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Paper Title: Underwater Optical and Electrical Connector Systems, Technical Innovations

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Abstract

There are many distinct industry sectors within the offshore Oil and Gas Industry and each of these demand specific knowledge, experience and understanding. However, there is also the need in today's environment to have an overview of all areas and the ability to enable cross-fertilization of information, developments, products, successes and failures between these sectors. This approach maximizes a company's ability to provide innovative technical solutions that enable it to develop and supply products that allow the industry to reach farther and deeper whilst working faster, smarter, safer, and more cost-effectively.

This paper will detail how having knowledge of all significant areas of the offshore Oil and Gas Industry has led to many technically innovative solutions in underwater optical and electrical connector systems.

Introduction

In today's industry it is important to understand the requirements of a specific sector of the industry and to use this understanding in the generation of solutions to meet these requirements. With previous experience obtained in a particular sector it is normal for companies to focus on this experience and develop existing designs using this experience to meet these requirements. However, due to the increasing need for innovative, yet cost-effective solutions, in ever decreasing timescales, it is becoming equally important to have the ability to call upon expertise from other sectors of the industry, to ensure that the preferred technical and commercial solution is offered, rather than just a development of existing equipment.

In underwater connector technology, the application of this approach enables key requirements, such as: correct connector selection for the application; CAPEX/OPEX models; the importance of qualification of new products coupled with field experience; the realization of the value of service and support; the necessity for reduction in size, weight and costs of equipment and the subsequent development of new solutions, to not only be examined in isolation but be combined with information and experiences from all sectors of the industry. This contributes to a greater overall understanding and leads to the technical innovations associated with the refinement of existing products in combination with the development of new products.

Industry Sectors

The industry sectors within with the offshore Oil and Gas Industry are vast and when coupled with the overlap into Geophysical and Naval sectors can form an extensive list. In order to understand the extent of these sectors examples are provided below, along with their key connector system design parameters:

- ROV Industry: Within the ROV industry there is the growing need for smaller size in deeper waters together with the need for high connector contact densities at lower-costs. Key connector system design parameters: small size, deepwater depth, high contact densities, and low-cost.
- Drilling Industry: Within the drilling industry there is the need to maintain drilling 'up-time' while meeting the extreme operating conditions of the connectors and cable terminations used. Key connector system design parameters: field installable and testable, reliability and robustness.
- Optical Production Control Systems: Within the subsea production industry there is the need to meet or exceed the oil and gas production quotas together with meeting the continued need for high-speed, long-distance, reliable communications. Key connector system design parameters: qualification, reliability, track-record and long-term operation.
- Electrical Production Control Systems: Similarly within the subsea production industry there is the need to meet or exceed the oil and gas production quotas together with meeting the continued need for reliable standard electrical power and communication systems. Key connector system design parameters: qualification, reliability, track-record and long-term operation.
- Commercial-Off-The-Shelf (COTS): With the increase in production volume, there is the need for Commercial-Off-The-Shelf, cost-effective electrical, optical and Hybrid (electrical/optical) connection options. Key connector system design parameters: short lead-times and low-cost.

- Down-Hole Systems: Within the down-hole industry, there is the need to manage production and maintenance quotas efficiently and cost-effectively, while meeting the high-pressure and high-temperature connection requirements for space-limited, down-hole environments and operations. Key connector system design parameters: small dimensional envelope, high-specification and reliability.
- Geophysical Industry: Within the highly competitive geophysical industry there is the strong need to supply the most cost-effective connection solutions for the state-of-the-art slim-line exploration arrays. Key connector system design parameters: small-size and low-cost.

Knowledge of any one sector within the industry enables a company to develop solutions based on their experience in that sector. However, a global approach covering not only, the breadth of all sectors within that industry, but including cross-over from many other industries, enables a company to maximize it's ability to draw from a vast wealth of knowledge and understanding. This knowledge of all areas enables a company the greatest opportunity to provide the required technical solutions and innovations that assist the industry in reaching farther and deeper, while working faster, smarter, safely, and cost-effectively.

ROV Industry

Introduction. Within the ROV industry there is the ever-growing need for connectors that are smaller in size and operating in deeper waters, while maintaining high-contact densities at lower-costs. These requirements are driven by a rapidly changing ROV industry that demands:

- Deeper operations
- More varied use such as inspections and operations
- Greater functionality, operations and more complex tasks such as difficult underwater repair work
- Lower cost units for inexpensive inspections/operations
- Used to minimize exposure of personnel to risk situations
- Autonomous operations increasing
- Smaller size and lighter weights

With these requirements, the key connector system design parameters become: small size envelopes, higher pressure ratings, higher contact densities and lower-cost. As an example for different ROV solutions, an ROV for deeper operations and a smaller less expensive ROV would normally result in the use of two separate underwater connector solutions. These being: a high-specification connector to meet the high-pressure requirements for deeper operations, and a very-small, low-cost connector to meet the requirements for small size and cost on the lower cost ROV's.

Technical Innovation. Although these requirements appear vastly different, there is a common theme, that being the need to reduce the connector size and increase the pressure rating, whilst maintaining a low cost. This common theme and the ability and experience of working in both the low-cost connector market and high-specification connector industry enabled this to be achieved. In order to meet the vastly differing requirements, SEACON's experience from two differing industries; the miniaturization of connectors (specifically the Minicon and MicroMinicon range of high-specification dry-mateable connectors), together with the wet-pluggable connector ranges (specifically the AllWet, WetCon), resulted in the ability to develop and deliver to the industry a new connector range, the Hummer.

Figure 1 – 12-pin Standard Hummer Miniature Connector

In order to develop this connector, focus was placed on the miniaturization aspects and the following key design parameters evaluated:

- **Voltage Rating:** Requiring an effective reduction in conductor spacing and hence insulation dimensions and the consequent use of high dielectric insulating materials.
- **Current Rating:** A practical balance between contact size and rating was achieved.
- **Contact Density:** The development of smaller contacts that can be efficiently and economically produced.
- **Wasted Space and Materials:** Ensuring the removal of all excess materials in a cost-effective way.
- **O-Rings:** There were significant challenges in adapting the theoretical modeling of new customized O-ring seals but these were overcome to meet the practicalities of repeatable, high quality and high quantity production.
- **Key/Keyway Heights:** New CNC machines and tools allowed repeatable production of new concept key/keyways enabling significant reduction on shell size.
- **Retaining Mechanism:** New tools and materials enabled viable miniature retaining mechanisms that offered more space to maximize the insert face diameter, thus allowing higher contact densities.
- **Minimal Wall Thickness:** Wall thicknesses reduced to their absolute minimum combined with new material choices such as titanium and incoloy allowing thinner walls for the same rated pressures.
- **Aft-End Technology:** Significant changes were made to the wire termination and cable area.
- **Mating Sequence:** Proper mating sequence is essential to ensure that the pins and the connectors are not damaged during engagement. It is important to take this into account for the smaller connectors and this can work against size reduction so new methodologies needed to be developed.

The Hummer is designed to be a standard 'off the shelf' item thus ensuring quick delivery of standard configurations. It is available in three different shell size ranging from 2 to 28 way contacts rated between 0.5 amps and 2.5 amps. The series is rated to 10,000psi and by special order open face pressure of 10,000 psi is also available. The Hummer is also available with PEEK shells and coupling rings instead of the more traditional metal shells. Although initially there may appear disadvantages in using PEEK; it is more expensive than even some of the more exotic metals and it is not as rugged as the metal versions, the connectors provide advantages with the capability to offers a non-metallic alternative for light-weight and non-magnetic underwater applications.

Figure 2 – 12-pin PEEK Hummer Miniature Connector

For the Hummer, the key connector system design parameters of small size, high-density, deepwater connector at a low-cost were met with a technically innovative solution. This solution has already captivated the industry with over 1,500 connectors having already been sold to the industry.

Drilling Industry

Introduction. Within the drilling industry there is the need to maintain drilling up-time and meet the extreme operating conditions of the connectors and cable terminations used. In this case the high operating pressures in combination with connectors and cable termination systems that are readily installed tested and deployed in the field, as well as being maintainable and extremely robust are required.

Technical Innovation. The main need for a field installable connector is driven primarily by the inability to cost-effectively transport the cable (due to large physical size and weight) to the connector manufacturers' factory for termination. In addition the installed connector and cable termination needs to be field maintainable and able to be replaced quickly on-site, keeping drilling downtime to a minimum. There is also the need for a field-testable assembly, which is driven by the fact that conventional pressure testing equipment is not suitable for a connector that is terminated to 5,000 plus feet of cable. Since pressure testing is not feasible, assurance is provided by knowing that the connector will continue to function with breaches in the cable jacket or if the connector becomes flooded with water. Due to the demanding requirements placed on connector manufacturers in this sector it is important that the client is closely involved with all phases of product selection, development and qualification. In working with one of these customers, to produce the next-generation cable termination connector, it was necessary to investigate and incorporate the following:

- Connectorization of terminations
- Positive pressure compensation systems
- Field installable systems
- Field testable systems
- Break-way units
- Cable bending/strain-relief through restricted-space areas.

The various solutions were based on similar conventional cable connectors that offered the ability for field installation. Positive-pressure compensation was added to provide additional security against water ingress. In addition faster installation times would be achieved by the use of a "no compound" philosophy which eliminates the need for epoxy-cure or polyurethane-cure wait times during the installation period. Through-life costs were also taken into account and the connector system was designed to allow for easy modification to accommodate different cables types, including the inclusion of fiber optic channels.

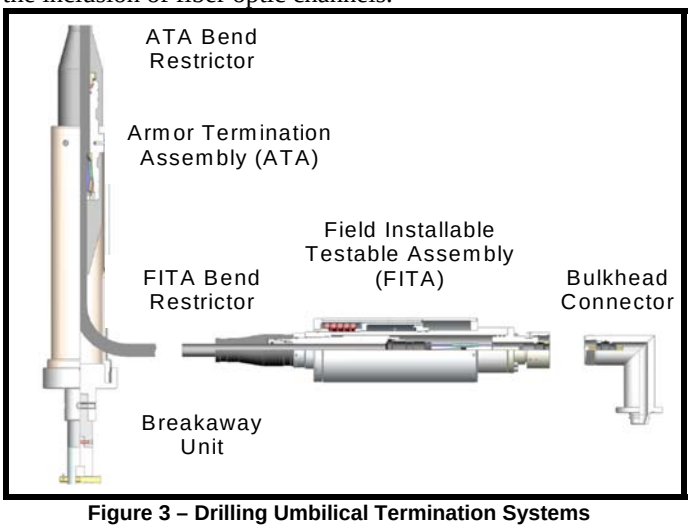

Figure 3 – Drilling Umbilical Termination Systems

Focusing on the technical requirements it was also mandatory to understand the CAPEX (Capital Expenditure for procurement and installation) verses OPEX (life-cycle Operating Expenditure) issues associated with the development of such a product to the extent of understanding the total cost of developing and qualifying such specific technology versus the in-service cost reductions that could be achieved. In trading off the full benefits of CAPEX versus OPEX, the advantages of the latest generation cable termination technology offered an extremely cost effective solution. Having supplied over 100 sets of connector and cable termination systems the result of this specific program of incorporating a series of individual design aspects and considerations has provided a technically innovative system of next-generation connector and cable terminations for the

drilling industry. Several of these next-generation cable termination systems have now been installed on several deepwater drilling rigs in the Gulf on Mexico with several more installations scheduled for 2005. One installation has been in operation for several months in up to 9,000 feet water depth.

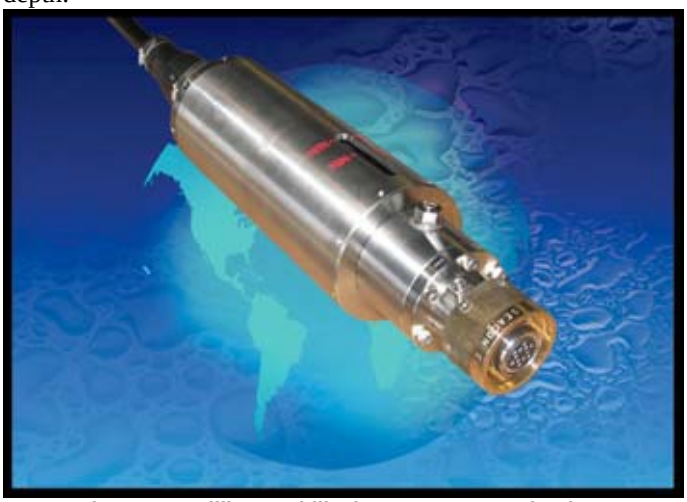

Figure 4 – Drilling Umbilical Connector Termination

Key connector system design parameters for field installation and testing, reliability and robustness were met with this technically innovative solution.

Optical Production Control Systems

Introduction. Within the subsea production industry there is the need to meet or exceed the oil and gas production quotas whilst meeting the continued and reliable need for high-speed and long-distance communications. As in the Drilling Industry, subsea production communication systems demand a very high degree of reliability. The main difference when compared with the Drilling Industry is, although the impact and downtime is extremely expensive for the direct costs, a remote production system had added indirect costs due to the requirement for vessels and personnel to be mobilized to diagnose, recover, replace and repair etc., these are huge additional costs.

Other important considerations and differences are:

- Subsea communication systems can operate several production wells on the same network – common-mode failure
- Subsea communication systems frequently include 'expansion ports' in the system for future requirements. Therefore, underwater connectors could be deployed months or even years after the initial systems are installed.

An important question on reliability is how reliability is proven. There are various methods available for reliability calculation and the majority of these are based on quantity of connectors 'in-service' and the number of failures. However, due to the vast differences in the system operations and environments, another important factor that must be included is rigorous qualification testing to ensure that all 'possible' occurrences are evaluated and tested for.

Technical Innovation. One of the major technical innovations within the production control system industry has been the advent of optical communication systems. These allow a significantly greater amount of data to be transferred at faster rates and at longer distances. Cost comparison of data-rate, over long distances yield very cost-effective solutions. However, there is still a perception that fiber-optic wet-mate solutions are new and unreliable. This is understandable considering the main challenges of wet-mate fiber optic connector design and manufacture are:

- The alignment and coupling of very fine 9μm diameter glass fiber cores, underwater, without any contamination across the optical faces nor degradation of optical performance
- The ability to operate underwater for long periods of time without discernable degradation

With the advent of extensive product qualification testing combined with an increasingly successful track record of operation in the field, the HydraLight connectors have achieved an unprecedented success. An enhancement of the original 1st-Generation HydraStar connector, the HydraLight is a 2nd-Generation optical wet-mateable connector. Enhancements were implemented based on customer feed-back, field experience, a customer Failure-Mode-Effects & Criticality Analysis (FMECA) and industry trends. This culminated in an extensive and expensive 18-month qualification test program. Now over 350 of these units have been manufactured, with over 1,600 wet-mate optical circuits. Of those connectors in the field and operating, over 2.9 million accumulated connector operating hours has been achieved, yielding a Mean Time Between Failure (MTBF) of better than 630,000 hours i.e. real reliability data based on actual field data.

It is not enough to specify the number of accumulated operating hours but you need to perform a chi-squared analysis of the data using the number of actual failures to predict when the next one could be. As a 2nd-generation product, numerous technical innovations have been incorporated into the HydraLight, examples are:

- Improved optical performance by key design knowledge gained over 14 years of optical connector design, manufacture and experience
- Enhancements to protect critical sealing surfaces
- Enhancements to protect critical connector operation
- Seawater compatible interior where the connector maintains operation optically and mechanically in the event of 100% flooding with seawater
- Standardized ROV interfaces
- Standardized industry standard Pressure Balanced Oil-Filled interfaces
- Improved chemical compatibility
- Improved compensation fluid

On top of these technical innovations were the combined and extensive testing conducted prior to the connectors achieving their extensive field experience.

The extensive qualification testing completed over an 18-month period was:

- Optical performance results based on over 10,000 measurements
- Optical performance longevity (mate-cycle testing)
- Maximum misalignment tests (rotational ±10º, angular ±5º and radial ±0.25")
- Locking device test
- 5,000N ROV force test
- Mating force tests
- Turbid tank tests
  - Coldwater
  - Continuously agitated, turbid sand, silt and seawater
  - 10,000psi
  - Horizontal, vertical and 40º inclination positions.
- Mechanical shock
- Vibration
- Thermal shock
  - High temperature: 158°F (70°C) to 32°F (4.5°C).
  - Low temperature: -40°F (-40°C) to 32°F (4.5°C).
- Extended mate/de-mate cycles
- Wet-mate test (ambient, coldwater, 10,000psi)
- Partial wet-mate test
- Hyperbaric test to the equivalent of 7,000m (23,000 feet)
- Compensation-oil loss/water ingress evaluation
- Cold mate/de-mate test (ambient and 10,000psi)
- Sliding Sleeve Integrity
- Mate/de-mate speed tests
- 24 hours helium leak test on seals
- Seal vacuum integrity test
- Compensation oil selection and verification
- Compensation oil cleanliness
- Hose and hose termination tests (Environmental stress tests, hose absorption/compensation, ozone resistance, ultraviolet resistance, thermal shock, tensile failure, burst pressure, crush resistance, outer sheath abrasion, hose kink testing)
- Jumper assembly (Oscillating jumper test, jumper pull test, drop test, jumper handling simulation test, simulated deployment test)

Figure 5 – HydraLight Underwater Mateable Connector

The overall main innovations here are the combination of in-service field data, product qualification and the incorporation of risk mitigation design into the connector solution. This overall approach has proved to be a huge innovation in the optical wet-mate connector industry and has resulted in the industry gaining the confidence in using this technology reliably and cost-effectively. Key connector system design parameters of reliability, track-record and long-term operation were met with a technically innovative solution.

Electrical Production Control Systems

Introduction. Similarly within the subsea production industry there is the need to meet or exceed the oil and gas production quotas whilst meeting the continued and reliable need for standard electrical power and communication systems.

Since Electrical wetmate connectors have been in existence for many years and there are numerous examples to select from, what could possibly be technically innovative about an alternative range of electrical connectors that have already been used successfully for many years?

The starting point for the development of this highly successful and technically sound design of high-integrity wet-mate electrical connectors was the innovative aspect of how it was developed by Lockheed Martin, a major Defense Contractor. In the mid to late 1990's, Lockheed Martin designed this range of connectors following a very detailed search and review of all of the patents and technologies available 'at that time'. Then in place of manufacturing a similar solution, Lockheed developed a technology different from technologies available at that time and included a number of additional technical advantages.

Technical Innovation. As long ago as 1979, reports and papers were being presented defining many approaches and solutions available for a wetmate electrical connector. These approaches for making wetmate electrical connectors had met with varying levels of success. In over 25 years, the 'state-of-the-art' of wetmate electrical connectors has advanced to remarkable levels and the technology of wetmate connectors has been advanced by the lessons learned in the competition to produce large quantities of reliable hardware for the offshore industry and other subsea applications.

In a review of these technologies conducted in the mid to late 1990's it was found that the 'state-of-the-art" electrical connectors followed similar guidelines and technologies that had resulted in three main solutions:

- Fluid-filled wet-mate connector.
- Redundant bladder shuttle pin wet-mate connector.
- Redundant wiper shuttle pin wet-mate connector.

However, in the late 1990's a fourth main solution was developed by Lockheed; the 'modular fully redundant wet-mate connector'.

Fluid-Filled Wetmate Connector. The pioneer of commercial wet-mate connector technology was introduced in the mid-1980's. This design set the standard for the industry and helped make implementation of subsea oil production control systems feasible. This design had several unique advantages. It was very simple with few parts. No mating

interface keying was required due to the coaxial contact design. The connector had been produced in impedance-matched coaxial, single-contact, two-contact, four-contact, six-contact, and eight-contact versions, all using identical probe sizes and entry seals.

Redundant Bladder Shuttle Pin Wetmate Connector. This connector addressed the need to provide redundant isolation between contacts by using an individual pin probe and bladder per circuit, and by adding a redundant bladder over all of the individual bladders. This design advanced the state-of-the-art by providing redundant isolation bladders between the individual socket contacts. The production design used individual inner bladders over each contact, but a single overall outer bladder with multiple entries for the outer barrier.

Redundant Wiper Shuttle Pin Wetmate Connector. This was another connector that appeared very similar in design to the design above, but has some differences in the arrangement of the fluid chambers and wipers.

Modular Fully Redundant Wetmate Connector. In the mid to late 1990's and following a review of the then current 'state-of-the-art' connectors, Lockheed Martin designed the CM2000 connector range. The CM2000 uses a modular design to provide redundant bladders for each contact, and separate entry seals for each bladder. This design is patented, and is licensed to SEA CON®/Brantner & Associates, Inc. by Lockheed Martin.

The CM2000 connector consists of a plug connector half containing electrical socket contact modules, and a receptacle connector with electrical pin contact modules. Each modular socket contact is enclosed in two nested dielectric fluid filled bladders, with each bladder having a separate entry seal. The probe of the pin module penetrates the sequential entry seals in the socket module to complete the connection. Each entry seal includes an elastomeric sleeve integrally molded to the end of each bladder. The sleeve extends axially through a formed wire closure spring, which squeezes the sleeve into a flat, sealed condition when the probe is withdrawn. Both closure springs are fully enclosed within the outer bladder. The stresses on the elastomeric throat and springs are low, and proven elastomers are used to ensure durability and long life.

Figure 6 – CM2000 Underwater Mateable Connector

The CM2000 was a new approach providing fully redundant bladders and entry seals over each contact. The use of individual pins requires keying, but mating forces are low and there are no forces tending to de-mate the connector once mated. The modular design allows freedom in the design of multi-contact configurations.

Over 1,500 of these connectors are now in service around the globe and have built up accumulated operating hours in excess of 35 million hours, yielding a Mean Time Between Failure (MTBF) of better than 7.5 million hours. Key connector system design parameters of reliability, track-record and long-term operation were met with a technically innovative solution.

Commercial-Off-The-Shelf (COTS)

Introduction. With the expansion in the use of fiber optic systems in subsea communications and other sectors of our industry the need for fiber optic connectors in systems has also expanded. Unlike harsh environment electrical connectors, which have been around for a much greater period and have extensive range of designs and configurations, fiber optic connectors are relatively new and have tended to be 'specials'. As 'specials' they have therefore demanded greater costs and leadtimes at perceived additional risks.

The expansion in the need and use of underwater connector systems has resulted in the need for Commercial-Off-The-Shelf (COTS) products to meet additional need for higher volume cost-effective products with shorter lead-times. These include electrical, fiber-optic and hybrid (electro/optical) connector products. Over the years SEACON has developed a number of unique technically innovative products to meet these specific requirements.

Examples of various COTS Connector ranges are:

- AllWet Electrical Connectors
- Hummer Electrical Connectors
- Micro WetCon Electrical Connectors
- OPTI-CON Optical and Electro/Optical Connectors
- 55 Series Electrical Connectors
- U-Mate Electrical Connectors
- MiniCon Electrical, Optical and Electro/Optical Connectors
- MicroMiniCon Electrical, Optical and Electro/Optical Connectors

Although SEACON has a huge variety of options available within each of these products, it is only possible to stock the most popular options or specific options for specific customers. However, one of the product ranges in particular has taken this concept one step further by utilizing specific additional and recent technical innovations to meet the COTS concept head-on. This is the OPTI-CON range of underwater connectors. This range of connectors was specifically developed to provide the industry with fiber-optic and electro/optical connectors as 'standards' in providing cost-effective solutions with shorter leadtimes

Technical Innovation. An innovative approach was required in order to short-cut the time to generate an extensive range of 'standard' connectors. To achieve this a philosophy

of standardized components combined with standard and interchangeable optical and electrical components was implemented to produce the OPTI-CON range of connectors.

Although the connector design was based on existing proven principals, the overall package was new. Therefore an important aspect was to ensure that the connector was qualified prior to releasing to the market. Qualification testing is always critical and due to the modular nature of the OPTI-CON series, qualification testing was conducted to simulate the extremes of operation. Also, due to the hybrid nature of the connector it was essential to conduct the qualification testing four times to ensure that Electrical, Optical (single mode), Optical (multimode) and Hybrid connectors were tested.

The net result of this innovative approach is a configurable connector that can meet almost any requirements for an optical or hybrid and is available as a 'Commercial Off The Shelf' product.

Figure 7 – OPTI-CON Connector

The OPTI-CON range is designed with 4 standard shell sizes to cover the standard 4, 8, 12 and 20 channels. Each of the channels is capable of being populated with either optical or electrical connections, or even blanked to provide an intermediate number of channels. The average optical insertion loss, for single or multimode, is <0.3dB and electrical contacts are rated to 600VDC at 4 amps. The complete range is pressure-rated to 7,500 psi.

In addition to considering the connector channels, the connector shell design and specifically the interface with the cables was also examined. The connector range is available with the rear shell capable of molding to standard cables. However, since one reason for connectors being defined as 'specials' is the need for the connector to interface with a myriad of cable designs, the OPTI-CON connector was designed with a Pressure Balanced Oil Filled (PBOF) cable interface, as standard. This approach provides the flexibility of the connector assemblies to be supplied with any number of conductors, without being reliant on specific cable designs, thus providing a fully flexible solution. Key connector system design parameters of short lead-times and low-cost were met with a technically innovative solution.

Down-Hole Systems

Introduction. Within the down-hole industry, there is the need to manage production and maintenance quotas efficiently and cost-effectively whilst meeting the high-pressure and high-temperature connection requirements for down-hole environments and operations. To enable this to be achieved there has been an expansion in the need for multiple monitoring and control devices to be deployed in a well and this has resulted in the development of "intelligent wells".

These monitoring devices and control devices need to be connected to the wellhead monitoring systems and control elements. Since the only route available to transfer the signal from the instrumentation and control devices downhole to the monitoring systems is the production pipework and tools the demands on the connectors are extreme. High pressure, high temperature solutions are required in an extremely small profile. In addition to this the number of instruments and control devices downhole has also expanded resulting in the need for not only a greater number of channels but in the use of electrical, optical and hybrid solutions.

Dry-Mate Technical Innovation. The extreme environments encountered downhole coupled with the limited space envelopes available demand an innovative solution to be adopted. For this extreme case the innovative solution was required in the area of the connector design and material selection. Using existing technology developed for many different customers over the years a new suite of products have been developed for small-bore high-pressure, high-temperature, electrical, optical and electro/optical applications specifically for intelligent wells.

Once again an important aspect of this development is the qualification testing. Due to the extreme requirements placed on this suite of connectors, in addition to the standard prototype qualification test program, a program of repeatable concept testing has been completed to verify the modules that make up the overall development. These include pre-prototype repeatable concept testing of:

- 15,000psi metal-to-metal seals
- 15,000psi internal pressure header barrier
- 125°C temperature testing of internal pressure header barrier
- 125°C temperature testing and performance of optical ferrules
- Simultaneous 15,000psi and 125°C temperature testing of internal pressure header barrier.

The purpose of this early testing was to qualify the major modular design elements during the design phase and to provide early testing information to continually feed back into the concurrent development program. This not only provided the repeatable design confidence but useful information about the design margins, for future enhancements. Basic parameters for these connectors are:

- Size: All connectors have a diameter of less than 1" and have design capability for significantly smaller diameter.
- Number of contacts:
  - Electrical: 2 channels (600VAC, 2.5Amps)
  - Optical: 2 channels (0.3dB IL, -50dB BR)
  - Electro/Optical: A combination of 4 channels (same parameters as above)
- Pressure: 10,000psi operating, 15,000psi test

- Temperature: -0°C to +125°
- Body material: Inconcel 625
- Seals: Primary, metal-to-metal and secondary, elastomeric

Wet-Mate Technical Innovation. In addition to the dry-mate requirements there is also the need for down-hole wet-mate connectors. As with all wet-mate connector principles, the functionality of this connector results is connectors with larger profiles than their dry-mate counterparts. In an environment where designing a dry-mate connector pushes designs to the limit the additional wet-mate requirement is even more challenging and needed a new approach to standard connector design.

This has resulted in the 'G3' design concept for a down-hole wet-mate connector. The 'G3' design concept utilizes the proven and reliable 'joined chamber' mechanism used in the highly successful HydraStar and HydraLight connector series. However, an innovative design envelope enables the connector to fit within the extreme dimensional restrictions and provides four configurable Optical or Electrical channels.

The 'G3' connector design concept is now available for onward development and qualification to provide the industry with the next generation downhole wet-mate connector.

Geophysical Industry

Introduction Geophysical Industry: Within the highly competitive geophysical industry there is the strong need to supply the most cost-effective connection solutions for the state-of-the-art slim-line exploration arrays.

Technical Innovation Cost is an ever-increasing factor in the Geophysical industry and therefore manufacturers need to supply cost effective connector solutions. One approach that has been adopted is, in place of supplying a complete connector assemblies, SEACON has worked with numerous customers to incorporate the connector housing designs into the clients system.

Taking this approach not only enables the cost to be minimized but also has the advantage of reducing size and weight of the final system. To provide a reliable solution with repeatable performance the connector insert and connector shell are designed to extremely close tolerance. Therefore, tolerance build-up understanding and monitoring is critical to achieve reliable and repeatable performance. To simply provide the client the connector insert and to allow the client to design the interfacing connector shell elements potentially leads to reduced performance and reduced reliability of the connector system. To minimize the risk in performance of the connector system, SEACON has designed the inserts to take a greater degree of misalignment. A close relationship is also required between supplier and customer in order to achieve a reliable solution.

A leading example of this was the development of a miniature fiber optical (and Hybrid Optical / Electrical) array insert. This insert is believed to be the smallest, highest density insert currently available. The insert measuring only 0.625" in diameter has 12 configurable optical or electrical channels. It offers an extremely small size and huge functionality without any compromise on optical performance.

Figure 8 – 0.625" diameter, 12-channel Optical Insert

Conclusions

Although innovation can be achieved by focusing on particular industry sectors, the approach adopted by SEACON maximizes its ability to understand each client's requirements within each industry and to provide the industry with the required technical solutions and innovations, in underwater connector technology.

By adopting this approach SEACON has been able to provide not only solutions borne from a particular industry, but has been able to use these solutions across numerous sectors. For example, the innovative designs and advantages achieved by the field installable solutions that benefit the Drilling Industry are also being used to provide the same benefits in the Electrical and Optical Production Control Systems. Also, the innovative 'Joined Chamber' concept used in the Optical Control System industry is being incorporated into the Downhole Industry. The need for Commercial-Off-The-Shelf products transcends all of the industrial sectors and this is a goal SEACON is striving to achieve in all sectors.

This approach ensures that SEACON is able to develop and supply products that allow the industry to reach farther and deeper, while working faster, smarter, safely, and more cost-effectively.

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