Low Smoke & Limited Combustible Cables Made With PVDF

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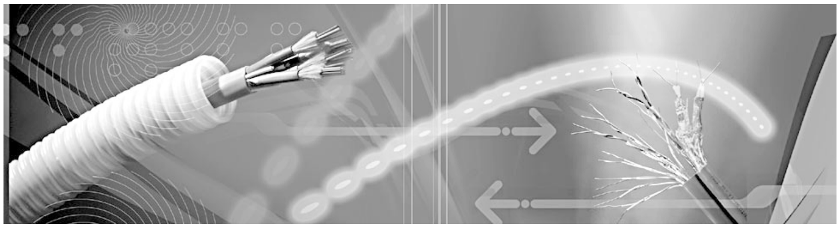
New grades of polyvinylidene fluoride match FEP and outperform flame retarded PVC in terms of flame and smoke performance.



Limited combustible cables made with Kynar® PVDF from Arkema Inc.

It is well understood that as a class, fluoropolymers are the best choice for wire insulation and jacketing materials when fire performance and low smoke generation are the primary requirements. Fluoropolymers in general are flame resistant, with Limiting Oxygen Index (LOI) values that range from the mid 40's up to 100 and *UL 94* flame ratings of V0. They have a relatively low fuel value and contribute very little heat in the event of a fire, greatly reducing the potential of flame spread.

The carbon-fluorine bonds in Kynar® PVDF (polyvinylidene fluoride) are very strong and high temperatures are required for decomposition to occur. Fluoro-polymer cables consistently provide exceptionally low flame and smoke values, well below the maximum limits for such applications. Fluoropolymers such as Kynar PVDF naturally char and can be used as cable jacketing to protect more vulnerable insulation materials underneath.

Over the past several years, the wire and cable industry has developed a new class of cables having superior "flame and smoke" characteristics. These cables, referred to as limited combustible (LC) or duct cables, will not support combustion, and produce much lower levels of smoke compared to existing plenum cables. LC cables provide the best in fire resistance by offering minimal flame spread, very low smoke generation, reduced fuel loading and by themselves are not capable of supporting combustion.

Cables manufactured using fluoropolymers such as fluorinated ethylene-propylene (FEP) and Kynar PVDF meet these stringent requirements and truly satisfy the requirements for limited combustible materials used in air handling spaces as is specified by the **NFPA**. Alternative products on the market such as flame retarded polyvinyl chloride (PVC) do not provide the low flame and smoke properties necessary to meet LC requirements, nor do they meet the fuel load requirements in many cable constructions. Fuel load is also of particular concern because of the large growth of CMP cables used in plenum air handling spaces. Other alternatives such as low smoke polyolefins are sometimes used as primary insulation in CMP type cables. But in general, they have high total heat contents and significant smoke generation, making them unsuitable for use in LC cable constructions.

Ultra Low Smoke PVDF Grades

There are many different materials offered with claims of possessing excellent flame and smoke properties. In general, the best flame and smoke properties are provided by fluoropolymers, with FEP and PVDF being the materials of choice. FEP is chosen in applications where its superior electrical properties are required. PVDF in general is better suited for all applications where the electrical performance of FEP is not absolutely needed (for example, power limited cables, all shielded cable jackets and fiber optic cable components).

In recent years, Kynar PVDF grades having ultra low-smoke characteristics as well as low total heat content have been developed. Flame retarded PVC compounds are available for existing plenum requirements, however they produce large enough quantities of smoke to make them unacceptable for limited combustible applications.

LSFOH (Low Smoke and Fume, Zero Halogen) compounds have limited use in existing plenum applications due to marginal smoke generation characteristics as well as high total heat output making them unacceptable for limited combustible applications.

Steiner Tunnel Testing of Plenum Cable

Underwriters Laboratories (UL) developed a test to measure the flame spread and smoke characteristics of communications cables back in the mid 1970s. The *NFPA 262* test, which was previously known as *UL 910*, utilizes the Steiner Tunnel, a test apparatus identified in *ASTM E-84 Standard Test Method for Surface Burning Characteristics of Building Materials.*

ASTM E-84 measures the surface flame spread of a material that is installed along the ceiling of the test furnace. In order to provide total flame engulfment of the cable samples, the *UL 910* test is performed by mounting the cables in a cable rack suspended below the tunnel ceiling. The requirements specified for plenum cables were an average optical density (AOD) maximum of 0.15 and a peak optical density (POD) maximum of 0.50.

Steiner Tunnel testing, per *NFPA-262*, was performed on cables produced with flame retarded PVC compounds and compared to identical cables produced using PVDF resins. The flame retarded PVC compound used was considered one of the premium plenum grade products on the market. The cables were constructed using 14 AWG (2.1 mm^2) copper with

0.008" (0.2 mm) of insulation (single twisted pair) as well as a 0.018" (0.46 mm) jacket. The cables were tested to the requirements of *NFPA-262* using the Steiner Tunnel located at UL in Northbrook, IL, USA. The results from the *NFPA-262* tests can be found in **Table 1**.

It is clear from the data in **Table 1** that Kynar PVDF has superior flame and smoke (F&S) properties compared to flame retarded PVC. Kynar PVDF produces virtually no smoke when burned, and the results are well below the limits established for *NFPA-262*. Flame retarded PVC was shown to produce smoke, though for this simple construction the cables were within design guidelines.

It is well understood in the wire and cable industry that as the complexity of the cables increases, the quantity of insulation used increases, resulting in higher levels of smoke generation. For such cables, the smoke values tend to approach the upper limits for plenum requirements, and often times exceed these limits.

And as previously noted, it is common practice to jacket such cables with fluoropolymers to allow the cable to meet plenum requirements.

Steiner Tunnel Testing of Limited Combustible Cable

Cables meeting the same sample specifications stated above were tested in the Steiner Tunnel to the limited combustible requirements specified in *NFPA-255*. The testing procedure used in *NFPA-255* is similar to that used in *NFPA-262*, but with the cables mounted closer to the tunnel ceiling, half the exposure duration and the smoke and flame index values being calculated in lieu of average and peak optical densities. It is well understood that passing the LC requirements is exceedingly more difficult because of the more stringent index requirements involved.

The LC requirements are defined as a smoke developed index (SDI) maximum of 50 and a flame developed index (FDI) of 25. An FEP control cable of the same construction was also included in the testing program to validate the test method. These tests are summarized in **Table 2**.

The fluoropolymer cables tested (Kynar PVDF and FEP) were both capable of meeting LC requirements. During the test, it was noted that smoke could not be observed in the tunnel when viewed from the back air intake for either fluoropolymer cable. The burning characteristics of the Kynar PVDF insulation were noted as being quite different than those observed for the FEP insulation. The PVDF cable charred in the vicinity of the burners and the cable was unaffected a short distance from the flame zone. The char remained on the cables throughout the test and protected the underlying insulation. The FEP cable did not show any char formation and like the PVDF cable, there appeared to be little damage to the cable at a distance just beyond the flame zone.

The burning characteristics of flame retarded PVC were quite different in both flame and smoke properties. The flame retarded PVC cables did meet the flame developed index requirement and it was noted that the insulation and jacket were charred well down the tunnel. The smoke developed index was recorded at 130, which is well above the maximum value of 50 for limited combustible materials. Therefore, premium plenum grade PVC compounds will not pass the smoke requirements for LC cables.

Table 1. *NFPA-262* Results for Kynar® PVDF vs. Flame Retarded PVC.

Material/Requirements	Average Optical Density	Peak Optical Density
Limits	***0.15 maximum***	***0.50 maximum***
Flame Retarded PVC	0.09	0.32
Kynar® PVDF	0.00	0.01

Table 2. *NFPA-255* Results for Kynar® PVDF, FEP & Flame Retarded PVC.

Material/Requirements	Smoke Developed Index	Flame Developed Index
Limits	***50 maximum***	***25 maximum***
Flame Retarded PVC	130	5
Kynar® PVDF	13.9	0
FEP	16.4	0

Fluorinated Polymers

There are a number of fluorinated products on the market for wire and cable applications, all of them being better than their non-fluorinated counterparts. FEP is commonly used as an insulation material for plenum rated category cables and provides exceptional flame and smoke properties as well as superior electrical properties, making it ideal for such applications. Kynar PVDF is most commonly used as a jacketing and insulation material for non-category cables.

PVDF offers excellent physical properties and easy processing, making it the preferred material for low smoke plenum jacketing and other applications like power limited and fiber optic constructions. It is a natural char former, and because it remains on the cable during a fire, it provides continued fire resistance by protecting underlying materials. There are other fluoropolymer materials used in plenum applications such as ethylene chloro trifluoro ethylene (ECTFE) and fluorinated elastomers that provide cable makers with fluoropolymers having a full range of physical and mechanical properties.

Flame Retarded PVC compounds*

PVC compounds have been used in plenum applications for many years, and cable manufacturers have a multitude of products available with various F&S characteristics. PVC has many desirable properties that lend itself for wire and cable applications. However, the F&S properties of PVC are marginal at best and often it does not meet plenum requirements.

PVC must be compounded with various F&S packages to obtain the desired properties to meet plenum requirements. In a typical flame retarded PVC formulation, aluminum trihydrate (ATH) and/or magnesium hydroxide (MgOH) is used as an endothermic filler for the same reasons it is incorporated into LSFOH compounds. In addition to ATH, flame retarded PVC often contains brominated plasticizers in conjunction with antimony trioxide (a well-known synergistic flame retardant package). Other commonly used F&S-enhancing components include molybdenum compounds such as molybdenum trioxide as well as calcium stearate and/or zinc stearate. The final compound will also contain stabilizers (lead stabilizers being the most common) and possibly other low cost fillers.

As for fire performance, flame retarded PVC compounds have been developed for a multitude of plenum cable applications. The smoke generation and flame spread properties are such that with careful selection and proper cable design, the cables can pass plenum requirements.

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However, flame retarded PVCs provide significantly less fire protection when compared to fluoropolymer cable coatings. The carbon-chlorine bond in PVC is approximately 40% weaker than the carbon-fluorine bond in fluoropolymers and thus decomposition begins at much lower temperatures. Thermogravimetric analysis (TGA) depicting the decomposition profile of flame retarded PVC is seen in **Figure 1**. It is noted that the extrapolated decomposition onset for flame retarded PVC begins at 265°C (509°F). In comparison, **Figure 2** shows the decomposition profile of PVDF, which exhibits an extrapolated decomposition onset temperature of 436°C (817°F).

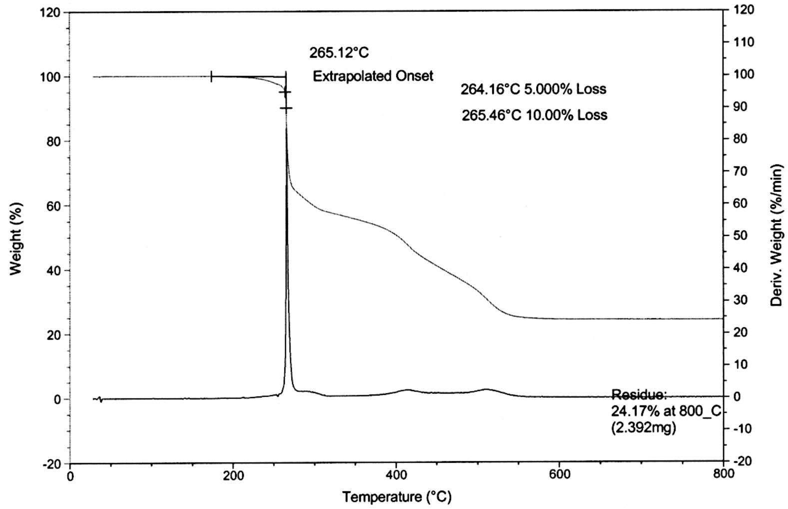

Fig. 1 — TGA curve of flame retarded PVC.

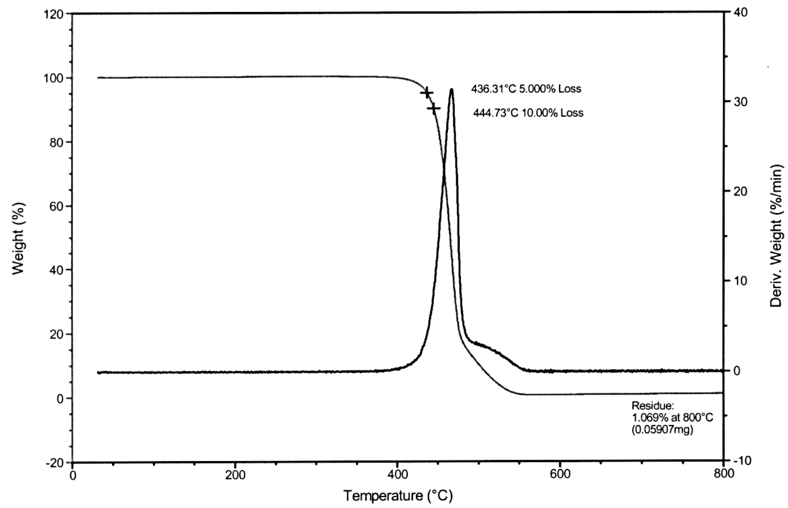

Fig. 2 — TGA curve of PVDF copolymer.

Low Smoke Polyolefin Compounds*

LSFOH compounds have been available to cable manufacturers for many years. In general, an LSFOH compound is comprised of a polyolefin containing high levels of either ATH or MgOH fillers. These particular fillers contain water of hydration that can be liberated at elevated temperatures. The water that is released creates an endothermic response, which removes the heat produced during combustion and slightly dilutes the reaction gasses.

The primary issue with LSFOH compounds is that once the filler has released its water of hydration, what remains is a highly flammable polyolefin material. High quantities of ATH are required to provide protection against burning during the onset of a thermal episode. Polyolefins have a very high gross heat capacity (46 MJ/Kg, which is double that of PVC and three to four times that of fluoropolymers) and contributes a significant fuel load in the event of a fire. The presence of ATH delays combustion during the initial stages of a fire but will not prevent the cables from burning or from ultimately contributing to fire propagation itself.

As for fire performance, LSFOH compounds generally do not perform as well as plenum-rated flame retarded PVC compounds and are not comparable to the performance offered by fluoropolymers. LSFOH compounds do not contain any halogens in their formulation and are marketed as a material preferred over PVC in applications specifying zero halogens. Best-performing LSFOH compounds are marketed as being equal to PVC in performance.

LSFOH compounds do not meet the existing plenum requirements for flame and smoke performance—requirements that are met currently by plenum rated PVC compounds and fluoropolymers, and would not be considered in a limited combustible application.

Based upon a report from the **American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE)**, titled, "Initial Investigations on Plenum Cable Fires," CMP (communication plenum) cables and especially fluoropolymer-based CMP cables produce the least amount of smoke and do not significantly contribute to the propagation or heat released during a fire when compared to CM/FT4 cables (general-purpose communications cable for use in areas other than risers or plenums—CM cable must pass *UL 1581* vertical tray test and FT4 is a cable rating assigned by the **Canadian Standards Association**). Additionally CMP cables require much higher temperatures to ignite and as such are less "involved" in a fire than other materials which ignite at much lower temperatures. According to the report, by the time the CMP fluoropolymer cables ignite, the CM cables have contributed significant amounts of smoke, have propagated the fire and have released significant levels of heat.

These are exactly the characteristics that are least desirable for plenum insulating materials.

To learn more, contact the authors or **Circle 208.** **WCTI**

** **Plastics Additives Handbook: Stabilizers, Processing Aids, Plasticizers, Fillers, Reinforcements, Colorants for Thermoplastics** / Editors: R Gachter and H. Muller. Assoc. Editor: P.P. Klemchuk. With contributions by H. Andreas...-3 Ed. Munich; Vienna; New York: Hanser 1990.*

__Company Profile...Arkema__ (formerly, __Atofina Chemicals__) has been established as part of the reorganization of the chemicals branch of oil company, __Total__, headquartered in Paris, France. Total is comprised of the three business groups: Total Petrochemicals, Arkema and the Specialties Group. Arkema includes the three business segments of Vinyl Products, Industrial Chem-icals and Performance Products. Comprising 14 business units, corporate structures and established geographic affiliates, Arkema offers many activities and brand names.