Critical Testing and Properties of Cable and Wire Markers

Our thanks to Brady for allowing us to reprint the following article.

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Introduction and Challenges

Industries that are driven by specifications, such as Aerospace, Defense, Mass Transit, Electrical and Control Systems, require high performance, durable solutions for their component, wire and cable identification solutions.

Therefore, materials science becomes critical in offering materials that are self extinguishing, chemical resistant, and able to withstand extreme environments, including high temperatures. Basic material construction, product improvements, print performance and the user application features become additional requirements, as well as the need for light-weight, flexible, conformable, and repositionable material for wire wrapping. The actual materials, set up, and labels are crafted and identified by chemistry and by specifications. Other performance needs, such as wrapped labels being used to reduce stress on connectors, become important on the final product design. Beyond that, business considerations include cost competitive choices with secured supply chains.

To remain competitive, companies are facing great challenges and are looking for opportunities to build better and safer products. Safety is a top priority; however conservation is important as well. The Boeing Environmental Report states: "Our customers want more airplanes that can be operated and maintained using less fuel and fewer hazardous chemicals."[1] From a macro view, this works to reduce prices and protect the environment for a customer. At a micro level, a supplier needs to build products that meet specifications and global compliance standards - from the large scale assembly down to the level the components are identified by a single label or wire wrap.

1 Creating a better Future: Message from Jim McNerney and Mary Armstrong
http://www.boeing.com/aboutus/environment/environment_report_11/message01.html

2 http://www.fire.tc.faa.gov/pdf/facilities/MaterialsFIRE-TEST_Facil.pdf

What does this mean to identification materials?

Beyond consumers and suppliers, governing organizations such as the Federal Aviation Administration (FAA) are dedicated to safety by minimizing and eliminating fire in aviation. According to the FAA, one of the identified in-flight fire problems is hidden fire that occurs in an inaccessible location.[2] This is where a wire and wire identification label is typically housed, thus there is a need for a highly specified and tested material solution. Materials can be tested to a number of standards and offer technical properties that help prevent flames and protect against other damaging elements, ensuring the wire identification will stay intact and remain legible.

While there are multiple options to identify wires, including heat-shrink sleeving, self-laminating wire labels and wire wraps, this whitepaper will use wire wraps as the basis for understanding the key performance requirements for harsh environment wire and cable identification. There are many requirements that go into a final construction, but there are four must-have absolute technical properties that work together to protect against and prevent fire in electrical systems. The four main technical properties that distinguish the material are:

1) Flame Retardant Properties
2) Chemical Resistance
3) Strength and Wrap
4) High Temperature Resistance

Let's understand these four properties and their importance, as well as related standards, test methods and potential solutions.

1) Flame Retardant Properties

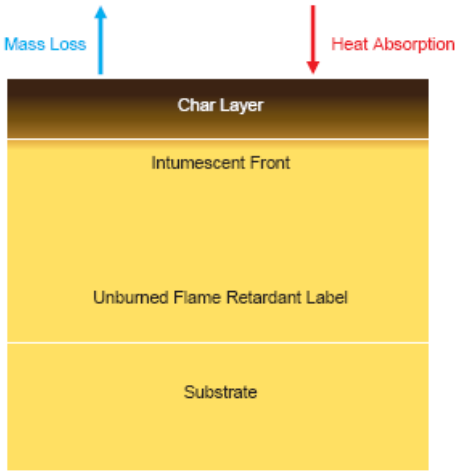
By definition, flame retardant applies to the property of a material that can withstand combustion and delay the passage of flame for a known time period. Material can be flame retardant by way of cooling, forming a protective layer or by dilution. For labeling in these applications, heat and mass loss are routinely measured as toxicity and smoke.

Tests Method Applied to this Property

ASTM D 1000 is a series of test methods that includes testing the flammability of a material. A narrow strip of label stock material is wrapped around a thin gauged wire and held in contact with a flame for 30 seconds. One of the many benefits of having a flame resistant/self extinguishing label is that the label material won't propagate a flame. If used to wrap along a wire, the flame will not propagate down the wire, rather it will be contained.

There are two main technical characteristics that encompass a superior flame retardant mechanism: char forming and the limiting oxygen index (LOI).

Char Forming (also known as charring)
When the material catches fire, it immediately begins working to reduce the heat of combustion, smoke evolution, oxygen depletion and toxic gas evolution. These reactions combine to create a protective barrier called the "char layer." This layer then protects the film from fire; everything beneath the char layer remains virtually unharmed.



This diagram illustrates how in a polyimide construction heat is absorbed, and the char layer forms a barrier. The oxygen binds when burning and creates the CO2 smoke which becomes the mass loss. This burned off layer protects the underlying material.

Flammability (Limiting Oxygen Index, or "LOI")
The limiting oxygen index, or LOI, is a measure of polymer combustion that shows how flammable a polymer is. Polyimide material has a much higher LOI than other polymers. It passes many flammability specifications, including ASTM D 1000 (extinguishing in less than 5 seconds!).

B-472 Flame Retardant Wire Wraps are made of polyimide material, which is inherently flame retardant. In fact, the material does not propagate a flame. Once a flame is removed from the label, the label extinguishes almost immediately. If the material is used to wrap a wire, the flame will not propagate down to the wire and expand the damage. Instead, the flame will be contained to the original area, and then extinguished. Brady B-437/B-637 (Tedlar®) is another film which offers inherent flame retardant properties by way of its chemical and mechanical design.

A higher LOI indicates that the material is *less flammable.* LOI Comparison of common wire wrap films in the market:

Material	LOI AVE	LOI Range
Tedlar (PVF)		22-30
PET	21	19-36
Vinyl	45	

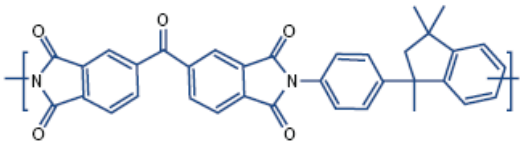
Material	LOI AVE	LOI Range
Polyimide	50	
PEEK	35	23-49

2) Chemical Resistance

The construction and assembly of wires, bundles, harnesses and corresponding final assembly comes into contact with a variety of solvents and chemicals. Beyond daily use, repair and maintenance can have incidental chemicals coming into contact with a label. The film and information on the label must remain legible for the life of the product. In order to measure true chemical resistance of a label or wire wrap, the combination of the ribbon, topcoat, film and adhesive needs to demonstrate resistance.

One method to meet this is to have a material based on a thermosetting polymer such as a polyimide. This type of material has chemistry that is made of cross linked polymers and thereby being permanently hardened.

Thermosetting polymers are inherently chemical resistant. Materials made from these polymers can withstand direct contact with such chemical reagents as solvents, oils, detergents and lubricating fluids. This chemical resistance is a result of strong interactions that take place between the polymer chains.



Cross link refers to an electrical force linking atoms.

Another type of material is thermoplastic such as Tedlar. This type of material is constructed by heating, melting and then hardening. This film has resistance to a wide range of chemical and solvents.

Test Method Applied to this Property

The following test is a typical test used to show that a material can withstand chemical exposure while in use:

A number of printed samples are applied to flat aluminum panels and wrapped around wires. The printed samples are then immersed into chemicals for 15 minutes. Below are some of the chemicals typically tested:

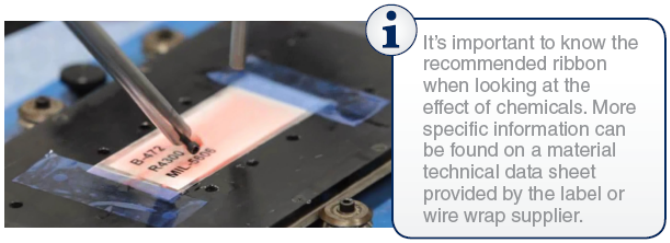
- JP-8 Jet Fuel
- MIL-H-5606 Oil
- Isopropyl alcohol
- Methyl Alcohol
- Deionized Water
- 5% Alconox Detergent
- 10% NaOH
- 10% Sulfuric Acid

After immersion, the samples are evaluated to see if they have been affected by the chemical. The samples are examined for any signs of topcoat softening, adhesive ooze, label edge lift, and unwrapping. Next, the samples are rubbed 10 times with a cotton swab soaked in the corresponding chemical. The samples are again examined for any effects of the chemical rub.

Additional testing can be performed with 3 minute immersion for MIL-STD-202 Method 215K. For more extreme conditions, it can be performed with 24 hours of immersion.

The Proof: Chemical Resistance Testing

As a result of the 15 minute test, it was determined that there was no effect to the actual film stocks of Brady's B-472 Flame Retardant Wire Wraps. As is typical, results varied from no effect, slight, to removal depending upon the material/ribbon/test chemical combination.



3) Strength & Wrap

Tensile strength for labels and wire wraps measures the force required to pull on the material to the point where it fails. This is especially important as wires are wrapped: the data should remain legible, not easily pulled and misshaped by a technician. When wires are pulled through a harness to complete a bundle or through equipment, the material needs to stay intact on the wire without sliding, stretching, pulling or breaking. Not only is strength and wrap a function of the film's tensile strength, but also the adhesive used to keep it attached to the wire, bundle, or harness.

Tests Method Applied to this Property

For the ASTM D 1000 test, a strip of material is put into a tensile testing machine. This machine pulls the material until it breaks. Then, the information is output to a computer to capture the data.

Strength:
As the material is being pulled, you will find its strength along with how much it will elongate. Elongation cannot be used to predict behavior of materials subjected to sudden or repeated loading. Materials are tested to be strong enough, yet flexible enough to wrap around a 0.125 inch diameter wire and remain secure, without becoming unwrapped.

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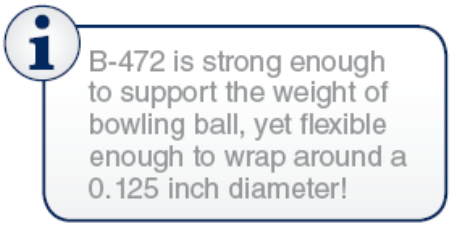
Wrap:
In addition to maintaining optimal mechanical properties for strength, a film should also offer superior flexibility in use. High film integrity can maintain its natural form – without significant wrinkling or deformation – despite being bent, curved, twisted or wrapped tightly around a wire. An adhesive created with environmental conditions in mind adds to being secured around the wire for the lifetime requirements.

The Power of Brady Materials

Brady materials for wires and cables have the unique mechanical properties mentioned above; a blend of strength and flexibility. The B-472 Flame Retardant Wire Wraps are a thinner, 1 mil base film that can maintain equal or greater strength than a standard sized PVF film. In fact, B-472 Flame Retardant Wire Wraps have a typical tensile strength of 36 pounds per inch, when tested in accordance to ASTM D1000. This means it would take 36 pounds of force to break a 1" wide sample of material.



4) High Temperature Resistance

The material must withstand extremely high temperatures without melting, fading or peeling. Wire markers made of thermosetting plastic are resistant to high temperatures. When the film sheet is made, curing causes the many polymer chains to interact. Because of this interaction, the melt temperature of the film becomes higher than the decomposition temperature. Once the material is produced into its final form, it cannot be reheated and melted back to liquid form. Materials that are not able to withstand high temperatures may discolor to the point where print is illegible, the adhesive fails, or the material becomes brittle and cracks – all of which is considered unacceptable.

Tests Method Applied to this Property

The following test is typically used to prove that wire wraps can withstand high temperatures:

A number of printed samples are created and applied to a flat aluminum panel and wrapped around wires. After being applied to the panel or wrapped on a wire, the samples are allowed to dwell for 24 hours at room temperature.

Next, the samples are exposed to elevated temperatures for 30 consecutive days.

After 30 days in the elevated temperature, the samples are evaluated to see if the temperature had any negative effects on the print or the material. The samples are examined for any signs of fading, discoloration, shrinkage, adhesion loss, ooze, material embrittlement, or topcoat cracking.

Resilient High Temperature Materials
The results of the test indicated that the B-472 Flame Retardant Wire Wraps are able to withstand elevated temperatures without any negative effects to the print or the material.

Flame Retardant Identification Materials Available In Market

Here is a high level comparison of materials available for component, wire and cable high performance identification. For more detailed information or additional specifications, please see the technical data sheets.

Polyimide – Polyimide material has extremely strong intermolecular forces between the polymer chains. Thermosetting polyimides are known for thermal stability, good chemical resistance, excellent mechanical properties, and characteristics. This type of polyimide is strong enough to be used in place of metals and glass in many high performance applications in the electronics, automotive, and aerospace industries.

PVF – Flouroplymer films (e.g. Tedlar) exhibit performance characteristics such as mechanical strength, chemical resistance and heat resistance. These polymer chains have added fluorine, and electronegative element, which provides thermal stability and low surface energy. Therefore, it is critical for chemistry of the adhesive and topcoat of the material to adhere to the film. (Source: F&S)

Brady Material #	B-472	B-437/B-637
Film Type I	PI - Polyimide	Tedlar - PVF – Polyvinyl Fluoride
Flammability per ASTM 1000D	Less than 5 seconds	Less than 10 seconds
Tensile Strength	36 lbs/in (630 N/100mm)	20 lbs/in (350 N/100mm)
Elongation	62%	150%
Market Availability	Multiple film suppliers	Single supplier
Weight	60 #/R (0.0098 g/sq cm)	82 #/R (0.0133 g/sq cm)

Please note: These results are simply a guideline. Brady recommends customers test the product in their application for a more accurate depiction of how it will perform to specific specifications.

Conclusion

Beyond the rigors of testing materials to specifications, there are additional considerations in selecting a material and provider. For a trusted solution, consider suppliers that are ISO certified with high level quality standards, and can provide materials science experts for their solutions.

Outside of the top performance requirements of flame retardant, chemical resistant, strength, wrap and high temperature resistance, it can also be valuable to explore the cost benefit ratio as it relates to the performance requirements. The addition of software, ribbons and printers can furnish a complete solution for hassle free and easy implementation and use.

According to a recent article in *Aviation Today,* there is "an increased awareness that wires are a contributing factor to aircraft safety."3 Even a single label can help these efforts "stick."

Learn more

To learn more about Brady's complete line of wire and cable identification solutions or to review the technical data sheets on materials, visit www.BradyID.com.

Authors of Whitepaper

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Special thanks to the Brady Toby Research and Development Center. Here the basis of materials science marries the performance to the application, and provides a wealth of knowledge and solutions.

Additional Sources:

Technical Data Sheets on www.bradyid.com

http://www.aviationtoday.com/av/commercial/Safety-in-Avionics-Avionics-Safety-Real-or-Illusory_12784.html

Fluoropolymer Films Market, Frost and Sullivan 2009

Global Market for Avionics (Aerospace/Aviation Electronics) Guideline, Inc. March 13, 2012.

http://www2.dupont.com/Tedlar_PVF_Film/en_US/

http://scholar.lib.vt.edu/theses/available/etd-04282000-15260034/unrestricted/debidunson2.pdf

UK: 2012 Global Aerospace and Defense Industry Outlook: A Tale of Two Industries, http://www.mondaq.com/x/167926/Aviation,+Aerospace+Maritime/2012+Global+Aerospace+And+Defense+Industry+Outlook+A+Tale+Of+Two+Industries

http://www.astm.org/

http://www.uow.edu.au/~mnelson/review.dir/oxygen.html

http://www.pslc.ws/macrog/imide.htm
http://upetd.up.ac.za/thesis/submitted/etd-01122007-112752/unrestricted/02chapter2.pdf

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