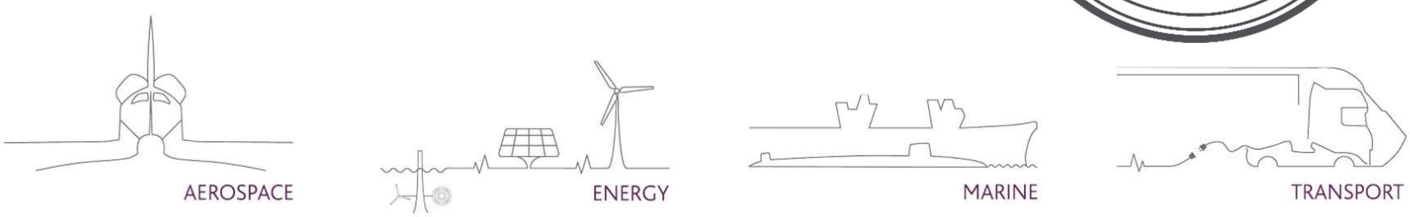


unassailable 'fit & forget' pressure moulded cable systems for hostile environments

CONSIDERATIONS FOR SUBMARINE CABLING DESIGN

Copyright

Contact Information

If you have any questions regarding this document, contact:

Scientific Management International Limited
8 North Way
Walworth Business Park
Andover
SP10 5AZ
UK
Tel: +44 (0)1264 357357
www.smi.group info@smi.group

Introduction

A combat, sonar or propulsion system is only as good as the infrastructure connecting it. Cabling, penetrators and connectors all have to be robust, reliable and effective for systems to deliver their design promise. In this document we are highlighting the technical considerations that should be applied in cable system design for new platform designs.

As military capabilities develop, demand grows for increased data rates and higher bandwidth. Cable architecture needs to bring together power, control, high frequency, and optical capabilities to optimise system performance and safeguard essential systems.

Background

Scientific Management International Limited (SMI) is an Andover based SME with a global presence in France, USA, Canada and Australia. The company designs and manufactures specialist cable assemblies for the marine defence, renewable energy, aerospace and transport sectors. Since 1992, SMI products have formed the central nervous system of Commonwealth naval platforms, guaranteeing the performance of critical systems in the most hostile environments.

SMI Polyethylene Pressure Hull Gland

SMI is the only company in the world to hold capability approval from the UK Ministry of Defence (MOD) for the manufacture of pressure hull glands and polyethylene moulded cable assemblies for use on the naval submarine and surface fleets. SMI employs 55 people and runs an apprentice programme.

Cable Jacket Material

Nearly all design considerations map back to the primary choice on cable jacket. The material for the cable sheath informs how this is processed, terminated and sealed. Making the right jacket selection for the application ensures that consequential design choices also meet the vigour of the operating environment.

Subsea cable jackets are generally made from two groups of materials: thermoplastics and rubbers. In the naval defence arena selection is typically made between Thermoplastic Polyurethane (TPPU) and Polyethylene (PE) another thermoplastic. Each material has advantages and disadvantages, and their effective use depends on in-depth knowledge of their properties.

Thermoplastic Polyurethane (TPPU)

TPPU is a thermoplastic material also supplied in granules that are melted and injected to manufacture cable jackets. It is a viscous elastomer, which means it has greater elasticity than PE and this offers different performance and properties.

Not suitable as an electrical insulation material, TPPU has some outstanding properties as a cable sheathing, making it suitable for high performance electrical cables in the most challenging of environments. Its anti-kink property, makes it ideal for flexible and retractable cables and it has better wear resistance than PE.

Critically however, TPPU is hygroscopic and absorbs moisture at a rate of 0.3% to 1% by weight over time, which increases as temperature and salinity rises. Given the changing mission space for the platforms this is a key consideration. The US navy has long favoured the use of PU cabling but the longevity concern is reflected in a replacement cycle of 7-9 years.

Polyethylene, Polythene (PE)

Invented in 1933, PE is a thermoplastic that is only supplied in granular form. It has a unique combination of excellent dielectric characteristics (particularly at high frequencies), high electrical resistivity, low moisture permeation, and low water absorption. As evidenced by the man-made plastic pollution of the oceans, PE does not degrade over time. A PE cable jacket will endure for the service life of the boat.

PE delivers orders of magnitude better insulation resistance than other materials, and this performance does not degrade at higher operating temperatures. PE does not absorb water or moisture over time.

PE expands and contracts volumetrically by more than 30% when heated to melting point and has a very low thermal conduction coefficient. This makes it notoriously difficult to process, and its low surface energy makes it very difficult to bond to any other materials which has deterred many manufacturers from adoption. Supplied with exemplary reliability on the Trafalgar and Vanguard classes, PE cabling and overmoulding is covered by Def-Stan 08-171.

Single or Dual Jacket

Cable jacket selection historically required a compromise between electrical performance and abrasion resistance.

While ideal for service, PE is not the best material for resisting the hostile dockyard environment where the platform build and installation process introduces conditions not always scoped as part of operational demands.

Dual jackets - PE (white) & PU (Black)

Cables designed with two jackets, and in different materials, have been in existence for many years, however to realise the advantages of both materials the jackets need to be separately water blocked and bonded. If this is not achieved the cable remains as weak as the poorest material.

A combination of PE with its superior dielectric and water-resistant performance and a rugged external PU jacket can be used, where the space envelope permits, to harmonise the advantages of both materials and deliver reliability for the life of the platform.

SMI's PlastEthUrm dual sealing is so robust that dual jacket mouldings are now offered with a standard guarantee against leaks of ten years.

Connectors or Glands

When it comes to bulkhead or hull transitions a choice needs to be made between gland through penetrations or connectorised penetrators.

SMI 19 Way Pressure Hull Gland

Connectors are regarded as easier to install and this approach can be beneficial in supporting a modular build. However, this needs to be balanced with tight controls on installation required as the effectiveness of a mounted connector relies on the consistent and appropriate application of torque settings, leaving much of the product assurance in the hands of the fitter.

Connectors inherently introduce additional points of failure and optical attenuation is significantly increased. Contact arrangements limit service density in the shell size so it is common to see multiple connectors utilised where fewer glands might be deployed. Connectors are often more expensive per penetration with penetrator, outboard and inboard plugs all being required.

Another consideration, often overlooked in initial design, is that connectors are designed to receive a single cable to the rear of the plug. Whilst the contacts may support many conductors & combinations of fibre optic, coaxial or copper, the selection of a connector drives the designer to specify a single, composite cable. In the event of damage to that cable, all of the supported services will be lost. This does not however preclude the selection of connectors. With design support from the harness manufacturer, a moulded, multi-cable presentation to the plug can be achieved if the COTS rear interface is not used. Utilising individual cables with separate sealing and water blocking offers additional reliability benefits should a cable be damaged in operation. (see *Functional Performance Attributes* for more information).

An SMI Connectorised Penetrator with Plugs

Four cable moulding to connector

Optical connectors are very vulnerable to dirt contamination, so installation and cleaning practices need to be prescribed and managed.

Another argument tabled in favour of connectors is their ease of replacement. Arguably mating cables could be replaced, however in practice these are typically embedded in cable runs and tray work and the reality is far more challenging. Should we not also question why this feature forms part of the design? Is it because the jacket selected requires regular replacement or are we designing for failure? Would it not be better to take a *fit and forget* approach where long-term reliability and performance foregoes the need to replace?

Finally, not all connectors are the same so performance will be driven by:

- Number of contacts and layout
- Diameter of pin contacts
- Scoop proof design
- Number and effectiveness of sealing barriers
- Material life of sealing barriers
- Maintenance cycles and seal replacement cycles, feasibility
- Torque control during installation
- Installation QC control and tampering during construction
- Open face sealing (water blocking in plug and receptacle)

- Hot or only cold processes viable for cable termination
- Single or multi cable termination & non-crosshosing
- Cleanliness of optical connectors

SMI colleagues can provide additional insights and advice on any of these features if required.

Bonding Technology

How a plug, receptacle or gland is integrated with a cable should be understood and mandated by the Design Authority as the implementation of this can radically influence the quality, performance and reliability of the harness.

> "Cable seal failure after a design has been adequately tested and proven can be traced invariably to poor bonding."
>
> R F Haworth 1973

It's crucial to understand the basic science applied to adhesion and polymer processing. Mechanical adhesion relies on roughening the adhering surface to increase surface area and mechanical interlocking. Chemical bonding by contrast provides a very high strength union. Chemical bonding occurs when the atoms of adjacent materials containing free electrons and electron holes in the respective outer shells, are encouraged to transfer across, to achieve a lower state of equilibrium, resulting in a chemical bond.

Chemical bonding requires the introduction of sufficient energy through high pressure and high temperature processes and critical monitoring of the moulding process, temperatures and time.

Functional Performance Attributes

Water Blocking

Water blocking is applicable to connectors, glands and cables. In the latter it is achieved by filling the interstitial space in the cable with a material which is intended to prevent water from travelling along the cable. These fillers work best on very long seabed cables where hydrostatic pressure is constant. Due to the pressure cycling that occurs with a submarine, water blocking can never be achieved in the cable and therefore intervention is required in the moulding to protect critical equipment and services.

Water blocking of glands & connectors uses epoxy resin and is important in connectors to prevent corrosion of contacts. In glands it also prevents water ingress into the submarine.

Where multiple cables are presented to a plug or gland, each cable should be separately water blocked.

Non-cross hosing

This is **critical to reliability** in multi-cable terminations and is a function that favours taking service through on multiple cables rather than a single large one. Damage to one cable is contained, with leak paths barred to other cables, preventing loss of all functionality.

Amalgamation

The introduced material at moulding stage and melted cable jacket fully amalgamates to achieve fit and forget functionality.

Amalgamation process is absolutely key to long-term sealing, as with no interface present, water can never enter a thermoplastic moulding at this critical junction.

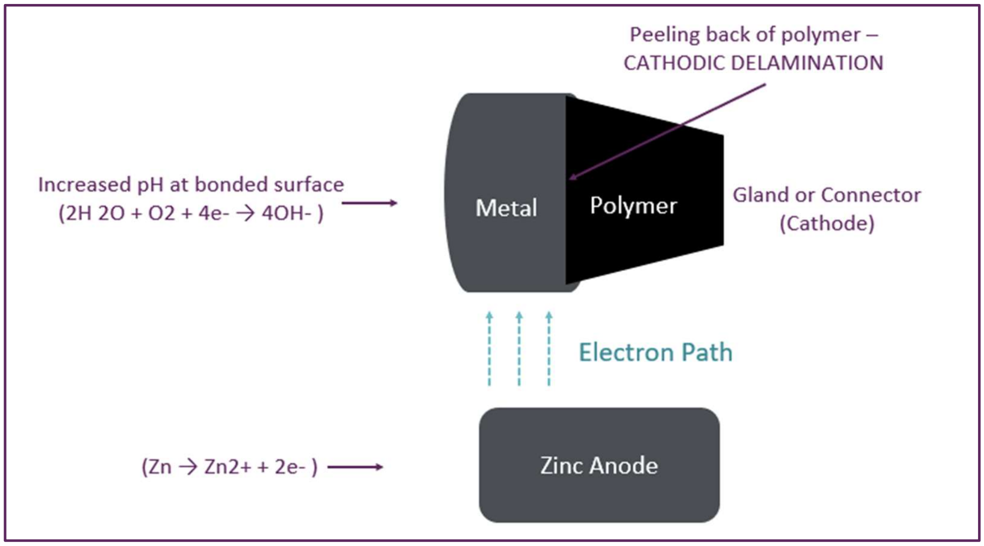
An example of SMI amalgamation

Cathodic Protection

Where amalgamation addresses any vulnerability between moulding and cable, Cathodic Protection is employed at the bonding between metal and polymer.

To prevent vital parts of subsea platforms from acting as an anode and therefore failing, marine engineers can specify impressed current protection and the addition of sacrificial anodes. Cathodic delamination is a related cathodic effect that can also lead to system performance loss. It is specific to bonded materials, for example where polymers are bonded to metals, such as the termination of plastic cables at metallic connectors. If sea water is able to penetrate through the polymer to the connector, it will act as an electrolyte, electronically connecting the metal structure as a cathode to a nearby anode. That connection will generate a significant increase in pH at the metal's surface, which is the site of its interface with the polymer. The high pH directly or indirectly causes the overlying polymer to delaminate from the cathodic polarised substrate.

As the polymer de-bonds from the metal surface, more water is able to penetrate the cable system, which is often electrical, rapidly exposing it to additional factors that will lead to its failure.



Cathodic Delamination

Cathodic protection should be designed in to gland or connector mouldings and is essential if the harness or gland is installed in proximity to zinc anodes

Manufacturing Assurance, Test and Inspection

Qualification of cable systems and hull penetrations is necessarily vigorous and should always include under water explosive shock (UWES) testing. However, the right in-process testing and inspection is essential in maintaining the quality of production items.

A key non-destructive test is radiographic interrogation of mouldings. Three plane shots with 60° rotation can give a visualisation of the bond surface. The x-ray contrast shows defects or cracks from the surrounding metal or polymer background area, voids or and bond failures as shadow. Metallic inclusions which could cause a leak path under pressure show up as white.

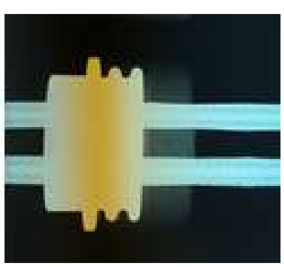


Figure A

Figure B

However, the power levels for radiography must be used advisedly and mindfully. Utilizing a higher power X-ray, typically associated with the interrogation of metal components, fails to generate the required contrast to illustrate these defects as seen in Figure A above. You do however get a lovely picture of your metal parts! The same item x-rayed iaw Def-Stan 08-171, with appropriate power levels, in Figure B enables interrogation of the bonded interface.

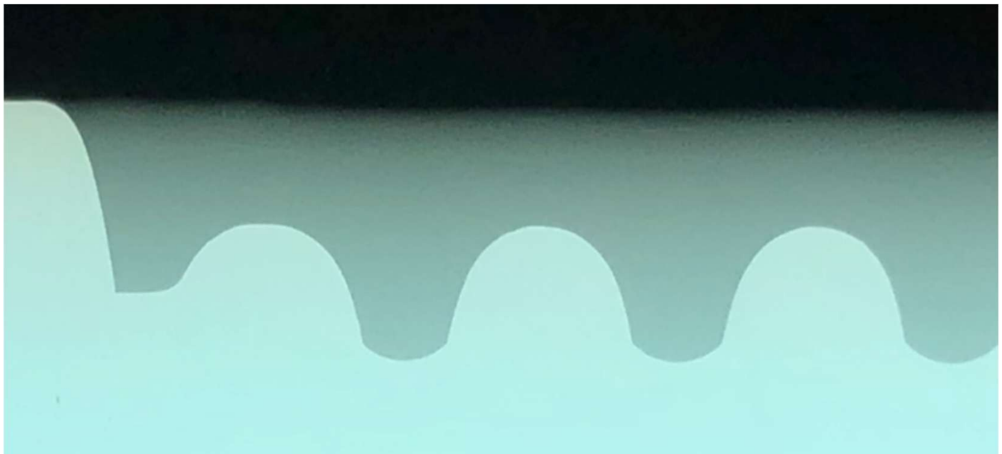


Figure C

Figure C shows an SMI gland stem with a bonded metal to polymer interface. The absence of shadowing on this line indicates no air is present and bonding is achieved and the x-ray confirms the item is void and inclusion free.

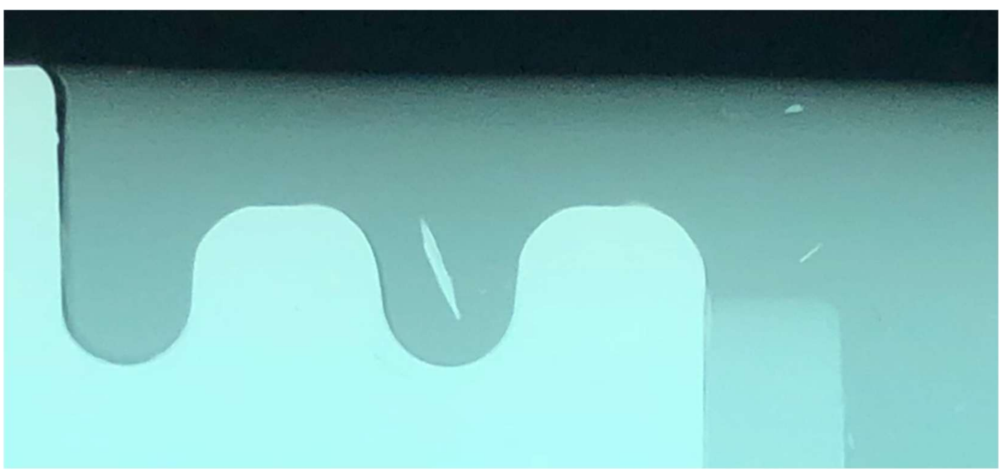


Figure D

Figure D shows a product from another manufacturer where the interface has shadowing along the unbonded interface points as well as metal inclusions.

One school of thought is that the use of opaque or translucent resins and epoxies enables visual inspection of the moulding. Whilst some inclusions may be visible near the surface, if these lie beneath a conductor or cable screen they would be invisible to the inspector. Magnification is utilised with the x-rays to visualise the bonded surface, if no radiography is applied the bonding failure is simply undetectable.

Service Density

As platform capability grows, especially that of the combat system, there is an exponential increase in the demand for bandwidth across all services in terms of power and data. There is, of course, no desire to increase the number of hull penetrations proportionally. Therefore, getting a higher service density through a single penetration point becomes a priority. Multiple Connectors or Glands can be taken through a single penetration utilising a junction box or multi-gland penetrator (MGP).

Junction Boxes for through hull penetrations

SMI Multi Gland Penetrator

Fibre optic offers increased data capacity at a fraction of the weight of copper systems but requires careful design and management in respect of bend radii and fragility.

Glands are not dependent on the number of number of contacts in a shell configuration and can support increased service density.

Metal Material Selection

Material selection for equipment used on future cable designs is key to the performance of the systems they support. Material properties for corrosion and shock are of upmost importance. Failure to adopt the right material for the application can lead to costly failures in service, and the safety of the platform itself. Marine applications have successfully used many differing materials, such as Marine Bronze, Super Duplex Stainless Steel, Titanium and Nickel Copper Alloys. Each material has strengths and weaknesses depending on the operating environment. An understanding of each material’s properties will enable the right material choice for the application, minimising failures in service. Some alloys have limited availability and global demand, so collaboration with Supply Chain colleagues during design is advised.

Additional Information

Further Resources including technical briefs and white papers are available at:

www.smi.group/insights/

About Scientific Management International

Scientific Management International designs, manufactures, supplies and installs, bespoke pressure moulded cable harness systems, through-hull penetrators and pressure moulded connectors for wide variety of applications across the most challenging and hostile environments on the planet.

Produced to the very highest engineering and quality standards – and designed for purpose – our molten pressure moulded cable systems are offered in a variety of materials from Polyurethane to Polyethylene to Elastomers and form the highest integrity, situational resilient, dual jacketed connections for hostile environment deployment.

SMI have a 30 year unblemished record for reliability established across more than 20,000 submarine installations with zero leaks.

SMI are the subject matter experts for through-hull penetrators and cables systems to the UK's submarine and surface fleets, in addition to installations in aerospace, energy and transport infrastructures. ISO 9001:2015 approved, we are the only company to continuously hold a Ministry of Defence Capability Approval Certificate for 30 years.

In 2023, SMI was named Subsea UK Company of the Year. For more information, please visit www.smi.group.