Q&A Summary

Webinar: Improving Cable Reliability in Harsh Environments

As you can see from many of these questions, answers often depend on the environmental issues of the specific application. Please contact us at electronics.usa@wlgore.com if you have an application that you would like to discuss.

Application-Specific Questions

1. Is it possible to improve the individual shielding of cables to avoid a bundle shield?

There are several methods available to improve shielding effectiveness. I mentioned one in the presentation when I was talking about engineered PTFE. For example, Gore has developed versions that are loaded with a new metal material for shielding against a magnetic field, and these can be combined with a good copper or foil shield depending on whether it's a static cable or it's flexing. I suggest that you contact us so we can show you some of the test results utilizing our engineered PTFE materials and how they improve the shielding effectiveness and signal quality of the cable.

2. In aerospace design, some of our biggest cable issues are abrasion and cut-through in doors and landing gear. How can we improve cable performance in these situations?

Cable routing and cable management are the most obvious way to reduce abrasion and cut-through, but routing can only go so far because you have to clamp tightly and it is a very cold environment in the wheel well. These cables are also exposed to contaminants such as salt spray and hydraulic fluids. I recommend that you list all of the environmental, mechanical, and electrical factors that come into play in this application. I think that one of the solutions containing engineered PTFE materials would be an excellent choice because of our ability to improve cut-through and abrasion resistance.

3. Are flexible cables available that are already qualified for civil aircrafts? If so, do these cables have any issues with smoke and toxicity requirements?

In Europe, Gore has developed cables and assemblies for the commercial aircraft industry that have met the Airbus Purchaser Technical Specifications. For example, we have a light-weight coaxial bulk cable (an alternative to RG 400) that is engineered in accordance to European Norm 4604-003 for use in in-flight entertainment systems for the Airbus A330 and A340. We also have a leaky line antenna assembly used for wireless network server systems for the Airbus A380, A330, and A340. During the qualification process for these cables, the burning characteristics (flame, smoke, and toxicity) were tested in accordance with Airbus ABD 0031.

4. Can you explain what Goddard Space Center calls deep dielectric charging of cable insulation? What are the system risks?

Deep dielectric charging is the charge from high-energy electrons that builds on dielectric materials in a spacecraft's interior. The electrons penetrate the nonconducting materials until the material's dielectric breakdown is reached and a discharge occurs. These discharges can create noise and interference in signals, distort instrument readings, and damage electronics. Most jacketing materials have a charging behavior; therefore, there is an interest in using antistatic materials, such as carbon-filled materials. For a complete discussion of deep dielectric charging, see Janet L. Barth's article, "Space Weather Effects on Spacecraft Systems" at NASA's Technical Report Server, ntrs.nasa.gov.

5. I have a downhole tool application where cut and abrasion are big problems during the routing process. Also, we are moving into higher temperature environments, exceeding 200°C. What type of hookup wire would you recommend?

This is the type of application in which solutions containing engineered fluoropolymers could really make a difference. Using these types of materials can increase durability and still survive the temperature and routing challenges of a downhole application.

6. Is there a maximum number of bends an OM cable can take before it fails?

Gore's 0M cable is engineered to provide outstanding RF performance and crush and kink resistance with handling. If your application requires high mechanized or repeated flexes, Gore recommends our smaller diameter, stranded Mini-CP Microwave cables, which are rated for over 25,000 flex cycles (50,000 bends). In addition, GORE™ Mini-CP Microwave Cables are rugged enough to torque 10,000 times (5,000 clockwise and 5,000 counterclockwise).

7. In my experience, fluoropolymers are not great in atomic oxygen environments. What type of materials do you recommend in these situations?

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Atomic Oxygen (ATOX) is the most abundant element in LEO space orbits (ranging from 180 to 650 km). Its effect on polymers depends greatly on the velocity and angle of the "atomic oxygen flux attack." Metal shielding, which involves applying protective coatings on the polymer material itself (e.g., SiO2), is a common mitigation technique. For cable insulation and jacketing, PTFE and PFA are among the best polymers that resist corrosion and mass loss in the presence of ATOX, and polyimide is among the worst. (REF "Degradation of Space Materials" Joyce Denver (et al) NASA Glen Research Center; see also NASA white paper MISSE PEACE November 2006).

Cable Design Questions

1. We experience 80% of our cable failures in backshell design. Are there any new developments in this area?

A number of issues can cause backshell failures, such as EMI, strain relief, environmental seal, and cable guide (90°/45°, etc). EMI is probably the most common issue, particularly how the cable shield transitions to the backshell. Gore has recently developed several new designs and process solutions. Also, Gore is addressing environmental sealing problems with moulds or by potting the inside of the backshell.

2. Do you have any ideas on how to reduce cable tangling?

Cable tangling occurs in applications where cables are in motion, particularly if they are in a cable chain or the cable is just moving. Packaging is critical; individual wires should be packaged into a round cable jacket, or at a minimum, a shrink tube or expando-sleeving should be put around the cable to hold the wires together and manage them. If you are doing some continuous motion or repeated flexing with rest in between, moving cables generate kinetic energy that allows the conductors and insulation to relieve the stress input during manufacturing of the materials. And when you input kinetic energy, the wires want to eliminate the stress. They will actually move, corkscrew, and tangle, so it's very important to manage the wires carefully so that they don't tangle.

The most effective way is to package them into a planar cable, also called a flat cable. Planar cables are revolutionizing the linear motion, high-flex area because they take individual round constructions and eliminate the need to put dividers and shelves into a cable chain to keep the round constructions from tangling. By packaging the cables into a flat construction, you now have a smaller, lighter cable, and you can use a smaller chain if the stroke length is long enough to need a chain. Flat cables are the ideal way to keep your cables from getting tangled.

3. My interest is to reduce the amount of testing required. Are there any tests that you can submit cables to that prove their fitness for harsh environments, or do you have to perform application-specific tests?

If you don't want to perform application-specific testing, then you should at least make sure your manufacturer understands the challenges of your environment and can provide sufficient data to ensure that the cable will not be compromised. Depending on how critical cable performance is and how harsh your environment is, you may need to work with your manufacturer to test the cable.

4. I have an application that uses TXL wire inside closed convoluted tubing. The wires vibrate so much that the insulation is wearing away. Would braiding the wiring harness be a potential solution instead of closed convoluted tubing?

If you braid the wires, the vibration will generate kinetic energy, and this will further reduce the cable's performance. I suggest that you evaluate your total cost of ownership for this application. If vibration is truly your biggest issue, you may want to consider a more durable wire.

Gore Product Questions

1. Does Gore offer any cable routing products such as tracks?

Gore's primary product for cable routing is our flat cable, which bundles multiple electrical and pneumatic lines into a single low-profile package for simpler cable management, eliminating the need for shelves and dividers in a cable track. Although Gore does not sell cable tracks, we have two alternatives that eliminate the need for these. First, GORE™ High Flex Flat Cable can be used for stroke lengths of 0.5 meters or less without requiring a cable track. Our GORE™ Trackless Cable is a self-supporting cable that functions with a stroke length of up to 3 meters. Both of these options eliminate the need for cable track altogether, which in turn eliminates particulation and reduces vibration, size, and weight.

2. What is the maximum working temperature for GORE™ Cables?

We work with a wide variety of materials in our cables, so the answer to this question varies, depending on the specific materials used in the cable. You can basically break down cable materials we work with into two broad application areas: below 100˚C and above 100°C. The applications below 100°C are mostly industrial that run at -40°C to 100°C. If you get below -40°C, PTFE is a great material to use, as is silicone, depending on how low the temperature goes. For applications above 100°C, PTFE is rated for continuous use to 260°C and can be used for short-term applications at 300°C and slightly higher.

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High Flex Questions

1. I have an application in which my cables continue to fail even though they are supposedly made for high-flex applications. Can you give me some guidance on how I can figure out what the problem could be?

To answer this one completely, I need details about the application, but let me structure it a bit differently. You need to identify the mechanical constraints. In a flexing application, the type of motion is the first thing you want to identify. Is it a rolling flex, torsion, or tick-tock motion, or is a person attached to it? If it's a rolling flex, which about 75% of automation motion are, the stroke length, length of travel of the system, acceleration, and velocity are some of the key parameters that help us select the best solution. Then we are interested in the minimum bend radius of the cable. Most cables are using standard copper conductors and shields, but in high-flex applications, say 20 million flex cycles or higher, we use copper alloys along with our engineered PTFE materials to increase the flex life of the cable.

2. Do you have any tips on how to design or arrange copper conductors in order to increase bending performance? Is there a correlation between bend radius and a cable's longevity?

When you talk about bend radius, you are talking about an automation application. Bend radius is involved with rolling flex and tick-tock flex, which is a more severe motion. Yes, bend radius has an exponential impact on a cable's longevity. I always advise customers to use the largest bend radius they can, but they usually don't have that luxury. They are usually asked to go smaller and lighter. If the bend radius is below three inches (75 mm), I would suggest using a flat cable construction. That gives you the highest flex life for the lowest dollars. If the bend radius is over three inches, then our standard round cable constructions will perform well.

3. What is worse for the cables in general, bending or torsion stress?

There isn't a direct answer to this question because it really depends on the speed, acceleration, bend radius, number of flex cycles, and the other environmental factors during the motion.

Material Questions

1. What standard cable materials bond best to epoxy encapsulants?

Polyurethane and PVC are the best materials for bonding to epoxy encapsulants. PTFE, FEP, and PFA must be etched first, then they bond easily.

2. I'm currently working with silicone in a flat cable application, and I find it's really difficult to prep the cables for connectors. Are there any other alternatives that would make the prep easier?

This sounds like another question that would benefit from using my process of listing all of the environmental, mechanical, and electrical factors that come into play in this application. First, I'd ask why you selected silicone cables, and is there a unique application requirement that only silicone can fulfill? One of the drawbacks of silicone cables is in termination. Although I didn't address cable termination in this presentation, it is one of the factors in total cost of ownership. If you need a very flexible cable and weight is not a factor, silicone is a good material to use, but it's going to cost more to gain access to the conductors in the cable — it's going to take more time. Without knowing the specific application requirements, I can't recommend other materials to use, but some are easier to access for termination.

3. Does Teflon® coating protect the cable from environmental stress?

Teflon® is actually a registered name for DuPont's PTFE product. Fluoropolymers is the generic name that applies to Tefzel®, FEP, PFA, and PTFE. Yes, they are resistant to most chemicals and acids in their specified temperature range. Tefzel® works well in temperatures of -60°C to 150°C; FEP in -60°C to 150°C; PFA takes you up to 200°C; and PTFE works for cryogenic to 260°C. So fluoropolymers are extremely good for use in chemical processing applications. I want to caution you about considering coatings because they can give the impression of something that will crack or flake off. Fluoropolymer wire insulations and cable jackets are either plastically extruded in one uniform layer or are wrapped and centered to form a homogeneous uniform wall that does not crack or flake during use.

4. What is the shore hardness of PTFE?

The Shore-d hardness of PTFE is 55-72 ASTM 53506.

5. Does the information you presented on PTFE also apply to FEP and PFA insulation materials? Can you discuss the pros and cons of these other materials versus PTFE or engineered PTFE?

FEP and PFA are both fluoropolymers like PTFE, and the statements about the pros and cons of fluoropolymers do apply to these as well. One of the differences among these three is in their maximum usage temperatures: FEP is 150°C, PFA is 200°, and PTFE and engineering PTFE is 260°C. Also, the flexibility varies, with PFA being the stiffest, followed by FEP, and then PTFE and engineered PTFE being the most flexible.

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6. Is it safe to say that all PVC jackets are inherently UV-resistant?

No. I wouldn't rank PVC very high on the UV-resistant chart because its plasticizers will outgas when exposed to UV and even to oxygen. So over time, PVC will become brittle. Usually a nylon coating on PVC will help its resistance to UV. That's the THHN type wiring that the National Electric Code specifies, so you have to have something in addition to PVC that's for a UV application.

7. What are the pros and cons of having a Santoprene outer jacket versus a Neoprene outer jacket?

Santoprene is a thermoplastic elastomer that doesn't require cross-linking after processing. More manufacturers can apply a santoprene jacket. Neoprene is cross-linked after processing, but I'm not as familiar with this as I am with Santoprene, so I can't say if there's a big difference in temperature or chemical resistance. I believe they are both used in similar environments, so to choose between which material is better, you should identify your application-specific constraints, particularly chemicals, temperatures, cut-through, and any other issues that can effect jacket thickness to help select the proper material.

8. I understand that other possible factors may drive the selection for a given application, but generally speaking, what is the preferred cable insulation material for cryogenic environments (to say, 77K)? How about UHV environments (to be maintained at 1E-9 Torr)?

The preferred cable insulation material for cryogenic environments is PTFE because it remains an effective insulator down to -250°C and unlike many materials, it retains some flexibility at cryogenic temperatures. PFA and FEP are also effective choices for environments down to -200°C. PTFE and its co-polymers also have the benefit of low outgassing, critical for UHV environments. Polyimide is another insulating material that remains stable down to -250°C with very low outgassing properties, but it is not very flexible in comparison.

9. What is the effect of a vacuum on the materials you discussed?

We've talked about silicone, polyurethane, polyethylene, fluoropolymers, and engineered PTFE materials. Again it depends of the application of the cable and the level of pressure; remember, vacuum is just a very low level of pressure. I only recommend the use of PTFE materials in vacuum because PTFE does not have any process additives, oils, lubricants, or plasticizers added to the material. Anything that is added to the insulation, jacket or even the conductors or shield wires in the cable will be outgassed in a vacuum environment. Outgassing is not bad in itself, except that when cable materials outgas, they condense on cooler surfaces, and these are typically the surfaces that are being worked on. For example, this could be very bad on a satellite where optics can be fogged by silicone oil or processing lubricants outgassing from a cable material. PTFE is chemically inert and has no materials that will outgas, so it passes all of the toughest NASA and ESA requirements. In addition to using clean materials, you must make sure that all of the components of the cable system (cable assemblies, connectors, backshells) are compatible with the vacuum environment.

In addition to making sure that materials used in the cable are compatible with vacuum, you need to make sure that the cable manufacturing process does not add oils and hydrocarbons that can contaminate some clean manufacturing processes. The cable itself must be cleaned thoroughly and packaged properly to ensure that when your customer unwraps that cable assembly in their cleanroom, it will not carry any contaminants that will affect their process.

10. Does Gore have any insulation grade materials that are rated up to 300°C? If so, what are they and how do I get more information?

Engineered PTFE has been used in applications up to 300°C, but these are very application-specific wires and material. I'd have to understand some of the other application issues before I could say that a general PTFE could be used here.