Getting the Undersea Cable You Need

A Program Quality Approach

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I. Introduction

In any given ocean project from concept to completion there are usually around 100 major and minor steps. Somewhere within these steps will be the need for design, manufacture, termination, and maintenance of the undersea cable. There are many applications for a cable to be used in an ocean or underwater environment. It could be that of supporting an ROV, providing an umbilical cable, connecting a bottom laid surveillance system, forming a communication network, providing a riser cable, connecting a research sensor grid, towing a fish or other types of application. A cable can be a single point of failure and a cable failure can bring the ocean project to a standstill. Therefore, designing, specifying, contracting, building and testing an undersea cable becomes of major importance.

The object of this paper is to provide guidance in getting the cable you want that provides the performance you need. Getting the cable you need requires a disciplined Project Quality approach through the whole project from conceptual design to final test. The following sections describe getting the requirements right, passing the requirements to the cable supplier, and managing the cable supplier through manufacture and test.

II. KNOW WHAT CABLE YOU NEED – DETERMINING THE REQUIREMENTS

In order to get the cable you need, you must first know what cable you need. Determining a good set of requirements is the initial step in getting an undersea cable that functions flawlessly.

A. Key Performance Requirements

The all important first step is to focus on the key performance requirements. The essential role of an undersea cable is as the life line to connect two ends and transmit signals, supply power, and carry the mechanical loads between the two ends. While a major component and possibly one of the top cost items of the project, the end use drives the cable; the cable does not drive the end use. While the end use is the main driver of the cable requirements, trade-offs for cable requirements are generally needed in the design of the system architecture. Trade-offs are most common in design of the electrical power distribution architecture where single phase or multi-phase power is provided. The number of conductors in a cable significantly affects its size and weight. Therefore, where needed, a system approach for the number of circuits in the electrical system architecture is needed to get the optimum cable. For example, creating an individual circuit for each motor may simplify the controls and power distribution but can result in a large and unwieldy cable. Therefore, the number of circuits must be optimized to get the best solution for both the cable and the entire system.

B. Interface Requirements

Next in importance are the interfaces. Nearly every ocean platform has limited storage space and weight allocated to the cable system. Therefore, the diameter and weight of an undersea cable are tightly constrained. The equipment to deploy the cable also places constraints on the diameter and bending radius of the cable. The primary task of cable requirements generation is getting a cable that provides the performance needed within the size and weight constraints of the platform and its hardware.

C. Handling the Other Requirments

With the key performance requirements and the interfaces in hand the remainder of the requirements can be generated. Other cable requirements are commonly forgotten and rarely misallocated. For example, the dimensions

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and weight of the full cable reel may not be determined until the final preparation for shipment. This can lead to a last minute scramble for shipping options if it comes out too large for standard transportation methods. Therefore, developing a check list for cable requirements for the application of interest is useful in making sure all applicable requirements are addressed.

The generic requirements "to function in a marine environment" or to use "proper workmanship" cover a great many hidden requirements. For example, marine use implies corrosion resistance and compatibility with materials found in common use on ocean platforms. It would be unwieldy to specify every possible material permissible for the cable construction or every compound that comes in contact with the cable. To cover this marine cable suppliers have developed working practices and qualified materials that have a history of successful performance. When trying to use a cable supplier that has not done work in ocean systems this may become a problem. One has to be careful to include more information on marine practices when developing new cable suppliers.

The following sections take a closer look at specifying the optical, electrical, mechanical, and physical requirements for undersea cable.

D. Optical (Communication) Requirements

Communications on undersea cable are nearly universally carried by optical fibers; twisted pair and coaxial communication media are obsolete except for some specialized applications. Therefore, this section will focus on optical communications. The primary requirement is the number of optical fibers needed and this is determined by the optical system architecture. Since optical fibers are small, the number of fibers has little impact on cable design except for very high fiber count or very small cables. The cable specifications must also pass on the optical fiber requirements for fiber type, attenuation, and dispersion. Often system designers simply pass on optical requirements typical of a trans-oceanic cable system. Trans-oceanic systems are state-of-the-art for combinations of high bandwidth and long distance. However, most applications not spanning an ocean can be handled with standard fiber types with greater attenuation and dispersion. For example, trans-oceanic cables may require maximum attenuation of 0.19 dB/km at 1550 nm to minimize the number of repeaters in a long span. If an application can work with a 0.25 dB/km maximum attenuation at 1550 nm the tighter requirement of the trans-oceanic cable will make every step from fiber procurement, through in-process testing to final test more difficult. Therefore, check if standard fibers are viable because they can provide lower cost and more availability than the specialized fibers for crossing oceans. A similar situation exists for bend resistant fibers. Most undersea cable types were developed to work with standard fiber and have performed well for decades. Don't immediately look at bend resistant fibers for working applications.

E. Electrical Requirements

The power carried by undersea cables is electrical. Electrical conductors can be limited by cable diameter or weight so optimizing the electrical architecture is often the key to getting a cable to meet both size limitations and power demand. The first step is to get a firm grasp on the power required and then optimize the architecture for number of circuits, conductor size, and operating voltage. The insulation takes up most of the space for insulated conductors, so minimizing the number of circuits will minimize the cable diameter. However, a lower number of power circuits make the distribution buss and control circuits at the ends larger and more complex. The number of circuits must balance the needs of the cable design and the electrical design of the mating components of the system.

Operating voltage is a function of insulation thickness and can also be optimized to minimize the size of the insulated conductors. One of the significant contributors to the cable weight, particularly the weight in seawater, is the copper conductor. Minimizing conductor size is often the major element in limiting the weight of a cable. Minimum conductor size is often determined by the current surge when starting electrical motors and not the steady state performance. Therefore, it is useful to analyze the transient voltage drop when starting a motor. The transient is usually acceptable if the conductors provide voltage regulation of 10% or less in normal use. The transient can be minimized by staggering the start of each motor when multiple motors exist.

Working cables commonly have severe bending requirements and their service is measured by number of bending cycles, service tension, and bending radius of the sheaves and handling gear. For the conductors in ocean cables failure in bending is either a cup and cone tensile failure or a Z-kink caused by compressive buckling. Undersea cable conductors typically do not fail from metal fatigue. Therefore, electrical conductors for severe bending service may need to be either high strength conductive alloy or have high bending stiffness. This is the opposite approach from most heavily bent cables, like welding cables, where limp, fine wire conductors are used. If a severe bending environment is expected a conservative approach is to estimate the number of bending cycles, service tensions, and sheave radii and develop a bending test with at least twice the expected number of cycles. Bending life is one requirement where qualification tests can prevent costly field failures.

F. Mechanical Requirements

The primary undersea cable mechanical requirement is the tension it must carry, or the working tension of the cable. For bottom laid cables, as an example, the first cut maximum installation tension is 1.5 μH and the first cut maximum recovery tension is 2.5 μH, where μ is the wet weight of the cable and H is the maximum installation depth. The maximum tension for working cables is typically a more complex calculation, but it should never be less than twice the static weight of the cable and payload. The classic solution for a suddenly applied load is twice the static weight and the doubling of load is seen frequently in tension logs regardless of rendering system used or care in handling.

Total load calculations are always done for maximum depth. However, if a moving system can be snagged then the maximum load may be with the least amount of cable out. Using an undersea plow cable as an example, maximum loads for a snagged plow are often greater in shallow water. At maximum depth the compliance offered by cable stretch and tightening of the catenary will lessen the dynamic load if the plow stops. However, there is no give in the cable at minimum depth. Therefore, the maximum transient load can be higher at minimum depth than in deeper water for the example of a stopped sea plow.

The bending environment, discussed in the electrical conductor section, is specified in the mechanical requirements. Often these requirements describe an existing handling system. The primary bending requirement parameters are bend radius, working tension, and number of bending cycles. The convention for a bending cycle is a straight-bend-straight cycle and represents a single pass over a sheave. Other bending parameters are sheave groove diameter and whether the bends are in the same direction or are reverse bends. If the handling equipment does not exist, increasing the sheave diameter is the most effective way of increasing cable life in bending. Use the largest sheaves possible.

For cables, such as ROV and tow cables that are cycled in and out the worst case bending condition must be identified and tested as discussed earlier. However, the most stressful condition may be twisting as the cable is manipulated to bring an ROV into the docking head or a towfish on board. Be sure to evaluate twisting as well as bending for working cables.

Other mechanical requirements to consider involve cable rotation, torque balance and breaking strength. Breaking strength is not considered a key requirement in this paper since it follows from the working tension.

G. Physical Requirements

The key physical requirements are size and weight. Nearly every cable system has strict limits on size and weight. The performance requirements for power, load capacity, and occasionally optical fiber count are limited by the size and weight limits and trade studies are normally done to get optimum cable performance. Therefore, understand your platform and set size and weight limits carefully.

Specific gravity may be important. Bottom laid cables must be dense enough to lay flat on the bottom and tow cables may need a specific gravity range to tow properly.

The requirements for storage and shipping are important physical requirements as well. Take note if a cable is to be spooled on a reel or coiled into a tank or pan. Coiling will involve a twist for each turn of cable and is harder on the cable than proper spooling on a reel.

Interfaces are mostly physical requirements and requirements for the terminations and connectors are needed to assure that the cable fits into the overall system.

Finally, specify how the cable and/or reel are to be marked. Undersea cables can all look alike. Be sure to have the cables marked in a way that best fits your needs.

With a clear and complete set of requirements, the specification can now be written.

III. COMMUNICATE THE REQUIREMENTS TO THE CABLE SUPPLIER – THE SPECIFICATION

Your needs must be communicated to the cable supplier. This is mainly the function of the cable specification which describes the cable. Meeting with the cable supplier and describing the mission is also a great help in having the supplier better understand your needs. Some of your more subtle needs may not always come across on the written page and face to face meetings are helpful. The specification technically describes the cable. However, the statement of work and other contracting documents are also essential in having the program run smoothly.

A cable specification should start with an introduction that summarizes the key cable functions and its interfaces in a page or less. A clear and concise summary helps keep the top level view in sight. It is easy to lose sight of the forest for the trees when writing a specification and a good summary can keep focus on the end goal.

The requirements need to be written clearly, concisely and completely. Use a standard specification format; it saves effort and standard formats cover all the aspects. The most widely used specifications are the MIL-STD specifications used for US military purchases. Most cable suppliers perform work for the government and are familiar with the format of these specifications. Therefore, the MIL-STD model may be a good place to start if there is no prior standard specification formats for your cable.

To be clear, state only one requirement per paragraph and keep the paragraph short and to the point. Requirements can be lost in long, rambling paragraphs with multiple requirements.

Use a checklist to verify that a complete set of requirements is given. Requirements can often be neglected in the rush to finish a specification.

Requirements should be performance requirements rather than design requirements when possible. This allows for the greatest freedom to design a cable to meet your needs. However, interfaces will constrict design and must be stated clearly.

When producing a specification make sure the requirements as written can be verified in a straightforward manner. Determine the exact way each requirement is verified as it is written. A good exercise is to imagine how each verification test will be performed and the measurements taken. Taking time early on will save disputes in verifying compliance with the specification later on. Know what is to be tested, when it is tested, and why it is tested.

Be cautious in the use of acronyms. Every organization may have its own set of acronyms and they may conflict. For example, there are at least 55 definitions of FAT. Therefore, minimize the use of acronyms and clearly define any ones used.

The specification describes the cable, but the statement of work (SOW) is a key communication to the cable supplier as well. The key items for the SOW are price, delivery schedule and points of contact. However, this is the document to clarify the data deliveries as well. Be clear in defining the data deliverables to assure that the test data, material certifications, and any other information needed is completely supplied and in a format that is convenient. Format is important in data management. Get the data you want in the format you need.

IV. GETTING THE CABLE YOU NEED – MANAGING THE SUPPLIER

The cable design, specification, and contacting tasks are complete. The final task is to manage the cable supplier through the manufacture and test of the cable.

Start with a plan. The complexity of the plan depends on the complexity of the cable being built and tested. A standard product supplied for an ancillary task may require just an occasional call to the manufacturer. A new cable design that is a critical part of an important system may need a more rigorous monitoring system with plant visits

and a tighter schedule to coordinate the manufacturing and testing phases. The effort involved with managing the supplier depends on the risks involved and the importance of the cable. Don't waste time on simple projects or neglect needed attention for a more important cable.
Have regular status meetings and a single point of contact for each side. Regular meetings reinforce the importance of the task and make sure good communications continue. The frequency of meetings can change as events dictate, but always have regularly scheduled meetings. A single of point contact is needed to keep the program heading in a single direction. For example, if engineering or quality control goes around the regular communication chain parts of the process can go in different directions and bog down the program. Keep control of communications with single points of contact. Side conversations are necessary since the specialists from both sides must talk directly to resolve some issues, but the points of contact should be aware of them and approve any decisions or changes in direction.

Configuration management is then needed to track and control any changes. Program details change and any changes must be agreed upon and documented so the program can proceed smoothly and in a single direction. Everyone involved in a program must be aware of the latest direction of the program, so changes must be carefully controlled and documented.

Quality assurance is crucial to getting the cable you expect. It is important to understand the supplier's processes and procedures and how they work with the overall program. Of particular importance are noncompliance issues. Know how noncompliance is tracked, communicated and resolved. The earlier a problem is identified and communicated to the customer the easier it is resolved. Dealing with noncompliance after the product is delivered creates a great deal of stress and wasted time in a program and must be avoided. Deal with noncompliance early and calmly to resolve the issues or they can overwhelm your program. In order for this to occur one needs to understand how the cable supplier handles non-compliances and communicates them to the customer and then make sure the avenues of communication stay open.

Don't skimp on testing. Testing is performed in-process, for acceptance, and for verification. In-process testing is useful in assuring that the manufacturing is progressing properly. Determine the amount of in-process testing based on its importance and get in-process results reported quickly. Getting the proper degree of in-process testing is important. Too much testing and one is buried under paperwork; too little and problems can't be addressed early. The in-process data are only useful if it is received in time to make a difference, so it is important to keep in touch with the supplier's Quality Control personnel.

Acceptance testing is used for customer acceptance of the cable. Have a plan for acceptance testing that everyone agrees to and can be executed in a straightforward manner. When a finished cable is sitting on the loading dock is no time to argue about what final acceptance testing is to be done. If an acceptance test fails, stay calm and check the test equipment and procedure first. A retest may settle a failure.

Verification tests assure that the cable performs as expected and are performed for a new cable design. However, if a cable is not manufactured for two years or more it is recommended that the verification tests be repeated. Personnel and equipment changes can make cable manufacture seem like it is done for the first time after a multiple year layoff. Like all testing, make sure to know what is tested, when it is tested, and why it is tested. The when is particularly important for verification testing since verification tests are likely to be performed at an independent test source. Therefore, coordination is important so that the customer, the cable manufacturer, and the testing supplier all work together.

Risk management will help a cable project run more smoothly. Identified risks are usually watched carefully with the result that issues that come up are rarely those that are expected. The two key elements of risk are the probability of a risk occurring and how severe is risk if it happens. Those items that have a high probability of occurring and have a severe impact on the program should be watched carefully. While it is essential to identify, analyze, and monitor risks, do not increase your risks. Don't make unnecessary work by focusing on risks that don't matter; that will take attention away from the important risks. Like every part of the program management place more attention on the more important items and less on those that matter less. However, watching the bigger risks goes a long way to preventing their occurrence.

By following a Program Quality approach from start to finish the result will be receiving a cable that performs as needed when needed with a predicted cost.

V. SUMMARY

Ocean systems have an undersea cable whose performance is essential to the system performing as needed. Since cables are single point of failure elements, they can be the weak link of the system. Therefore, a disciplined Program Quality approach to cable procurement is essential to getting the undersea cable you need to support the entire system. The Program Quality approach starts with generating the proper requirements then proceeds to writing a clear and complete specification and concludes with managing the supplier through manufacture and test.

Requirement generation starts with a focus on the key requirements of working tension, power demand, communication requirements, and size and weight constraints. Cable design follows the demands of the overall system, but trade-offs in cable requirements are often needed early in system design to get an optimum solution that balances demands of the cable and the system. The key to this balance is getting the mechanical, optical, and electrical performance needed within the size and weight constraints. With the key requirements in hand, the other requirements can be filled out. Develop a checklist for a given application to assure that requirements are not neglected.

The requirements go to the cable supplier via a cable specification that must be clear, concise, and complete. Use good specification writing practice to get a specification that describes the cable you need. Other contracting documents should cover the data needed and the format. Get the data you need in the format you want.

The disciplined Program Quality approach then applies to cable supplier management through cable manufacture and test. Make a plan that complements the complexity and importance of the cable being provided. Understand how the supplier's quality control system works and have single points of contact to maintain clear communications. Be sure to have a practical and complete test program. Know what is tested, when it is tested, and why it is tested. Use risk management tools to avert common problems.

By following a disciplined Program Quality approach for undersea cable procurement the needed cable will be supplied when required at the expected cost. Taking a rigorous course of action to cable procurement assures that the cable will perform flawlessly in support of the whole ocean system for years to come.