PROTOTYPE
FACULTY OF ENGINEERING AND APPLIED SCIENCE
Journal of Undergraduate Engineering Research and Scholarship

PT-2013: Coastal and Ocean Engineering ENGI.8751 Undergraduate Student Forum
Faculty of Engineering and Applied Science, Memorial University, St. john's, NL, Canada March, 2013

Paper Code. (PT-2013 - Alexander)

Laying the First Transatlantic Cable

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ABSTRACT

In the early 1800s the electrical telegraph was developed to transmit written messages through a wire. By 1850 there was a submarine telegraph cable laid beneath the English Channel followed by a cable across the Cabot Strait in 1856. By this time Cyrus West Field formed the Atlantic Telegraph Company with the purpose of laying the first transatlantic telegraph cable.

The telegraph cable was intended to reduce the time required to send messages across the ocean. Previously, it would take 10 days to cross the Atlantic Ocean by ship to deliver a message, but with a telegraph cable it would take only minutes.

The cable began to be laid in 1857 off the coast of Ireland where the cable broke over the telegraph plateau which is over 3000m deep. Following this failure construction was abandoned for the year and the ships; HMS Agamemnon and USS Niagara were refitted for a second attempt. Three more failures occurred in June of 1858 where a maximum of 300 km of cable was laid before failure. Finally, on July 29 1858 the cable was spliced in the middle of the ocean and the ends of the cables reached Trinity Bay, Newfoundland and Knightstown, Ireland on August 4th and 5th respectively.

The first message was sent on August 16th 1858 from Queen Victoria to US President Buchanan and took 16 hours to send. The cable only lasted for three weeks and the insulation failed due to poor handling practices when laying the cable and the use of high voltages by one of the engineers on the project.

Ultimately the first transatlantic cable was a failure but the persistence of Cyrus Field a successful cable was laid in 1866. The new cable used the lessons learned from the first attempt regarding the cable construction, handling practices and operation to ensure its success. The manner in which these lessons were learned over the course of laying the first cable will be discussed in detail in the following paper along with a more in depth history.

1 INTRODUCTION

The electrical telegraph was a system developed to transmit written messages through a wire using electrical signals in the early 1800s. In the United Kingdom the telegraph had been in use on the railroads as early as 1837, the first system in North America was built in 1844 and by 1851 a cable was laid across the English Channel. [1]

In 1852 Frederick N. Gisborne laid the first deep-sea cable in North America between New Brunswick and Prince Edward Island. Gisborne had proposed another cable between New York and St. John's that would form a relay system where messages would be sent by telegraph to St. John's and then carried by boat to Europe and vice versa. Construction of this system was halted when Gisborne encountered financial difficulty crossing the rough interior of Newfoundland. Gisborne travelled to New York looking for more investors to complete the project where he met Cyrus W. Field. Field took over the project and immediately began investigating the feasibility of a transatlantic cable between Newfoundland and Ireland. [2][3]

Field founded the New York, Newfoundland and London Electric Telegraph Company in 1854 and finished cable between New York and Newfoundland by 1856. It was then demonstrated using the relay scheme that 2 to 3 days could be saved transmitting messages across the Atlantic Ocean which showed the potential of a transatlantic cable and garnered more interest in the project. Field then founded the Atlantic Telegraph Company where William Thompson (Lord Kelvin) and Wildman Whitehouse became involved. [3]

2 TECHNICAL OBSTACLES

The transatlantic cable had numerous obstacles to overcome in order to complete the project, most of which were due to the unprecedented scale.

2.1 Route

The selection of a route for the cable could have posed a significant challenge. It would need to be as short as possible while not being too deep to lay cable; conversely the water depth couldn't be too shallow so that it avoided being damaged by iceberg scour or ships' anchors. Fortunately the U.S. Navy had discovered such a path in 1953 that was essentially a straight line between St. John's and Ireland. The route was 3000 km with a maximum depth 4.8 km. [1]

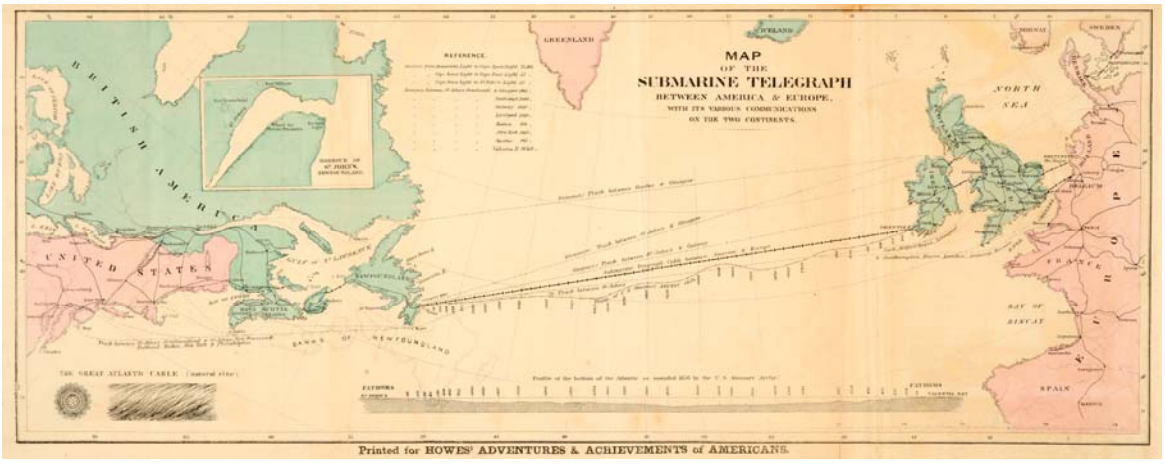

Figure 1 Map of the Route between Newfoundland and Ireland [4]

2.2 Materials

The design of the cable was based on the 1851 cable that crossed the English Channel between Dover and Calais. It used a copper conductor with 7 strands, gutta-percha insulation and galvanized iron wire for protection. The Atlantic Telegraph Company rushed the selection of the cable materials which Kelvin deemed to be too light. The initial quantities were as follows: [1]

- 26 kg/km of Copper
- 64 kg/km of gutta-percha insulation
- 460 kg/km of galvanized iron sheathing
- Totalling 550 kg/km

The rushed nature of fabrication lead to a number of other problems as well. The iron sheathing was manufactured by two different companies and they had wound the wires in opposite directions. This was simply overcome by splicing the cable with a connection that didn't transfer torque but made splicing the cable in the middle of the Atlantic Ocean more difficult than it needed to be. [2]

Kelvin had started testing the electrical conductivities of copper and discovered that the purity of the metal was directly related to its conductivity. The conductivity of the cable would be important for the signal transmission over the long distance to cross the Atlantic Ocean. The specification of the cable however, did not require the copper to be of a specific purity and by the time Kelvin had realised this it was too late. This first cable failed during installation and subsequent cables were manufactured with high purity copper. [3]

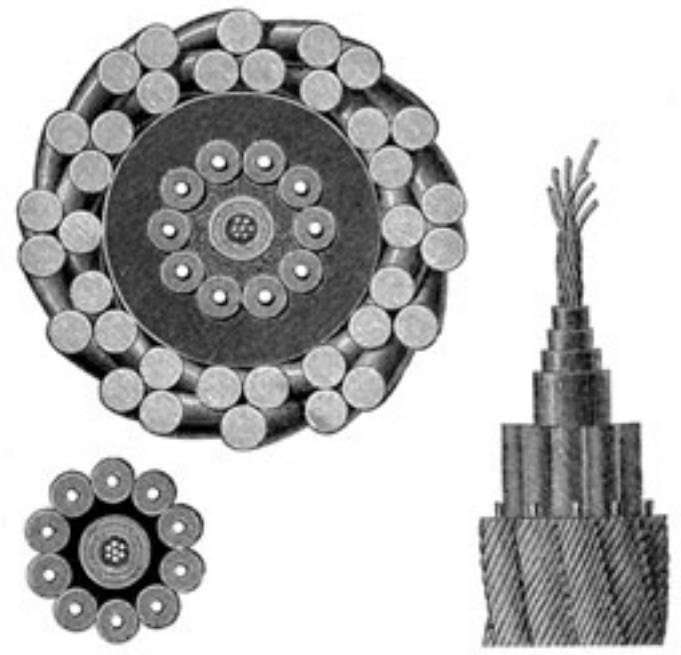

Figure 2 1865 Cable Cross Sections for shallow and deep water. [1]

2.3 Construction Methods

The scale of the project had the most apparent impact on the construction methods. Firstly, the cable was too big for a single ship at the time so it had to be laid with two ships and spliced in the middle of the Atlantic Ocean. This raised the problem of how to sequence the laying of the cable. Each

ship couldn't simply start at either end and meet in the middle since there would be a significant risk that they would not end up at the same point. One ship could start from Ireland and lay its cable with the second ship following it to the middle, splicing the cable and continuing until it reached Newfoundland. This would have the advantage of maintaining communication (through the cable) to Ireland throughout construction. The other option was to start by splicing the cable in the middle of the ocean and for each ship to lay its cable in the opposite direction, this would cut the construction time in half but there would be no communication to shore during the process. [2]

Secondly, there weren't any ships that could lay cable 4.8 km deep and the process for outfitting the vessels to do so was just as hastily done as the specification of the materials. The cable laying machinery relied on a manually operated brake that controlled the release of the cable and subsequently the tension in the cable as it was being laid. The operator of the brake was tasked with paying out enough cable so that the tension in the cable didn't exceed its capacity which required constant monitoring and any mistake made lead to the cable being damaged or broken. After the first attempt to lay the cable failed due to this flaw the ships were fitted with similar new machinery that incorporated a self-releasing brake that could be calibrated to release at a given load. [2]

Thirdly, to compound the difficulty of releasing the cable at the appropriate rate if the cable did break the ships did not have grappling equipment capable of retrieving the broken cable at the depths required. [3]

2.4 Signal Transmission

The transmission of an electrical signal across a great distance of 3000 km had never been attempted before and an underwater cable between Holland and England which was only 180 km long showed evidence of signal retardation (the impulse is smoothed out into a weaker, longer lasting impulse). Previously, overland telegraph signals would be regenerated by a relay allowing for great distance to be covered without loss of signal strength. The transatlantic cable on the other hand could not have relays in the middle of the ocean. The effect of signal retardation could have a significant impact on the financial and practical viability of the cable if it slowed the transmission of messages down to severely. Before Field began to raise funds he sought out and received assurances from Samuel Morse and Michael Faraday regarding the feasibility of the long distance transmission. [1]

In practice it was left Kelvin and Whitehouse to overcome the effects of signal retardation. Whitehouse believed that applying a higher voltage across the cable would solve this problem. The high voltage did not produce the desired results and in fact damaged the insulation of the cable. [3]

Kelvin discovered that retardation is proportional to the resistance, capacitance and the distance squared. He then devised a method to shorten the length of the impulse and invented the mirror galvanometer which was able to detect much weaker impulses of current. This technical advancement was key to the success of the transatlantic telegraph cable. [3]

3 SEQUENCE OF EVENTS

3.1 Pre-1857

Upon founding the Atlantic Telegraph Company in 1856 Field raised 350,000 GBP through stock offerings. He then negotiated agreements with both the British and American governments who would guarantee the investment and each supply a ship for laying the cable.

3.2 1857 – The First Attempt

The first attempt was conducted in the summer of 1857. The British sent HMS Agamemnon and the United States sent the USS Niagara and each were fitted with cable laying equipment earlier in the year. The cable was tested to find out whether a signal could be sent through the 3000 km length and it was deemed acceptable but there was need of improvement for the speed of transmission. Half of the cable was loaded onto either ship and it was decided that the cable would be started by the Niagara and spliced in the middle of the ocean and paid-out the rest of the way by the Agamemnon. Work began on August 5, 1857.

On August 7, 1857 the USS Niagara departed Valencia. After approximately 610 km had been laid, the cable failed on August 11th due to the machinery not paying out enough cable to control the tensile load. The cable was lost and even though attempts were made to recover it they were unsuccessful since there was no experience with grappling cables at a 3.6 km water depth.

After this first failure cable laying was abandoned for the year and the remaining cable was stored for the winter.

3.3 1858 – Brief Success

Over the winter the cable laying machinery with the self-releasing brake was developed and installed on the ships. During the spring the new equipment was tested and the crewmen trained in its use. On June 10, 1858 the ships set out again but this time they were to splice the cable in the middle of the ocean and lay the cable in both directions. By June 20th they were in the middle of the Atlantic Ocean but due to the weather were delayed in splicing the cable until the 26th. The weather had caused the cable on the Agamemnon to become damaged and it had to be recoiled.

By the 27th 50 km had been laid when the cable inexplicably broke. It is believed that the cable was broken in the deep water.

The cable was spliced again on the 28th but then after another 260 km were laid the cable broke at the Agamemnon on the 29th. The ships were unable to locate each other for another attempt and therefore returned to Queenstown.

The failures had taken their toll on the Atlantic Telegraph Company and abandoning the enterprise was considered. Field and Kelvin realised that if they were unable to complete the cable in 1858 that they were unlikely to be able to raise the funds and support to try again in 1859. They persuaded the board of directors to allow one final attempt.

The ships again left Queenstown on July 17th and assembled in the middle of the ocean on the 28th. On the 29th the cable was spliced and both ships set out for opposite sides of the Atlantic. On August 5, 1858 the USS Niagara arrived in Trinity Bay, Newfoundland and the Agamemnon arrived in Valencia.

Upon completion Whitehouse began running high voltages through the cable to overcome the signal retardation effects. This had caused further damage to the cable's insulation and it was believed that the cable had already deteriorated during its storage and handling. Eventually by using Kelvin's galvanometer the first message was sent on August 13, 1858. Unfortunately the cable quickly deteriorated and by September 18 messages could no longer be sent.

During its brief life the cable was able to transmit 271 messages including an exchange between US president Buchanan and Queen Victoria. Another message was sent to report the collision of two steamers and another to verify the safety of its passengers. A valuable message was sent by the British government regarding troop movement that saved it 60,000 GBP. These messages showed the potential of a reliable transatlantic cable.

After this failure there was no interest amongst investors to begin work on another cable and it would be years before it was attempted again.

3.4 1863 to 1866 – Renewed Interest

In 1863 a new consortium was finally assembled that could finance another attempt to lay a transatlantic telegraph cable. Since the previous cable had been laid the science and technology of the telegraph and cable laying had been substantially developed. [2]

This time Cyrus Field was able to raise 650,000 GBP [1] and specified a heavier cable that was now 881 kg/km as opposed to the original 550 kg/km. This heavier cable would also require bigger ships to lay it and by luck, Field was able to purchase the SS Great Eastern which was the largest ship that had been constructed at the time and was capable of carrying the entire cable. The ship was fitted with improved cable lay equipment and large storage tanks that would protect the cable from deterioration during the laying process. The ship was also fitted with new grappling equipment that was designed for use in deep water but was as of yet still unproven. [2]

The Great Eastern departed Valencia on July 23, 1865 and began laying cable heading towards Newfoundland. After laying 2000 km of cable and 1000km remaining the cable failed on August 2nd. After repeated attempts to retrieve the cable the grappling equipment proved to have a minor flaw and the cable was abandoned and another attempt was delayed until the following year. [3]

On July 13 1866 the Great Eastern departed Valencia once more for Newfoundland and within 14 days reached Heart's Content and communication between North America and Europe was established on July 28th. The grappling equipment's problem had been resolved over the winter and following the success of the cable the Great Eastern went out and found the previous years abandoned cable. On September 2nd the abandoned cable was successfully retrieved and spliced to a new cable and then there was a second fully functional transatlantic telegraph cable. [3]

Figure 3 The SS Great Eastern in Heart's Content, Newfoundland in 1866 [5]

4 CONCLUSION

The transatlantic cable proved to be a monumental success and played a significant role between North America and Europe in both trade and diplomacy. Furthermore it was a huge technical achievement that required perseverance and a deeper understanding of the existing technology to enable it to function on such an immense scale.

While the first attempts in the 1850s were failures and were due to the under appreciation of the stresses it was subjected to during the laying out process. This was primarily due in part to a lack of experience in laying cable at such great depths and the rushed nature of the planning process. In addition to the cable being under designed mechanically the electrical technology was being developed during the construction and competing theories as to how the cable should be operated contributed to the failure of the 1858 cable. [6]

Once these lessons had been learned the final successful cable had been laid with much less difficulty and even the initial failure was turned into a success so that there were 2 available cables. Since 1866 these lessons learned have had a continued impact on present subsea cable and pipeline laying processes.

REFERENCES

[1] M. Schwartz, J. Hayes, "A history of transatlantic cables," *Communications Magazine, IEEE* , vol.46, no.9, pp.42,48, September 2008

[2] G. Saward, “The Trans-Atlantic Submarine Telegraph Cable”, 1878

[3] B. Crossland, “Kelvin and Engineering”, *Kelvin: Life, Labours and Legacy*, Oxford, UK, OUP, 2008, Ch. 9

[4] http://en.wikipedia.org/wiki/Transatlantic_telegraph_cable

[5] http://www.library.mun.ca/qeii/cns/photos/

[6] M. Kelly, G. Radley, "Transatlantic communications: A historical résumé," *American Institute of Electrical Engineers, Part I: Communication and Electronics, Transactions of the* , vol.75, no.6, pp.841,842, Jan. 1957