Harsh Environment Connector Material Selection Guide

Introduction

To ensure robust and reliable system performance, harsh environment fiber optic (HEFO) connectors must meet certain requirements. To meet these varied requirements across different applications, connector manufacturers must use many different materials. Interconnect devices, particularly fiber optic interconnects, have requirements that are both independent of and dictated by the application environment. They must:

- Connect two terminated ends of fiber and/or electrical cable repeatedly and reliably.
- Isolate the electrical and fiber connections from the mechanical, thermal, electromagnetic, and chemical conditions found in harsh environments.
- Work with a variety of cable configurations and sizes.
- Seal against water, dust, and electromagnetic emissions.

To properly function in so many different environments, manufacturers use all sorts of metals, plastics, rubbers, and ceramics throughout the connector to meet both interconnect and harsh environment requirements. Internal components vary in material due to performance and cost. External components, connector shells and inserts are often metal and can be aluminum, stainless steel, brass, titanium, or even composite to meet the demanding harsh environment conditions.

Common Connector Materials

Metals

Aluminum

Aluminum is the material manufacturers primarily use to satisfy both environmental and interconnect requirements. Aluminum has an ideal combination of strength, light weight, corrosion resistance, and cost, that makes it effective for a majority of harsh environment interconnect applications. A variety of surface finishes available for aluminum enable it to satisfy various differing requirements and environments:

- **Cadmium** plating, the historical standard finish of military and industrial connectors, offers thousands of hours of salt spray corrosion resistance while maintaining metal-to-metal conductivity.
- **Zinc-Nickel or Zinc-Cobalt** alloy plating provides salt spray corrosion resistance comparable to cadmium but is harder and more scratch resistant. These Zinc-Alloy finishes are conductive but corrosion can inhibit some conductivity compared to Cadmium plating. Both Zinc-Alloy finishes are available in black or olive drab.
- **Anodize and Hard Anodize-PTFE** finishes are relatively low cost aluminum finishes. Regular sulfuric anodize allows a variety of colors.

This anodize finish is not conductive and only affords a medium to low level of corrosion protection. Hard Anodize-PTFE finishes are harder than regular sulfuric anodize finishes but equally non-conductive. A PTFE film is applied to the hard anodize surface to improve its corrosion resistance and increase surface lubricity. Natural hard anodize surfaces are grey to green in color depending on the processing time and the base material. It is also available dyed black.

- **Nickel and Nickel-PTFE (Ni-PTFE)** alloy plating provides additional salt spray corrosion resistance to the aluminum base metal. The Ni-PTFE plating has corrosion resistance comparable to cadmium but is harder and more scratch resistant. Nickel finishes are silver and Ni-PTFE finishes appear silver to grey in color depending on the processing time and under plate material and thickness.

Stainless Steel

Corrosion resistant steel (CRES), or stainless steel, is often specified for environments where corrosion resistance is of paramount importance. CRES also boasts increased chemical resistance to certain chemicals and is stronger than aluminum. CRES is corrosion resistant by design and needs no additional plating to aid its performance in a corrosive environment.

- **303 CRES** is the “standard” stainless steel Amphenol uses for increased corrosion resistance compared to plated aluminum. It is the only shell material available in Amphenol’s SMPTE304 broadcast connector and Mil-ST connector. Due to both raw material and increased machining costs, 303 CRES is approximately 3-4 times more expensive than comparable aluminum parts.
- **304 and 316 CRES** are special order materials for especially harsh chemical environments or continuous use marine environments. Amphenol also offers Nickel-plating on 316 CRES for increased conductivity in specific applications. Due to both raw material and increased machining costs, 304 and 316 CRES is approximately five times more expensive than comparable aluminum parts.

Brass

Brass, like CRES, is corrosion resistant by design. Brass is relatively soft and machines easily, but costs more than aluminum. It has the added benefit of being a non-sparking metal, uniquely satisfying a requirement for underground mining use. Brass does not require additional surface treatment but it is often nickel and chrome plated for increased hardness, wear resistance, and enhanced appearance.

Marine Bronze

Another copper alloy, marine bronze, is often used as a threaded mating component to a CRES or titanium component to prevent thread galling. Marine bronze has excellent temperature and corrosion properties without additional surface treatment.

Titanium

Titanium is often specified for environments where corrosion resistance and weight are of paramount importance. Titanium is also used in high temperature environments. These high performance parameters come at a substantially higher cost compared with aluminum components.

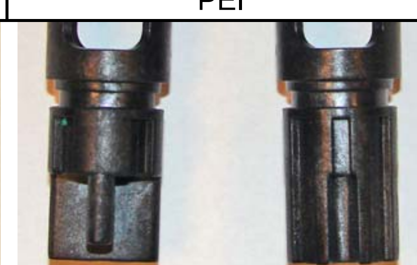
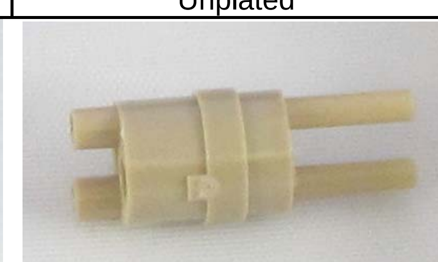
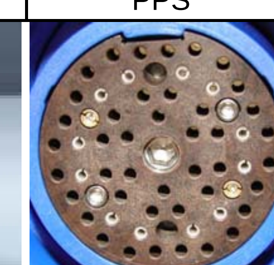
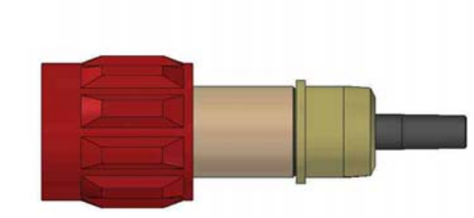
Material and Finish Comparison Table

Figure 1 contains a table comparing the various base materials and finishes common in the connector industry. These are relative comparisons among the materials for cost, weight, electrical conductivity, and corrosion resistance. Also included are temperature and salt spray corrosion resistance performance characteristics of the base material and finish. Finally, RoHS compliance is identified and colors are noted for their availability in the material and finish listed. Figure 2 depicts typical performance and material requirements by end market. Within these markets there are individual project applications that call for specific connector characteristics. They may call for greater environmental or corrosion protection levels, stronger materials or electrically isolated components. Manufacturers can use any number of materials for specific applications. This is by no means a complete listing of all connector material options, but it is a good starting point when defining important characteristics and requirements needed for connectors.

Figure 1

	Material and Finish					
Base Material	6061-T6 Aluminum					
Finish Material	Cadmium	Zn-Ni	Zn-Co	Anodize	Hard Anodize PTFE	Nickel PTFE
Attribute						
Cost (1-6, 6 most expensive)	2	3	3	2	2	3
Temperature Range	-55 to 175 C	-55 to 175 C	-55 to 175 C	-55 to 175 C	-55 to 175 C	-55 to 175 C
Salt Spray Corrosion Resistance	2000 hours	500 hours	500 hours	300 hours	> 2000 hours	1000 hours
Weight (1-6, 6 heaviest)	2	2	2	2	2	2
Conductivity (1-3, 3 least conductive)	1	2	2	3	3	1
RoHS Compliant	No	No	Olive Drab (No), Black (Yes)	Yes	Yes	Yes
Color Availability	Olive Drab	Olive Drab, Black	Olive Drab, Black	Red, Green, Blue, Grey, Tan	Natural (grey-green), Black	Silver/Grey

	Material and Finish						
Base Material	303 CRES	304 CRES	316 CRES		Brass	Marine Bronze	Titanium
Finish Material			Unplated	Ni plated			
Attribute							
Cost (1-6, 6 most expensive)	4	5	5	5	4	5	6
Temperature Range	-55 to 175 C	-55 to 175 C	-65 to 225 C	-55 to 175 C	-55 to 175 C	-65 to 225 C	-55 to 175 C
Corrosion Resistance	Very Good	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Weight (1-6, 6 heaviest)	5	5	5	5	6	6	3
Conductivity (1-3, 3 least conductive)	1	1	1	1	1	1	1
RoHS Compliant	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Color Availability	Natural (silver), Black	Natural (silver)	Natural (silver)	Natural (silver)	Brass	Bronze	Natural (silver)

	Material and Finish					
Base Material	Zytel (PA66)	PEI	PEEK		PPS	Estaloc RETPU
Finish Material			Unplated	Ni plated		
Attribute						
Cost (1-6, 6 most expensive)	1	2	3	3	2	1
Temperature Range	-55 to 175 C	-55 to 175 C	-55 to 175 C	-55 to 175 C	-55 to 175 C	-55 to 175 C
Corrosion Resistance	Good	Very Good	Excellent	Excellent	Very Good	Good
Weight (1-6, 6 heaviest)	1	1	1	1	1	1
Conductivity (1-3, 3 least conductive)	3	3	3	1	3	3
RoHS Compliant	Yes	Yes	Yes	Yes	Yes	Yes
Color Availability	Various	Natural (tan), Black	Natural (tan), Black	Nickel	Natural (tan), Black	Various

Composites (Plastics)

Manufacturers also offer a variety of composites, or plastics, as an alternative to metal components for specific applications. Composites offer some beneficial characteristics including lighter weight and corrosion resistance and can be lower in cost when manufactured in high volume. Manufacturers can also plate composites for increased surface hardness, corrosion resistance, and conductivity. It is best to consider composite components early in the design process to tailor the connector design for the manufacturing methods, dimensions, and tolerances required by composite materials.

PEEK (Polyether ether ketone), PEI (Polyethylene imine), and PPS (Polyphenylene sulfide)

These strong glass-filled engineered structural thermoplastics serve as non-conductive aluminum replacements for hybrid optical and electrical interconnect systems. PEEK, PEI, and PPS are particularly suited for the fiber optic industry due to their excellent dimensional characteristics and low moisture absorption. The chemical resistance and temperature range of these materials make them well received in oil and gas industries for hybrid connectors. Systems engineers also specify these thermoplastic shells as lightweight alternatives to aluminum connector shells. When necessary, these composite shells can be Nickel-plated to add critical conductivity capability to these lightweight connectors.

- **Nickel and Nickel-PTFE (Ni-PTFE)** alloy plating provides additional conductivity absent in the PEEK or PEI base materials. The Ni-PTFE plating has additional corrosion resistance comparable to nickel-only plating. Nickel finishes are silver and Ni-PTFE finishes appear silver to grey in color depending on the processing time and under plate material and thickness.

Nylon (Polyamide 6,6) and Estaloc®

These thermoplastics, which are made of nylon and polyurethane materials, perform well as external connector components. They are not only abrasion, chemical, and UV resistant and last in harsh industrial environments but also offer affordable prices. Specific formulations may be used in some high tolerance internal component applications, but the dimensional characteristics typically cause their use on components with looser tolerances.

Typical Fiber Optic Interconnect Requirements by Market					
Environmental Attributes	Shipboard	Tactical	Aero	Geophysical	Industrial
Operating Temperature	-40 to 85 C	-55 to 85 C	-50 to 85 C	-55 to 120 C	-50 to 85 C
Corrosion Resistance	500 hrs Salt Spray	500 hrs Salt Spray		> 1000 hrs Salt Spray	Application Specific
Conductivity	Required	Application Specific	Required	Application Specific	N/A
Weight	Medium Priority	Medium Priority	High Priority	Medium Priority	Medium Priority
Color	Olive Drab	Olive Drab & Black	N/A	Black	Black
EMI Shielding Effectiveness	80 dB	80 dB	80 dB	N/A	Application Specific
Typical Materials Used In Each Market	* Cadmium Plated Aluminum * 316 CRES * Nickel Plated 316 CRES * Hard Anodize PTFE Plated Aluminum	* Zn-Ni Plated Aluminum * Zn-Co Plated Aluminum * Hard Anodize PTFE Plated Aluminum * 303 CRES	* Cadmium Plated Aluminum * Nickel Plated Composite * Durmalon Plated Composite	* Hard Anodize PTFE Plated Aluminum * 303 CRES * 316 CRES * Brass * Marine Bronze	* Anodized Aluminum * Hard Anodize PTFE Plated Aluminum * 303 CRES

Figure 2

Company Overview

Amphenol Fiber Systems International (AFSI), a division of Amphenol, provides reliable and innovative fiber optic interconnect solutions that withstand the harsh environments of military (ground systems, avionics, and shipboard), energy and broadcast applications. After more than 18 years in business, AFSI maintains its position as a global leader in fiber optic interconnect components and systems such as termini, M28876, 38999 assemblies, MIL-ST, TFOCA and the TFOCA-II® connector, which AFSI developed and patented. AFSI has delivered millions of fiber optic connectors in more than 34 countries. Whenever there is a need for superior cost-effective fiber optic systems and products that will stand up to demanding operating environments, you can rely on AFSI for engineering know-how, top-quality products and expert technical support.

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About the Author

Jon Woodruff is currently the Engineering Manager with Amphenol Fiber Systems International. He has been with AFSI for ten years and has spent the past twelve years working in various capacities in fiber optic product design and development. Jon is named on one patent. Prior to his tenure at AFSI, Jon spent five years with Texas Instruments Defense Systems Group, now a part of Finmeccanica DRS, designing optoelectronic systems and components. Jon Woodruff received his Bachelor of Science degree in Mechanical Engineering from the University of New Mexico in 1994.