TRANSMISSION

from VICTORIANS DECODED: ART AND TELEGRAPHY

Edited by
Caroline Arscott and Clare Pettitt

With contributions by:
Caroline Arscott
Anne Chapman
Natalie Hume
Mark Miodownik
Cassie Newland
Clare Pettitt
Rai Stather

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BACK AND FRONT COVER:
James Tissot, *The Last Evening*, 1873 (details), The Guildhall Art Gallery, Corporation of London.

TRANSMISSION

CASSIE NEWLAND

TELEGRAPHIC COPPER

Before the advent of the telegraph, copper wire was produced solely for mechanical purposes. The main consumer was the women's hat-making industry.[1] To avoid sharp ends sticking through the expensive and delicate fabrics, the wires were closley wound in silk or cotton thread. These wrapped wires were know as 'bonnet wire'. When the early electrical engineering pioneers, for example Charles Wheatstone or Michael Faraday were looking for sources of insulated wire they turned to readily available bonnet wire.[2] The existing hand-wound bonnet wire industry was initially able to meet demand but as the electrical engineering sector grew a larger scale solution was required. William T. Henley was an early pioneer who had set up shop as a maker of electrical equipment using bonnet wire. Recognising the growth in demand for wrapped wire Henley developed a 'six head wire covering machine' which he patented in 1837: the same year as Cooke & Wheatstone's first telegraph line was laid. Henley was not the only scientific instrument maker cashing in on the demand for bonnet wire. Mills notes that the respected instrument firm Watkins & Hall were also advertising bonnet wire in their 1838 catalogue.[3]

Early telegraph wires, such as that manufactured at Henley's Telegraph Works, had an irregular, eliptical cross section.[4] This is an artefact of the process of making wire. A rod of cold copper is pulled through a hole in a metal plate of smaller diameter, stretching it, rounding it and reducing it in size. This is done several times using ever smaller holes to achieve the thickness of wire required. If the plate is not entirely perpendicular to the direction of pull the resulting wire is slightly oval in cross section. Unbeknown to early telegraph engineers an eliptical cross section impacts badly on the carrying capacity, frequency, working distances, insulation requirements and electrical performance of a wire. The first attempts to explore these erratic performances came in the 1850s when the stakes were raised by the largest-scale telegraph project of them all: the Atlantic Cable.

In 1857 Professor William Thomson gave a lecture to the Royal Society in which he identified the purity of copper as a potential source of problems. When Thomson analysed the copper cable being produced by four leading manufacturers he found that even the worst performing wire was over 99.75 per cent pure and concluded that 'very slight deviations from perfect purity must be sufficient to produce great effects on the electric conductivity of copper'.[5] After Thomson's investigations, impurities in copper were widely blamed for the variable performance of telegraph and other electrical equipment. Thomson was so convinced of the connection between small impurities and falls in conductivity that in the late 1850s he led a call for copper smelters to improve the purity of their product. He succeeded in having a minimum standard for the purity of copper written into the specification for the 1865 and 1866 Atlantic cables. After the success of the operation 'high conductivity copper' became standard on all new cable schemes.

The purest copper in the world was smelted in Chile and was shipped in the form of best 'picked' or 'selected' 'chili bars' (sic). The 'chili bar' had been established in the 1840s to provide an international standard product for export. They were six inches long by two inches square (15 x 5.8cms) and of a standard purity.[6] It was the engineers' product of choice, consistently of 'high quality and abundance'.[7] Chili bars could be bought at 96-97 or 99 per cent fine copper.[8] Only copper with the highest purity available was used in the manufacture of telegraph wire. Chile had been exporting processed copper since the 1830s when reverberatory furnaces had been introduced from Swansea.[9] Copper must be smelted (baked but not melted) to remove other minerals from the desired metal. The copper of found in Chile had a particularly easy composition to smelt and few stubborn impurities. Smelting of chili bars in Chile itself really took off in 1842 when trade tariffs made the export of raw, un-smelted ore uneconomic.[10] From these beginnings Chile rose to become one of the world's biggest exporters of copper exploiting many mining districts and establishing an increasing number of copper smelting operations.

The Chilean smelting industry was dominated by a few, large factories. Smelting operations were established in the 1840s and 1850s at Guayacán, Coquimbo and Tongoy, and Tamaya in the north; and at Lirquén and Lota in the south.[11] The refineries at Guayacán and Tongoy were owned by the Urmeneta Y Errázuriz Company (hereafter known as Urmeneta), which by 1860 had become established as Chile's largest smelting concern. Urmeneta's 'chili bars' were considered to be of the very highest quality. When the market price for 'good' 'chili bars was £67 per ton, those smelted at Urmeneta commanded £68.[12] Guayacán, in particular, concentrated its efforts on supplying a greater percentage of the highest quality bars for use in the telegraph industry.[13]

Chile's access to the world copper market was mediated by international brokers and commission houses who exercised substantial control over the industry. They bought Chilean copper and set the market rate. They exported the copper and charged commission on all copper sold. They also filled the role of financiers, lending money to the smelting firms, with repayments to be made in copper for export. Interest rates appear to have been between eight and twelve per cent per annum.[14] The London-based commissioning house of Gibbs & Co contracted the Urmeneta company to supply them with copper on an exclusive basis.[15] Gibbs & Co exported Urmeneta 'chili bars' to the UK in Barques. Barques were ships specially built for the Cape Horn run between the UK and Chile, and known colloquially as 'Cape Horners' or simply 'Horners'. A typical copper barque, such as The Zeta,[16] was fully rigged, constructed of iron and (from the 1870s) fitted with a steam engine.[17] Like all barques, The Zeta was designed to cope with the densely heavy copper cargoes it would carry and was fitted out to operate in Chile's basic coastal ports. On the outward journey, anthracite coal was exported from Swansea to Chile to be used in smelting. The barque would then make the return journey carrying raw ore for processing

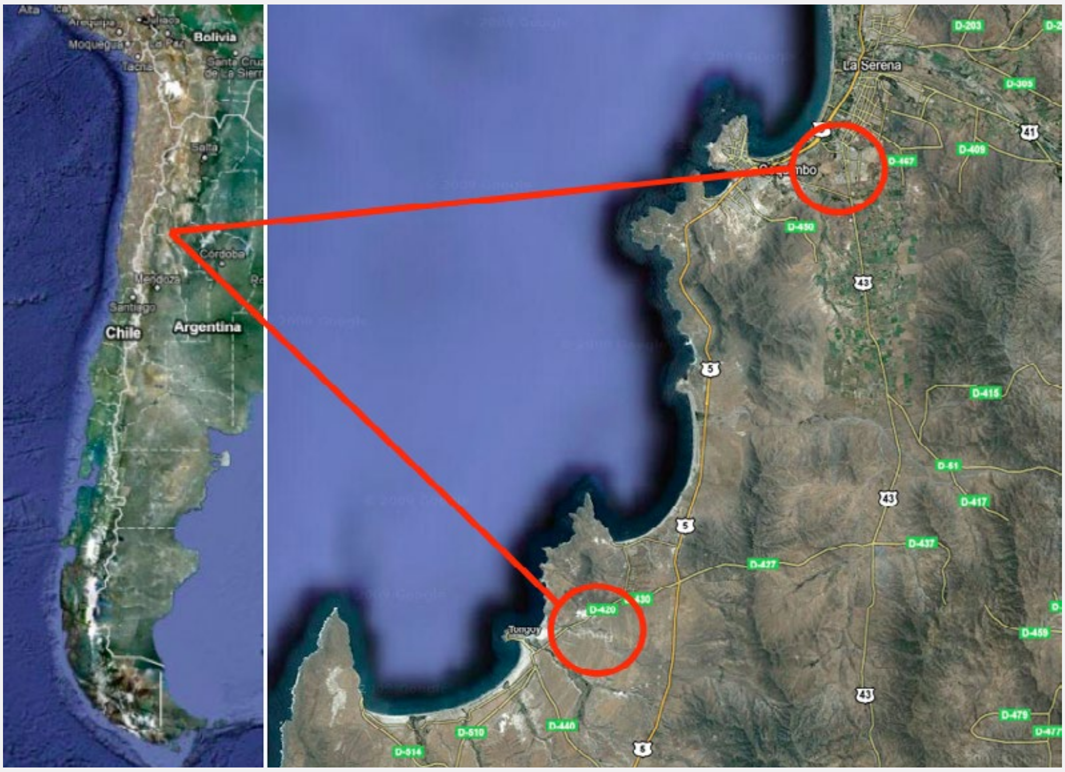

Fig. 1, Map of Chile showing location of smelting works at Guayacán (top) and Tongoy (bottom). Google Maps, 2010, with overlay by author.

at Swansea and fully refined 'chili bars'.

Once the high purity 'chili bars' hit the shore they would be bought up by one of the leading companies in the emerging field of conductivity copper, such as the Birmingham based firm of Bolton & Sons. Bolton & Sons were asked to manufacture the copper core for the first cross-channel cable in 1851. The copper core was revolutionary: the first attempt to manufacture wire in continuous, 500 yard lengths (80 yards was standard). Indeed, Moreton notes that when the factory foreman was notified of the order he responded 'does the man take me for a fool?'.[18] The Atlantic cable succeeded on the second attempt and this event appears to have inspired the managing director's son, Alfred Bolton, to rebuild and re-equip the factory with the plant necessary to supply the great lengths required by the burgeoning telecommunications industry. A year later Alfred Bolton took on a large site in the Churnet Valley: Oakamoor.[19] It was at this site that Moreton argues 'the main contributions to copper-making and the electrical industry were made'.[20]

Business boomed and in the first five months of the Oakamoor factory opening it had manufactured 55 tons of copper wire exclusively for the telegraph industry. Many of the larger cable orders, such as that for the Atlantic cables of 1865 and 1866, required such huge lengths of cable in such short order that collaboration between several companies appears to have been fairly standard across the industry. Alfred Bolton's close working relationship with the noted telegraph engineer William Preece did much for the firm's reputation and ensured that Bolton & Sons remained at the leading edge of telegraph copper making.[21] It was at their manufactory at Oakamoor where the next big breakthrough in high conductivity copper was made.

The conclusions that Thomson had made back in 1858 - that small impurities have large electrical effects – although true, was not the whole story. As copper smelters and wire manufacturers strove for ever greater purity of copper, their wires still failed to live up to their mathematically projected conductivity. In 1861 the government commissioned a report from respected chemist and physicist Augustus Matthiessen. Matthiessen carried out extensive tests which supported Thomson's observations on purity and conductivity but also highlighted a previously unknown problem: oxygen contamination. During the drawing process, where wire is pulled through successively smaller holes, oxygen bubbles from the air become trapped inside the metal. These bubbles increased its porosity and greatly reduced its conductive properties. Bolton & Sons rebuilt the machinery at Oakamoor to take advantage of Matthiessen's new discoveries. Air was excluded from copper in a molten state, and rolling – rather than drawing – was used to turn the of cut strips of copper into wire, greatly reducing the amount of oxygen introduced into the metal. The introduction of inert gas atmospheres for wire drawing at the very beginning of the twentieth century solved this problem permanently.

The composition of wires tells us more about an artefact than just a date (approximate or otherwise). The 'bonnet wires' of early, experimental telegraphy can, for example, be seen as reflecting a period of great transition in manufacturing. The large variations in physical appearance displayed by early cables were characteristic of early-Victorian engineering systems where products were never identical, and tolerances expressed in hundredths of inches. The embryonic telegraph industry, in contrast, required an attention to detail more characteristic of the precision scientific instrument industry. Telegraphic instruments were one-off pieces crafted by men in workshops.[22] These two industrial traditions clashed in the development of larger, long-distance telegraphy systems. Precision-engineered materials were required on an industrial scale and there was simply no industry capable of supplying them. The internal structures and chemical compositions of the wires speak volumes about the state of contemporary knowledge in chemistry, physics and electrical engineering and about the dialogue between the theoretical and the technical within these fields. Detailed physical analysis allows us to eavesdrop on the conversation between people and materials as they negotiate new relationships on microscopic – if not invisible – scales.

1. A. A. Mills, 'The Early History of Insulated Copper Wire', *Annals of Science*, vol. 61, no. 4 (2004), p. 456.

2. T. Martin (ed.), *Faraday's Diary of Experimental Investigation*, Vol. 1 (London: Royal Institution of Great Britain, 1932). p. 367.

3. Mills, 'Copper Wire' (2004). pp. 456-7.

4. Ibid., p. 460.

5. William Thomson, 'On the Electrical Conductivity of Commercial Copper of Various Kinds', *Proceedings of the Royal Society* (1857), p. 552.

6. W. Culverand, R. Cornel, 'Capitalist Dreams: Chile's Response to Nineteenth-Century World Copper Competition', *Comparative Studies in Society and History*, vol. 31, no.4 (1989), p. 736.

7. Ibid., p. 736.

8. L. Valenzuela, 'The Copper Smelting Company "Urmeneta y Errázuriz" of Chile: An Economic Profile, 1860-1880', *The Americas*, vol. 53, no. 2 (1996), p. 236.

9. Ibid.

10. S. Collier & W. F. Sater, *A History of Chile 1808-2002* (Cambridge: Cambridge University Press, 2004), p.79.

11. Ibid., p. 80.

12. Mineral Statistics, 'Mineral Statistics of the United Kingdom of Great Britain and Ireland for the Year 1871' (1871).

13. Valenzuela, 'Copper Smelting Company' (1996), p. 243.

14. Ibid., p. 255.

15. Ibid., pp. 255-256.

16. The Zeta was the first ordinary trading ship to run the Straights of Magellan. Its engines also came in handy when blockade running during the War of the Pacific (1879-84) (Burrow n.d.). It was also the ship that Catherine Zeta Jones is named after. Her great grandfather was the ship's captain.

17. Lloyd's Register for Ships (1875), http://tinyurl.com/jdm2xed (accessed 22/08/2016).

18. J. Moreton, 'Thomas Bolton & Sons and the rise of the electrical industry', *Engineering Science and Education Journal* (Feb 1999), p. 6.

19. Legend has it that his father Thomas had sent him up to buy some plant but he returned having bought the entire factory.

20. Moreton, 'Bolton & Sons' (1999), p. 7.

21. William Preece, 'On Electrical Conductors', *Minutes of the Proceedings of the Institution of Civil Engineers*, Vol. 75 (1883), pp. 67-8.

22. P. Israel, *From Machine Shop to Industrial Laboratory: Telegraphy and the Changing Context of American Invention, 1830-1920* (Baltimore: John Hopkins University Press, 1992).