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# **Examination Standard for Fume and Smoke Exhaust Duct Systems for Cleanrooms**

**Class Number 4922**

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# Foreword

This standard is intended to verify that the products and services described will meet stated conditions of performance, safety and quality useful to the ends of property conservation. The purpose of this standard is to present the criteria for examination of various types of products and services.

Examination in accordance with this standard shall demonstrate compliance and verify that quality control in manufacturing shall ensure a consistent and reliable product.

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# 1. INTRODUCTION

## 1.1 Purpose

- 1.1.1 This standard states testing and certification requirements for cleanroom ducts used for exhausting noncombustible chemical fumes, corrosive vapors and smoke in fire situations.
- 1.1.2 Testing and certification criteria may include performance requirements, marking requirements, examination of manufacturing facility(ies), audit of quality assurance procedures, and a surveillance program.

## 1.2 Scope

- 1.2.1 There are three classifications for industrial ducts (See Appendix B):
- Fume and Smoke Exhaust Duct Systems (FM 4921)
  - Fume and Smoke Exhaust Duct Systems for Cleanrooms (FM 4922)
  - Fume Exhaust Duct Systems (FM 4923)
- 1.2.2 This standard evaluates fume and smoke exhaust ducts for use in cleanrooms for their performance in regard to fire spread on the inner and outer surfaces of the duct, smoke damage due to the contamination caused by products of combustion from the duct exterior, the ability of the duct to be used for smoke removal.
- 1.2.3 This standard is not intended to determine the suitability for all end use conditions of a product. Conditions under which a duct assembly is used vary widely. This standard does not evaluate the corrosion resistance of the duct materials. It is the responsibility of the manufacturer to determine the suitability of the duct system for specific corrosive environments. The manufacturer should be consulted for recommended corrosive fume applications. Further, it is required that the manufacturer comply with all requirements of the Accepted Industry Practice for Industrial Duct Construction published by the Sheet Metal and Air Conditioning Contractors National Association, Inc. (SMACNA).

## 1.3 Basis for Requirements

- 1.3.1 The requirements of this 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 The requirements of this standard reflect tests and practices used to examine characteristics of ducts for the purpose of obtaining certification.

## 1.4 Basis for Certification

Certification is based upon satisfactory evaluation of the product and the manufacturer in the following major areas:

- 1.4.1 Examination and tests on production samples to evaluate:
- the suitability of the product;
  - the performance of the product as specified by the manufacturer and required for certification; and
  - the durability and reliability of the product.
- 1.4.2 An examination of the manufacturing facilities and audit of quality control procedures may be conducted 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. Subsequent

surveillance may be required by the certification agency in accordance with the certification scheme to ensure ongoing compliance.

### 1.5 Basis for Continued Certification

The basis for continual certification may include the following based upon the certification scheme and requirements of the certification agency:

- production or availability of the product as currently certified;
- the continued use of acceptable quality control procedures;
- compliance with the terms stipulated by the certification;
- satisfactory re-examination of production samples for continued conformity to requirements; and
- satisfactory surveillance audits conducted as part of the certification agency's product surveillance program.

### 1.6 Effective Date

The effective date of this certification standard mandates that all products tested for certification after the effective date shall satisfy the requirements of this standard.

The effective date of this standard is eighteen (18) months after the publication date of the standard for compliance with all requirements.

### 1.7 System of Units

Units of measurement used in this standard are United States (U.S.) customary units. These are followed by their arithmetic equivalents in International System (SI) units, enclosed in parentheses. The first value stated shall be regarded as the requirement. The converted equivalent value may be approximate. Conversion of U.S. customary units is in accordance with ANSI/IEEE/ASTM SI 10.

### 1.8 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the cited edition applies.

American Society for Testing and Materials (ASTM International)

- ANSI/IEEE/ASTM SI 10, *American National Standard for Metric Practice*
- ASTM D1929, *Standard Test Method for Determining Ignition Temperature of Plastics*
- ASTM E1642, *Standard Practice for General Techniques of Gas Chromatography Infrared (GC/IR) Analysis*
- ASTM E1252, *Standard Practice for General Techniques for Obtaining Infrared Spectra for Qualitative Analysis*
- ASTM E84, *Test Method for Surface Burning Characteristics of Building Materials*
- ASTM D240 *Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter*
- ASTM D482, *Standard Test Method for Ash from Petroleum Products*

- *ASTM E2058, Standard Test Methods for Measurement of Material Flammability Using a Fire Propagation Apparatus (FPA)*

American National Standards Institute/FM Approvals LLC (FM)

- *ANSI/FM 4910, American National Standard for Cleanroom Materials Flammability Test Protocol*
- *ANSI/FM 4880, American National Standard for Evaluating the Fire Performance of Insulated Building Panel Assemblies and Interior Finish Materials*

Sheet Metal and Air Conditioning Contractors National Association, Inc. (SMACNA)

*Accepted Industry Practice for Industrial Duct Construction*

## 1.9 Terms and Definitions

For purposes of this standard, the following terms apply:

### ***Chemical Fumes***

A gas, dust, smoke, or corrosive vapor given off by a substance as a result of a chemical transformation or in its original state.

### ***Corrosive Vapors***

Acids or alkalis capable of reacting with solid materials.

### ***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.

### ***Smoke Damage Index (SDI)***

Smoke yield multiplied by FPI. It is an indicator of the extent of smoke contamination of the environment during fire propagation.

### ***Thermal Response Parameter (TRP)***

Thermal Response Parameter is an indicator of the ignition resistance of a material.

### ***Peak Chemical Heat Release Rate (PCHRR)***

The peak value of heat released as a result of chemical reactions during a fire test.

### ***Gasket***

A round or rectangular shaped rubber, P.T.F.E. or other material used to seal joints in duct assemblies.

### ***Fluoropolymer Coatings***

Are blends consisting of resins and dry film fluoropolymer lubricants. The finished result produces a smooth, solid, coating, which provides corrosion and chemical resistance.

### ***Identified Components***

Are components of materials used in the make-up of duct assemblies, such as, but not limited to resin systems, fluoropolymer coatings, and/or joint sealants (i.e., gaskets). Identified Components are components that have been placed under the certification agency's surveillance program and can be utilized in duct assemblies.

***Significant Ingredient Change***

A change to a formulation of a certified product that has been reviewed by the certification agency and categorized as either a single ingredient change or a multiple ingredient change. Significant ingredient changes include, but are not limited to, changing an ingredient, changing a supplier of an ingredient, and/or changing manufacturing tolerances of ingredients of an existing certified formulation.

***Single Ingredient Change***

A single ingredient change is one significant component change, deemed by the certification agency, from the original formulation utilized for satisfying all required performance tests under this standard. Changes deemed by the certification agency as insignificant are not considered a single ingredient change.

***Multiple Ingredient Change***

A multiple ingredient change is two or more significant component changes, deemed by the certification agency, from the original formulation utilized for satisfying all required performance tests under this standard. One component change may be considered a multiple ingredient change if it is the second ingredient change from the original formulation utilized for satisfying all required performance tests under this standard. Changes deemed by the certification agency as insignificant are not considered a multiple ingredient change.

***Metal***

A solid material that is typically hard, shiny, malleable, fusible, and ductile, with good electrical and thermal conductivity (e.g., iron, gold, silver, copper, and aluminum, and alloys such as brass and steel).

***Glass Reinforced Plastics***

Line

***Liner***

A corrosion barrier/liner is when non-porous corrosion resistant materials are used in the interior of a steel or FRP air duct systems to protect from corrosive substances.

***Cleanroom***

An enclosed area in which the amount and size of particulate matter in air, temperature, humidity, and pressure are closely controlled.

***Smoke Exhaust Duct***

A smoke exhaust duct is used as part of the smoke and heat controls of a building to draw contaminated or smoke filled air from within a building.

***Fume Exhaust Duct***

A fume exhaust duct is used to capture, contain, and exhaust harmful or dangerous chemical fumes or corrosive vapors and particulate matter generated from manufacturing processes or in their natural state.



## 2. GENERAL INFORMATION

### 2.1 Product Information

2.1.1 Duct materials may be, but are not limited to, metal, coated metal, glass fiber reinforced plastics (FRP) . Configurations include preformed, rigid, round, rectangular, or oval ducts.

2.1.2 Resins used to fabricate certified ducts are eligible to be listed in the certification directory as Identified Components.

### 2.2 Certification Application Requirements

The manufacturer shall provide the following information with any request for certification consideration:

- A complete list of all models, types, sizes, and options for the products or services being submitted for certification consideration;
- general assembly drawings, complete set of manufacturing drawings, materials list, desired liner or wall thicknesses, anticipated marking format, piping schematics, nameplate format, brochures, sales literature, spec. sheets, installation, operation and maintenance procedures, etc...; and
- the name, contact information and location of duct, duct resin system and components 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 certification examination, the manufacturer shall submit samples for examination and testing based on the following:

- Sample requirements to be determined by the certification agency following review of the submitted information.
- A representative of the certification agency shall inspect the manufacturing facility for, witness the production of, and place their identifying mark on, each sample to be evaluated.
- The production of the resin and/or production of the sheet material used for testing manufactured from the resin shall be witnessed by a representative of the certification agency.
- If a formulated resin material or other formulated components from external suppliers are used in the composition of the material being examined for certification, prior to witnessing of the test samples, the certification agency may require a representative to inspect the manufacturing facility for, witness the production of, and place their identifying mark on, containers of the formulated component to be used in test sample production.

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

2.3.3 It is the manufacturer's responsibility to provide any necessary test fixtures, such as those which may be required to evaluate the ducts.

2.3.4 All submitted products shall be representative of production material. Manufacture of the resin system and duct material tested shall be monitored by a representative of the certification agency.

### 3. GENERAL REQUIREMENTS

#### 3.1 Review of Documentation

- 3.1.1 During the initial investigation and prior to physical testing, the manufacturer's specifications and details shall be reviewed to assess the ease and practicality of installation and use. The certification examination results may further define the limits of the final certification.

#### 3.2 Marking

- 3.2.1 Each section of duct, elbows and fittings shall bear the manufacturer's name, model number or trade name, and the certification agency's mark of conformity with the words "Duct Approved Fume And Smoke Exhaust for Cleanrooms".
- 3.2.2 When ducts are produced using more than one resin system, markings shall include a code or notation which corresponds to the resin system used.
- 3.2.3 Each container of resin that is listed as an Identified Component shall bear a label indicating the resin manufacturer's name, product designation, and the wording that it is an "Identified Component Resin System".
- 3.2.4 Labels denoting certification or status as an Identified Component Resin System shall be applied by the manufacturer only within and on the premises of manufacturing locations that are under the certification agency's surveillance audit program.
- 3.2.5 All markings shall be legible and durable.

#### 3.3 Manufacturer's Installation and Operating Instructions

- 3.3.1 The manufacturer shall:
- prepare instructions for the installation, maintenance, and operation of the product;
  - provide facilities for repair of the product and supply replacement parts, if applicable; and
  - provide services to ensure proper installation, inspection, or maintenance for the product where it is not reasonable to expect the average user to be able to provide the installation, inspection, or maintenance.

#### 3.4 Other Requirements

- 3.4.1 If the manufacturer wishes to obtain certification for diameters and sizes greater than 60 in. (1524 mm), the 16 ft (4.9 m) High Parallel Panel Fire Test (Section 4.4) is required. If the duct is equipped with an interior liner or interior coating system, the thickness of the interior liner or coating system certified shall be representative of the largest diameter/size duct for which Certification is desired, or additional certification testing may be required. In the case of a single wall duct, the single wall duct thickness shall be representative of the largest diameter/size duct for which Certification is desired, or additional certification testing may be required.
- 3.4.2 If the material produces excessive quantities of smoke during the fire tests making it difficult to determine the fire spread performance, additional testing may be required.
- 3.4.3 Vertical sections of duct shall not exceed 15 ft (4.6 m) unless so certified, nor penetrate to other fire areas.

### 3.5 Calibration

- 3.5.1 Each piece of equipment used to verify the test parameters shall be calibrated within an interval determined on the basis of stability, purpose, and usage. A copy of the calibration certificate for each piece of test equipment is required. The certificate shall indicate that the calibration was performed against working standards whose calibration is certified and traceable to an acceptable reference standard and certified by an ISO/IEC 17025 accredited calibration laboratory. The test equipment shall be clearly identified by label or sticker showing the last date of the calibration and the next due date. A copy of the service provider's accreditation certificate as an ISO/IEC 17025 accredited calibration laboratory should be available.
- 3.5.2 When the inspection equipment and/or environment is not suitable for labels or stickers, other methods such as etching of control numbers on the measuring device are allowed, provided documentation is maintained on the calibration status of this equipment.

### 3.6 Formulation Changes

- 3.6.1 All formulation changes of a certified duct shall be reviewed by the certification agency prior to implementing a change. Formulation changes include, but are not limited to:
- ingredient change(s),
  - changing a supplier of an ingredient, and/or
  - changing manufacturing tolerances of ingredients of an existing certified formulation.

Formulation changes shall be determined by the certification agency as significant or insignificant. Significant changes will be categorized by the certification agency as either a single or multiple ingredient change.

- 3.6.1.1 A single ingredient change shall require:

- a thermal response parameter (TRP) test,
- a propagation test and
- a combustion test

The thermal response parameter (TRP) test and peak chemical heat release rate from the propagation test are used to determine the FPI of the material. The FPI and the smoke yield from the combustion test are used to determine the SDI of the material.

The TRP, FPI and SDI of the reformulated material shall be less than or equal to the TRP, FPI and SDI of the original formulation utilized for satisfying all required performance requirements under this examination standard.

- 3.6.1.2 Only one single significant ingredient change shall be allowed from the original formulation utilized for satisfying all required performance tests under this standard. Any further ingredient changes shall be considered a multiple ingredient change.
- 3.6.1.3 A multiple ingredient change requires all applicable performance tests under this standard to be conducted.
- 3.6.1.4 An alternate supplier of an ingredient shall be reviewed by the certification agency in order to determine if any testing is necessary. At the discretion of the certification agency, alternate suppliers may be considered a single or multiple ingredient change as detailed above.

- 3.6.1.5 All changes to the manufacturing tolerances of ingredients of an existing certified formulation shall be reviewed by the certification agency. Changes to tolerances that require testing may be considered a single or multiple ingredient change as detailed above.
- 3.6.1.6 All changes to the formulation shall be submitted with adequate information for review. This information can include, but is not limited to the following: safety data sheets, technical data sheets, formulation details, etc.

### 3.7 Determination of Average Coating Thickness for Metal Ducts

Manufacturers must establish a target coating thickness value prior to applying for certification. They shall demonstrate that the target thickness can be consistently achieved through quality production practices and verified by individual measurement readings taken during final QC inspection.

- 3.7.1 All values are based on the nominal diameters shown below for ducts that are a nominal 4 ft (1.2 m) in length.
- 3.7.2 Testing of interiorly coated stainless steel ducts shall be at the greatest coating thickness for which certification is desired.
- 3.7.3 The allowable average coating thickness certified is that which is witnessed during the final QC, and subsequently fire tested.
- 3.7.4 All measurements shall be recorded and kept on file for inspection during surveillance audits.
- 3.7.5 Readings are taken at three (3) locations along the length of the duct. Measurements shall be taken 6 to 10 inches (150 to 250 mm) in from each end of the duct and at the approximate midpoint.
- 3.7.6 The minimum number of readings shall be taken at each location as shown in Table 1. The locations are defined as above. One measurement shall be taken adjacent to the longitudinal weld seam with the other readings approximately equally spaced along the circumference.
- 3.7.7 At each location (both ends and midpoint), the average of equally spaced readings shall not exceed the maximum allowed thickness by more than 15% with no individual reading at any location exceeding the maximum allowed thickness by more than 25%. Further, the average thickness of all readings shall not exceed the maximum allowed thickness. See example below of the maximum average coating thickness and allowable readings:

Maximum average coating thickness allowed: 0.011 in. (0.28 mm)

Maximum average reading allowed [ $t_{ave} \text{ max} \times 1.15$ ] 0.0127 in. (0.323 mm)

Maximum individual reading [ $t_{ave} \text{ max} \times 1.25$ ] 0.014 in (0.356 mm)

- 3.7.8 For lengths that exceed 4 ft (1.2 m), the number of locations and measurements shall increase proportionally to the length of the duct in relation to the standard 4 ft (1.2 m) length. For diameters that exceed 5 ft (1.5 m), the number of locations and measurements shall increase proportionally to the diameter of the duct as shown in Table 1.

Table 1

Nominal Diameter	Number of Measurements per Location	Total Number of Measurements per Piece
Less than 12 inches (300 mm) if applicable	4	12
12 inches (300) up to and including 28 inches (700 mm)	6	18
Greater than 28 inches (700 mm) up to and including 44 inches (1100 mm)	8	24
Greater than 44 inches (1100 mm) up to and including 60 inches (1500 mm)	10	30
Greater than 60 inches (1500 mm) up to and including 76 inches (1930 mm)	12	36

### 3.8 Determination of Duct Liner and Wall Thicknesses for Non-Metallic Ducts

Manufacturers must establish target duct wall thickness values prior to applying for certification. They shall demonstrate that the target thickness can be consistently achieved through quality production practices and verified by individual measurement readings taken during final QC inspection.

- 3.8.1 All values are based on the nominal diameters shown below for ducts that are a nominal 4 ft (1.2 m) in length.
- 3.8.2 Testing of interiorly lined ducts shall be at the greatest thickness for which certification is desired.
- 3.8.3 The allowed liner thickness approved is that which is witnessed during the final QC, and subsequently fire tested.
- 3.8.4 All measurements shall be recorded and kept on file for inspection during surveillance audits.
- 3.8.5 Readings are taken at three (3) locations along the length of the duct. Measurements shall be taken 6 to 10 inches (150 to 250 mm) in from each end of the duct and at the approximate midpoint.

- 3.8.6 The minimum number of readings shall be taken at each location as shown in Table 2. The locations are defined as above. Measurements shall be taken longitudinally with the other readings approximately equally spaced apart along the circumference.
- 3.8.7 At each location (both ends and midpoint), the average of equally spaced readings shall not exceed the maximum allowed thickness by more than 5%. A tolerance of 5% is acceptable given the average thickness of all readings does not exceed the allowed thickness.
- 3.8.8 For lengths that exceed 4 ft (1.2 m), the number of locations and measurements shall increase proportionally to the length of the duct in relation to the standard 4 ft (1.2 m) length. For diameters that exceed 5 ft (1.5 m), the number of locations and measurements shall increase proportionally to the diameter of the duct as shown in Table 2.

Table 2

<b>Nominal Diameter</b>	<b>Number of Measurements per Location</b>	<b>Total Number of Measurements per Piece</b>
Less than 12 inches (300 mm) if applicable	4	12
12 inches (300) up to and including 28 inches (700 mm)	6	18
Greater than 28 inches (700 mm) up to and including 44 inches (1100 mm)	8	24
Greater than 44 inches (1100 mm) up to and including 60 inches (1500 mm)	10	30
Greater than 60 inches (1500 mm) up to and including 76 inches (1930 mm)	12	36

## 4. PERFORMANCE REQUIREMENTS

### 4.1 Duct Diameters and Sizes $\leq 5$ ft. (1.5 m)

In order to qualify as a certified duct for both noncombustible fume or corrosive vapor and smoke exhaust used in cleanrooms, the duct must exhibit its ability to retain its structural integrity and continue to exhaust smoke as well as limiting fire spread by satisfying the performance criteria listed below.

#### 4.1.1 Horizontal Duct Fire Test

Requirements:

Performance shall be considered satisfactory if all the following conditions are met during the 15 minute duration of the test:

- flaming shall not spread on the interior of the duct from the fire exposed end to the 23 ft (7.0 m) point;
- the interior duct temperature recorded at the 23 ft (7.0 m) point shall not exceed 1000°F (538°C);
- the duct and all field applied joints shall maintain their structural integrity without developing any through openings that may emit fire, smoke or other particulates;
- flames shall be continuous entrained into the inlet end of the duct after ignition of the ducts interior and cannot veer off for a period greater than 10 seconds;
- there shall be no flaming on the exterior of the duct due to autoignition or temperature transmission from the interior of the duct. In cases where flaming appears on the exterior surface as a result of the external fire exposure, the flaming shall be intermittent in nature and shall not propagate beyond the first field joint located 4 ft (1.2 m) from the fire exposure;
- no portion of the duct or joint material shall fall, drip or melt off the test sample;
- no smoke or other particulates shall be emitted from the inlet end or the exterior surface of the duct (Exception: smoke or other particulates shall be allowed to be emitted from the exterior surface of the duct provided that the exterior surface meets the requirements of ANSI/FM 4910, Cleanroom Materials Flammability Test Protocol.

Test/Verification

The horizontal apparatus is used to evaluate duct diameters and sizes ranging up to 5 ft. (1.5 m) for horizontal runs and maximum vertical runs of 15 ft. (4.6 m). See sections 4.1.5 (Vertical Duct Fire Test) or 4.2.2 (16 ft High Parallel Panel Test) for vertical runs  $> 15$  ft. (4.6 m).

The apparatus consists of a 24 ft (7.3 m) length of horizontal duct 12 in. (305 mm) in diameter or size, incorporating at least two field-assembled joints, an exhaust blower with an adjustable damper, a draft-free enclosure or draft shield containing the fire exposure, and supporting framework with supports spaced in accordance with the manufacturer's installation instructions. The first joint is located 4 ft (1.2 m) from the exposure source. If the manufacturer wishes to obtain certification for ducts smaller than 12 in. (305 mm) in diameter an additional test is required on the smallest diameter or cross section (minimum 4 in. [100 mm] diameter) for which the certification is desired. The duct is supported above the floor with the duct intake end inserted into a 4 ft  $\times$  4 ft  $\times$  7 ft (1.2  $\times$  1.2  $\times$  2.35 m) high draft shield (3 walls and a roof), flush with the inside surface of the enclosure wall. The exhaust end is connected through a transition piece to the blower which pulls air through the duct at the required air velocities.

The fire exposure consists of a square steel pan 1 ft  $\times$  1 ft  $\times$  8 in. (0.3 m  $\times$  0.3 m  $\times$  0.2 m) deep, containing 4 in. (100 mm) of heptane on 3 in. (75 mm) of water. At the start of the test the liquid surface is 24 in. (0.6 m) below the inside bottom surface of the duct. The pan itself is positioned so that it is centered directly below the central axis of the duct, and its closest vertical surface is 1½ in. (38 mm) ahead of the duct opening. Four thermocouples are positioned 1 in. (25 mm)

below the top inside surface of the duct, directly above the central axis, monitor temperatures during the test. The four points of measurements are 6 in. (152 mm), 6 ft (1.8 m), 12 ft (3.7 m), and 23 ft (7.0 m) from the fire exposed end of the duct.

The induced draft velocity through the duct is measured at the center of the horizontal duct 6 ft (1.8 m) from the exhaust end. Velocity measurements are taken at ambient temperature before each test. The induced draft velocity for this test is adjusted to 600 ft/min (3 m/sec). The fire exposure source shall be kept covered while the draft velocity is obtained and until the test is started. After the required draft velocity has been verified and set, the fire exposure source is ignited to start the test. Observations of the performance of the duct and the temperatures achieved within the duct are made continuously for the full 15 minutes of the test.

#### 4.1.2 Smoke Removal Ability Test

##### Requirement

Performance shall be considered satisfactory if the following conditions are met:

- there shall be no reduction in the cross-sectional area of the duct;
- there shall be no interruption or reduction of air movement through the duct;
- no smoke shall be emitted from the inlet end or from the exterior surface of the duct and field applied joints (Exception: smoke or other particulates shall be allowed to be emitted from the exterior surface of the duct provided that the exterior surface is tested in accordance with, and meets the requirements of ANSI/FM 4910, Examination Standard for Cleanroom Materials.
- conformance to all performance criteria as specified in Paragraph 4.1.1 above.

##### Test/Verification

After subjecting the duct to the horizontal fire exposure test Paragraph 4.1.1, the ability of the duct to exhaust smoke effectively shall be evaluated.

Immediately following the Horizontal Fire Test, the exposure source is removed and the fan speed increased to induce an air velocity of 2000 ft/min (10 m/sec)  $\pm$  100 ft/min (0.5 m/sec), and maintained for 10 minutes. The induced draft velocity through the duct shall be measured at the center of the duct 18 ft (5.5 m) from the intake. Velocity measurements shall be taken at ambient temperature readings preceding the Horizontal Fire Test.

#### 4.1.3 Cleanroom Materials Test for Duct Exterior

##### Requirement

The ability of the duct's exterior surface to limit fire propagation and restrict the emission of smoke shall be investigated. Materials tested in the Fire Propagation Apparatus (FPA) shall satisfy FPI and SDI requirements listed below.

- $FPI \leq 6 \text{ (m/s}^{1/2}\text{)/(kW/m)}^{2/3}$ . The FPI is used as a criterion for non fire propagation beyond the ignition zone. The FPI value is the maximum value calculated from a 15 second running average of the data.
- $SDI \leq 0.40 \text{ [(m/s}^{1/2}\text{)/(kW/m)}^{2/3}] \text{ [g/g]}$ . The SDI is used as a criterion for significantly limiting smoke concentration for non propagating fires beyond the ignition zone.

Materials not examined in the FPA shall be subjected to the 8 ft. (2.4 m) Parallel Panel Test:

- The test shall not be terminated for any reason before the end of the normal 12 minute test duration.
- Two minutes after the burner is turned off, the measured heat release rate shall drop to 25%



of the maximum rate that is determined within 10 seconds before the burner is turned off.

- Maximum observed average flame height shall be less than or equal to 6 ft (1.83 m).
- Maximum measured heat flux at 4 ft (1.22 m) above the sand burner shall be less than, or equal to, 40kW/m<sup>2</sup>.
- 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. The smoke generation rated integrated over the total 12 minute test time shall be less than 60 g.

Test/Verification

ANSI/FM 4910, Cleanroom Materials Flammability Test Protocol

#### 4.1.4 Fire Propagation Index (FPI) Test

The FPI Test is used to determine the Fire Propagation Index of the duct interior surface or the duct wall material in cases where the duct is made up of a single wall construction.

Requirement

The ability of the duct's interior lining surface to limit fire propagation shall be investigated. Materials shall satisfy the FPI requirement listed below.

- $FPI \leq 7 \text{ (m/s}^{1/2}\text{)/(kW/m)}^{2/3}$ . The FPI is used as a criterion for non fire propagation beyond the ignition zone. The FPI value is the maximum value calculated from a 15 second running average of the data.

Test/Verification

ASTM E2058, Standard Test Methods for Measurement of Material Flammability Using a Fire Propagation Apparatus (FPA)

#### 4.1.5 Vertical Duct Fire Test (Optional)

The Vertical Duct Fire Test may be used to assess vertical runs >15 ft (4.6 m). As an alternative, see section 4.2.2 below.

Requirement

Performance shall be considered satisfactory if all the following conditions are met during the 15 minute duration of the test:

- flaming on the interior of the duct shall not spread to within 10 ft (3.1 m) of the top of the duct;
- flaming on the exterior of the duct shall not spread to within 5 ft (1.6 m) of the top of the duct
- the interior duct temperature recorded 1 ft (0.3 m) from the top of the duct shall not exceed 1000°F (538°C);
- the duct and all field applied joints shall maintain their structural integrity without developing any through openings;
- no portion of the duct or joint material shall fall, drip or melt off the test sample;
- no smoke or other particulates shall be emitted from the inlet end or the exterior surface of the duct (Exception: smoke or other particulates shall be allowed to be emitted from the exterior surface of the duct provided that the exterior surface meets the requirements of ANSI/FM 4910, Cleanroom Materials Flammability Test Protocol.

NOTE: Passing this test with a 40 ft (12.2) long duct grants certification to unlimited height.

Passing at any other length limits vertical runs to the length tested.

#### Test/Verification

The test set-up consists of a specified length ( $>15$  ft (4.6m),  $\leq 40$  ft (12.2 m)) of vertical duct 12 in. (305 mm) in diameter, incorporating field-assembled joints every 5 ft (1.5 m) and supporting framework with supports spaced in accordance with the manufacturer's installation instructions. The vertical duct shall extend down to within 1 ft (0.3 m) of the exposure. The first joint shall be located 5 ft (1.5 m) from the bottom edge of the duct with additional field joints spaced every 5 ft (1.5 m) thereafter. If the manufacturer wishes to obtain certification for ducts smaller than 12 in. (305 mm) in diameter an additional test is required on the smallest diameter or cross section (minimum 4 in. [100 mm] diameter) for which the certification is desired, in addition to the 12 in. (305 mm) diameter test. Testing of the smaller diameter vertical run can be waived at the sole discretion of the certification agency if the 12 in. (305 mm) diameter test is deemed more critical during the Horizontal Duct Fire Test.

The fire exposure consists of a square steel pan 1 ft  $\times$  1 ft  $\times$  8 in. (0.3 m  $\times$  0.3 m  $\times$  0.2 m) deep, containing 4 in. (100 mm) of heptane on 3 in. (75 mm) of water. At the start of the test the liquid surface shall be 12 in. (305 mm) below the inside bottom surface of the duct. The pan itself shall be positioned directly below the central axis of the duct. During the test the fire is then drawn into the duct where it may or may not ignite the duct and propagate the full length of the duct.

Thermocouples are positioned 1 in. (25 mm) from the inside surface of the duct to monitor temperatures during the test. The first thermocouple shall be located approximately 5 ft (1.5 m) above the bottom of the duct with subsequent thermocouples placed on approximately 5 ft (1.5 m) centers except for the uppermost thermocouple which is placed 1 ft (0.3 m) from the top edge of the duct.

The fire exposure source is ignited to start the test. Observations of the performance of the duct and the temperatures achieved within the duct are made continuously for the full 15 minutes of the test.

## 4.2 Duct Diameters and Sizes $> 5$ ft. (1.5 m)

### 4.2.1 All Tests as Required per 4.1.1 – 4.1.4 Above

### 4.2.2 16 ft (4.9 m) High Parallel Panel Test

The 16 ft (4.9 m) High Parallel Panel Fire Test is used to determine performance of ducts with diameters or sizes  $> 5$  ft. (1.5 m). The 16 ft (4.9 m) High Parallel Panel Fire Test may also be used as an alternative to the Vertical Duct Fire Test to assess vertical runs greater than 15 ft (4.6 m) as noted in Paragraph 4.1.5 above. The 16 ft (4.9 m) High Parallel Panel Fire Test supersedes an FPI value  $\leq 7$ .

#### Requirement

For ducts with diameters and sizes  $> 5$  ft. (1.5 m), a 16 ft (4.9 m) High Parallel Panel fire test with a propane gas ignition source of 360 kW shall be required.

The peak gross chemical heat release rate (PCHRR) during a 16 ft (4.9 m) High Parallel Panel fire test with a propane gas ignition source of 360 kW shall be less than, or equal to, 830 kW.

#### Test/Verification:

ANSI/FM 4880, Appendix D: 16 ft (4.9 m) High Parallel Panel Test

### **4.3 Small Scale Quality Control Tests**

A series of laboratory scale quality control tests are also required for certification. These tests are designed to allow monitoring of quality controls exercised in the manufacturing process and/or to characterize individual materials used in the make-up of the duct assembly.

#### **4.3.1 Heat Content**

Requirement

Oxygen bomb calorimetry tests shall be conducted on nonmetallic materials used in the make-up of the duct assembly.

Note: These tests are conducted for identification purposes. The certification agency places no limits on the values obtained for the purpose of this standard.

Test/Verification:

ASTM D240, Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter

#### **4.3.2 Ignition Properties**

The following tests shall be conducted on nonmetallic materials used in the make-up of the duct assembly.

Requirement:

The self-ignition and flash-ignition temperatures of nonmetallic materials used in the make-up of the duct assemblies shall be determined.

Note: These tests are conducted for identification purposes. The certification agency places no limits on the values obtained.

Test/Verification:

ASTM D1929, Standard Test Method for Determining Ignition Temperature of Plastics

#### **4.3.3 Ash Content**

Ash content shall be conducted on nonmetallic materials used in the make-up of the duct assembly.

Requirement:

The total ash content of materials used in the make-up of the duct assemblies shall be determined.

Note: These tests are conducted for identification purposes. The certification agency places no limits on the values obtained.

Test/Verification:

ASTM D482, Standard Test Method for Ash from Petroleum Products

#### **4.3.4 Fire Propagation Apparatus (FPA) Testing**

Requirement:

The Ignition, Fire Propagation and Combustion Tests shall be conducted on all nonmetallic materials used in the make-up of the duct assembly.

Test/Verification:

ASTM E2058, Standard Test Methods for Measurement of Material Flammability Using a Fire Propagation Apparatus (FPA)

#### **4.3.5 Identification Tests – Standard Practice for General Techniques for Obtaining Infrared Spectra for Qualitative Analysis**

Requirement:

For nonmetallic material used in the make-up of the duct assemblies and other components as applicable, FTIR spectra shall be determined and reported at the sole discretion of the certification agency.

Note: These tests are conducted for identification purposes. There are no limits on the values obtained.

Test/Verification:

ASTM E1252, Standard Practice for General Techniques for Obtaining Infrared Spectra for Qualitative Analysis

#### **4.3.6 Identification Tests – Thermal Desorption Gas Chromatography Mass Spectrometry (TD/GC/MS)**

Requirement:

For nonmetallic material used in the make-up of the duct assemblies and other applicable materials, TD/GC/MS Spectrograms shall be determined and reported at the sole discretion of the certification agency.

Note: These tests are conducted for identification purposes. There are no limits on the values obtained.

Test/Verification:

ASTM E1642, Standard Practice for General Techniques of Gas Chromatography Infrared (GC/IR) Analysis

## 5 MANUFACTURER'S REQUIREMENTS

### 5.1 Demonstrated Quality Control Program

5.1.1 A quality assurance program is required to assure that subsequent batch of resin or duct and fittings produced by the manufacturer shall present the same quality and reliability as the specific duct and resin sample(s) examined. Design quality, conformance to design and performance are the areas of primary concern.

- Design quality is determined during the examination and tests and may be documented in the certification report.
- Continued conformance to this standard is verified by the certifier's surveillance program.
- Quality of performance is determined by field performance and by periodic re-examination and testing.

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

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

#### 5.1.3 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.

#### 5.1.4 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.

#### 5.1.5 Drawing and Change Control

- The manufacturer shall establish a system of product configuration control that shall allow no unauthorized changes to the product. Changes to critical documents, identified in the certification report, may be required to be reported to, and authorized by the certification agency prior to implementation for production.
- Records of all revisions to all certified products shall be maintained.

## 5.2 Surveillance Audit

- 5.2.1 An audit of the manufacturing facility may be part of the certification agency's surveillance requirements 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 ensure a uniform product consistent with that which was tested and certified.
- 5.2.2 Certified products or services shall be produced or provided at, or provided from, location(s) disclosed as part of the certification examination. Manufacture of products bearing a certification mark is not permitted at any other location prior to disclosure to the certification agency.

## 5.3 Product Modifications

- 5.3.1 The manufacturer shall notify the certification agency of changes in product construction, components, raw materials, physical characteristics, coatings, component formulation or quality assurance procedures prior to implementation.

# 6 BIBLIOGRAPHY

ISO/IEC 17025, *General Requirements for the Competence of Testing and Calibration Laboratories*.

## APPENDIX A

### SUMMARY OF REQUIRED TESTS

SUMMARY OF REQUIRED TESTS – FM 4922				
Duct Diameter and Sizes:	≤ 5 ft (1.5 m)		> 5 ft (1.5 m)	
Duct Construction:	Metal <sup>5</sup>	Other	Metal <sup>5</sup>	Other
Horizontal Duct Fire Test <sup>1</sup>	✓	✓	✓	✓
Smoke Removal Ability Test	✓	✓	✓	✓
Cleanroom Materials Test <sup>2</sup>	NR	✓	NR	✓
Fire Propagation Index (FPI) ≤ 7 Test	✓	✓	✓	✓
Vertical Duct Fire Test <sup>3</sup>	O	O	NR	NR
16 ft (4.9 m) High Parallel Panel Test <sup>4</sup>	NR	NR	✓	✓
Small Scale Quality Control Tests for All Duct Diameter/Sizes				
Heat Content <sup>2</sup>	NR	✓	NR	✓
Ignition Properties <sup>2</sup>	NR	✓	NR	✓
Ash Content <sup>2</sup>	NR	✓	NR	✓
Fire Propagation Apparatus (FPA) Testing	✓	✓	✓	✓
Applicable Identification Tests	✓	✓	✓	✓

✓ = Required

NR = Not Required

O = Optional

<sup>1</sup> The 12 in. (300 mm) diameter Horizontal Duct Fire Test is used to assess duct diameters and sizes ranging from 12 in. (300 mm) to > 5 ft (1.5 m). The 4 in. (100 mm) diameter Horizontal Duct Fire Test is used to assess duct diameters and sizes ranging from 4 in. to 12 in. (100 to 300 mm).

<sup>2</sup> If the exterior surface of the duct is a bare metal, the Cleanroom Materials, Heat Content, Ignition Properties, and Ash Content tests are not required.

<sup>2</sup> These tests are required for nonmetallic materials used in the makeup of ducts or duct exterior wall if the duct is equipped with multiple walls (i.e., interior liner).

<sup>3</sup> The Vertical Duct Fire Test is optional and used for certifying vertical runs > 15 ft (4.6 m).

<sup>4</sup> The 16 ft (4.9 m) High Parallel may be used as an alternate test to certify ducts for unrestricted vertical riser heights and supersedes FPI ≤ 7 results.

<sup>5</sup> Metal = Bare metal duct exterior with interior liner or thermoplastic coating system.

## APPENDIX B

### SUMMARY OF TESTS PER EXAMINATION STANDARD

There are three examination standards for industrial ducts:

- Fume and Smoke Exhaust Duct Systems (FM 4921)
- Fume and Smoke Exhaust Duct Systems for Cleanrooms (FM 4922)
- Fume Exhaust Duct Systems (FM 4923)

Test Requirements	FM 4921	FM 4922	FM 4923
<b>Duct Diameters/Sizes ≤ 5 ft. (1.5 m)</b>			
Horizontal Duct Fire Test	✓	✓	✓
Smoke Removal Ability Test	✓	✓	NR
Cleanroom Materials Test	NR	✓	NR
Fire Propagation Index (FPI) ≤ 7 Test	✓	✓	✓
Vertical Duct Fire Test	O	O	O
Small Scale Quality Control Tests	✓	✓	✓
Test Requirements	FM 4921	FM 4922	FM 4923
<b>Duct Diameters/Sizes &gt; 5 ft. (1.5 m)</b>			
16 ft (4.9 m) High Parallel Panel Test	✓	✓	✓
Horizontal Duct Fire Test	✓	✓	✓
Smoke Removal Ability Test	✓	✓	NR
Cleanroom Materials Test	NR	✓	NR
<sup>1</sup> Fire Propagation Index (FPI) ≤ 7 Test	✓	✓	✓
<sup>1</sup> Vertical Duct Fire Test	O	O	O
Small Scale Quality Control Tests	✓	✓	✓

✓ = Required    NR = Not Required    O = Optional

<sup>1</sup>16 ft (4.9 m) parallel panel test results supersede FPI (≤ 7)