LOW SMOKE ZERO HALOGEN WIRE AND CABLE BEST PRACTICES

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SUMMARY

Even though they are still predominant in the industry, the use of halogenated compounds in wire and cable has decreased over the past several years. Polymers such as PVC are being phased out in certain applications, especially in enclosed, high-density cable applications. Relatively new low-smoke and zero (or low) halogen compounds, which are typically polyolefin based with a heavy doping of inorganic hydrated minerals, give off cleaner smoke when burned. This mineral doping also reduces certain physical properties so the wire and cable industry has attempted to develop low-smoke and halogen-free compounds that have the same or better functionality than the common halogenated compounds currently in use in industrial applications. However, it is important to understand that smoke production and halogen content are not mutually exclusive. Halogenated low-smoke compounds exist as do halogen-free compounds that are not low-smoke. It is always best to consult with wire and cable experts when choosing a cabling solution.

HISTORY OF LSZH MATERIALS

Since the 1970s, the wire and cable industry has been using low-smoke, low-halogen materials in a number of applications. The objective was to create a wire and cable jacketing that was not only flame retardant but also did not generate dense, obscuring smoke and toxic or corrosive gases. Several notable fires over the years (such as the King's Cross Fire that killed 32 people in London's underground subway in 1987) increased the awareness of the role that wire and cable jacketing plays in a fire and contributed to a greater adoption of LSZH cables. With an increase in the amount of cable found in residential, commercial and industrial applications in recent years, there is a greater fuel load in the event of a fire. Wire and cable manufacturers responded by developing materials that had a high resistance to fire while maintaining performance. Low-smoke, zero-halogen compounds proved to be a key materials group that delivered enhanced fire protection performance. Today, low-smoke, zero-halogen cables are being used in applications beyond the traditional transit, shipboard, military and other confined-space applications.

Low smoke, zero halogen has many different abbreviations, and some of the more common ones are listed in **Table 1** along with other abbreviations seen in association with LSZH cable. In the U.S., LSZH is the most common term and will be used throughout this paper.

Abbreviation	Meaning
LSZH	Low smoke, zero halogen
LSF	Low smoke, fume
LS0H	Low smoke, zero halogen
LSHF	Low smoke, halogen free
LSNH	Low smoke, nonhalogen
NHFR	Nonhalogen, flame retardant
HFFR	Halogen free, flame retardant
FRNC	Fire retardant, noncorrosive
LS	Low, limited smoke
ST	Smoke test (limited smoke)
FRLS	Fire resistant, low smoke
RE	Reduced emissions
LC	Low corrosivity
LH	Low halogen

Table 1: Common LSZH Abbreviations

Low smoke and zero halogen have different meanings and cannot be used interchangeably. A cable can be low smoke without being halogen free or vice versa. Halogen-free materials typically produce clearer, whiter smoke while chlorinated polymers tend to produce, in part due to their flame resistance, thicker, dark smoke when burned.

LOW SMOKE CABLES

When burned, a low-smoke cable (also known as limited-smoke cable) emits a less optically dense smoke that releases at a lower rate. During a fire, a low-smoke cable is desirable because it reduces the amount and density of the smoke, which makes exiting a space easier for occupants as well as increases the safety of firefighting operations.

Several standards describe the processes used for measuring smoke output during combustion (see **Table 2** for examples). During these tests, a technician burns a cable and measures the optical density of the smoke given off. There are various means of measuring optical density: peak smoke release rate, total smoke released, and smoke density at various points and durations during the test. Results must be below a certain value and the cable must pass the burn test in order for the material to be labeled as low smoke.

According to UL standards, a low-smoke designation (abbreviated as "-LS") can be added to certain types of UL Listed cables if they pass the UL 1685 test. To pass the test, a cable must have a total smoke release of less than 95 m^2 and a peak smoke release rate under 0.25 m^2/s. UL also defines a ST1 (smoke test one) rating that measures peak and total smoke emission for some wire types [2].

The National Electrical Code (NEC) only requires that cable used in plenum spaces be rated as low smoke; this requirement first appeared in the 1975 code [6]. There has been debate about the need for plenum cables to be low smoke [1] because typical plenums don't contain the same fuel load and exposure to ignition sources as other areas. A major concern is that toxic or corrosive products from a localized fire can spread through the plenum spaces to other areas of the building. The National Fire Protection Association (NFPA) maintains the standard used to qualify cables for plenum air spaces, NFPA 262 (formerly UL 910) [3]. This test is also commonly referred to as a Steiner tunnel test and is regarded as one of the more difficult industry fire tests to pass. Most polyolefin-based LSZH sold in the U.S. cannot pass the Steiner tunnel test.

Name	Description
ASTM D5424	Smoke obscuration of insulating materials in a vertical tray configuration
ASTM E662	Specific optical density of smoke generated by solid materials
BS EN 61034	Measurement of smoke density of cables burning under defined conditions
C22.2 No. 0.3	Test methods for electrical wires and cables
Def Stan 02-711 (formerly NES 711)	Smoke index of the products of combustion from small specimens
IEC 61034	Measurement of smoke density of cables burning under defined conditions
NFPA 262 (formerly UL 910)	Flame travel and smoke of wires and cables for use in air-handling spaces
UL 1685	Vertical-tray fire-propagation and smoke-release test
UL 2556	Wire and cable test methods

Table 2: Industry Smoke Tests

ZERO HALOGEN CABLES

A zero-halogen cable does not contain any of the chemical elements defined as a halogen. Even though some materials used in wire and cable contain no halogens, many others include a high percentage of halogens with the most common being chlorine, fluorine and bromine. Because halogens are effective fire retardants, they are added to naturally halogen-free materials to allow a cable to pass an industry flame test. **Table 3** lists the halogen content in some typical wire and cable polymers.

Polymer	Halogen Content (% by weight)
XLP (cross-linked polyethylene) with halogen-free flame retardants with halogenated flame retardants	<0.02 <0.02 7–17
EPR (ethylene propylene rubber) with halogenated flame retardants	<0.02 9–14
PU (polyurethane)	<0.02
PE (polyethylene) with halogen-free flame retardants	<0.02 <0.02
CSPE (chlorosulfonated polyethylene)	13–26
CPE (chlorinated polyethylene)	14–28
PVC (polyvinyl chloride)	22–29
FEP (fluorinated ethylene propylene)	62–78
<0.02 generally considered zero halogen	

Table 3: Typical Halogen Content of Common Wire and Cable Materials

Low halogen is not as clearly defined as low smoke. UL does not define an equivalent to the "-LS" rating for halogen-free products, and many materials that are often defined as zero halogen still contain trace amounts of halogen, even though they are not considered harmful. For example, the military standard MIL-DTL-24643 dictates a halogen content of less than 0.2 percent by weight. Other standards reference the volume of the acid gas given off, but do not define halogen levels.

A common standard in the U.S. is ICEA T-33-655, which covers low-smoke, halogen-free polymeric cable jackets. However, this standard only addresses the cable jacket, not the cable insulation, because the jacket is the first part of the cable to undergo combustion. Many cable constructions reference this standard and are described as low halogen but still contain halogenated materials. The drawback is that all polymeric materials will eventually combust in a fire scenario, so halogen combustion products will still be present if the cable burns completely.

In recent years, halogens have come under scrutiny for the toxicity and corrosivity of their combustion byproducts. Their reactive nature that makes them effective flame retardants can also present a danger to building occupants by giving off toxic gases when burning and by risking damage to electronic equipment and metallic structures. Standards for corrosivity and toxicity testing exist as well and may be more appropriate indicators of a cables suitability for a certain application than the halogen content.

Despite the concerns related to halogenated materials, the majority of cable in plenum spaces contains halogen. There is now concern that if this material burns, it can represent a significant safety risk. The opposing viewpoint is that while halogen combustion products may be dangerous, the flame retardant properties of halogenated materials make it less likely to burn and, therefore, safer overall.

FLAME TESTING

It is important to separate the fire performance of wire and cable from the LSZH label. Almost all modern cables are required to pass some type of flame test. A typical LSZH flame test measures five criteria in order to predict how a cable will behave in the event of a fire:

1. How easily the cable ignites
2. How fast and far fire will propagate along the cable
3. How much smoke is generated by the cable when it combusts
4. The toxicity of the products of combustion
5. The byproducts' corrisivity

Industry tests exist in the U.S. and abroad to measure each of these factors, but there is continuing debate around how best to measure and test wire and cable for fire performance. Developing LSZH compounds and cables that maintain costs and processing characteristics has been a constant challenge for the industry. There is also ongoing research into correlating small-scale, also called bench tests (e.g., UL 94 or cone calorimeter tests) to large-scale fire tests.

HALOGEN FREE FLAME RETARDATION METHODS

Products containing halogenated polymers (such as polyvinylchloride [PVC] and fluorinated ethylene propylene [FEP]) are inherently flame resistant. When burned, the materials generate free radicals that slow down the combustion process by reacting with the high-energy free radicals. One of the products of this process is a halogen acid gas such as hydrochloric acid (HCl).

For other materials that are not naturally flame retardant, polymer flame retardation is achieved by using supplementary additives. These supplementary additives, along with synergistic additives, are added to the polymer. Adding inorganic hydrates, such as aluminum trihydrate (ATH) or magnesium hydroxide (MDH) will achieve flame retardation. In the event of a fire, both of these materials undergo an endothermic chemical reaction that absorbs heat energy and releases steam when the compound reaches a certain temperature.

$$2Al(OH)_3 \rightarrow AL_2O_3 + 3H_2O \ (230° C)$$

$$Mg(OH)_2 \rightarrow MgO + H_2O \ (330° C)$$

The steam disrupts combustion and a char layer that protects the remaining material and traps particulates then develops. Because these materials replace the base polymer, the total amount of fuel available for combustion is also reduced.

MDH reacts at a higher temperature (330° C) than ATH (230° C), which makes processing easier as it allows higher extrusion temperatures. However, MDH is more expensive than ATH, which makes ATH much more common. Recent statistics show ATH represents approximately 50 percent of the European flame retardant market by weight [7].

The main challenge with mineral-based fillers is the high loading levels required to pass industry flame tests (up to 65–70 percent) This loading can have a negative affect on the cable's physical properties, which typically results in a lower elongation, elongation at break and tensile strengths. Processing can be more difficult with these materials, but many methods of improving the processing exist, including using silicone additives and surface coatings. Manufacturers use a wide variety of compound blends as different polymers process and perform better with some additives than others.

Other materials exploited for flame retardation include intumescents, which are materials that undergo an endothermic reaction and swell when exposed to heat to provide a protective layer. Nanocomposite fillers, which are typically a type of clay, are used at lower loadings (~5–10 percent) [4] as a synergistic additive with other flame retardants to improve the processing and flame performance. Synthetic clays further enhance performance, and in the future-carbon nanotubes or other carbon-based nanostructures may be available for commercial use.

THERMOSET VS. THERMOPLASTIC LSZH

Thermoset wire and cable typically offers better performance than thermoplastic wire and cable. A thermoset is a material that assumes its final form after processing. A thermoplastic can be melted and given a new form after processing. Chlorinated thermoset jackets are common in industrial applications due to their desirable physical features and ability to pass the most rigorous flame tests. LSZH does not have the long track record of performance that chlorinated thermosets possess, and there are questions about the lifespan and performance of these cables.

Recent advances in compounding technology have allowed manufacturers to offer thermoset LSZH cables that pass many of the same tests as chlorinated thermosets, such as the IEEE 1202 and UL VW-1 flame tests. A past problem has been the water absorption tests required in many cable standards. LSZH material typically absorbs a greater amount of moisture than non-LSZH material. Moisture absorption affects the physical and electrical characteristics of wire and cable. New compounds and processing techniques have allowed manufacturers to overcome this problem. [8].

SUSTAINABILITY

The ultimate goal for a sustainable wire and cable industry is to develop and use materials that safely perform physically and electrically while continuously reducing the total amount of energy for a given set of performance criteria. Even though compound selection is important, you must also consider the total processing energy versus field performance. Some studies have shown that halogenated compounds require less overall processing energy. Even if there were processing advantages, the added performance you get from halogenated compounds could potentially outweigh them. Getting a precise measure of the total lifetime environmental impact is difficult. This is why regulations such as the European Union's WEEE (which make producers responsible for recycling any electrical products they put on the market) have become more common in recent years.

Reprocessing is also another sustainability consideration. It is more difficult to reprocess thermoset materials than thermoplastic materials because they don't remelt (they're basically heat-set, as the name implies). But if you get a greater overall longevity out of a cable population because you used thermoset materials then you could argue the lifetime value of the thermoset material is higher. It is certainly a complex problem, and one that is certain to get more attention in the coming years.

Ultimately, no wire and cable user wants to sacrifice performance, and certainly not safety. Most wire and cable is built to industry standards that ensure it can pass various electrical and physical tests. Technically this allows the end-user to select whatever cable design they feel most comfortable with while ensuring the cable is of good quality and will perform at a standardized level. Local building codes such as NFPA 70 (National Electrical Code) used in the United States dictate that cable types installed within a building comply with the appropriate fire rating based on its specific use case. For example, communications cabling installed in ducts, plenum and other spaces used for environmental air shall be rated CMP, which means it must pass the difficult NFPA 262 flame test. Currently, there is not a commercial zero-halogen cable that can pass this test and other mechanical tests required by cable standards. Beyond the technical considerations, the end-user must also consider special certifications and allowances that require the use of certain materials. For large cable projects, it is important to consult with wire and cable experts to choose the correct cable system for that application.

APPLICATIONS

The clearest uses for LSZH are confined spaces with large amounts of cables in close proximity to humans or sensitive electronic equipment. Submarines and ships are classic examples, which is why the military was one of the first adopters of LSZH standards. Additionally, mass transit and central office facilities are common applications for LSZH, and many telecommunication standards require LSZH cables.

The use of LSZH cables in Europe has been widespread since the 1980s. It has never achieved such widespread acceptance in the United States, primarily for cost reasons, but also because of performance concerns. Some of the cable designs used in Europe cannot pass U.S. test standards, and the high additive loading needed to pass the U.S. flame tests can lead to reduced physical properties if not done carefully.

Installation at lower temperatures can also be affected. Reduced flexibility due to the high additive loading in the materials can prevent cables from being installed in cold environments. The high mineral content can also result in fractures of the material if the installation is not done carefully. Research of the cracking behavior of LSZH has been done with the goal of improving performance [9].

One advantage of LSZH is that it typically has a lower coefficient of friction, although lubricant suppliers recommend a special pulling lubricant for low-smoke, zero-halogen jackets [5]. Though there has been a trend toward jackets that do not require lubrication, some installations will still require lube to help with difficult pulls.

There are still questions about the necessity for LSZH cable in some applications. Fires are dangerous, but so is electricity, and if a higher voltage or mission-critical cable is more likely to be damaged during installation or from physical or chemical damage during its lifetime, this could conceivably result in a statistically more dangerous product than a halogenated cable.

Another consideration is the environment in which the cable will be installed. If a fire occurs in an open area in which smoke concentration is not sufficient to obscure escape routes, using a LSZH cable may not be beneficial. There is also the question of the fuel load in a building other than cabling. The smoke being given off by other materials burning can vastly outweigh the contribution of the wire and cable. Of course, this is highly dependent on the installation and the relative amounts of cable present as well as the building's function and contents.

However, there is no question that the amount of cable installed in buildings has increased as data communication has proliferated. Central office telecommunication facilities were some of the first places that LSZH cables became common due to the large relative fuel load represented by wire and cable.

Modern data centers contain large amounts of cabling, and are usually enclosed spaces with cooling systems that can potentially disperse combustion byproducts through a large area. In industrial facilities, the relative fuel load of cables will not be at the same level. Other materials burning may also contribute greater amounts of dangerous gases that outweigh the effect of the cables. There have been notable fires where cables burning contributed to corrosion (the Hinsdale Central Office fire is a famous example), but in some instances, better fire response techniques could have prevented this damage.

The nuclear industry is another area where LSZH cables have been and will be used in the future. Major cable manufacturers have been producing LSZH cables for nuclear facilities since the early 1990s. The expected construction of new nuclear plants in the U.S. in coming years will almost certainly involve some LSZH cable.

One of the most important things to understand about LSZH cable (and of course cable in general) is that no two products are the same and that there are many factors that will define the suitability of the final product to its application. In fact, research done by a major pulling lubricant supplier tested 27 LSZH compounds and found a huge variation in physical properties. So even using material that meets the base requirements of one of the many specifications available may not result in the best material for the application. Understanding the goals, results and limits of these tests are key to finding the right product. In any case, the trend to consider environmental concerns with a greater weight relative to performance has increased and it can be generally stated that there is an enlarging market for cable that can be demonstrated to be environmentally friendly.

CONCLUSION

Low-smoke and zero-halogen cable technology has advanced significantly. It is well suited to some, but not all, applications. With further research and investigation into compounds that can pass industry flame tests and offer improved processability, the uses and adoption will increase. If the technology improves to the point where it is equivalent to or exceeds other materials, the industry will continue to see increased adoption of LSZH standards and specifications.

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