INNOVATIVE JOINTING & STABLE TECHNOLOGY – CLOSER THAN WE THINK

Maurice E. Kordahi, Jeremiah Mendez, Marsha A. Spalding, Robert K. Stix

mkordahi@tycotelecom.com

Tyco Telecommunications, Eatontown, NJ 07724 USA

Abstract: The goal of offering innovative jointing techniques, compatible with the existing, globally-deployed shipboard jointing infrastructure, presents a challenge not only to system suppliers but also to ship operators and system owners. Over the past two decades, the undersea telecommunications community has equipped its undersea cable installation and maintenance fleet with purpose-built jointing equipment that most marine providers use to assemble at-sea joints. Although it is possible to take a forward leap in innovative jointing methods which would likely require new investment in shipboard infrastructure, would the resulting improvements in assembly time or performance justify the re-investment?

Today's shipboard jointing methods focus on achieving standardized connections among a variety of cable types from different suppliers, using a minimal set of designs, tools and procedures. This principle, by its very nature, limits the breadth of possible technologies, and does not readily lend itself to novel innovations. Recently, however, newer cable designs have afforded opportunities for jointing method improvements, which could become the impetus for introducing changes over time that may fundamentally alter the concept of having a single, stable approach to "jointing". This paper presents a study of some of the challenges that face the industry, and suggests ways forward.

1 BACKGROUND

1.1 Jointing Origins

Undersea fiber-optic cable jointing is built on a foundation of core technologies. Many of these are direct descendants of the jointing used in the first trans-Atlantic and trans-Pacific fiber-optic cable systems. Joints have been surface laid on—and buried in—ocean bottoms ranging from silt to rock. They have proven themselves to be robust in the wide range of harsh conditions around the world.

Systems and cables are designed and provided by a variety of manufacturers. In addition, they have varying protection requirements depending on deployment depth, sea bottom conditions, maritime activities, and so forth. This results in numerous configurations of cables and often different optical fiber types.

1.2 History of Universality

Originally, each system supplier deployed equipment and parts to install and maintain their own particular cable type. Typically, a ship was outfitted with several suites of jointing equipment and the personnel trained to use it.[1] Additionally, the ships had to carry parts kits for each specific supplier's jointing platform. It rapidly became apparent that there would be great advantages to system owners if there were common maintenance and repair capability for all cable types, thereby reducing the tooling required, training, and proliferation of kits.

To this end, jointing technology, equipment, and operations have evolved into a common or *universal* approach, shared by a number of systems, owners, suppliers, and marine operators. It is based on the following precepts:

- Shared Quality Standards
- Technology re-use
- Common tooling
- Parts Modularity
- Common procedures
- Simplicity & Repeatability
- Wide availability
- Competitive supply

Although the approach is *universal*, the jointing parts are not. Specific adapter kits are required to join different types and brands of cables. Hence, there are dozens if not hundreds of cable jointing end specific kits (ESKs). The tooling and approach are—for the most part—standard. That is, all of the ships that have *universal* suites of tools have the potential of jointing most cables.

[1] Suites of equipment for a specific cable or system and special teams of cable-specific jointers were mobilized at the time of need.

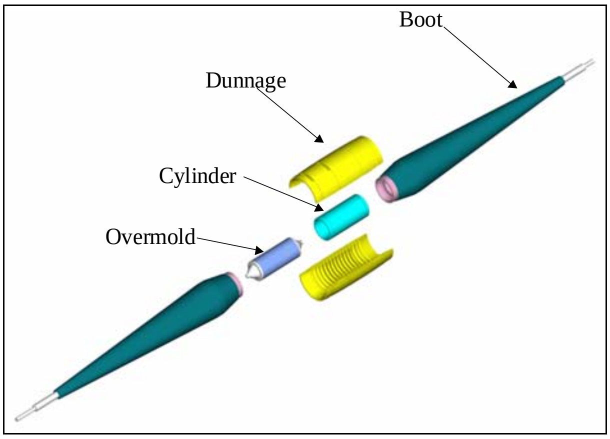

Figure 1. Example *universal* Armorless Joint

Jointing uses several fundamentally similar steps and processes including:

- cable preparation,
- termination,
- linking of cable terminations,
- splicing,
- fiber storage,
- closure,
- insulation, and
- protection.

Figure 1 shows a typical armorless joint. Armored joints are similar but have outer protection hardware to link the strength of the cable armoring.

2 GOAL

The aim of jointing improvements and innovation is to bring about versatile, straightforward, robust, reliable, and cost-effective jointing technologies. Jointing developers work to offer innovative designs and techniques that advance the state-of-the-art of undersea cable jointing. Previous experience along with extensive development, sea trialing, testing, and field performance have culminated in current jointing methods that are a balance of all of these.

Around the world, these platforms,[2] with well-proven performance have been purchased and mobilized. Stake holders have a vested interest in seeing that innovations are compatible with existing infrastructure. This presents a challenge not only to jointing developers but also system owners, maintenance authorities, and ship operators.

[2] Platforms consist of customer-approved equipment suites, parts inventories, and trained personnel.

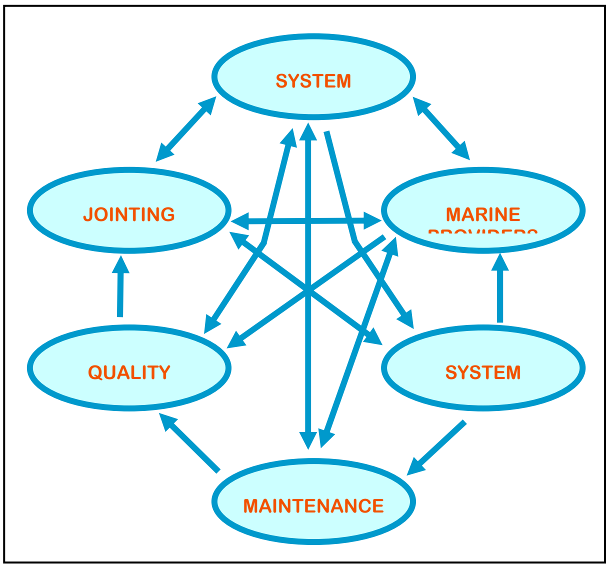

Figure 2. Stake Holder Interactions

3 STAKE HOLDERS

Stake holders have diverse interests and motivations. The major interests are borne by system owners, system suppliers, maintenance providers or maintenance authorities, marine providers, jointing developers, and consultants. Figure 2 shows the informational relationship between the major parties.

Contractually, system owners, maintenance authorities, and marine providers look for cost-effective solutions to system repair and maintenance. Frequently, several cable systems and cable types are maintained by the same ships and personnel. In many cases, system owners have their own inventory of cable and jointing kits. In some cases, they may subscribe to maintenance plans in which the maintenance providers offer worry-free repairs using their own kits and equipment.

4 ROAD BLOCKS

There are a number of challenges to improving the current jointing technologies. Table 1 lists a number of the factors affecting innovation. Below, we discuss these and other impediments.

Table 1. Factors Affecting Innovation

Platform: design, technology, qualification, requirements, commonality, universality, complexity, ergonomics, shipboard environment, capability
Cable: cable conformance, fiber types, cable end preparation, fiber handling
Splicing: strength, fiber handling, process/equipment, available technology
Insulation: voltage, wall thickness, insulation material
Equipment: calibration, maintenance, training
Kits: quality/conformance of components (piece-parts), packaging, storage, inventory

Other factors: product life-cycle, reliability, regulations, customer expectations, backwards compatibility, documentation, performance, stake holders, cost, collaboration, shared responsibilities, shared interests, contracts, sales, marketing

Jointing Infrastructure

With the advent of fiberoptic systems, the undersea telecommunications community has equipped nearly every cable installation and maintenance vessel with purpose-built jointing equipment This is the *universal* equipment that most marine providers use to assemble at-sea joints.

Any jointing improvements that require new investment in shipboard infrastructure or parts inventories would necessarily be met with rigorous scrutiny to determine if the enhancements justify the re-investment or cost to replace or upgrade their fleets.[3]

Jointing platforms are currently deployed and meeting the needs of system owners, operators, and maintenance authorities. These support ongoing imperatives to provide expedient repair of systems in the field. In addition, they are often used to install new systems.

The implementation of jointing platforms requires overcoming the inertia associated with the following:

- Qualified Designs
- Qualified Jointers
- Qualified Procedures
- Documentation
- Parts Supplies
- Qualified Tooling
- Tooling Availability

Improvements and innovation must factor in the customers' needs for current product / system support as well as capital invested in inventory and tooling. For innovation to take place and make it to the field, changes must often be retro-qualified and backward compatible to replace current methods, hardware, tools and the like.

In a limited number of cases, process improvements have avoided the infrastructure issue by not significantly changing parts or tools. Since they only affect qualification, documentation, and training, the cost of introducing them is relatively small.[4]

[3] In some cases, equipment or support for the equipment is discontinued and becomes unavailable, thereby, necessitating replacement and the associated expense.

[4] As a cautionary note, it may be difficult to determine the reliability impact of such improvements or the net cost.

4.1 Design Constraints

Joints are designed to provide reliable service under a wide range of conditions for 25 years or more. Jointing processes including techniques, materials, and procedures applicable to undersea fiber-optic systems are confined to well-proven, repeatable, and cost-effective approaches. Every supplier in the industry is bound by the same constraints and has arrived at similar solutions using these essential principles, approaches, and equipment.

Cable families typically embody full product lines covering a wide range of cable varieties and applications ranging from deep-water (lightweight) to heavy rock armored types. Each of these requires joints for field installation and maintenance around the world. In addition, they are often required to be joined or interconnected to other equipment manufacturers' repeaters and cables.

Joint technology which is specific to a certain cable type is typically quicker, but when considered for interconnecting a broader base of cable designs will inherently have drawbacks that reduce their suitability and, therefore, overall appeal.

4.2 Performance & Reliability

Undersea cable systems are typically high-voltage, high-reliability, transmission systems carrying large volumes of commercial traffic. Customers expect additional assurances of quality and reliability so as not to degrade the reliability of installed systems. Since there is no way to non-destructively test all aspects of joints made, demonstrating this can be difficult at best.

Performance and reliability are dependent upon the use of proven materials, methods, qualification, training, process control. A preponderance of evidence is formed to show that jointing is reliable—rather than inspection and testing alone. To this end, joints have carried with them the proven performance and reliability of the previous jointing methods. A typical design is the result of numerous enhancements stemming from years of practical experience combined with detailed attention to customer needs and requirements.

Jointing developers are always looking for ways to improve jointing performance, reduce cost, while maintaining quality and reliability. Additionally, they need to carefully consider the cost of process/equipment/part changes and the associated expenses that may ultimately find their way to the customer or end-user. The aim of developers is to balance the cost of improvements with the expected benefits to satisfy customer needs for reliability, longevity, and *universality*.

5 CHALLENGES

Interests of various stake holders drive improvement but ironically also form the major hurdles and conflicting needs associated with implementation. Often, this results in local optimization rather than global optimization. That is, the cost-benefit of various changes affects different stake holders in different ways.

Today's jointing platforms strive for *universality*[5] of connections among a variety of cable types from different suppliers. Because of stake holders' interests, requirements, and desire for *universality*, possible technologies and feasible innovations are limited.

If jointing platform designers come up with a new set of parts or innovative method that is easier—and more reliable—to assemble, the cost of implementing it (development, training, and any tooling) must ultimately be passed along to the customers.

6 NEWER CABLE DESIGNS

The majority of newer cables have migrated to a structure that—from inside out—consists of five major elements:

(1) fiber bundle,

(2) high-strength steel strand,

(3) copper sheath for conductivity and hermeticity,

(4) electrical insulation, and, if required,

(5) external armoring.

Additionally, the cables have been carefully thinned down to minimize cost while maintaining performance. The resulting similarity in structure and size is seen in the majority of the world's current undersea cables. In essence, cables now conform to de facto standards as do the various "universal" jointing platforms.

Wide-spread use of these cables with similar designs has opened up new possibilities for jointing platform improvements. Fundamentally, they may allow a *universal* approach that accommodates changes over time while remaining stable and reliable enough for stake holders.

7 WAY FORWARD

Without adversely impacting universality and cost, how can jointing move forward? Here are a few ideas.

One way to innovate in the jointing realm is to optimize for the local environment. This can be done without affecting the jointing infrastructure of inventoried parts and deployed/existing tools. An example of this is to improve on the time-motion aspect of the at-sea operation. This involves planning, training, practice, and execution but does not rely on any changes to the jointing platform or equipment suite.

Another way that has been used to varying degrees is to improve upon non-specialized tools and equipment. Ships can be outfitted with generic tools or benches to make gains without affecting the jointing design, performance, or reliability. These kinds of process improvements have the potential for direct benefits in performance without impacting the universality of the jointing platform. [6]

Another avenue is to selectively apply jointing platforms only to those cables that are in the mainstream or are the most wide-spread. That is, the jointing designers could focus their efforts solely on majority cables. While this approach could potentially reduce the cost and improve performance for some systems and owners, it could isolate and place a disproportionate share of jointing costs on older or so-called non-standard cable systems. Since the bulk of maintenance R&D would be directed toward mainstream jointing, it is likely that systems containing other cable types would become difficult and expensive to maintain. Where would this leave the minority cables—and their owners?

Another direction is to apply tailored jointing to systems that can tolerate specific limited jointing capability. For example, the limitation could be on deployment depth or deployment tensions. Another approach is to limit the sea state of activities for the particular jointing platform. Additionally, it would mean that the inventory of older parts would become obsolete and newer parts would need to be provided.

Other approaches could include segmenting the market into categories other than cable design-specific. For example, jointing could be partitioned to:

- Deep water vs. Shallow water
- High-voltage vs. Low-voltage
- High-pressure vs. Low-pressure
- Repeatered vs. Non-repeatered
- Long-life vs. Short-life
- Purpose built vessels vs. Ship of opportunity
- Any combination of the above.

Quite possibly, these specific approaches could require their own suites of specialized jointing equipment. If

[5] *Universality*, here, refers to standardized connections, methods, and minimal sets of equipment.

[6] Note that these sorts of modifications may inadvertently lead to process variations and, thereby, produce latent defects. Careful and cautious implementation of any *local* improvements is required.

this approach is repeated for each segment or interconnection, then the capitalization would be prohibitive. It would also be difficult to maintain effective teams of qualified jointers.

Jointing as it is today is aimed at universality and commonality—global optimization and value-oriented platforms—rather than cable-specific platforms that have limited application and require costly duplication of jointing infrastructure. In any case, jointing suppliers must focus on the needs of system owners, system suppliers, and maintenance authorities, in looking for ways to improve overall system repair and maintenance.

8 OBSERVATIONS & CONCLUSIONS

The primary driver for improving jointing is certainly cost—direct or indirect. Improvement is measured as the summation of many factors including ship time, reliability, system availability, and customer satisfaction. Innovation and improvements must be evaluated in terms of these as well as quality, reliability, and safety.

To the casual observer, shipboard undersea cable jointing appears to be comprised of old technologies and processes. In spite of the perceived stodginess of the current well-proven jointing platforms, innovation continues to be pursued and brought to the jointing realm.

Daily, the current jointing platforms are performing their duty on a wide-ranging array of cable types supplied by a variety of manufacturers using common equipment suites, methods, and standards. It is clear that the present universal platforms are meeting the needs of the vast majority of stake holders as is evidenced by the universality of jointing; its proliferation around the world; its high-quality performance & reliability; their ongoing record in system repair, maintenance, & installation; as well as the vast improvements made since the inception of undersea fiber optic cables.

The actual present situation is that the industry as a whole is enjoying *universal* jointing that is both cost-effective and well-proven. “Innovative jointing & stable technology” is “closer than we think” and stake holders are receiving the best value—right now.

9 ACKNOWLEDGMENTS

We are grateful for the diligent support, contributions, and guidance we received from our colleagues in the jointing industry—too numerous to name individually.