The Rise, Fall and Potential Recovery of British Naval Cable Excellence

Glen Richardson CEng, MIET. Engineering Director,
Scientific Management International Limited, Andover, UK

Abstract — This paper delves into the historical significance of British naval cable technology, particularly its peak during the Cold War. The focus is on polyethylene (PE) cables, which revolutionized submarine cable systems due to their exceptional durability and reliability in harsh underwater environments.

The paper highlights the decline of this expertise and the subsequent shift towards less reliable polyurethane-based systems. This shift has led to increased maintenance requirements and reduced operational efficiency for modern submarines.

However, recent years have seen a renewed interest in PE technology, driven by the need for longer lasting and more reliable cable systems in increasingly challenging marine environments. The paper discusses the potential for the UK to reclaim its leadership in this field, emphasizing the importance of preserving existing expertise, adopting innovative manufacturing techniques, and maintaining rigorous quality standards.

By examining the historical context, technical advancements, and current industry trends, this paper argues that a resurgence of British naval cable excellence is not only feasible but also crucial for the future of the Royal Navy.

1. Introduction

In the depths of the cold war, British naval engineering achieved something remarkable. The Royal Navy became the world leader in submarine cable technology, developing systems so reliable they could operate without maintenance for decades in one of Earth's most hostile environments. This is the story of how that excellence was achieved, how it was lost, and how it might be recovered.

The story begins in the 1960s, when subsea technology faced two parallel challenges. The first was strategic: submarines needed to dive deeper than ever before. The second was technological: the first transatlantic voice telecommunication cables were being laid, requiring unprecedented reliability under extreme pressure. These twin challenges catalysed a revolution in cable technology for submarines led by industry and supported by the Admiralty Research Labs and MOD Naval Architects.

2. The Impact of Cable Jackets and Standards

At the heart of this revolution was a material that would prove both brilliant and troublesome: polyethylene (PE). Unlike the rubber and polyurethane cables that came before it, PE offered extraordinary durability underwater. It was chemically inert, absorbed minimal water, and maintained stable electrical properties even after decades of submersion. But PE was also notoriously difficult to work with, requiring complex processing and specialized bonding techniques that many considered more art than science. So challenging was this work that in MOD circles, it became known as "black magic".

The British mastered this black magic. Through the development of rigorous standards and processes, particularly the exacting requirements of Def Stan 08-171, they created cable systems that could operate maintenance-free for the entire life of a submarine. This was a capability no other nation possessed. While other navies accepted regular cable replacement as routine maintenance, British submarines operated decade after decade without cable failures.

Control and monitoring of the quality and performance of both product and contractors' PE design and manufacturing capabilities regulated by PTS14299 have been instrumental in guaranteeing success. This standard's successor DefStan 08-171 requires manufacturers to demonstrate capability to the UK MOD tri-annually whereas PTS 14299 only required suppliers to demonstrate capability approval once, allowing continual product supply for years thereafter. But excellence, once achieved, is not easily maintained. Regular capability demonstration has ensured that contractors not only achieve competence but retain it. As the cold war ended and submarine construction in Britain entered a long hiatus, the expertise began to fade. Experienced personnel retired, establishments closed, and critical knowledge was lost.

The PTS and Def-Stan specifications ensured quality and reliability. The current trend is to allow the Defence Standards to fall into obsolescence due to lack of SQEP support and to seek to adopt commercial standards. There are no commercial standards equivalent to DefStan 08-171 or many of the supporting Defence Standards used for the cables and there can be no coincidence that having failed to implement on boats in service today, performance deficiencies have emerged.

The application of PE to stringent Defence Standards, including rigorous testing and non-destructive examination stood the test of time for all UK submarines in service from the Oberon Class in the 1960’s right up to the Trafalgar, Vanguard and Victoria (ex-Upholder) Classes still performing without cable harness problems today.

By comparison, foreign manufactured submarines have relied on materials and technology involving low cost, easy to mould, non-thermoplastic and non-amalgamated processes to polyurethane or rubber jacketed cables for their outboard systems. And all navies using these materials have had to schedule harness replacement regularly throughout the life of their submarines.

3. Polyethylene (PE) and Polyurethane (PU)

Polyethylene (PE) and polyurethane (PU) materials continue to vie for selection by boat specifiers and customers [Ref 1]. Temperature effects on water absorption in PU and PE based polymers has been studied by academia. Literature describes the maximum water up take of these polymers exposed to ocean water at a series of different temperatures. It was discovered that temperature affects water diffusion kinetics: an increase in temperature leads to faster water diffusion. The consequence of increased water diffusion leads to faster polymer degradation and to large modification of tensile behaviour of the material. Low water uptake means that it will require far longer for stress at break to occur i.e. the higher the water content present in the polymer the quicker the stress at break point is reached.

Hydrolysis of the PU urethane bond, denoted by the asterisk in Figure 1, in water at higher temperatures leads to chain scissions in the polymer leading to formation of carbon dioxide [1], alcohol [2] and amine [3] based by-products, by route 1 (blue arrow) and route 2 (red arrow) as shown below.

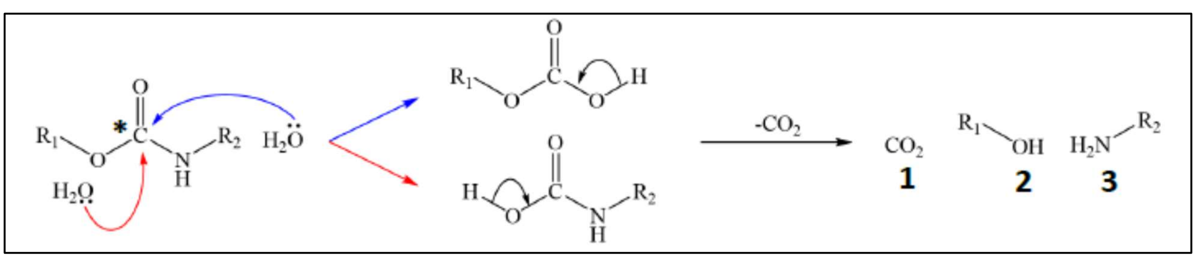

Figure 1 Hydrolysis of the PU urethane bond

The effect of water and temperature creates the foundation of polymer degradation, the higher the temperature of sea water leads to higher water diffusion and thus leads to faster rates of polymer degradation. Hydrolysis is a slow reaction at low temperatures, and only appears to happen quickly when polymers are exposed to higher water temperatures.

The polymers most suited for marine use are those that have limited capacity for chemical reactions, meaning they are essentially ‘inert’. Only PE offers this characteristic.

4. Consequences of Modular Build and Other Navy Developments

When submarine construction resumed with the Astute Class, the landscape had changed dramatically. New procurement strategies made industry wholly responsible for design and construction, and modular build techniques demanded different approaches to cable installation.

Looking for solutions, Britain turned to American expertise in modular construction. This seemed logical at the time, but it came with an unexpected cost. The American approach, based on their Mil Spec standards, assumed regular cable replacement throughout a submarine's life. This was fundamentally different from the British philosophy of "fit and forget" that had served so well for decades.

The consequences became apparent as the submarines entered service. The Royal Navy's world-leading polyethylene cable systems were largely replaced by shorter-lived polyurethane alternatives. Boats began spending as much time in maintenance as at sea, echoing problems seen in the American fleet.

The science explains why: polyurethane, while easier to work with, is vulnerable to hydrolysis. Water slowly breaks down the material, particularly in warmer seas, leading to inevitable failure.

Naval architects accepted the introduction of additional points of failure from connectorised systems to exploit the convenience of modular build, departing from the utilisation of pressure hull glands that had been deployed before.

However, they did not appreciate the greater compromise to quality that the cable material represented [Ref 2].

But this story isn't just about technical decline. As global waters warm up and submarines are required to operate in increasingly hostile environments, there's renewed interest in PE technology. The French Navy, facing similar challenges, has already adopted British PE expertise for their submarines. Their solution, using a dual-jacket system with PE inner and polyurethane outer layers, combines the best properties of both materials. The outer polyurethane protects against installation damage, while the inner PE provides long-term sealing integrity.

Australian submarines, operating in even warmer waters, have followed suit. Their Collins class submarines have used PE-based systems that have achieved over 25 years of continuous service. This success in challenging environments demonstrates that the fundamental superiority of PE technology remains unchanged.

5. Fibre Telemetry System (FTS)

When SMI was selected to develop the cable system for FTS, the opportunity was taken to incorporate lessons learned from the recent build programme. The result was a dual cable jacket incorporating PlastEthUrm dual jacket sealing technology now fully developed and proven. This may be the first time a UK cable harness design had fully considered the robustness required to survive the construction environment which is not easily or fully definable in requirement specifications.

Due to the thermoplastic moulten pressure moulding and bonding of both PE and PU used in the PlastEthUrm process, the sealing integrity is backed by a 10-year moulding warranty. Irrefutable in-service evidence that cathodic delamination, a phenomenon which affects metal to polymer bonds, had been solved was needed before the 10 years warranty on the moulding/sealing could be offered.

Between the Technology Demonstrator Programme (TDP) where all the cables were supplied with PlastEthUrm thermoplastically moulded cables and the main production programme for Dreadnought the contracting arrangement changed. The manufacturer supplying the new penetrator connector for the FTS system carrying all the power and data was selected to terminate the connectors for the penetrators. As the company does not hold Def Stan 08-171 capability approval, the requirement for dual PE and PU sealing, as delivered in the TDP, was not made a requirement of the main contract specification.

If the third-party has not attempted or achieved bonding of the PE jacket relying only on a thermoset cast PU moulding to the outer jacket, the benefits from the lessons learned, design in robustness and through life cost savings will have been forfeited. Harmonising commercial and technical solutions is just as important to achieve whole boat life performance.

6. Surface Cable System Experience

Renewed interest in PE has been driven by the demand for a step change in current cable harness performance~~.~~ This coincides with the requirement for the Royal Navy to be deployed for longer to increasingly warmer oceans where PE retains its dielectric strength and resistance properties over 30-40 years continuous immersion [Ref 3].

The Royal Navy surface fleet adopted PE cable harnesses for all its sonar cables during the 1960’s. For similar reasons of adopting US sonar technology, cable materials migrated away from PE. The increasing surface sea temperatures especially around the equator has had disastrous consequences.

This experience drove the new Hull Mounted Sonar harness design to incorporate connectors and hull glands thermoplastically moulten pressure moulded to PE jacketed cables. These have now been proven in-service in all sea temperatures for T23 frigates following the LIFEX programme and are now in mass production for installation on the T26 for both Royal Navy and export platforms.

7. Path to Recovery

The path to recovery exists. New innovations like the Multi Gland Penetrator (MGP) and PlastEthUrm dual jacket technology offer ways to combine PE's superior durability with modern modular construction techniques. These technologies have already proven successful in surface vessels and could be adapted for submarine use.

To retain technical supremacy in this area and ensure that combat, propulsion and control systems have the central nervous system that delivers their full potential, subject matter expertise and manufacturing capability must be safe guarded. The "black magic" of PE processing is now practised by very few companies, raising concerns about security of supply and monopoly risks. Knowledge transfer and sovereign retention remain priorities into future programmes.

The opportunity exists for Britain to regain its world leadership in underwater cable systems. Doing so would require a return to PE-based technologies, implementation of modern manufacturing processes, maintenance of stringent quality standards, and technical expertise development across the enterprise. The need is clear: as submarines are required to spend more time deployed in increasingly warmer waters, the superior performance of PE becomes not just desirable but essential.

This is a critical moment for British naval technology. The knowledge and capability to produce world-leading cable systems still exists, but time is running out to preserve and build upon this expertise. The question is not whether PE-based systems are superior –

decades of service have proven they are. The question is whether Britain will choose to reclaim its leadership in this vital technology.

The decisions made now will determine whether future generations of British submarines will benefit from the same excellence in cable technology that served previous generations so well. The path to recovery is clear, but it requires recognition of past excellence, understanding of present challenges, and commitment to future innovation.

8. Securing Future Supply

The objective of this paper is to promote the unquestionable success of British PE technology as the solution for the future. The design knowledge, tooling, process technology and chemistry is a very rare commodity and only one company has achieved and maintained capability approval to the Def Stan over the last 30 years.

This presents a commercial challenge in terms of security of supply, monopoly and ensuring long term value for money for the boat/ship builders and MOD. SMI recognises this position and is committed, to once again return the Royal Navy to “Ruling the Waves” of underwater cable systems, and to consider how this can be mutually achieved.

While not relevant to defence, the same interest has developed in parallel for renewable tidal energy, foiling boat transportation and future commercial aircraft who all share the same need for critical cable systems that are “fit and forget” and only need installing once.

SMI faces the challenge many founder lead businesses confront: continuing to support UK naval excellence and realising its incredible growth potential, whilst enabling both shareholder retirement and safeguarding sovereign capability. A challenge all the greater when the core technology of the business is internationally coveted.

With over 500 products supplied both directly to MOD, the primes and sub tier manufacturers for surface and submarine, it is recognised that the company is critical to not only our own naval defence capabilities and the nuclear deterrent but also to those of other nations.

References

[1] G.Richardson, J. Shaw and K.Wells, “Breaking the cycle of submarine cable failures”, SIA Submarine Science, Technology and Engineering Conference SubSTEC5 Conference Proceedings, (2019)

[2] R F Haworth “General Dynamics (Groton Ct Electric Boat Div) Handbook of pressure-proof connector and cable harness design”, Naval Research Laboratory, Orlando (January 1973)

[3] Andrady, A.L.,”Plastics and their impacts in the marine environment”, Proceedings International Marine Debris Conference on Derelict Fishing Gear and the Marine Environment, Hawaii, August (2000)

Author/Speaker Biographies

Glen Richardson CEng MIET

Glen is SMI’s Engineering Director and has more than 25 years’ experience in thermoplastic moulding, building theory and practice from shop floor expertise to bring a synergy of design concept, engineering principles and manufacturing practice to bear into the fit and forget ideology of the company.

Glen’s technical training was incubated under the mentorship of John Wise and Keith Wells, the company’s founders, who brought together expertise in materials, chemistry, subsea telecoms and mechanical engineering to originate the technical solutions used to this day.

Highly respected in the industry, with an impressive track record for bringing innovative products to market, Glen is using his expertise and vision to steward critical technology developments in both marine and aerospace sectors. He is a subject matter expert for naval defence cable infrastructure providing many pioneering solutions for future platforms above and below the waterline.