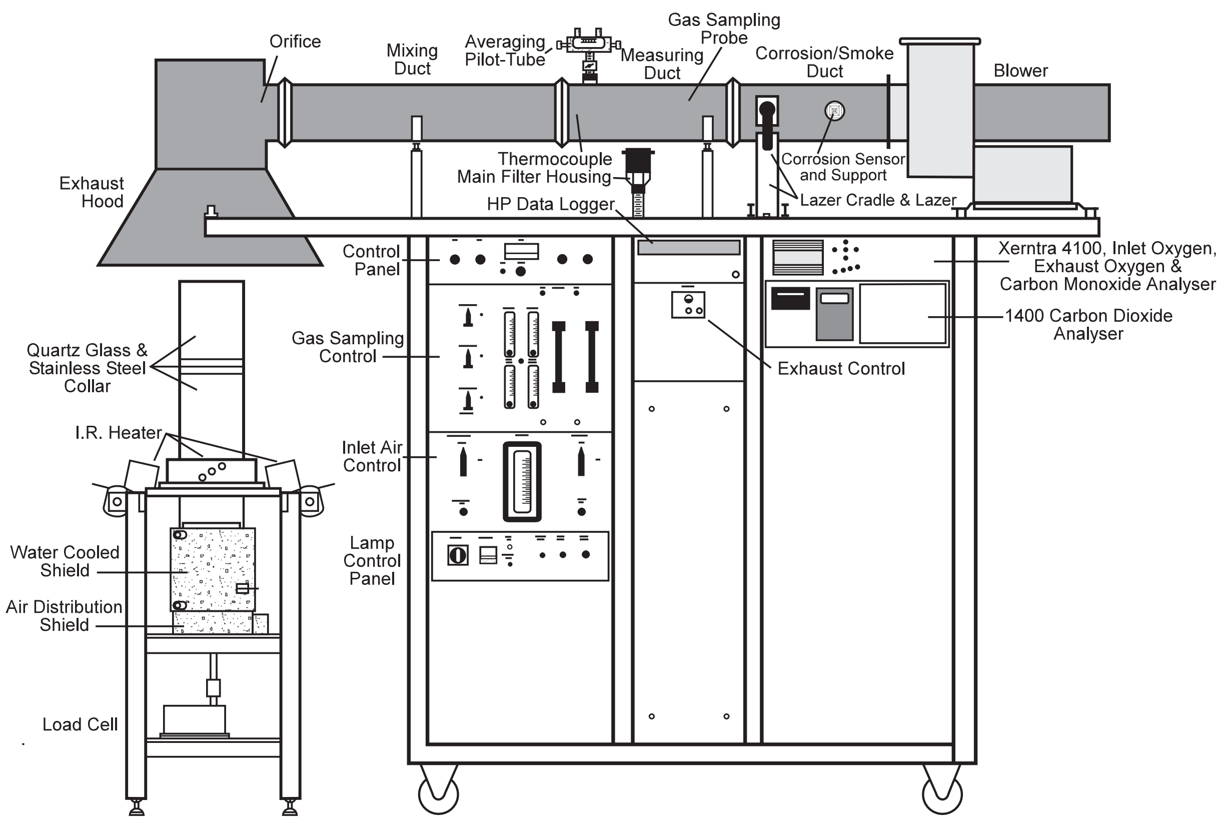

Fig. 2. Fire Propagation Apparatus

3.3 IGNITION TEST

3.3.1 The ignition test shall be performed in the open under natural airflow (no quartz tube in Fig. 1). The pilot consists of a vertical 0.25 in. ± 1⁄16 in. [6 mm ± 1.6 mm]) diameter copper tube with perforated ceramic tip bent at a right angle to be horizontal near the sample surface. The position of the burner shall be adjusted such that the tip of the burner shall be 0.4 in. ± 0.06 in. [10 mm ± 1.6 mm] above the sample surface and 0.4 in. ± 0.06 in. [10 mm ± 1.6 mm] from the perimeter of the sample, toward the centerline. A premixed ethylene-air mixture flowing through the burner shall be used as the combustible gas mixture for the pilot flame. The gas mixture that flows through the burner shall be adjusted such that the flame shall be blue and average 0.4 in (10 mm) in length.

3.3.2 In the ignition tests, sample surfaces shall be exposed to various external heat flux values. The heat flux value shall be fixed in each test with a tolerance of ± 5%. Both time to vapor formation and time to sustained-ignition shall be measured visually with a stop watch. Four to five tests shall be performed. The data shall be used to calculate the *Critical Heat Flux (CHF)* and *Thermal Response Parameter (TRP)*, using the *Ignition Test Data Calculations* described in Section 5.1.

3.4 FIRE PROPAGATION TEST

3.4.1 The fire propagation test shall be performed in the Fire Propagation Apparatus shown in Fig. 2, with a co-flowing oxygen-air mixture having 40% ±1 % oxygen concentration[1]. 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, shall be uniform within 5%. The mixture flow used in the test shall be set at 7 cfm ± 0.35 cfm (0.00333 m^3/s ± 0.0002 m^3/s).

3.4.2 In the Fire Propagation test, the bottom 4 in. ± ⅛ in. (100 mm ± 3 mm) of the 12 in (300 mm) long and 4 in (100 mm) wide vertical sample shall be exposed to 50 kW/m^2 of external heat flux in the presence of a pilot flame. Above this bottom 4 in (100 mm) area, defined as the ignition zone, the fire may propagate by itself, supported mainly by the heat flux from its own flame. The ignition zone shall be preheated by the external flux for one minute. If ignition and fire propagation has not occurred during this preheating period, the premixed ethylene-air pilot flame shall be moved into contact with the sample surface at a position 3 in. ± ¼ in. (75 mm ± 6 mm) from the bottom of the sample. Once ignition and fire propagation have been initiated, the pilot flame shall then be moved away from the sample.

3.4.3 The fire propagation test shall be continued until there are no visible flames and no material vapors are issuing from the front, sides, or back of the sample. The test shall be aborted if the sample starts to melt sufficiently to form a liquid pool and/or burns very intensely such that flames enter the sampling duct. When this situation occurs, the FPI shall be assigned a value > 6.

3.4.4 In the test, measurements shall be made for flame height and the generation rates of CO and CO_2 Data on CO_2 and CO generation rates shall be used to calculate the Fire Propagation Index (FPI) following the *Fire Propagation Test Data Calculations* described in Section 5.3.

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

3.5 COMBUSTION TEST

3.5.1 The combustion test shall be performed in co-flowing normal air in the Fire Propagation Apparatus (Fig. 1). 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, shall be uniform. The air flow used in the test shall be set at 7 cfm ± 0.35 cfm (0.00333 m^3/s ± 0.0002 m^3/s).

3.5.2 In the combustion test, the sample surface shall be exposed to 50 kW/m^2 of external heat flux. Measurements shall be made for: 1) times to vaporization and sustained ignition, 2) flame height, 3) release rates of material vapors (sample mass loss rate), convective energy, CO, CO_2, total hydrocarbons, and smoke. The data shall be used to calculate chemical and convective heat release rates, the heat of combustion and yield of smoke by using the *Combustion Test Data Calculations* described in Section 5.4.

4. PARALLEL PANEL FIRE TEST

4.1 PURPOSE

The Parallel Panel Test shall be performed when the FPI and/or SDI values obtained from the Fire Propagation Apparatus fall into the uncertain range (between 6 and 7 for FPI and between 0.4 and 0.5 for SDI) [see Par. 2.4].

4.2 PARALLEL PANEL TEST ARRANGEMENT

4.2.1 The Parallel Panel test shall be performed under the Fire Products Collector (FPC). This apparatus is at least a 1 MW heat release rate calorimeter. For details, see the Parallel Panel Test arrangement shown in Figs. 3 and 4.

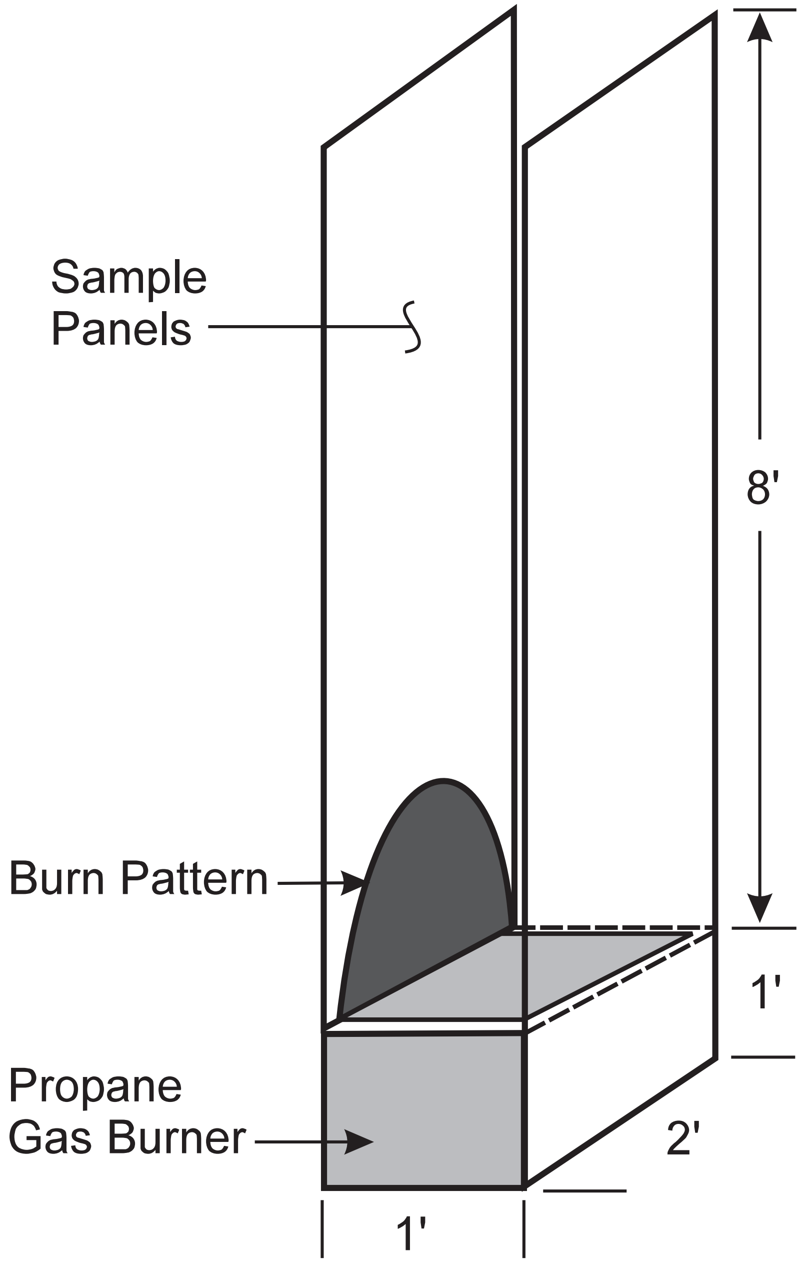

Fig. 3. Parallel Panel Test Arrangement

4.2.2 Two vertical parallel panels shall be constructed. Each panel shall be 8 ft ± ½ in. (2.4 m ± 13 mm) long and 2 ft ± ½ in. (0.61 m ± 13 mm) wide. The outer layer of each panel shall be rigid plywood backing of ½ inch (13 mm) minimum thickness. The inner layer shall be a minimum 1 inch (25 mm) thick calcium silicate insulation board. The samples shall be at least 0.375 in (9.5 mm) thick. This minimum sample thickness shall be achieved without the use of multiple material layers held together by fasteners or adhesives that are not a normal component of the sample material.

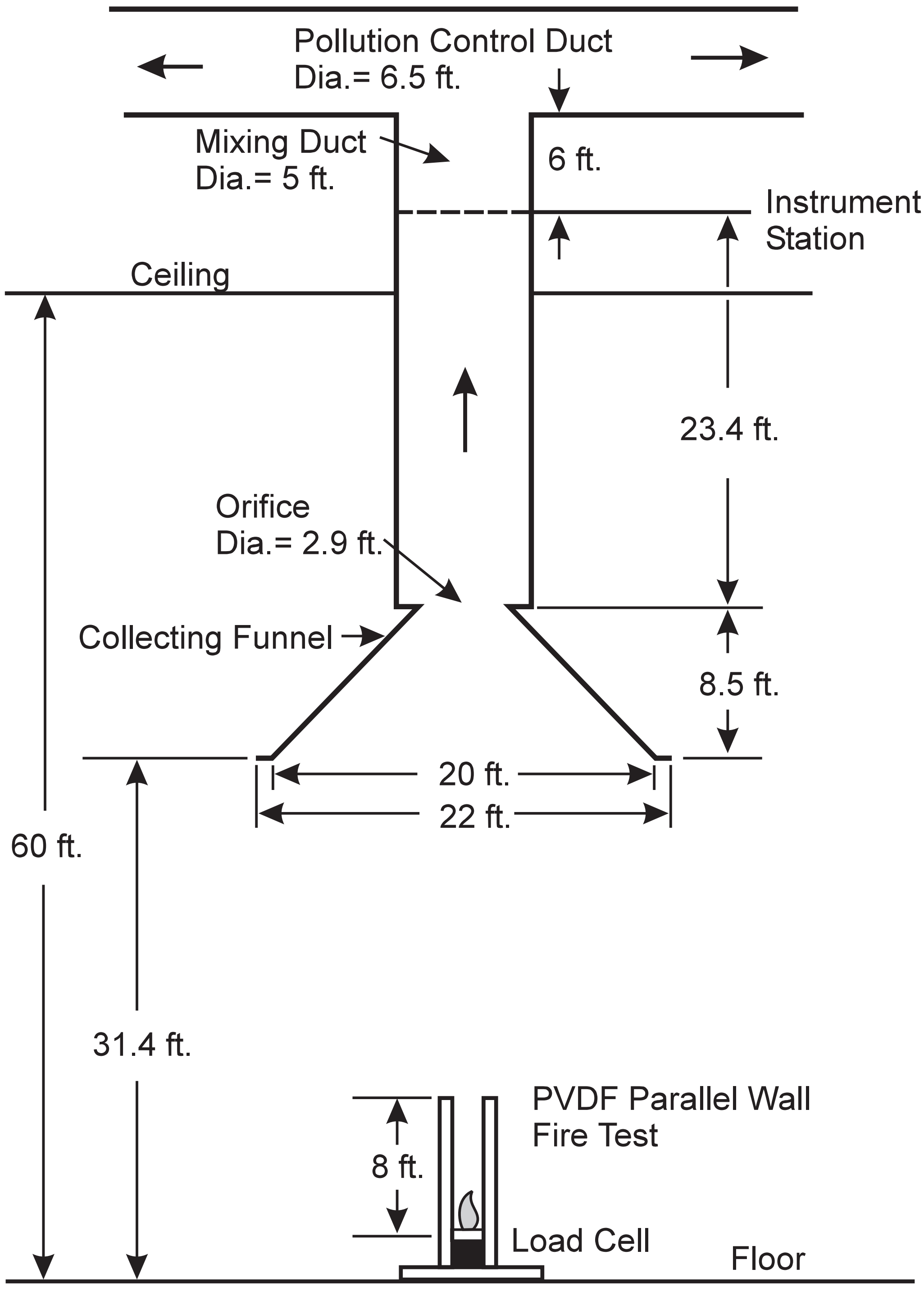

Fig. 4. The Fire Products Collector Used For Large Scale Tests in the Parallel Panel Fire Test

4.2.3 Each sample sheet shall be in thermal contact with the insulation board side of the panel through the use of eight fasteners and a nominal 1 inch (25 mm) angle iron clamped along the two 8 ft long edges of the sample. The ignition source, a nominal 2 ft (0.61 m ± 13 mm) long by 1 ft (0.31 m) wide by 1 ft (0.31 m) high propane sand burner shall be located between the assembled panels to provide a 1 ft ± ¼ in. (305 mm ± 6 mm) separation between sample sheets. The panel assembly shall be positioned such that the top surface of the burner is in contact with the bottom edge of the vertical sample material. To further insure that the sample separation distance is 1 ft ± ¼ in. (305 mm ± 6 mm) throughout the test, two threaded rods shall be installed to connect the panels together at the top of each long edge of the assembly.

4.2.4 A heat flux gauge shall be installed on the vertical centerline [± ¼ in. (± 6 mm)] of one panel at a height of 4 ft ± ¼ in. (1220 mm ± 6 mm). Propane gas flow to the burner shall be adjusted to provide a heat release rate of 60 kW and a heat flux of at least 40 kW/m^2 measured by the gauge at the 1 ft (305 mm) height when no sample material is present. The panel/burner assembly shall be placed on top of a load cell transducer.

4.3 CONDUCT OF TEST

4.3.1 The test duration shall be 12 minutes (+ 0.1 min, -0) consisting of propane sand burner operation at the prescribed 60 kW (±2 kW) heat release rate for the first 10 minutes (+ 0.1 min, -0), followed by 2 minutes (+ 0.1 min, -0) without burner operation. If at any time flaming is observed above the top of the panels while the burner is operating, propane flow to the burner shall cease. A hose stream shall be applied to the panels and the test terminated thirty seconds after stopping propane flow to the burner if flame height continues to increase above the top of the panels. The test shall also be terminated and a hose stream applied if the panels do not stay intact for any reason (i.e., obstruct the top of the sand burner).

4.3.2 During the test, measurements shall be made for the release rates of material vapors (mass loss rate, $\dot{m}$), heat flux to the panel at the three gauge locations, flame height and heat and smoke release rates using the FPC instrument section shown in Figure 4. Following the test, data on fire burn patterns shall also be collected.

5. PROCEDURES TO CALCULATE FLAMMABILITY DATA

5.1 IGNITION TEST DATA CALCULATION

In the ignition tests, time-to-ignition shall be measured at various external heat flux values. The time-to-ignition follows one of the following relationships:

5.1.1 <u>Thermally Thick Material Relationship at External Heat Flux Values Much Greater than the Critical Flux for Ignition</u>:

At applied heat flux much greater than the critical flux for ignition, materials exhibit thermally thick behavior, as follows:

(1)

$$\sqrt{\frac{1}{t_{ig}}} = \frac{\dot{q}''_e - \dot{q}''_{loss}}{TRP}$$

where t_{ig} is time-to-ignition(s), $\dot{q}''_e$ is the externally imposed heat flux (kW/m^2), $\dot{q}''_{loss}$ is the heat loss from unit exposed sample area, and *TRP* is the *Thermal Response Parameter* ($kW\text{-}s^{1/2}/m^2$).

5.1.2 Thermally Thin Material Relationship at External Heat Flux Values near the Critical Flux for Ignition

At applied heat flux near the critical flux for ignition, materials exhibit thermally thin behavior, as follows:

$$\frac{1}{t_{ig}} \propto \dot{q}''_e - \dot{q}''_{loss} \qquad (2)$$

5.1.3 In the ignition test procedure, data for the inverse of square root of time-to-ignition versus external heat flux shall be examined. Fig. 5 shows that the data are linear at higher external heat flux values, between 15 and 60 kW/m^2. A linear regression analysis of these data shall be performed and TRP value shall be the inverse of the slope of the resulting linear fit, using Eq. 1.

5.1.4 The maximum heat flux at or below which there is no ignition, defined as *Critical Heat Flux (CHF)* shall be determined from the intercept on the x-axis of the line obtained from the measured inverse of times-to-ignition versus external heat flux values. This follows from Equation 2, where inverse of ignition time is zero when the externally applied heat flux just equals the heat flux loss. Higher CHF and TRP values represent higher resistance to ignition and fire propagation.

5.2 CHEMICAL HEAT RELEASE RATE CALCULATION

5.2.1 Fire Propagation and Combustion Tests in the Fire Propagation Apparatus and Parallel Panel Tests under the Fire Products Collector require that chemical heat release and smoke generation rates be measured in a measurement duct where the flow is well-mixed.

5.2.1.1 The chemical heat release rate shall be determined from the following equations:

$$\dot{Q}_{ch} = 13{,}300\left(\dot{G}_{CO2} - \dot{G}^0_{CO2}\right) + 11{,}100\left(\dot{G}_{CO} - \dot{G}^0_{CO}\right) \qquad (3)$$

where $\dot{G}_{CO2}$ is the mass flow rate (kg/s) of CO_2 and $\dot{G}_{CO}$ is the mass flow rate (kg/s) of CO in the measurement duct of the Fire Propagation Apparatus or the Fire Products Collector and is the corresponding mass flow rate (kg/s) before specimen ignition. The coefficients 13,300 kJ/kg and 11,100 kJ/kg in Eq. 3 shall be replaced by coefficients recommended in Reference 1 if the composition of the specimen is known.

5.2.1.2 The mass flow rates of CO_2 and CO shall be determined from the following equations:

$$\dot{G}_{CO2} = A_d K \sqrt{P_{atm}/101{,}000}\sqrt{2 \times 353 \Delta p_m / T_d} \times 1.52 X_{CO2} \qquad (4)$$

$$\dot{G}_{CO} = A_d K \sqrt{P_{atm}/101{,}000}\sqrt{2 \times 353 \Delta p_m / T_d} \times 0.966 X_{CO} \qquad (5)$$

where A_d *(m^2)* is the cross sectional area and T_d the gas temperature for flow in the appropriate measurement duct, K (-) is the flow coefficient and Δp_m (Pa) the differential pressure output corresponding to the device sensing gas velocity in the measurement duct, P_{atm} (Pa) is actual atmospheric pressure during the measurement, X is the mole fraction of CO_2 or CO measured in the duct and 353 (kg K/m^3) is the product of air density and temperature at normal atmospheric pressure.

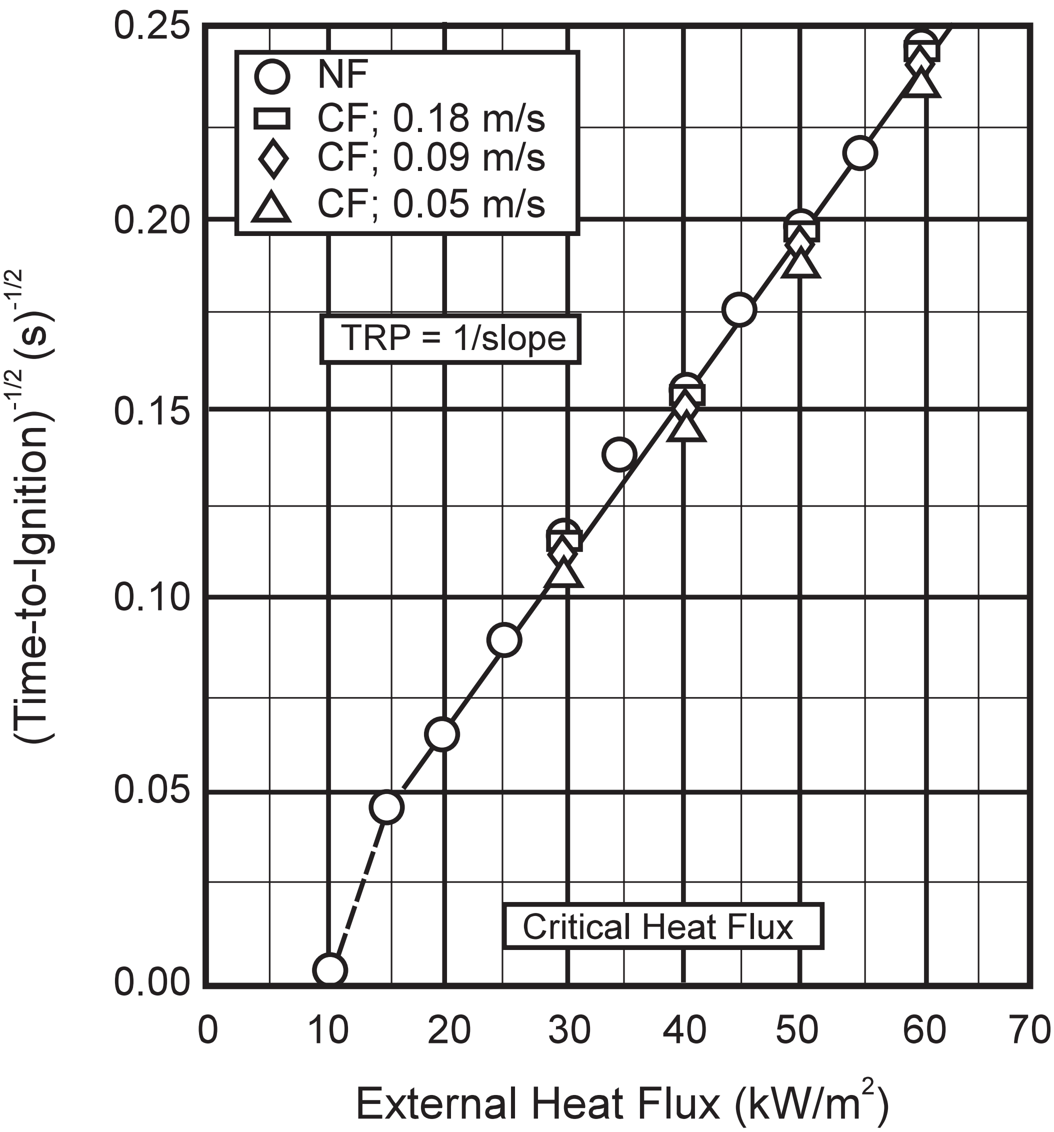

Fig. 5. Example of Time to Ignition Heat Flux Data from the Flammability Apparatus

NF = Natural Air Flow; CF = Cp Air Flow
Numbers in ( ) are Air Flow Velocities

5.2.2 Smoke generation rate, $\dot{G}_{s_s}$, shall be determined from the following equations:

$$\dot{G}_s = 0.157\lambda D\dot{v} \tag{6}$$

where $\lambda\ (\mu m)$ is the wavelength of light (which shall be in the range 0.6328 to 0.6348) used to measure the extinction coefficient, D (m^{-1}) in the measurement duct and $\dot{v}$ (m^3/s) is the total volumetric flow rate in the measurement duct.

5.2.3 The volumetric flow rate shall be determined from the following equation:

$$\dot{v} = A_d K \frac{\sqrt{2\Delta p_m T_d / 353}}{\sqrt{P_{atm} / 101{,}000}} \tag{7}$$

where all parameters have been defined above.

5.2.4 The extinction coefficient in the duct shall be determined from the following equation:

$$D = \frac{\ell n\left(I_a / I\right)}{L} \tag{8}$$

where I_a/I is the ratio of the average measured light intensity before the test to that during the test and L is the path length in the duct for the measurement of this light intensity.

5.3 FIRE PROPAGATION TEST DATA CALCULATION

5.3.1 The chemical heat release rate during a Fire Propagation Test shall be calculated from the expressions in Section 5.2 and then this calculated heat release rate shall be used in the following equation to calculate the Fire Propagation Index (FPI) as a function of time:

$$FPI = 1000 \frac{(0.42\,\dot{Q}'_{ch})^{1/3}}{TRP} \tag{9}$$

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

5.4 COMBUSTION TEST DATA CALCULATION

5.4.1 The chemical heat release rate and smoke generation rate during the Combustion Test shall be calculated from the expressions in Section 5.2. Release rates of chemical heat and material vapors (mass loss rate, $\dot{m}$) and the generation rate of smoke shall be integrated to calculate the total amount of chemical energy, material vapors and smoke that are released. These integrated quantities shall be used to calculate:

5.4.2 average chemical heat of combustion: calculated from the ratio of the total chemical energy to the total amount of material vapors released, as follows:

$$\text{Average Chemical Heat of Combustion} = \frac{\int \dot{Q}_{ch}\,dt}{\int \dot{m}\,dt} \tag{10}$$

5.4.2.1 average smoke yield: calculated from the ratio of the total amount of smoke released to the total amount of material vapors released, as follows:

$$y_s = \frac{\int \dot{G}_s dt}{\int \dot{m} dt} \quad (11)$$

5.5 SMOKE DEVELOPMENT INDEX (SDI) CALCULATION

5.5.1 Smoke Development Index *(SDI)* shall be defined as the average smoke yield multiplied by the Fire Propagation Index *(FPI)*, or,

$$SDI = FPI \times y_s \quad (12)$$

5.5.2 Since *FPI* is an indicator of the propensity of a material to support fire propagation beyond the ignition zone, *SDI* is an indicator of the total amount of smoke generated as the result of fire propagation.

5.6 PARALLEL PANEL FIRE TEST DATA CALCULATION

See Section 5.2, Eq. 6, for the calculation of smoke generation rate from Fire Products Collector measurements.

6. CONDITIONS OF ACCEPTANCE

6.1 FIRE PROPAGATION APPARATUS TESTS

When the Fire Propagation Apparatus is used to evaluate a material's suitability for use in cleanroom applications (see Section 3), materials shall meet both of the following conditions of acceptance:

$FPI \leq 6$ $SDI \leq 0.4$

6.2 PARALLEL PANEL FIRE TESTS

When the Parallel Panel Fire Test is used to evaluate a material's suitability for use in cleanroom applications (see Section 4), materials shall meet all five of the following conditions of acceptance.

1) The test shall not be terminated for any reason before the end of the normal 12 minute test duration.

2) After the burner is turned off, the measured heat release rate shall drop at least by half after one minute and at least by a factor of 4 after 2 minutes, from the maximum rate that is determined within 10 seconds before the burner is turned off.

3) Maximum observed flame height is less than or equal to 6 ft (1.83 m).

4) Maximum measured heat flux at the 4 ft (1.22 m) elevation is less than or equal to 40 kW/m^2.

5) The maximum measured smoke generation rate shall be less than or equal to 0.23 g/s during the 10 minute burn period, the measured smoke generation rate at the end of the 12 minute test duration shall be less than or equal to 0.07 g/s, and the smoke generation rated integrated over the total 12 minute test time shall be less than 60 g.

Printed in USA