Flame Test Standards for Data Communications Cable

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DATA COMMUNICATIONS COMPETENCE CENTER

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Executive Summary

Purchasers of data communication cabling products are primarily interested in the data transmission characteristics of these cables. However, these products must typically meet various flame test requirements in order to ensure the safety of building occupants in the event of fire. Over the years, a number of fire safety standards for data communications cable have evolved in North America and the European Union. This paper will discuss and compare the most common flame test protocols used in North America and the European Union. In addition, this White Paper will describe the "Fire Cycle" and how these flame test protocols affect material selection for data communication cables.

Introduction

The majority of data communication cables are designed to meet specific fire test standards. The standards which will dominate data communications cable fire testing in the near future are described within the American NEC (National Electrical Code) and similar Canadian fire test standards, the European EN 50266, and the European EN 50399 as part of the European Construction Products Directive (CPD). Also, many of the data communications cable fire test protocols used outside of North America and the European Union are derived from the fire test protocols in the codes and standards described above.

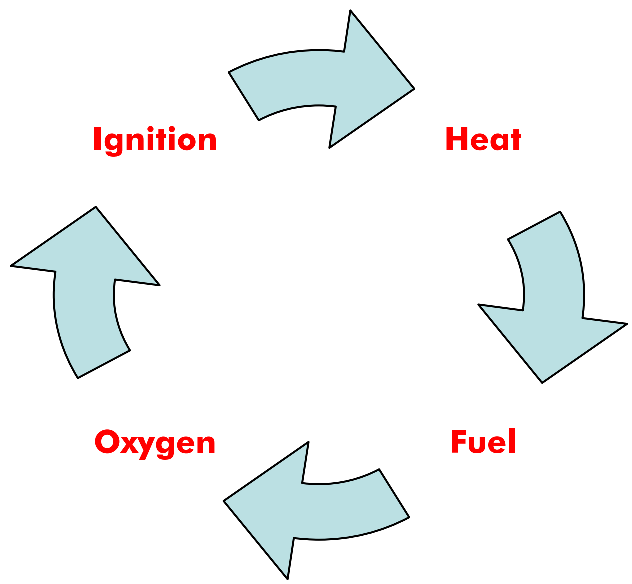
The NEC is administered by the National Fire Protection Administration (NFPA) and although participation is voluntary, it is the de facto standard throughout most of the US. Some large cities have codes which deviate from the NEC, most notably Chicago and Las Vegas. The NEC contains articles which cover specific types of premise wiring installed in buildings. Within these articles are references to the UL / NFPA flame tests which these specific types must meet in order to comply with the code.

EN 50266 and IEC 60332-3 are virtually identical except for minor editorial differences and are still the most commonly specified large ignition source (20kW or greater) European Union flame tests for data communications cable. However, EN 50399 is part of the recently ratified CPD and should become a commonly specified flame test protocol over the next few years.

The "Fire Cycle" and Material Chemistry

Before entering into a detailed discussion about flame testing of wire and cable constructions, the "Fire Cycle" will be discussed.

Fire Cycle



There are four elements to the fire cycle, heat, fuel, oxygen, and ignition. Heat causes the plastic in the cable to degrade. When the plastic degrades, it creates combustible materials in both gas and liquid form. In the diagram above, we refer to these combustible materials as "Fuel". The fuel combines with oxygen, ignites and releases heat. The heat released by combustion causes more plastic to degrade and form combustible material, which combines with oxygen, which then ignites, which then creates more heat. This cycle repeats endlessly until one of the elements necessary to continue the cycle are eliminated or reduced sufficiently to prevent the cycle from continuing. Common ways to interrupt the fire cycle are:

- Reducing the amount of fuel available to burn
- Reducing the availability of oxygen to chemically react with the fuel
- Reducing the amount of heat available to degrade the plastic

Some plastics, like polyvinyl chloride (PVC) and most fluoropolymers, have inherent flame resistance due to their chemical structure. Other polymers like polyethylene and polypropylene require additives to impart flame resistance. The flame retarding technologies used to impart fire resistance to polymers generally fall into two categories, halogen based and halogen free.

Halogen Containing Flame Retardant (FR) Plastics:

PVC and fluoropolymers contain halogens in their polymer backbone and thus are considered halogen based materials. Sometimes sources of halogen are added to plastics in order to improve flame retardant properties. Fluorine, chlorine, bromine, and iodine are all considered halogens with chlorine and bromine being the two halogens most commonly used to flame retard plastics. Halogens generally function in a fire by scavenging the free radicals that form in the flame region during combustion. These free radicals are necessary to continue the conversion of fuel into heat and keep the fire cycle going. By reducing the amount of free radicals available to continue combustion, less heat is generated. If less heat is generated, a lesser amount of polymer (fuel) is decomposed and available to burn. By reducing the amount of heat available, the fire cycle can be slowed or stopped.

Halogens perform a secondary flame retarding function as well. When halogen containing plastics burn, they typically release acidic compounds which can help to form a layer of char (intumescence) to protect the plastic. The flame retarding function of this intumescent layer is discussed in greater detail below.

Halogen Free Flame Retardant Plastics:

Unlike halogen based flame retardant plastics, the majority of halogen free flame retardant plastics do not contain additives which scavenge free radicals in the flame region during combustion. Since PVC and fluoropolymers contain halogen in their structure, they can not be used in halogen free products. The base polymers most commonly used in halogen free FR plastics are olefinic based materials such as polyethylene, polypropylene based copolymers, and ethylene vinyl acetate (EVA). Typical FR additives for halogen free flame retardant plastics used in wire and cable perform the following functions:

- Extracting heat from the polymer region to interfere with the fire cycle. This is typically accomplished by adding mineral fillers which contain water in their structure to the plastic. As these mineral fillers release water during a fire, heat is absorbed. This reduces the amount of heat available to continue the fire cycle.

- Displacement of oxygen by water vapor released from the mineral fillers during combustion. If oxygen is displaced by water vapor (steam), there is less oxygen available to participate in the fire cycle.

- Forming a heat-resistant char (intumescence) that creates an insulating barrier between the plastic (fuel) and the flame (heat source). This intumescent layer has two major functions. The first is to help thermally insulate the polymer fuel from the heat source. This insulation concept is similar to how ceramic tiles protect a NASA Space Shuttle during re-entry into the earth's atmosphere. The second function is to impede the movement of degraded plastic fragments into the flame to serve as fuel. Both of these functions interfere with the fire cycle.

Comparison between Halogen Containing and Halogen Free FR Data Cables:

NEC compliant halogen free FR data communication cables tend to be more expensive than their halogen based counterparts. Also, halogen free data cables meeting a specific NEC requirement will typically have inferior physical property performance versus an equivalent halogen based product meeting the same requirements

Halogen free systems do have several advantages over halogen based FR systems. Cables based on halogen free systems generally emit less smoke and less acidic gas for equivalent mass of polymer burned than their halogenated counterparts. Cables based on halogen free FR systems also typically generate less toxic gas per pound or kilogram during combustion than those based on halogenated FR systems. However, the relative fire safety of these cables is very dependant on the combustion conditions of the cable. In a fire test like the NFPA 262, cable constructions based on halogen free FR systems typically generate more smoke and higher levels of toxic gases like carbon monoxide than competing halogen containing cable constructions which pass this test.

Fire Tests for Data Cables

There are two main cable orientations in flame tests, vertical and horizontal. At equal burner intensity, the vertical orientation is typically more severe. Below, the large ignition source (20kW or greater) flame tests most commonly specified for data communications cable in North America and the European Union are discussed:

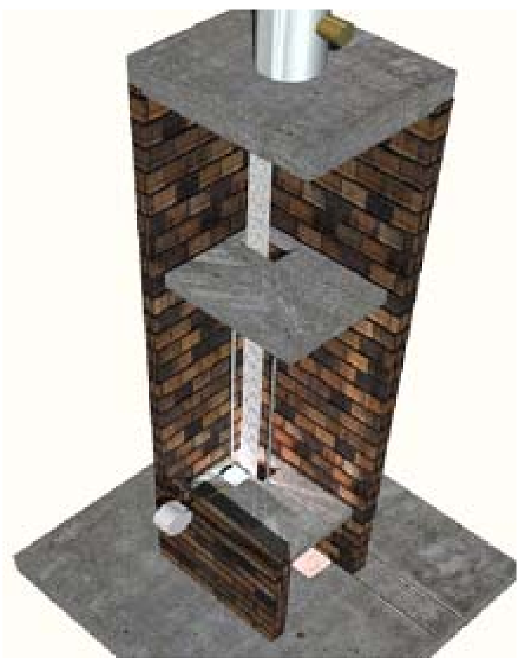
Vertical Fire Propagation Tests:

UL 1685	US (Vertical Tray)
UL 1666	US (Riser)
FT-4	Canada
EN 50266	Europe (formerly IEC 60332-3)
EN 50399	Europe and currently under consideration by China. Used for CPD classification.

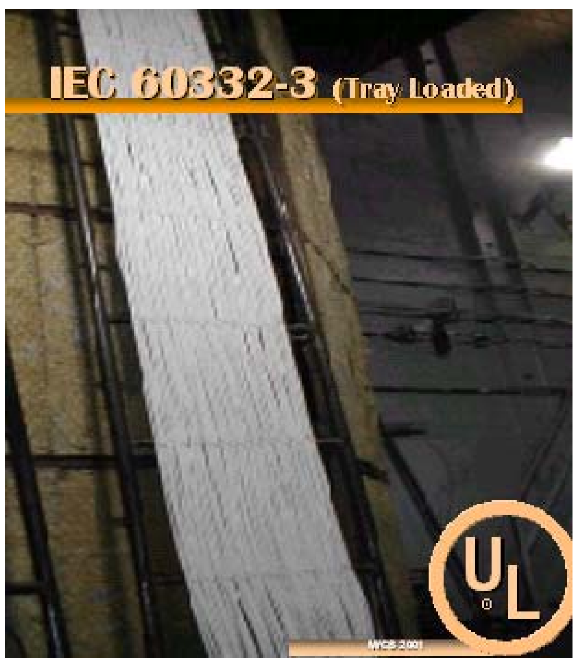
Table 1: Vertical Fire Propagation Test Conditions and Pass / Fail Requirements

	UL 1666	EN 50266	EN 50399**	UL 1685	FT 4 (IEEE 1202)
Test chamber	Full scale – three stories	4m/13' high	4m/13' high	Full scale	Full scale
Fire size	154kW 527k BTu	20kW 70k Btu	20/30kW 70k/102k BTu	20.6kW 70k BTu	20.6kW 70k BTu
Air flow	3.5 ms^{-1} slot velocity	$5m^3\ min^{-1}$	(i) $5m^3\ min^{-1}$ (ii)$8m^3\ min^{-1}$	$0.65\ m^3\ s^{-1}$	$0.65\ m^3\ s^{-1}$
Sample Arrangement	Single layer 12" wide	Based upon combustible content of cable	Single layer or bunched based upon cable dia.	½ cable dia. separation 12"x8' tray	½ cable dia. separation or bundles for small cables 12"x8' tray
Duration	30 mins	20 mins	40 mins	20 mins	20 mins
Flame Spread	12' max	2.5m limit^	>1.5m to >2.5m^	<8' char length^	<1.5m char^
Smoke Release	n/a	Not measured	Required	$0.25m^2\ s^{-1}$ peak $95m^2$ total smoke for LS rating	$0.4m^2\ s^{-1}$ peak 150 m^2 total smoke for LS rating
Heat Release	850^0F Max*	Not measured	Required	Not measured	Not measured

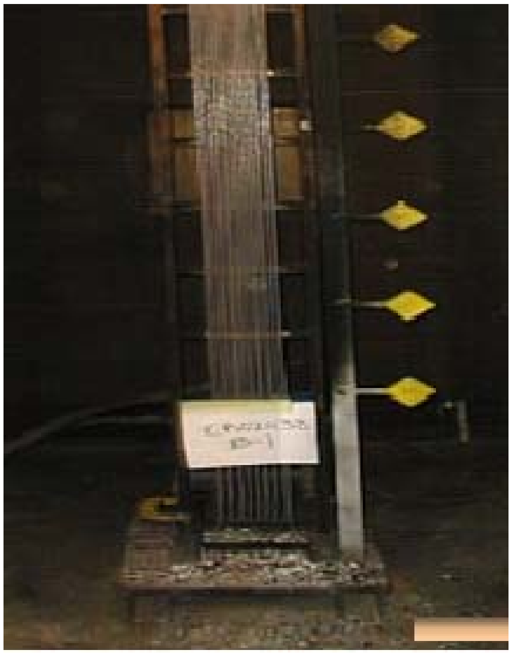
* Max chamber temperature, heat release not measured.
** Two test conditions (scenarios 1 & 2) used for Euroclassification (CPD).
^ Measured at the boundary of charred: undamaged cable jacket surface.



UL 1666 Riser (1)



EN 50266 / IEC 60332-3 (1)



UL 1685 Vertical Tray (1)

FT 4 / IEEE 1202 (1)

1) images from UL literature

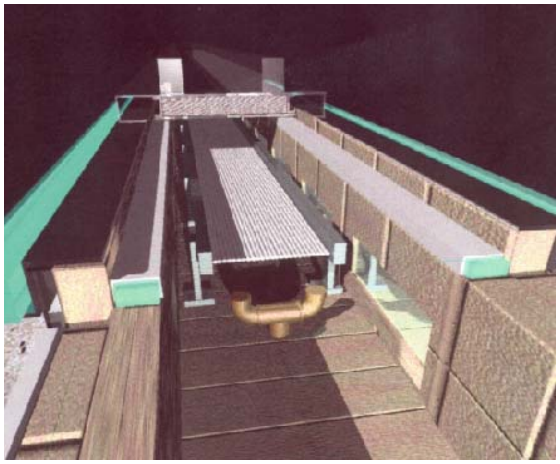
Horizontal Fire Propagation Tests:

NFPA 255 US (Limited Combustible Cable)
NFPA 262 US (Plenum Cable)
FT-6 Canada (test protocol identical to NFPA 262)

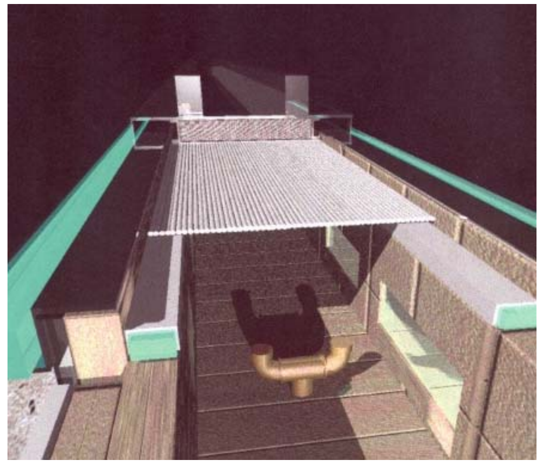
Table 2: Horizontal Fire Propagation Test Conditions and Pass / Fail Requirements

	NFPA 262	**NFPA 255**	**FT-6**
Test chamber	25′ horizontal	25′ horizontal	25′ horizontal
Fire size	88kW/320k Btu	88kW/320k Btu	88kW/320k Btu
Air flow	240 ft sec^{-1}	240 ft sec^{-1}	240 ft sec^{-1}
Sample arrangement	11.25″ tray loaded to single cable depth/ 25′	20.25″ tray loaded to single cable depth/ 25′	11.25″ tray loaded to single cable depth/ 25′
Test duration	20 min	10 min	20 min
Flame Spread	5′ max	25 flame spread index^	5′ max
Smoke Release	.5 peak/ .15 average	50 Smoke Developed Index^	.5 peak/ .15 average
Heat Release	n/a	*	n/a

*measured separately using an oxygen bomb calorimeter (NFPA 259).
^ Red Oak = 100



NFPA 262 / FT 6 cable arrangement (1)



NFPA 255 cable arrangement (1)

1) images from UL literature

NEC Fire Test Hierarchy

In order to understand the NEC Fire Test Hierarchy, we need to understand the three main applications for Premise data communications cable:

Plenum: Cable intended for use within buildings in ducts, plenums, or other spaces used for environmental air distribution. Any cable used in these areas must be plenum rated in order to be installed without conduit. In order to pass NFPA 262, these cables must have outstanding resistance to flame spread and generate low levels of smoke during combustion. Plenum rated cable is the highest in cost of the three major premise data communications cable types specified by the NEC.

Riser: Cable intended for use within buildings in vertical shafts between floors. Cables for these areas must be either Plenum or Riser rated in order to be installed without conduit per the NEC. In order to pass UL 1666, the cable must have outstanding resistance to flame spread. Riser rated cable is significantly lower in cost than plenum cable.

General Purpose: Cable intended for general use within buildings. Typically these are cables installed within a building which do not fall within the Plenum or Riser cable classifications. These cables must meet the UL 1685 flame test requirements, which require less resistance to flame spread than Plenum or Riser rated products. Because of this, the NEC permits Plenum or Riser cable to be installed in General Purpose cable applications without conduit. General Purpose cable is the lowest in cost of the three types. However, the price differential between General Purpose and Riser cable is less than the price differential between Riser and Plenum cable.

The NEC has created a cable fire performance hierarchy based on these data communications cable applications and it is described by the diagram below:

Plenum	MPP	⇨	CMP	OFCP	⇦	OFNP
			⇩	⇩		
Riser	MPR	⇨	CMR	OFCR	⇦	OFNR
			⇩	⇩		
General Purpose	MP (MPG)	⇨	CM (CMG)	OFC (OFCG)	⇦	OFN (OFNG)

Note the downward direction of the arrows moving between the Plenum, Riser, and General Purpose categories. According to the hierarchy, Plenum rated cable may be used for Riser and General Purpose applications. Riser rated cable may not be used in Plenum applications, but may be used in General Purpose applications. The use of General Purpose cable is not permitted in either Riser or Plenum applications. The flame tests required for each application become more difficult to pass as you move up the hierarchy from general purpose to plenum rated products.

European Union Fire Test Classes

In Europe, the test most frequently cited for data communications cable is EN 50266 (IEC 60332-3). This fire test has a series of classes where the amount of cable tested is determined by the amount of combustible materials.

Table 3: EN 50266 Fire Test Classes

Class	Description
3AF	7.0 liters of combustible material per meter of cable. Two layers of cable, one mounted on front of the tray, the other on the rear. Only used for large cables with a conductor size exceeding 35 mm^2.
3A	7.0 liters of combustible material per meter of cable. One or more layers of cable mounted on the front of the tray only.
3B	3.5 liters of combustible material per meter of cable.
3C	1.5 liters of combustible material per meter of cable. Intended to be used only for smaller cables with a low amount of combustible material.
3D	0.5 liters of combustible material per meter of cable. Only for small cables with a diameter less than 12 mm.

These classes appear to form a hierarchy; however, this is not truly the case. A FIPEC (Fire Performance of Electrical Cables) study completed by the European Council in the late 1990's clearly identified that the very small ignition source (20kW), the limited airflow (5m^3/min) and sample positioning specified in EN 50266 were inadequate to fully release the fuel potential of the cable sample and that the escalation 3D to 3AF did not provide a hierarchy. It has been observed that many small diameter cables pass class 3A more easily than class 3C. That is one of the reasons why the Construction Products Directive created EN 50399.

Table 4: EN 50399 Fire Test Classes

Class	Description
A	Incombustible – EN ISO 1716.
B1	Bunched cable flame test with backboard – flame spread <1.75 meters.
B2	Bunched cable flame test without backboard – flame spread <1.5 meters.
C	Bunched cable flame test without backboard – flame spread <2.0 meters.
D	Bunched cable flame test – no flame spread limit – total heat release at 20 minutes < 70 MJ.
E	Single cable flame test.
F	No performance determined.

EN 50399 uses the same chamber design as EN 50266. The key difference is that the EN 50399 protocols address many of the FIPEC issues with EN 50266 related to ignition source, airflow, and sample positioning.

North American and European Fire Test Comparison

Prior to the introduction of the CPD and with the presumption of hierarchy for the North American tests, the severity of the EN 50266 test protocol was somewhat similar to that of the UL 1685 Vertical Tray test in terms of resistance to flame spread. However, some of the classes in the new EN 50399 have test protocols approaching those of the most severe UL flame tests for data cable in terms of flame spread resistance.

Although we have not discussed EN 50289, this protocol has high level regimes that can be considered equivalent to the NFPA 262 (Plenum) and NFPA 255 (Limited Combustible). The reason EN 50289 has not been mentioned to this point is because these tests have not been assigned to any European Union applications at this time.

Table 5: Summary of Flammability Measurements between North American and European Union Data Communications Cable Flame Test Standards:

Measurement	**UL 1666** Vertical	**UL 1685** Vertical	**FT4** Vertical	**EN 50266** Vertical	**EN 50399** Vertical	**NFPA 255** Horizontal	**NFPA 262** Horizontal	**FT6** Horizontal
Flame Spread	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Smoke Generation	No	LS only	LS only	No	Yes	Yes	Yes	Yes
Heat Release	Max. Temp.	No	No	No	Yes	O_2 bomb	No	No
Acid Gas Evolution	No	No	No	No	Yes	No	No	No

- All of the data communications flame tests listed in Table 5 routinely measure flame spread.

- Smoke generation is routinely measured by the horizontal North American flame test standards as well as EN 50399. UL 1666 and EN 50266 do not have any smoke requirements. Although the UL 1685 and FT4 standards have a smoke requirement in order to obtain the LS (Limited Smoke) designation, there is little demand for LS rated data communications cables.

- Heat release can be measured directly in EN 50399. NFPA 255 measures heat release of cable materials separately in an oxygen bomb calorimeter. Neither EN 50266 nor any of the North American tests measure heat release during the flame test. Although UL 1666 does have a maximum temperature requirement, it is not truly a heat release measurement.

- Only EN 50399 has any provisions to measure acid gas generation, none of the other standards listed in Table 5 do this.

Data Cable Materials Selection

The major difference between North American and European data communication cable material selection is that North American data cables generally contain some halogenated polymer in their construction while European Union data cables typically use halogen free materials. The prevailing view in the European Union is that the desire to eliminate acidic and potentially toxic gases takes precedence over the North American desire to minimize flame spread and smoke generation.

Data cable materials selection in North America and the European Union is driven by differences in flame test standards that have evolved independently between the two regions. The majority of Category 5e or Category 6 data communications cable sold in North America passes the NFPA 262 test. As of now, there are no halogen free material technologies that enable Category 5e or Category 6 compliant halogen free cables to meet the flame spread and smoke generation requirements of NFPA 262. Conversely, most of the halogen based data cables sold in North America which meet NFPA 262 would have difficulty meeting the requirements within EN 50399 related to acid gas generation.

One must remember that even though significant differences exist between North American and European Union flame test protocols and philosophies, the end result is the same. Both approaches have been extremely successful at what matters most, ensuring the safety of people.

Data Communications Competence Center

Nexans' Data Communications Competence Center, located at the Berk-Tek Headquarters in New Holland, Pennsylvania, focuses on advanced product design, applications and materials development for networking and data communication cabling solutions. The Advanced Design and Applications team uses state-of-the-art, proprietary testing and modeling tools to translate emerging network requirements into new cabling solutions. The Advanced Materials Development and Advanced Manufacturing Processes teams utilize sophisticated analytical capabilities that facilitate the design of superior materials and processes. The Standardization and Technology group analyzes leading edge and emerging technologies and coordinates data communication standardization efforts to continuously refine Nexans' Technology Roadmap. An international team of experts in the fields of cable, connectors, materials, networking, standards, communications and testing supports the competence center. The competence center laboratories are a part of an extensive global R&D network that includes eight competence centers, four application centers and two research centers dedicated to advanced technologies and materials research.

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