

Fire Performance Properties of Spears® CPVC Products

**Flame Spread & Smoke Development Characteristics
Flammability
Limiting Oxygen Index
Heat of Combustion
Ignition Temperature**

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Introduction

Selection of thermoplastic piping system components frequently requires evaluation of the product's fire performance characteristics to assure its safe and proper use. The information in this manual is designed to provide a relatively in-depth understanding of the criteria and test methods used to establish the fire performance capabilities of CPVC product lines produced by Spears® Manufacturing Company¹. This information is applicable to the following products:

Spears® CPVC Fittings (e.g., Fittings, Unions, & Flanges)

Spears® CPVC Thermoplastic Valves

Spears® LabWaste™ CPVC Corrosive Waste Drainage System

CPVC inherently exhibits excellent fire performance properties without the use of fire retardants or special additives. CPVC has been approved and used in a variety of industrial, commercial and residential installations for both pressure and non-pressure applications including process piping systems, hot and cold water distribution systems, chemical drainage systems, and fire sprinkler systems.

Evaluation of a product's fire performance involves consideration of several factors. Flame spread/smoke development, and flammability are the primary, certified product and material tests used. However, additional consideration must be given to limiting oxygen index, heat of combustion and ignition temperature. Each of these factors contributes differently to a product's overall fire performance characteristics while, at the same time, are very interrelated.

Flame spread and smoke development characteristics are not only fundamental indicators of a product's fire performance, but also have special significance in applications involving air handling systems, such as air plenum installations. It should be noted that CPVC fire sprinkler system pipe and fittings produced by Spears® and numerous other manufacturers have been approved for use in air plenums by Underwriters Laboratories, Inc. Testing of Spears® CPVC products for flame and smoke characteristics has focused on *actual product* performance testing, as opposed to conventional "sheet material" tests. Details of Spears® CPVC product ratings has been provided.

A flammability test of plastic materials under UL94 is one of the most widely used indicators of a plastic product's fire performance. Spears® CPVC material has been evaluated and classified under UL94 for flammability with the highest ratings available under this test. Details of this test protocol, along with definition and description of classifications are included.

A material's **Limiting Oxygen Index (LOI)** is significant in evaluation of a product's capacity to support combustion. Spears® CPVC material displays a relatively high LOI indicating that it will not support combustion. A brief description of the ASTM test along with comparisons between several plastic materials has been provided.

Heat of combustion, a measurement of a material's heat release rate, is not just 'one of many' variables used to evaluate a product's fire performance. It is, perhaps, one of the most important variables in evaluating fire performance. Heat of combustion rate is the driving force of a fire. In simplest terms - heat makes more heat. Spears® CPVC material has a relatively low heat of combustion, nearly 1/3 that of Polypropylene, as discussed in this section's content.

Ignition temperature is temperature required to ignite a material. CPVC has a relatively high ignition temperature as compared to many common materials and other plastics. A brief description of the ASTM test along with a table of comparisons has been provided.

¹ Spears® FlameGuard™ CPVC Fire Sprinkler Products is a specialty line subject to specific application and listing requirements separately addressed and are not included in the scope of this report other than general reference to them.

FLAME SPREAD & SMOKE DEVELOPMENT CHARACTERISTICS

UNDERWRITERS' LABORATORIES OF CANADA

(Spears® ULC File CR2689)

Compliance:

Spears® Manufacturing Company Rigid Chlorinated Polyvinyl Chloride (CPVC) products have been evaluated in accordance with the Standard Test for Surface Burning Characteristics, CAN/ULC-S102.2, establishing a flame spread rating of 25 or less and a smoke development rating of 50 or less. These are below the maximum allowable values specified for use in return air plenums.

General Character and Use:

These products are intended for use as a building material as permitted by the authorities having jurisdiction, and are classified as to surface burning characteristics per CAN/ULC-S102.2:

Table 1: Flame Spread & Smoke Developed ²

| Material Details | Flame Spread | Smoke Developed |
|--|--------------|-----------------|
| Spears® CPVC Fittings 1/4" (6mm) to 12" (300mm) length of exposed piping between fittings 1" (25mm) min. | 5-10 | 15-50 |
| Spears® CPVC Pipe ULC Listed CPVC LabWaste™ pipe produced for Spears® 1-1/2" to 12" (300mm) | 0 | 5-20 |
| Spears® CPVC Valves 1/4" (6mm) to 12" (300mm), length of exposed piping between valves 18" (460mm) min. | 5 | 5-10 |
| Spears® CPVC Duct Fittings Fabricated from ULC Listed CPVC seamless round duct 6" (150mm) to 24" (600mm) maximum diameter. | 5 | 15-25 |

Spears® CPVC piping products have been subjected to fire exposure testing by Underwriters' Laboratories of Canada to determine the flame spread rating and smoke generation characteristics as indicated in Table 1. Values were obtained during exposure temperatures up to 1770°F for a period of ten minutes.

Products are classified as to surface burning characteristics by comparing values obtained to that of known combustibles (red oak) and known non-combustibles (asbestos cement board), as indicated in Table 2 and accompanying graphs located on the following pages.

Results of testing demonstrates that Spears® CPVC products have flame spread and smoke generation characteristics of 25/50 or less when tested as a finished product. These are below the maximum allowable values in building codes that reference a 25/50 flame spread/smoke generation requirement for products installed in return air plenums.

It should also be noted that Spears® CPVC products are made from the same CPVC compounds used in CPVC fire sprinkler systems approved for use in return air plenums by Underwriters Laboratories, Inc., in accordance with UL 1887, *Standard for Safety for Fire Test of Plastic Sprinkler Pipe for Flame and Smoke Characteristics*. CPVC product and material used in this specialty line manufactured by Spears® differ only in their distinguishing orange color.

² Ratings from tests conducted in accordance with CAN/ULC S102.2

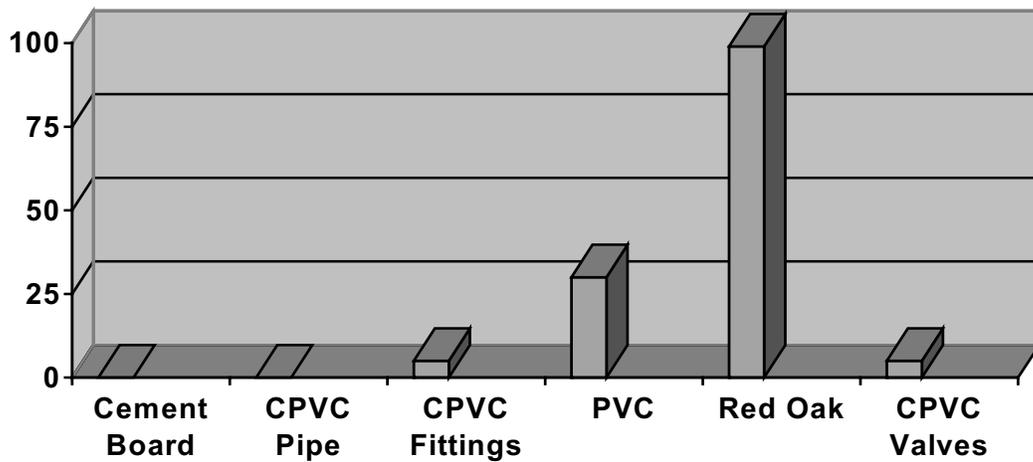
Table 2: Relative Flame Spread & Smoke Development of Spears® CPVC Products ³

| MATERIAL | FLAME SPREAD | SMOKE DEVELOPED |
|-----------------------|--------------|-----------------|
| Red Oak | 100 | 100 |
| Spears® CPVC Fittings | 5-10 | 15-50 |
| Spears® CPVC Duct | 5 | 15-25 |
| Spears® CPVC Valves | 5 | 5-10 |
| Spears® CPVC Pipe | 0 | 5-20 |
| Cement Board | 0 | 0 |

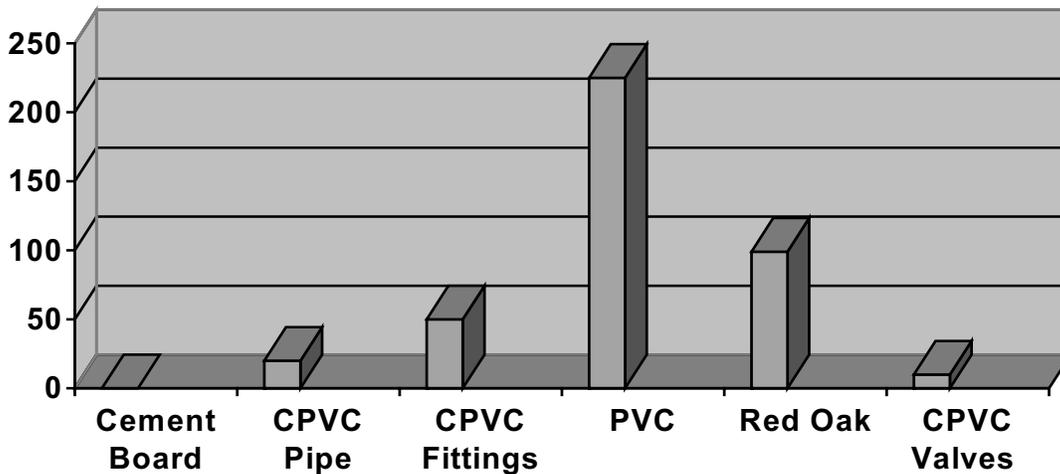
Graphical Representation of Data: ³

**Underwriters' Laboratories of Canada
Surface Burning Characteristics of Plastic Material
CAN/ULC-S102.2**

Graph 1: Flame Spread (FS)



Graph 2: Smoke Developed (SD)



³ Results based on tests conducted in accordance with CAN/ULC-S102.2

Official ULC Listing for Spears® CPVC Fittings & Valves:

**Underwriters' Laboratories of Canada
List of Equipment and Materials
Building Materials
March 2000**

[Ref: Page 84 - 85]

Plastic Fittings and Valves (40 U8.16.6)

Plastic materials manufactured into fittings and valves are classified as to their surface burning characteristics as indicated in the following individual listings.

Fittings and valves are injection-molded from thermoplastic plastic materials and are tested in accordance with the Standard Method of Test for Surface Burning Characteristics of Flooring, Floor Covering and Miscellaneous Materials and Assemblies, CAN/ULC-S102.2M.

Fittings and valves are tested when solvent-cemented to ULC listed plastic pipe at specified intervals. Unless otherwise indicated in the individual listing, a single piping system is positioned along the center line of the tunnel floor.

The surface burning characteristics are derived in comparison with untreated red oak as 100. Authorities having jurisdiction should be consulted before installation.

Listing Service-Fittings and valves classified as to surface burning characteristics are listed under the Label Service or the Integral Marker Assurance Service of Underwriters' Laboratories of Canada. Under the Label Service, periodic examinations and tests are conducted on samples selected at random from current production and stock.

Each fitting or valve is identified by a label which reads

**UNDERWRITERS' LABORATORIES OF CANADA
LISTED
PLASTIC FITTINGS OR VALVES**

Issue No. _____ C

Form No. _____ C

**Classified as to Surface Burning Characteristics
In Accordance with the Standard CAN/ULC-S102.2M.**

together with information concerning the flame spread and smoke developed applicable to the listed material.

Under the Integral Marker Assurance Service, periodic examinations and tests are conducted on samples selected at random from current production and stock.

Each fitting or valve is identified by the Integral Marker which reads:



together with information concerning the flame spread and smoke developed applicable to the listed material.

The ULC label or listed marking on a product is the only evidence provided by Underwriters' Laboratories of Canada to identify products which have been produced under the Listing and Follow-Up Service

SPEARS® MANUFACTURING COMPANY, INC., Sylmar, CA 91342

CPVC valves and fittings solvent-cemented to ULC listed CPVC piping having flame spread 0, smoke developed 0. Classified as to surface burning characteristics in accordance with CAN/ULC-S102.2 as indicated.

Classification or Rating

| Material Details | Flame Spread | Smoke Developed |
|--|---------------------|------------------------|
| CPVC valves, 6 mm to 300 mm, length of piping between valves 460 mm min | 5 | 5-10 exposed |
| CPVC fittings, 6 mm to 300 mm, length of piping between fittings 25 mm min | 5-10 | 15-50 exposed |

Marking: ULC label on each package of valves and fittings

Test Protocol of CAN/ULC S102.2 vs. ASTM E-84:

Both CAN/ULC S102.2 and ASTM E-84 are valid tests recognized for evaluation of surface burning characteristics through flame tunnel testing. However, the selection of CAN/ULC S102.2 was made due to its provisions for testing of *actual pipe, fittings and valve assemblies*.

ASTM E 84 is a test (developed circa 1950) that is designed for sheet testing of surface finish materials, as stated in the scope of the standard: *“This fire-test response standard for the comparative surface burning behavior of building materials is acceptable to exposed surfaces such as ceilings and walls.* Although “atypical” testing has been performed by various parties, the ASTM E 84 test protocol does not provide for the testing of shapes, such as pipe and fitting assemblies. The question must be asked: If in fact E 84 is fully suitable for testing of finished piping products, then why have alternative product tests such as UL 1887 for approval CPVC Fire Sprinkler Systems in air plenums been required? This UL test is an alternative flame tunnel test of *actual CPVC piping*, dry and unfilled, using the same calibration basis from the test values for fibrous cement board and select red oak. An acceptable UL 1887 test requires a flame spread of 5 or less and a peak optical density of 0.5 or less for smoke development. As previously noted, the CPVC materials used in Spears® LabWaste™ are the same as those tested and approved under UL 1887, except for color.

In comparison, CAN/ULC S102.2 (developed circa 1979) provides not only for testing of surface finish materials, but also for miscellaneous materials and assemblies, including shapes such as pipe and fittings. The standard further states: *“This method...may also be applied to materials that cannot conveniently be tested in a ceiling mounted configuration. Thermoplastics and loose fill materials might be included in this category.”*

While these are not the same test and there is no direct comparison of their indices, the protocol of CAN/ULC S102.2 test is technically equivalent to ASTM E 84 in that these are both “Steiner Tunnel” type flame tests, ten (10) minutes in duration, using a flame spread and smoke development index in which fiber cement board = 0 and select red oak = 100. Notable differences in these tests are that the tunnel in S102.2 requires more combustion fuel for red oak calibration, thus produces more heat in the test; the calculation method of S102.2 yields approximately a 9% higher result for material performing identically in both test chambers; and the floor position mounted shapes (such as pipe) in S102.2 eliminates loss of flame front, a potential problem recognized within ASTM E-84.

The extent to which identical performance would be attained between tests cannot be accurately determined without reviewing specific data and procedures on an individual basis. It would be inappropriate to suggest that ASTM E-84 is a more severe testing protocol representative of real fire scenarios than ULC 102.2 since both tests methods have been useful in assessing the relative flame and smoke properties of many different types of materials for several years.

It should be also noted that Underwriters' Laboratories of Canada (ULC) is an affiliate of UL and shares the same mission, working for a safer world. Headquartered in Toronto, Ontario, Underwriters' Laboratories of Canada (ULC) is one of North America's most widely recognized third-party certifiers in a number of electrical and fire protection related categories. ULC is part of one of the world's leading standards development, certification and registration organizations through its affiliation with UL in the United States. Only products that have had samples tested by a UL company to meet rigorous standards and periodically checked at the manufacturing facility can carry a UL Mark. ULC is fully accredited and offers manufacturers access to the UL Marks for Canada and the United States.

FLAMMABILITY

Underwriters Laboratories, Inc.

Compliance:

Spears® Manufacturing Company Rigid Chlorinated Polyvinyl Chloride (CPVC) materials used in the production of CPVC fittings, CPVC valves and CPVC duct have been tested in accordance with UL 94, Test for Flammability of Plastic Materials for Parts in Devices and Appliances. These CPVC materials have a flammability rating of V-0, 5VA and 5VB, the highest ratings available under this test.

UL 94 Overview:

Introduction

UL 94 is the test used by Underwriters Laboratories, Inc. for evaluation of plastic materials used to produce Spears® products. This is the best and most stringent test for flammability. This test is NOT conducted with finished product, as is the ULC test for surface burning characteristics.

UL intends this standard to serve as a preliminary indication of a plastic's acceptability for use as part of a device or appliance with respect to its flammability. It is not intended to reflect the hazards of a material under actual fire conditions.

UL 94 flammability testing is the first step toward obtaining a plastic recognition and subsequent listing in the "Plastics Recognized Component Directory" (formerly known as "Yellow Cards"). UL 94 contains the following tests: 94HB, 94V, 94VTM, 94-5V, 94HBF, 94HF and Radiant Panel.

The 94HB test describes the Horizontal Burn method. Method 94V is used for Vertical Burn, a more stringent test than 94HB. The 94-5V test is for enclosures for products that are not easily moved or are attached to a conduit system. The 94HBF and HF are used for nonstructural foam materials; i.e., acoustical foam. Radiant panel test is an ASTM (E162) test to determine the flame spread of a material that may be exposed to fire.

The following is a brief description of three tests that apply to stock shape products (sheet, rod, tube, film, including pipe and fittings) and how the rating system works. This is not meant as a procedure for running the tests nor as a way of determining the acceptability of a material for a particular application. Those who would like more details should contact UL or obtain a copy of this and other UL Standards by visiting the UL's Standards Department web site, at <http://ulstandardsinfontet.ul.com>.

Figure 1: UL 94 Test for Flammability of Plastic Materials for Parts in Devices and Appliances

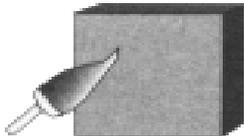
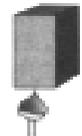
| SURFACE BURN | VERTICAL BURN | HORIZONTAL BURN |
|---|---|--|
|  |  |  |
| Doesn't Ignite Under Hotter Flame | Self Extinguishing | Slow Burn Rating |
| UL 94 5VA UL 94 5VB | UL 94 V-0 (Best) UL 94 V-1 (Good) UL 94 V-2 (Drips) | Takes more than 3 min. to burn 4 inches |

Table 1: UL94 Classification Descriptions

| | |
|-------------------------------|--|
| 5VA Surface Burn | Burning stops within sixty seconds after five applications of five seconds each of a flame (larger than that used in Vertical Burn testing) to a test bar. Test specimens MAY NOT have a burn-through (no hole). |
| 5VB Surface Burn | Burning stops within sixty seconds after five applications of five seconds each of a flame (larger than that used in Vertical Burn testing) to a test bar. Test specimens MAY HAVE a burn-through (a hole). |
| V-0 Vertical Burn | Burning stops within ten seconds after two applications of ten seconds each of a flame to a test bar. NO flaming drips are allowed. |
| V-1 Vertical Burn | Burning stops within sixty seconds after two applications of ten seconds each of a flame to a test bar. NO flaming drips are allowed. |
| V-2 Vertical Burn | Burning stops within sixty seconds after two applications of ten seconds each of a flame to a test bar. Flaming drips ARE allowed. |
| H-B Horizontal Burn | Slow horizontal burning on a 3mm thick specimen with a burning rate of less than 3"/min or stops burning before the 5" mark. H-B rated materials are considered "self-extinguishing". This is the lowest (least flame retardant) UL 94 rating. |

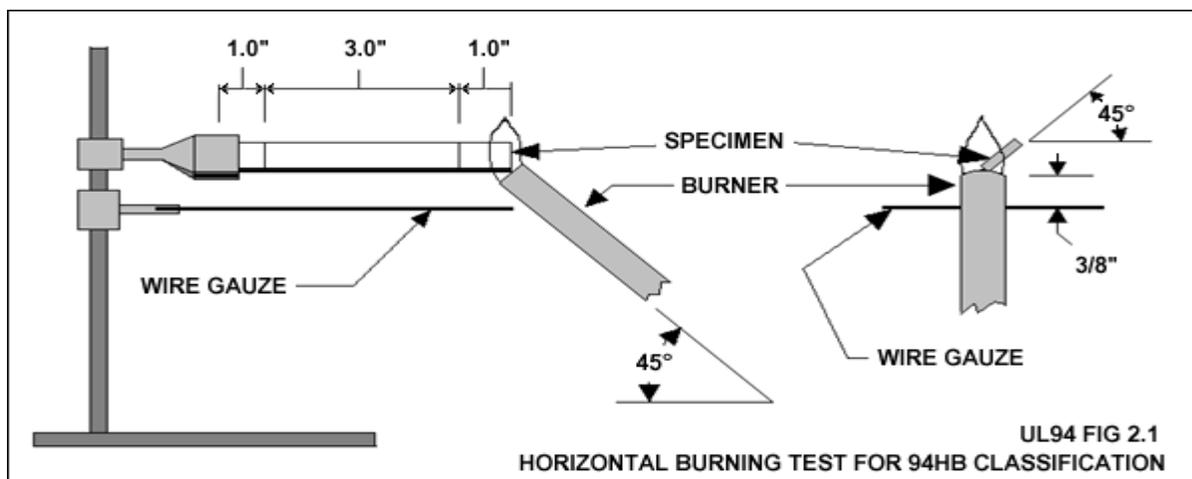
94HB Horizontal Burning Test

This is generally considered the easiest test to pass and materials that pass any of the V tests will usually be accepted by UL for applications that require 94HB. To be sure, check with the UL representative assigned to the device in which the film will be used. The 94HB rating would typically be acceptable for portable, attended, intermittent-duty, household-use appliance enclosures (i.e., hair dryers) or for decorative parts.

The test uses a ½" x 5" specimen held at one end in a horizontal position with marks at 1" and 5" from the free end. A flame is applied to the free end for thirty seconds or until the flame front reaches the 1" mark (See Fig. 2). If combustion continues, the duration is timed between the 1" mark and the 5" mark. If combustion stops before the 5" mark, the time of combustion and the damaged length between the two marks are recorded. A set of three specimens is tested.

A material that is less than 0.118" in thickness will be classified 94HB if it has a burning rate of less than 3" per minute or stops burning before the 5" mark. If one specimen from the set of three fails to comply, then a second set of three is tested. All three of this second set must comply.

Figure 2: UL 94 Horizontal Burning Test for 94HB Classification



94V Vertical Burning Test

This test includes three classifications – 94V-0, 94V-1 and 94V-2 – and would typically be acceptable for portable, unattended, intermittent-duty, household-use appliances (i.e., coffee makers). Which classification applies to a particular application depends on many factors, including:

- Size and thickness of part.
- Distance from un-insulated live parts.
- Hot wire ignition.
- High current arc ignition.
- High voltage arc tracking rate.

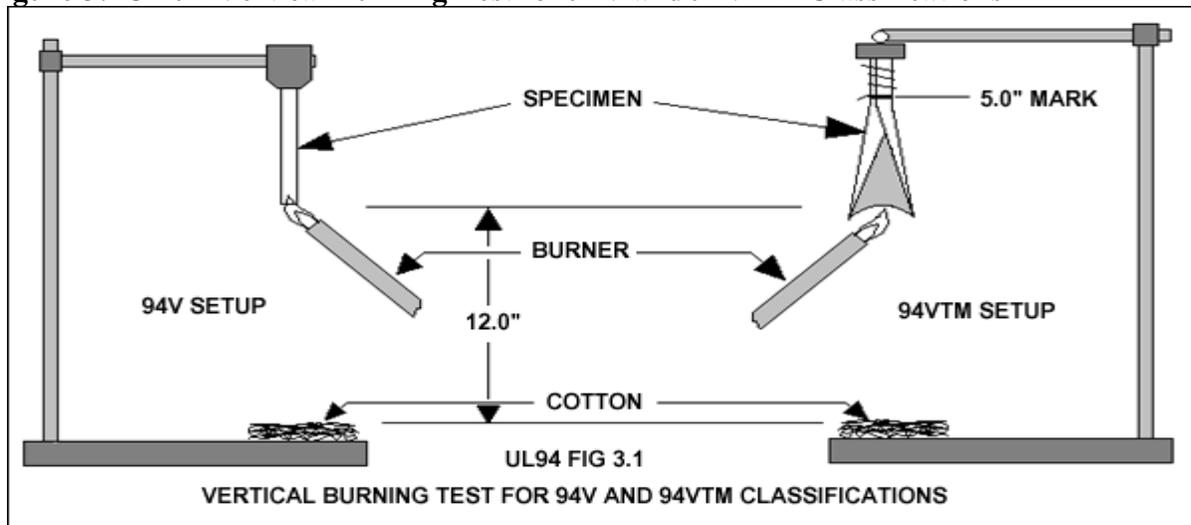
This test uses a ½" x 5" specimen which is held at one end in the vertical position (See Fig. 3). A burner flame is applied to the free end of the specimen for two, ten second intervals, separated by the time it takes for flaming combustion to cease after the first application. Two sets of five specimens are tested. The following are recorded for each specimen:

- Duration of flaming combustion after the first burner flame application.
- Duration of flaming combustion after second burner flame application.
- Duration of glowing combustion after second burner flame application.
- Whether or not flaming drips ignite cotton placed below specimen.
- Whether or not specimen burns up to holding clamp.

Table 2: Material Classification

| Criteria Conditions | 94V-0 | 94V-1 | 94V-2 |
|--|-------|--------|--------|
| Total flaming combustion for each specimen | ≤ 10s | ≤ 30s | ≤ 30s |
| Total flaming combustion for all five specimens of any set | ≤ 50s | ≤ 250s | ≤ 250s |
| Flaming and glowing combustion for each specimen after second burner flame application | ≤ 30s | ≤ 60s | ≤ 60s |
| Cotton ignited by flaming drips from any specimen | NO | NO | YES |
| Glowing or flaming combustion of any specimen to holding clamp | NO | NO | NO |

Figure 3: UL 94 Vertical Burning Test for 94V and 94VTM Classifications



LIMITING OXYGEN INDEX

An important component of any plastic material's fire resistance capability is its resistance to burning that is expressed as its Limiting Oxygen Index (LOI). ASTM D2863, *Standard Test Method for Measuring The Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)* is the test used to determine LOI. This test measures the minimum concentration of oxygen in a nitrogen – oxygen mixture that is required to just support combustion of the sample under specified test conditions. The test involves placing the material sample in a cylinder and introducing a mixture of oxygen and nitrogen, the relative concentrations of which can be gradually varied at measured rates. A flame is applied to the top of the sample until it ignites, then is withdrawn. If the flame extinguishes, the concentration of oxygen is increased and the sample is re-ignited until it finally continues to burn. The concentration of oxygen at this point is the index of flammability, calculated as

$$\text{Oxygen Index} = \frac{\text{O}_2}{\text{O}_2 + \text{N}_2}$$

where O_2 is the minimum volumetric concentration of oxygen which will just support combustion, and N_2 is the associated nitrogen concentration.

CPVC material used in Spears® products has a relatively high LOI value of 60, as illustrated in Table 1. This means CPVC will not sustain burning or support combustion. Since the earth's atmosphere is approximately 21% oxygen, CPVC will not burn unless a flame is constantly applied and will stop burning when the flame source is removed. Materials with a low Limiting Oxygen Index will support combustion.

Table 1: Comparison of Limiting Oxygen Index for Plastic Materials⁴

| Material | LOI |
|-------------------------------|-----|
| CPVC | 60 |
| PVC, rigid | 45 |
| PVDF | 44 |
| Flame Retardant Polypropylene | 27 |
| ABS | 18 |
| Polypropylene | 17 |
| Polyethylene | 17 |

HEAT OF COMBUSTION

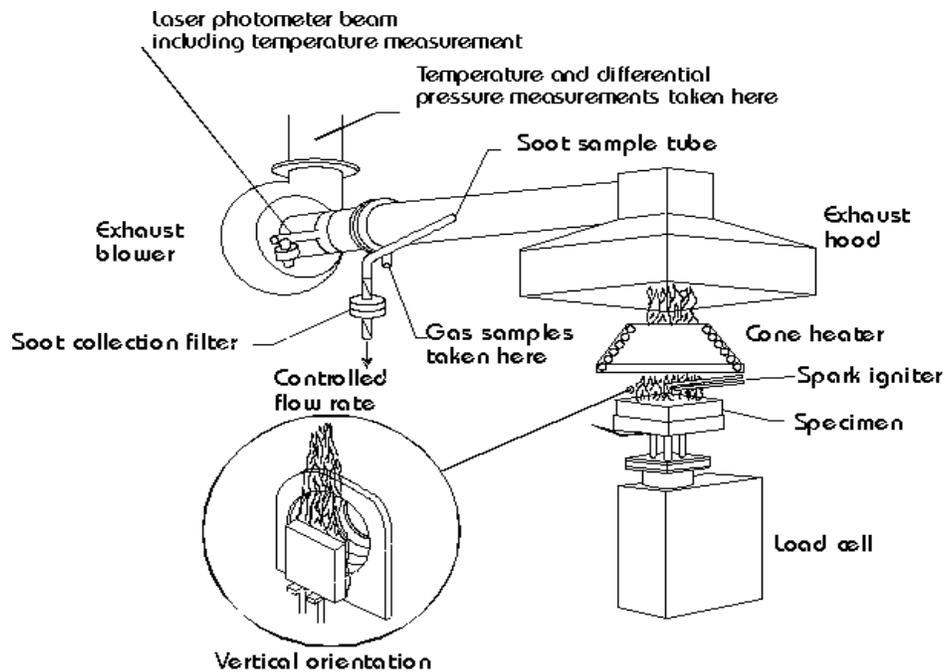
Heat of Combustion (Heat Release Rate) is the amount of heat released per unit mass or unit volume of a substance when the substance is completely burned. ASTM E1354, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter* is the fire-test-response standard used to determine a material's ignitability, heat release rates, mass loss rates, and effective heat of combustion.

This test involves complete burning of a material and measuring the heat released and mass loss. The Cone Calorimeter is the test apparatus used to determine this measurement, as illustrated in Figure 1 on the following page. The burning environment of the Cone Calorimeter is considered to be a good representation of the majority of actual fire conditions⁵.

⁴ *Flammability Handbook for Plastics*, 5th edition, C.J. Hilado, Technomic Publishing, 1998 and commercially available information.

⁵ *Heat Release and Fire Hazard*, Vol. I, Y. Hasemi, ed., Building Research Institute, Tsukuba, Japan (1993).]

Figure 1: Cone Calorimeter Test Apparatus



CPVC has a significantly lower heat of combustion at 7,700 BTU’s / lb. when compared to Douglas fir at 9040 BTU’s / lb. and Polypropylene at nearly 20,000 BTU’s/lb. Materials with a high heat of combustion perpetuate a combustible mixture which, when ignited, creates more heat and causes the burning process to be self sustaining. CPVC cannot be the ignition source of a fire or support combustion.

It should also be noted that flame retardants in materials do not significantly change total heat release, specific heat of combustion, and carbon monoxide and soot yields. These materials burn less vigorously than those without the addition of flame retardants, but they burn longer.

IGNITION TEMPERATURE

Ignition temperature is the minimum temperature of a material at which sustained combustion can be initiated under specified test conditions. It is an estimate of the lower flammability limit. ASTM D1929, *Standard Test Method for Determining Ignition Temperature of Plastics* is the fire-test-response standard used to determine flash ignition temperature and spontaneous ignition temperature of plastics using a hot-air furnace. The test sample is placed in a container and uniformly heated with its temperature monitored. Periodically, as the temperature is increased, an ignition source is inserted into the container and this is repeated until the lowest temperature where a flash occurs is identified. CPVC has a flash ignition temperature of 900°F which is the lowest temperature at which sufficient combustible gas is evolved that can be ignited by an ignition source, such as a small external flame. Ignition temperature comparisons of various materials are shown in Table 2.

Table 2: Flash Ignition Temperature Comparisons⁴

| Material | °C | °F |
|---------------|-----|-----|
| CPVC | 482 | 900 |
| PVC, rigid | 399 | 750 |
| Polypropylene | 343 | 650 |
| Polyethylene | 343 | 650 |
| White Pine | 204 | 400 |
| Paper | 232 | 450 |

Progressive Products From Spears® Innovation & Technology



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