

Low-Cost, Miniature Connectors for Underwater Use on Homeland Security Applications

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Abstract

SEACON/Brantner & Associates have been working on many projects with the principle aim of reducing various key parameters, such as size and weight, of electrical and optical connectors for extreme environments, at a low-cost and without major compromises on performance. This has primarily been for applications where space or weight is a limiting factor such as: smaller Remotely Operated Vehicles; Autonomous Underwater Vehicles; divers, swimmer or marine-mammal-deployable systems; low-profile surveillance systems; underwater lighting, underwater security; use of lower cost and smaller operational vessels of opportunity and use of small-bore modular array systems. This technology is not limited to underwater applications but those in tactical and support environments including airborne and field applications subject to extreme operating conditions. This presentation highlights some leading examples of miniature, low-cost connectors for specific underwater use on Homeland Security Applications.

1. Introduction

There are many factors driving the reduction of both cost and size of electrical and optical connectors, designed for extreme environments. Most of these are driven by particular and unique customer requirements for each of their particular applications.

2. Reduction in Size

Reduction in connector size can be achieved by several means, however it is important to understand the parameters that have the most significant impact on size and these are:

- Voltage Rating
- Current Rating
- Contact Density
- Wasted space and material
- O-Rings
- Key/Keyway Heights
- Retaining Mechanism
- Minimal Wall Thickness
- Aft End Technology
- Mating Sequence

3. Reduction in Cost

Reduction in connector cost is also achieved by several means, in this case the main parameters are:

- Manufacturing quantity and economy of scale
- Reduction in the number of components in each connector
- Simplification of connector design
- Reduction of wasted space and material
- Lowering manufacturing and support overheads
- Manufacturing in low-cost-base environments

4. Connector Classifications

For the purposes of this paper there are two main connector classifications:

- **Dry-Mate Underwater Connectors** – electrical, optical or a combination of both. They are coupled and uncoupled in the air or “dry” before deployment underwater or into a hostile environment.

- **Wet-Mate Underwater Connectors** – these can be electrical, optical or a combination of both. They can be repeatedly coupled and uncoupled underwater at up to full ocean depths.

5. Connector Examples

The connector examples selected are based on small, low-cost products offering the greatest suitability for the above systems:

- **Dry-Mate Connectors**
 - HUMMER electrical connector
 - OPTI-CON optical and hybrid connector
- **Wet-Mate Connectors**
 - MICRO WETCON electrical connector
 - S-SERIES optical & hybrid connector

6. HUMMER Dry-Mate Electrical Connector

Dry-mate electrical connectors have been around for many decades. The rubber-molded variants were predominant with typically 12 contacts within a maximum diameter of 1” however the trend towards miniaturization combined with low-cost has led directly to the development of the HUMMER range of connectors which can meet the requirements for 28 contacts within a diameter of less than Ø0.69” at much less cost.



Figure 1 – HUMMER (12-Way) Connector

The standard HUMMER is a miniature configuration that incorporates the proven characteristics of existing SEACON field proven designs. It was developed specifically to meet the requirements for Commercial-Off-The-Shelf (COTS), low-cost, miniature connectors within the industry. The bulkhead half consists of a metal shell with molded glass-reinforced epoxy inserts, whilst the cable half is molded in neoprene to standard or custom cable lengths, with a metal coupling ring.

Available in 2 to 28 contact configurations, the diameter sizes are Ø0.43” for 2-contacts up to Ø0.69” for 28 contacts. The main specifications of the HUMMER range complement a total low-cost solution and are:

- 10,000psi open face and mated pressure
- Voltage rating of 300VDC
- Current rating from 0.5Amp to 2.5Amp
- Insulation Resistance of >200MΩ

The HUMMER is also available with PEEK shells and PEEK coupling rings instead of the more traditional metal shells. The main advantage of PEEK is that it offers a non-metallic alternative to metal shells for lightweight and non-magnetic underwater applications. The main disadvantages of PEEK are: that it is more expensive than even some of the more exotic metals; it is not as rugged as the metal versions and the pressure rating is reduced due to the lower tensile strength of the PEEK.



Figure 2 – PEEK (12-Way) HUMMER

The small size, field-proven design techniques, economy of scale and enhanced production techniques of the HUMMER series have contributed to the significant cost savings over other products. Table 1 highlights the Percentage Cost Reductions achieved over previous and earlier connector series for both connectors with low and high contact counts.

Low Contact-Count	High Contact-Count
65% to 85% cost reduction over equivalent XS and MING Series	70 % cost reduction over equivalent MINL Series

Table 1 – HUMMER Contact Count vs Cost Reduction

Further to this as an example of how other cost-reductions can be achieved we looked at the per-contact cost savings possible by the use of high contact-count connectors compared to low contact-count connectors as shown in Table 2.

Per Contact Cost Reduction	Criteria
75%	Using HUMMER-28 compared to HUMMER-2

Table 2 – Per Contact Cost Reduction using Multi-Contacts

7. OPTI-CON Modular Dry-Mate Hybrid Connector

The OPTI-CON modular hybrid dry-mate connectors also provide a range of Commercial-Off-The-Shelf (COTS) electro/optical dry-mate connectors. They provide functionality of 4, 8,12 and 20 within a range of 4 shell sizes. The smallest a 4-channel version offers 1.4” in diameter and is able to be configured for electrical, optical or a combination of contacts (hybrid). It offers significant cost-savings over any of the other range of dry-mate optical products. This is achieved by economy of scale whilst still retaining small size and flexibility.



Figure 3 – OPTI-CON (4-Way) Optical

The main specifications of the OPTI-CON range also complement a total low-cost solution and are:

- 7,500psi mated pressure
- Voltage rating of 600VDC
- Current rating to 4 Amps
- Insulation Resistance of >500MΩ
- Optical Insertion Loss of better than 0.5dB
- Optical Back Reflection of better than –25dB

Table 3 highlights the Percentage Cost Reductions achieved over other connector series for both connectors with low and high contact-counts.

Low Contact-Count	High Contact-Count
25% cost reduction over equivalent MIN Series	20% cost reduction over equivalent MIN Series

Table 3 – OPTI-CON Contact Count vs Cost Reduction

Table 4 shows the per-contact cost savings possible by the use of high contact-count connectors compared to low contact-count connectors.

Per Contact Cost Reduction	Criteria
35%	Using OPTI-CON-8 compared to MIN4

Table 4 – Per Contact Cost Reduction using Multi-Contacts

9. MICRO WETCON Wet-Mate Electrical Connector

The MICRO WETCON is what is known as a wet-mateable connector in that connections can be made underwater, on-deck or in any weather condition. It is an inexpensive high-volume rubber molded connector based on the extremely popular and reliable WETCON series although smaller as shown in Table 5.

Contacts	WETCON Ø	MICROWETCON Ø
2	Ø1.00"	Ø0.61"
8	Ø1.25"	Ø0.61"

Table 5 – WETCON OD vs MICRO WETCON OD



Figure 4 – MICRO WETCON

The change in specification from a WETCON to a MICRO WETCON, as shown in Table 6 may appear significant but the reality is that they offer a practical, small and inexpensive instrumentation connector that suits a majority of applications requiring acceptably lower performance to an industry standard configuration. The smaller size allows for smaller through-ports in a pressure-vessel and a greater density of conductors in a compact area.

Parameter	WETCON	MICRO WETCON
Voltage	600VDC	300VDC
Pressure	20,000psi	10,000psi
Wire Size	#14awg, #16awg or #18awg	#18awg on 2-pin, #20awg on 8 pin

Table 6 – WETCON vs MICRO WETCON

The other main specifications of the MICRO WETCON range also complement a total low-cost solution and are:

- Current ratings available in 3 Amp, 6 Amp and 10 Amp configurations
- Insulation Resistance of >200MΩ

Table 7 highlights the Percentage Cost Reductions achieved over the WETCON connector series for both connectors with low and high contact-counts.

Low Contact-Count	High Contact-Count
55% cost reduction over equivalent WETCON Series	35% cost reduction over equivalent WETCON Series

Table 7 – MICRO WETCON Contact Count vs Cost Reduction

Table 8 shows the per-contact cost savings possible by the use of high contact-count connectors compared to low contact-count connectors.

Per Contact Cost Reduction	Criteria
60%	Using MICRO WETCON-16 compared to MICRO WETCON-2 or WETCON-16

Table 8 – Per Contact Cost Reduction using Multi-Contacts

10. S-SERIES, S-1 Optical Wet-Mate Connector

The S-SERIES connector was designed and qualified as a small lower cost, lower specification alternative to the high specification optical wet-mate connectors such as the HydraStar, HydraLight and MicroStar. It was designed with modular optical or electrical contacts. The electrical contacts utilize the 3mm contacts from the CM2000 range of underwater-mateable electrical connectors.

The S-1 is the smallest configuration and is a modular single-channel optical version. Figure 5 shows the production S-1 plug and receptacle with a maximum diameter of just 1.1" at the largest cross-section.



Figure 5 – S1 Single Channel Optical Wet-Mate

The main specifications of the S-SERIES range also complement a total low-cost solution and for the electro/optical (hybrid) are:

- 1,000psi mated pressure
- Optical Insertion Loss of better than 1dB
- Optical Back Reflection of better than -25dB
- Voltage rating of 3.3kV
- Current rating of 30 Amps
- Number of mate-cycles typically 25

Recent advancements have allowed improvement in the optical performance with the following values being achieved over 20 mate-cycles, at pressure:

- Optical Insertion Loss - Average of 0.20dB with a Standard Deviation of 0.08dB
- Optical Back Reflection - Average of -48dB with a Standard Deviation of 6dB

Table 9 highlights the Percentage Cost Reductions achieved over other connector series for both connectors with low and high contact-counts.

Low Contact-Count	High Contact-Count
40% cost reduction over equivalent HydraLight Series	30% cost reduction over equivalent HydraLight Series

Table 9 – S-Series Contact Count vs Cost Reduction



Table 10 shows the per-contact cost savings possible by the use of high contact-count connectors compared to low contact-count connectors and specifically highlights the cost savings by the use of an S8 multi-channel connector over an S1 or a single channel HydraLight.

Per Contact Cost Reduction	Criteria
65%	S8 compared to S1
75%	S8 compared to Single Channel HydraLight

Table 10 – Per Contact Cost Reduction using Multi-Contacts

11. Homeland Security Applications

There are many factors driving the reduction of cost, size and weight of electrical and optical connectors for extreme environments. Most of these are driven by particular and unique customer requirements although many are a result of a considered opinion of potential customer requirements and in particular for maritime related Homeland Security applications we can list the following examples:

- **Smaller Host Vehicles** – Remotely Operated Vehicles (ROV), Autonomous Underwater Vehicles (AUV) and other underwater vehicle systems become reduced in size, or there is a reduction in available space due to increased vehicle complexity.
- **Diver Systems** – Weight reduction or increased density of electrical or optical functionality for manual diver connection systems.
- **Swimmer or Marine-Mammal-Deployable Systems** – Similar to diver systems but with a specific emphasis on not only small size, but small mass and weight and simple operation.
- **Low-Profile Surveillance Systems** – Examples require key connection products to be hidden; undetectable; EMI compliant; physically small and non-metallic; but still operational in extremes of environments, including deepwater, sub-surface or buried.
- **Underwater Lighting and Security** – Smaller and lower cost connection systems assist with the economic viability of large-scale underwater and security operations and systems.
- **Lower Cost & Smaller Vessels-Of-Opportunity** – Similarly with an emphasis on cost reduction, which can focus on the use of smaller and cheaper underwater vehicles or vessels of opportunity rather than specialized and more expensive ocean-going vessels.
- **Slim-Line, Small-Bore Modular Arrays** – A combination of the examples above requiring increased complexity but a reduction in size and weight as part of an automatic deployable system.

12. Summary

SEACON is without doubt the largest, the most diverse and the most experienced Underwater Connector Company in the world. This has meant that, over the years, we have been able to significantly re-invest resources to work with customers in defining, developing and manufacturing their specific and latest requirements. This has led to a significant number of innovations and new products that has added to the diverseness of the product base. A key element of this has been at the forefront of initiatives to reduce connector size and cost and this, we hope, we have been able to demonstrate within this paper/presentation.

References

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