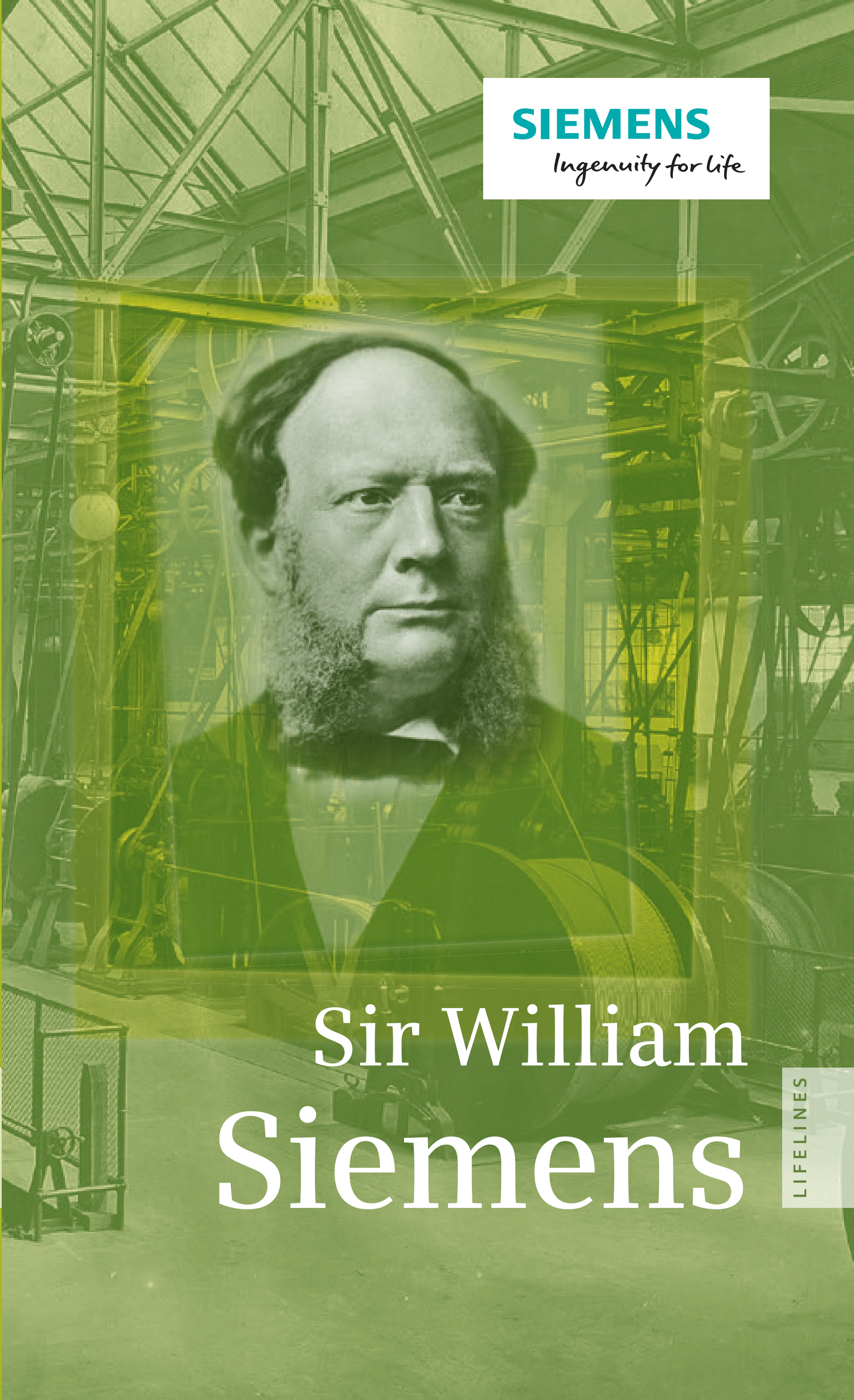
SIEMENS

Ingenuity for life



Sir William Siemens

LIFELINES

William Siemens was a member of the founding generation of the Siemens company. Born in Germany in 1823, he emigrated to England, where he headed the Siemens office in London, and also worked as an independent engineer and entrepreneur. His work embraced fields as diverse as the global telegraph system and innovations in metallurgy; his name is associated with the Siemens-Martin process, which remained the world's most important steel production process for a century. William Siemens' achievements earned him esteem as a member of the British scientific community, and a great many honors and accolades.

The brochure is the eighth volume in the **LIFELINES** series, which presents portraits of individuals who have shaped the history and development of Siemens in a wide variety of ways. This includes entrepreneurs who have led the company and members of the Managing Board as well as engineers, inventors, and creative thinkers.

Sir William Siemens

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April 4, 1823 – November 19, 1883

LIFELINES

Sir William Siemens, ca. 1860

Introduction – An engineer with plans of his own

Siemens & Halske was founded in the mid-19th century, the era of Germany's early industrialization. This was a time when German industry endeavored to get industrialization underway at home and catch up to the British model. This was most successful in technologies that were new at the time, like electrical telegraphy. In any event, the innovations in telegraphy produced by the company that Werner von Siemens founded in 1847 were without doubt on the same level as those of the British.

Werner von Siemens involved his family in building up the company. Werner, Carl, and William constituted a "league of siblings"[1] headed by Werner, who largely set the course for the Siemens companies in the 19th century. It was Werner who clearly defined the triumvirate's tone. But his brothers Carl and William both played significant roles as well in Siemens' evolution into a global player – Carl in building up the Russian business, and William in taking care of the English side. Business in England soon became especially important because England was where the transoceanic cables that significantly advanced the process of globalization were designed and produced.

Werner's younger brother Wilhelm grew up in Germany, but later chose the United Kingdom as his home, became a British subject, and adopted the name William. Although he certainly continued to view himself as a member of the Siemens league of siblings, he, more than the other brothers, pursued his own interests. He represented the Siemens companies in England, but also

1833 Wilhelm Weber and Carl Friedrich Gauss build the first electromagnetic telegraph.

Technical expertise combined with a diverse range of interests: William Siemens, ca. 1847

operated as an independent engineer, scientist, and entrepreneur. Those efforts did not proceed entirely free of conflict with his brothers, especially Werner.

William wanted to push Siemens' English business forward as much as possible. Working from England, he believed, offered the opportunity to make Siemens the world's leading telegraphy company. But his brothers Werner and Carl – not to mention their business partner and company co-founder Johann Georg Halske, who headed production in Berlin – were unwilling to back this high-risk strategy. In the years following, William made an effort to delegate at least some of his tasks at the English subsidiary Siemens Brothers so as to have more time for his technical and scientific research, though he did not entirely abandon his commitment to the family firm.

William Siemens was a highly qualified and highly respected mechanical engineer for whom telegraphy was just one interesting

1867 Johann Georg Halske, no longer willing to back the company's increasingly expansionist policies, leaves the Telegraphen-Bauanstalt by mutual agreement.

field among many. And in fact, telegraphy gradually lagged behind mechanical engineering and metallurgy as a focus of interest for him. In these two fields, he achieved noteworthy successes. Although he did not achieve his own goals, he made a crucial contribution toward a new steelmaking process, which was named the Siemens-Martin process after him and a French ironworking family. This was the world's most significant steelmaking process for an entire century.[2] William's technical and scientific achievements, as well as his personal charm, opened the door for him to take on influential positions in the English engineering world and in science.

The brief sketch presented here deals with a man who in many regards does not fit the standard image of a Siemens brother involved in the family firm: a German who became an Englishman; a mechanical engineer, not an electrical engineer; an engineer and scientist who worked in a wide range of fields; a liberal who opposed Prussian triumphalism; and an independent personality who did not shy away from conflict, whether within the business or within the family.

The relevant biographical literature on William is limited to a work by William Pole, published in English in 1888 and in a German translation in 1890.[3] Pole, a friend and colleague of William's, was asked by the family to prepare the biography after William's death. He examined letters and records that in some cases are no longer available. He sought information from William's relatives, colleagues, and friends, as well as from institutions where William had been a member.

Two of the collections of sources on William Siemens are of particular importance. The first key group is William's letters to family members, held in the corporate archives of the Siemens Historical Institute. Among others, these include 2,236 letters between William and Werner, and 580 between William and his younger

1861 William Pole is elected to the Royal Society, the most famous learned society in Britain.

Big brother and mentor both – Werner von Siemens, ca. 1843

brother Friedrich, who worked with William for several years and logged his own achievements in the energy-saving fabrication of glass. A bundle of letters that the English Electric Company acquired in 1953 from a cousin of William's wife Anne and then edited[4] is a valuable supplement to this collection of sources. William's own publications provide a second important resource. By far the majority of his English-language publications are available in an exemplary edition prepared by his private secretary, Edward F. Bamber.[5] A number of works were translated into German; some articles were published in German only.

1907 The Siemens Archive is the second corporate archive ever to be founded in Germany.

England – Wilhelm's yearning desire

Wilhelm Siemens took the name William only after moving to England. Accordingly, here we will call him Wilhelm initially, and William later. He was born on April 4, 1823, the seventh child of Christian Ferdinand Siemens and Eleonore Siemens, née Deichmann. His father leased and managed an agricultural estate – essentially, a large farm – in the Kingdom of Hanover. Wilhelm's birth year, 1823, was an especially turbulent one for the family. The Napoleonic Wars and the subsequent agrarian crisis had plunged the leased farm into economic trouble, and the father finally had to give it up. He sought a new property, which he found in the Archduchy of Mecklenburg-Strelitz, one of Germany's tiny semi-independent states. Wilhelm was born in the transitional period between the leases on the two farms.

Wilhelm was first educated by tutors at home. Later – like his younger brothers Carl and Friedrich – he attended a private, practically oriented secondary school, a Realschule, in Lübeck. The parents thus acceded to their sons' preferences, which leaned more toward business and science than ancient languages. The school emphasized modern languages – English and French – as well as arithmetic and natural history. Wilhelm left school in 1838, at the age of 15; his education was probably roughly that of a Mittlere Reife from a German school today, which is equivalent to a high school diploma without qualification for university study.

His parents' deaths in 1840 and 1841 left Wilhelm an orphan at the age of 17. Over the next few years, Werner, seven years

1815 The Congress of Vienna defines the post-Napoleonic balance of power on the European continent. Mecklenburg-Strelitz is declared an Archduchy.

Wilhelm's senior, grew into the function of a mentor and teacher. Werner had attended the Army's Artillery and Engineering School in Berlin. The knowledge he accumulated there between 1835 and 1838 was certainly comparable to that of a degreed engineer. While the parents were still alive, and with influence from Werner, the family eventually chose an engineering career for Wilhelm, sending him in 1838 to the Trade and Commerce School in Magdeburg. This was not an engineering school, but a combination of general education and hands-on training for workers in the trades and commerce.

After completing school in Magdeburg, Wilhelm started at the University of Göttingen in 1841. Between May 1841 and March 1842, he studied a diverse assortment of subjects there, emphasizing science but enriched through mathematics, physical geography, and technology. At the university, Wilhelm probably acquired a broad, though superficial, understanding of the fundamentals of science. The next step on his path to becoming an engineer was an apprenticeship at a machine factory. Werner found a place for his protégé at the Stollberg'sche Maschinenfabrik in Magdeburg in March 1842. This was a well-known company that made a wide range of products, including steam engines – which might be called the supreme specialty in mechanical engineering in those days. All in all, Wilhelm remained at the factory for two years, with an interruption for a trip to England.

In 1842, Werner developed an electroplating method by which thin coatings of gold, silver, or copper could be applied to non-precious metals. The technique was used to produce splendid-looking yet affordable art objects and utensils, including busts, goblets, and other vessels. With this process in his luggage, the 20-year-old Wilhelm headed off for England in February 1843, on a mission for his brother. The trip was intended to help market

1737 Georg-August University opens its doors in Göttingen. Today it is the oldest surviving university in Lower Saxony.

Just one chapter in Wilhelm's education – steam boilermakers in machine construction, undated

the technique, but it also fulfilled Wilhelm's "yearning desire to see England." One center of the electroplating industry was in Birmingham, at a firm called Elkington, Mason & Co. Wilhelm's master stroke was to sell the technique to the two owners, who paid the young engineer 1,600 pounds sterling. As Werner said, this was a "colossal sum which put an end for some time to our financial difficulties."[6]

1842 Josiah Mason joins Elkington & Co.

The first step is the hardest – Tremendous innovative spirit, but meager sales success

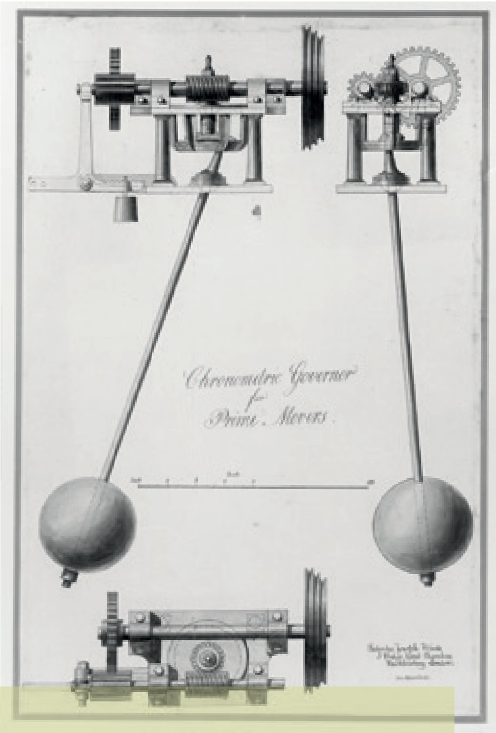
The financial success of the electroplating process seemed to point the way to a brilliant professional future for the two brothers: coming up with inventions and marketing them, especially in England. When Wilhelm left for his second trip to England in January 1844, he was carrying two more inventions with him: a new type of governor for steam engines and a new printing process. Steam engines do not run uniformly; to get a uniform speed, a governor is needed. The governor by James Watt that was commonly used at the time was sluggish and did not respond quickly to changes in speed.

The chronometric governor that the Siemens brothers developed avoided the drawbacks of Watt's design. Werner and Wilhelm got the governor patented in several countries. A number of German and English machine factories tried it out, with satisfactory results. Wilhelm and his partners presented the governor to English engineering associations and at the Great Exhibition of 1851 in London, where it attracted extensive praise and won an award. The chronometric governor was thus a technical success, but it was a commercial loss. For most applications, the cheaper, less sensitive Watts governor and its improved versions were adequate. To a certain extent, the Siemens brothers' governor presented a solution for something that most potential customers did not even feel was a problem.

The other innovation that Wilhelm carried with him on his second trip to England in 1844 was the "anastatic" printing process.

1788 The Scotsman James Watt patents his centrifugal governor for steam engines.

This was a kind of copying technique whereby old prints were transferred to a metal plate and prepared chemically there for re-printing. The brothers were thinking of not just making reprints of books and magazines, but also printing wallpaper and textiles. The technique's high quality aroused considerable attention when it was presented. Reproductions of several pages of an English cultural magazine were highly praised. The technique was also presented with great success at meetings of engineering associations. But ultimately the experience was a repeat of that of the chronometric governor. Commercial success failed to materialize. Wilhelm entirely abandoned the anastatic printing process early in 1847 because it had no chance of success against lithography.



An invention with no commercial impact –
the chronometric governor, patent drawing, 1845

Thus, neither the steam engine governor nor the printing technique could duplicate the business success of the electroplating method. All in all, Wilhelm estimated that the two innovations had run up losses of several thousand pounds sterling each. He cursed the mistaken investment in printing:

"Printing has been from the very first the cause of our misfortunes, and it is with genuine delight that I now take the opp(ortunity) to fling it into the abyss of eternal oblivion!"

The outstanding debts from these losses continued to burden Wilhelm's career far into the 1850s. In the 1870s he still lamented that the two failed inventions "impeded my rise for many long years."[7] Governors and printing were not the Siemens brothers' only ill-fated investments. In 1845 they obtained a license to fabricate artificial stone. The associated expectations largely failed to pan out. One contributing factor was that Portland cement was now beginning its triumphal march through the construction industry.

By the mid-1840s, Werner and Wilhelm Siemens realized that their work on inventions had largely failed, and they felt they were looking into an uncertain future. The funds they had brought in from Elkington, Mason & Co. were spent, and the brothers had gone into debt for their innovations. In 1845 Werner bewailed his "desperate situation" and to an extent notified Wilhelm that their association for inventions was over.[8] But he also thought he saw a light at the end of the tunnel, a light on which he now wanted to concentrate: electric telegraphy. At the end of 1847, he announced, "Electricity is our *spiritus familiaris*! It will finally haul us out of the mud."[9]

1824 Joseph Aspdin patents Portland cement, named after Portland stone, which was often used for construction in England at the time.

Siemens in London and Berlin – A tense relationship

Wilhelm becomes William – the younger brother emigrates to England

Wilhelm Siemens responded differently than his brother to the invention disaster. He stubbornly held to his activity as an inventor and decided around 1846 – the exact date is no longer determinable – to seek his fortune in England. The deciding factor here may well have been that the British Isles offered far greater technical and business options than Germany did. On top of that, the young engineer felt motivated by the recognition he had received from his British colleagues. And finally, this would allow him to emancipate himself from the influence of his overpowering brother Werner.

Furthermore, he found German politics – and especially Prussian politics – appalling. He castigated the suppression of the national liberation movements and had nothing good to say about the royal house of Prussia. Even into the days when the German Empire was being founded, he viewed himself as a republican. He maintained close relationships with political émigrés like Johann Gottfried Kinkel and Gottfried Semper. When Kinkel resettled to Switzerland in 1866, Wilhelm gave the address at his farewell party. After the German Empire was founded in 1870–71, Wilhelm adopted a more moderate tone, but without joining in the widespread hymns of praise for the "Iron Chancellor," Otto von Bismarck. He held firm to his liberal sympathies. This was especially evident

1849 After becoming involved in the March Revolution, Gottfried Semper flees Saxony. It will be many years before he returns. The architect designed Dresden's Semper Opera, named after him, while in exile.

around 1880, when his brother Carl joined in the rising trend toward baiting Jews. William objected, and took a stance that was unreservedly on the side of the Jews' defenders in the antisemitism controversy.

Wilhelm held consistently to his decision to move to England, yet without cutting off his connection to German culture – though from this point on he would call himself William. He made efforts to be accepted into the English engineering associations and socialized with British families. In 1859 he married Anne Gordon, a Scottish woman from a respected family, and took up English citizenship. He explained that this would make it easier for him to get English patents and that he wanted his children to grow up as English subjects. The marriage, however, remained childless. William's wife brought him extensive advantages. She improved her linguistically gifted husband's English – soon he was publishing articles in English and speaking fluently at conferences and meetings, to the amazement of his English colleagues in the profession. And she supported him in his expanding ceremonial duties. Anne accompanied William on many of his business trips, including visits to world fairs and expeditions to lay telegraph cables.

Support and resistance – the relationship with brother Werner

After settling permanently in England, William continued to represent his brother Werner's interests. He tried to market Werner's inventions in the British Isles, he arranged for them to be patented, he presented them to the professional world in lectures, and he took up a lance for them when he felt that Werner was not getting a fair mention and fair credit for his innovations. When Werner

1880 Famed classical historian Theodor Mommsen denounces widespread antisemitism and later becomes a founding member of the Association for Defense against Antisemitism.

William's wife, a bastion of support – Anne Siemens, née Gordon, undated

decided in 1846 to focus largely on telegraphy, the pointer telegraph he had developed provided him with what might be called his technological seed capital. The pointer telegraph worked with two electrically synchronized devices on which the desired letter was displayed directly on the receiving unit. But the brothers' pointer telegraph met with only limited success in England. The English were reluctant to abandon the old needle telegraph,

1839 Englishman Charles Wheatstone builds one of the first pointer telegraphs.

which displayed the letter at the intersection of magnetic needles. And then in the 1850s, the Morse telegraph – which worked with a code and acoustic signals – began its triumphal march.

In 1848, Werner von Siemens got the company's first big order – namely, to lay a telegraph line between Berlin and Frankfurt am Main. At that point, he decided to lay the lines underground. After some initial difficulties, this system proved its worth as telegraphy began expanding in Germany. In England, though, it was standard practice to run lines overhead between telegraph poles. William urgently recommended his brother's system to the British Parliament instead.

Telegraph lines could be laid underground only if they were well insulated. In the 1840s, a new insulating material came on the market: gutta-percha, made from the juice of a rubber tree. Gutta-percha proved to be especially well-suited for laying submarine cables. William became acquainted with the new material at a meeting of the Society of Arts in 1845. He sent a sample to his brother in Berlin, and Werner introduced it into cable production in subsequent years.

Later, a controversy arose between Werner von Siemens and English engineers about priorities in coating electric lines with the use of a gutta-percha press.[10] William helped bring about a consensus – after protracted discussions that were not free from nationalist tendencies. The final wording gave Werner von Siemens credit for the first seamless coating of telegraph lines. It also concluded that William's brother and English engineers had arrived essentially simultaneously at theories on laying submarine cables and methods for locating cable defects. In the matter of defining a unit for electric resistance, on the other hand, William saw no hope for establishing the mercury unit that Werner had proposed for the purpose. Among his brother's achievements that William

1843 Gutta-percha is classified botanically. This rubber-like material is obtained from the gutta-percha tree that grows extensively in Southeast Asia.

presented in England were the discovery of the dynamo-electric principle in 1866, the study of selenium in 1876, and the design and construction of electric railways around 1880.

In England, William led a kind of double professional existence: first as the representative of the Siemens family firm and second as an independent inventor and entrepreneur. In the process, his involvement outside the Siemens companies steadily increased. He marketed his innovations through his own companies and participated extensively in technical and scientific associations. Telegraphy, Siemens' core business, was only a small part of his technical, scientific. and business interests. He saw himself primarily as an inventor and innovator in numerous fields, and his areas of focus changed several times.

Werner von Siemens, on the other hand, had other ideas for his family firm. Since the mid-1840s he had been clearly focused on telegraphy, although he was open to other business ideas if they showed a promise of earning money. He intended to engage his brothers strategically in expanding the business, with Carl in Russia and William in England. He wanted them to be utterly devoted to that task. Thus, William's involvement outside the Siemens empire was a perpetual source of irritation. Even into the 1860s he had still not abandoned the hope of getting William more closely involved in the family firm, in accordance with his own concept of how things should be.

William's plans for his own life were not going to fall into line with Werner's ideas. Ultimately there were compromises, in which both sides made concessions. William had been trying to relieve some of the burden on himself since the second half of the 1850s. Here his attention turned to his brother Carl, among others. But Carl turned him down on multiple occasions. Carl was intrigued by business opportunities in the Caucasus, which had caught his

1879 Werner von Siemens presents the electric railway he has developed at the Berlin Industrial Exposition.

In charge of Siemens' business in Russia – Carl von Siemens, ca. 1865

eye while he was the head of Siemens' business in Russia. But the biggest impediment was his wife Marie, who was in ill health and did not want to go to London on any basis. When Marie died in 1869, Carl's path to England was open. He took over the management of Siemens Brothers; he and William worked together without a hitch. Yet this did not bring William the relief he was hoping for because Carl became ill and spent extended periods abroad. In 1880, Carl returned to Russia.

It cannot be said that William took no interest in the English Siemens companies. For example, he wanted to get into the cable

1853 Carl von Siemens begins representing Siemens & Halske in Russia.

business to a far greater extent than his brothers did. But he was not willing to devote his life entirely to telegraphy and the family firm and thus abandon his other activities thereby. What he would really have liked was to concentrate on strategic questions and delegate operational matters to others. He was still willing to negotiate with investors, business partners, and government representatives, and to represent the company externally. But he did not want to organize production or head up cable-laying operations. His frustration came from his inability to make these desires a reality.

After an initial hesitancy, Werner ultimately had no choice but to go along with his brother's ideas, or at least tolerate them. William had by now become invaluable and irreplaceable for the English company. The two brothers well understood that in English business life, personality played an even bigger role than in other countries. By around 1860 at the latest, William had earned an outstanding reputation in British society and in the worlds of business and science, which had a positive effect on Siemens' image. In every field, he had personal networks that he could draw upon for the company's benefit if needed. On top of that, for a time, Siemens in England considerably outperformed the business in Germany. Werner was well aware of these connections. In 1860 he explained to their brother Carl,

> *"Our interest with regard to Wilhelm is very complicated. The English business stands and falls with him. Without the English market, our business here cannot survive, because our other sales are too small. In the telegraphic regard alone, the English business has a future, and possibly quite a substantial one. If we drop Wilhelm, that will be the death of our telegraphy business after the Russian remontes run out. So we must keep Wilhelm on top."*[11]

1850 March 16: Siemens & Halske founds its first sales agency abroad, in London.

These "remontes" were lucrative maintenance contracts for a telegraph line that was erected between 1853 and 1855, during the Crimean War in Russia. These contracts ran until 1867.

Heading the English Siemens company – William takes entrepreneurial responsibility

In March 1850, William also formally took over as the representative of Siemens & Halske in England.[12] His duties included procuring materials on the continent for the company's plants. But most importantly, he was responsible for selling in England the equipment that was made in Berlin – a business that was slow to take off. The first rather large orders came in around the mid-1850s, including from rail companies. Siemens & Halske entered into a cooperation agreement with a stranded-wire and cable factory, R. S. Newall & Co. The brothers had already given thought at an early stage to setting up their own production facility in England. In 1858 William put the idea into action in London, though this was a small factory that employed only 80 to 100 workers. William set up a small laboratory there for his research work.

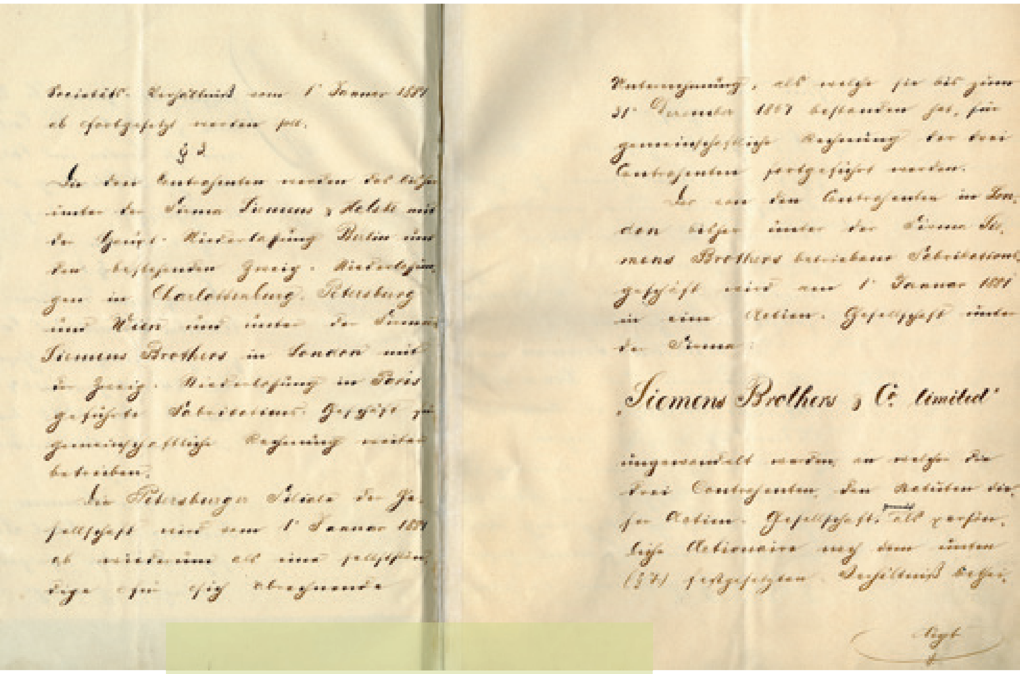
Production operations were initiated concurrently with the founding of an English Siemens & Halske company in London in 1858. Tensions soon arose between Werner, as head of the Berlin company, and William, as head of the English branch. London procured a large share of its equipment from Berlin. William considered this an unreasonable expectation. His feeling was that he could meet his needs much more cheaply in England. In any case, William pushed for the English branch's business to be more independent. A complete separation of the two companies even came up in conversation between the brothers. But they ultimately decided to continue working together.

1853–1855 Within just two years, Siemens lays some 9,000 kilometers of telegraph cable in Russia – many times the total of all the young company's previous orders.

As a result of the brothers' debate, their contractual relationship was revised in 1865 with the founding of Siemens Brothers. The plan was that high-risk cable-laying ventures would no longer jeopardize the Berlin home office. But contrary to the gloomy expectations, the cable business performed well in subsequent years, bringing in substantial profits. The new business form and the reallocation of shares did not solve every problem. Even after 1865, there were arguments between London and Berlin about the level of independence, dividing up the world market, and what they should supply to each other. Werner primarily pinned the blame on Ludwig Löffler, who had held a management position at the English company since 1858. William and Werner were in agreement that Löffler was an astute businessman, but a difficult personality: ambitious, greedy, and rather undiplomatic. On the other hand, Löffler's view was that Berlin contributed little to the business's success, yet carried off a substantial portion of the profits

Expanding production in England – the Siemens Brothers cable works in Woolwich, 1866 that Löffler felt that he himself had mainly earned. William held onto his manager because Löffler relieved him of his unwelcome daily chores.

Carl was involved with Siemens Brothers between 1869 and 1880. When he returned to Russia in 1880, the English company was converted to a stock corporation at William's instigation. Löffler received a 2.5 percent share and was made managing director. William had no trouble keeping Löffler in check. After William's death, tensions rose between the unpopular manager on the one side, and Werner and Alexander Siemens on the other. Alexander was a distant relation who had been adopted by William and followed in his footsteps. Late in the 1880s, Löffler gradually withdrew from the company, and Alexander took over managing it


Siemens Brothers & C° limited

Rearranging the company's structure – articles of association of Siemens Brothers & Co. Ltd., 1880 until 1899. After the turn of the century, Siemens expanded its efforts in electric power technology, in particular, which had by then overtaken telecommunications. During World War I, Siemens Brothers was seized by the British as an enemy-owned foreign asset. During the interwar period, Siemens thus had to rebuild its English business from the ground up.

1871 Alexander Siemens, age 24, starts work at Siemens Brothers; in 20 years, he will be managing director.

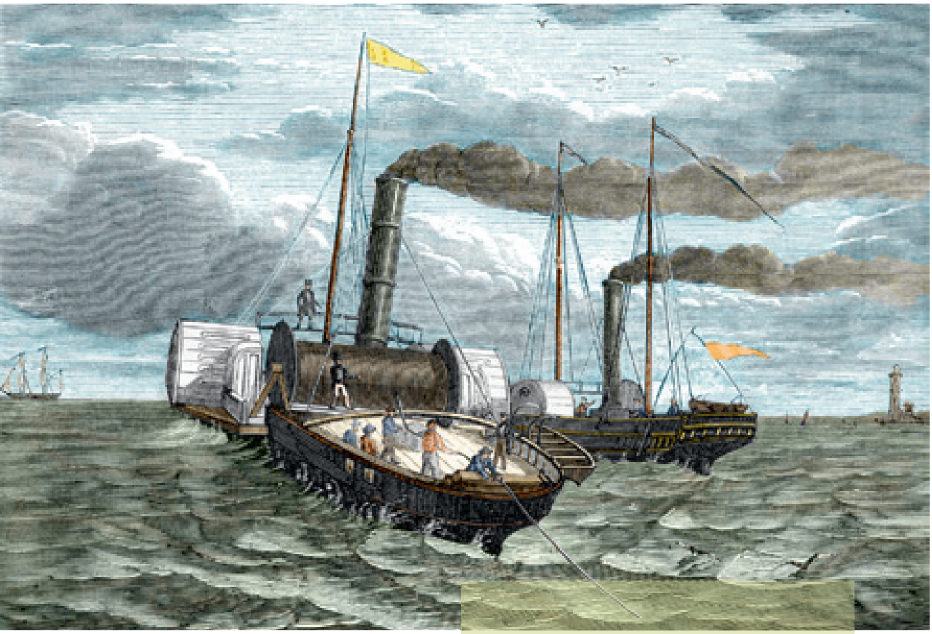
Cabling the world – Siemens plays a part in globalization

Globalization, understood as a coalescence of the world, can be viewed as a process that took many centuries – with delays and accelerations. One acceleration occurred in the second half of the 19th century. It was buoyed by global telegraphy using transoceanic cables, the introduction of the steamship, and the construction of great canals like the Suez Canal, which opened in 1869, and the Panama Canal, inaugurated in 1914. In 1867, Werner von Siemens told his two brothers that he wanted to build a "global firm à la Rothschild."[13] He later talked about a "global business in the Fuggers' style."[14] Those were bold goals. But in any case, by the 1850s, operations in Russia and England had already made Siemens an international company that would soon be operating globally.

The main business from mid-century to William's death in 1883 was telegraphy.[15] Electrical power engineering to deliver light and power lagged far behind. Transoceanic telegraph cables between continents were the most spectacular projects in telecommunications engineering. Laying cables across the seas was an important contribution to globalization. It offered the opportunity, for the first time, to communicate almost instantaneously across vast distances. But the companies operating in this global line of business had to overcome the immense technical and organizational challenges associated with such projects.

A first spectacular project was laying a telegraph cable across the English Channel in 1850 and 1851. Werner Siemens, who would

1837 The *Sirius* becomes the first entirely steam-powered ship to cross the Atlantic. The era of transatlantic steamer voyages begins.



A telegraph connection to the continent –
laying the Dover-to-Calais cable, 1850–51

very much have liked to take on the project himself, asked William to try to get the contract. But the concept Siemens had worked out never got a chance. Bridging the great oceans posed a colossal technical challenge that went far beyond the Channel project.[16] It involved laying several thousand kilometers of cable between continents, at depths sometimes exceeding 1,000 meters, even though the topography of the sea floor was little known. For this purpose, suitable cables had to be developed and produced, the cable-laying ships had to be equipped with reliable feed-out machinery, and

1850 The first telegraph cable laid along the Channel works only briefly. A fishing net damages it shortly after the first telegram is sent.

stable signal transmission had to be assured. And these were just some of the most significant problems.

No small number of early cables failed because they had not been made carefully enough and were not handled properly. Cable makers responded to these problems by constantly monitoring the cable's electric properties and thus the quality of the insulation – whether in production, during storage, or while laying the cable. This made it possible to detect defects and vulnerabilities quickly and swap out the faulty cable sections. What's more, the cable was not stored dry, but in flooded cable tanks – both at the factory and on board the laying ship.

During the laying of the cable, it experienced mechanical stress from the feed-out process, the water depth, the ship's speed, and wave action. The engineers thus designed cable-laying machinery composed of several drums and equipped with a braking system and dynamometer. Over time, operators learned to pick up broken cable with drag anchors. The breaks were spliced, and the laying process could continue. Transmitting and receiving signals posed additional difficulties. Unlike overland telegraphy, there was no way to amplify the signals in transit. A high-sensitivity receiver was thus crucial. A first satisfactory solution here was the mirror galvanometer produced in 1858 by William Thomson (Lord Kelvin), which was further developed in 1870 to receive text.

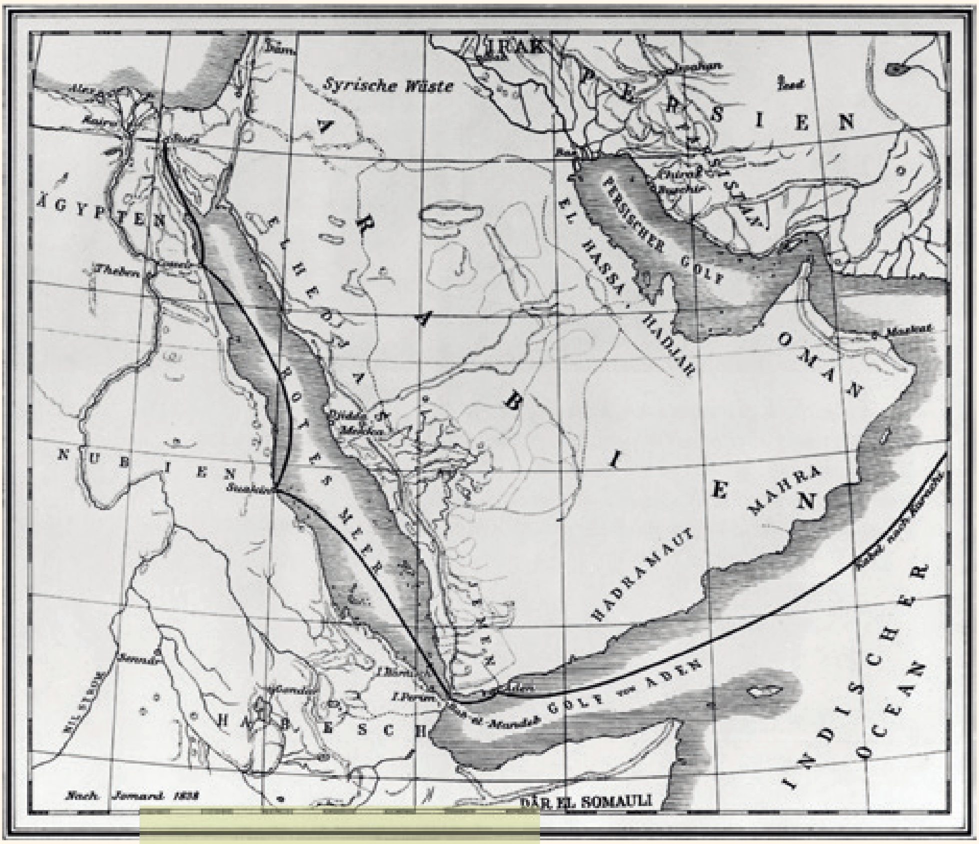
To get into the marine cable business, Siemens established a cooperation agreement in the 1850s with R. S. Newall & Co. One of that company's founders in 1839 was William Siemens' later brother-in-law, Lewis G. B. Gordon. Late in the 1840s, he joined with Robert Stirling Newall to found a wire-cable factory. The plant got into the submarine cable business around 1850. The successful English Channel cable of 1851 and part of the first transatlantic cable of 1856 were among the cables that Newall supplied.

1892 William Thomson is raised to the nobility as Lord Kelvin.
In recognition of his achievements in the realm of thermodynamics, the "Kelvin" physical unit of temperature will later be named for him.

Newall contributed cable fabrication to the cooperative venture; Siemens contributed its electrical engineering skills. Thus in 1853, Siemens procured a cable from Newall for the telegraph connection between St. Petersburg and Kronstadt. This collaboration expanded over the coming years. Siemens handled the electrical monitoring of the cables that Newall laid, and supplied the company with telegraph equipment. From the very start, however, this collaboration was not free from tension. The Siemens brothers declared themselves discontented with the contract terms and complained that Newall did not regard them as equal partners. Ultimately, at William's instigation, the joint effort was terminated in 1860.

The connection between Newall and Siemens came to an end after two major failures. After the cable had been laid successfully across the English Channel, people's attention turned in the 1850s to the seas and oceans, at first the Mediterranean, but also the Atlantic, as well as a connection to India via the Red Sea and the Indian Ocean. Newall and Siemens initially committed to a Mediterranean cable between Sardinia (Cagliari) and North Africa (Bona) in 1857. The telegraph connection's performance was ultimately unsatisfactory, and the project was abandoned. Newall and Siemens also divided the labor in 1859 for laying a cable between Suez and Aden through the Red Sea. It worked for a few months and then went dead. The consequence was arguments and reciprocal blame between Newall and Siemens about the reasons for the failure.

1864 Robert Stirling Newall is not just an engineer and entrepreneur, but a respected astronomer. He is admitted to the Royal Astronomical Society this year.



Helping to connect the world by cable – submarine cables in the Red Sea and Gulf of Aden, map from 1838

1859 Werner von Siemens is shipwrecked while laying a cable through the Red Sea.

By land and water – telegraph cables link continents

Newall's und Siemens' failed cable-laying ventures were not the only ones in the 1850s; other innovators had to take their knocks as well. The biggest challenge, but the one that also promised the greatest profit, was a telegraph connection between Europe and North America, across the Atlantic Ocean. During the first two attempts at laying a cable in 1857 and 1858, the cable snapped. A third attempt succeeded in 1858, but the connection stopped working after about a month. The failure ended with a loss of about half a million pounds sterling. No further attempts were made for the time being; the American Civil War delayed any further efforts until the mid-1860s.

The failures of the cables across the Atlantic and through the Red Sea raised questions about causes. Pessimists doubted that such ambitious transoceanic connections could ever succeed. Given that situation, the British Board of Trade established a commission in 1859–60 to investigate the feasibility of submarine cables. The commission conducted its own investigations and consulted numerous expert witnesses, including the Siemens brothers, who ultimately arrived at an optimistic assessment that William also presented in lectures to engineering associations. The brothers attributed the failures primarily to inadequate production methods. The cables should have been continuously checked electrically during manufacture. Additionally, the brothers pointed to weak points in the cable design and signaling. Other experts came to similar conclusions, and the commission then addressed.

Siemens & Halske had earned such a good reputation by now that the English government awarded the company the contract to provide electric monitoring for the cables that the government

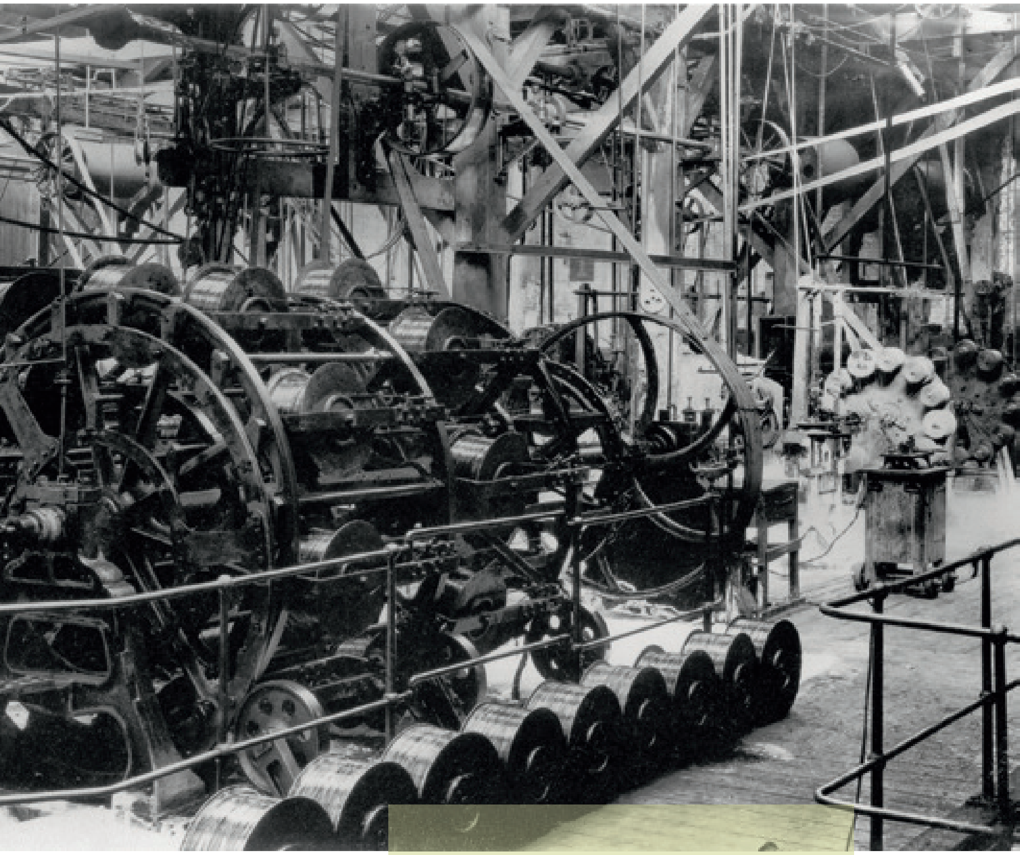
1858 The telegram of congratulations sent on the occasion of the commissioning of the first submarine cable between Europe and North America takes 16 hours to arrive.

would arrange to lay. The first project was a cable between Malta and Alexandria, undertaken in 1861 by a competitor, Glass, Elliott & Co., one of England's four cable makers. But Siemens' collaboration with the Board of Trade did not last long. After the Malta-to-Alexandria cable was laid, Siemens terminated the cooperation, to the authorities' displeasure, because the company had had a bad experience and was not given a chance to operate the cable.

The two brothers evinced optimism to the English government and the public. But within the company's management there were considerable differences about how far to get involved in transoceanic telegraphy. Thus far, Siemens had largely limited itself to monitoring cables electrically. Now the question was whether Siemens should also make, lay, and operate cables. William argued for an extensive involvement in transoceanic telegraphy, but he could not prevail against his brothers Werner and Carl, as well as Johann Georg Halske. They all shied away from the immense risk associated with laying cable. Ultimately, the Siemens companies pursued a middle course. They participated in producing and laying cables without entirely counting on this dynamic line of business; they largely refrained from operating telegraph cables; and they arrived at accommodations with major competitors more often than fighting them.

Nevertheless, William began building the company's own cable factory in Woolwich on the Thames between 1862 and 1865. An important argument in favor of this was the order he landed in 1863 from the French government to establish a telegraph connection between Cartagena in Spain and Oran in Algeria. But in the cable-laying operation of 1864 and 1865, neither the cable-laying machinery nor the new cable William had designed worked out. The venture ended with a loss for Siemens.

1814 Malta becomes a British colony and develops into a key strategic naval base in the Mediterranean.



The latest production equipment – a cable braiding room at the Woolwich cable works, ca. 1870

1870 The plant in Woolwich begins making complete submarine cables.

Unlike his brother Werner, William was even willing to get involved in laying a transatlantic cable. But the order went to the market leader, Glass, Elliott & Co. The laying operation began after the American Civil War ended. The cable broke on the first voyage; the next year, 1866, it was picked up again and repaired, and a second transatlantic cable was laid. This successful cable-laying operation in 1866 emphatically proved that submarine cable telegraphy was feasible. In subsequent years and decades, a network of submarine telegraph connections spread around the world. In 1870 the British laid a submarine cable across the Mediterranean, the Red Sea, and the Indian Ocean; in 1871 it was extended to China, Japan, and Australia. A submarine cable reached South America in 1873, and one reached South Africa in 1879. By the end of the 1870s, the worldwide network comprised between 70,000 and 100,000 kilometers of submarine cables.

The successful transatlantic cable of 1866 served English textile entrepreneur John Pender as a gateway into the telegraphy business. In subsequent years, he assembled a conglomerate of companies that largely controlled the global cable business. Attempts by the French and Americans to disrupt Pender's quasi-monopoly met with little success. William Siemens also experienced Pender's market domination as a perpetual irritant. He attacked him in public speeches in which he particularly pointed out that Pender's monopoly was impeding technical progress. Pender riposted by casting doubt on William's competence as a businessman.

The real question was how and to what extent Siemens Brothers would be able to hold its own in this cartel-ridden cable market. The laying of cable was generally done by private companies. A group of entrepreneurs would raise the necessary capital by issuing stock and then engaging a duly instructed company to lay the connection and in some cases to operate it. Countries granted

1896 By the year John Pender dies, his company owns some 136,000 kilometers of submarine cable – one-third of all the cable laid in the world at the time.

rights to come ashore, which as a rule did not result in problems. In some cases, they guaranteed a certain amount of use for the telegraph connections. Governments themselves only rarely acted as cable entrepreneurs.

One such exception was the telegraph connection between the United Kingdom and India. The line not only connected the British homeland with its most important colony, but also involved England's political spheres of interest in the Mediterranean, Egypt, and the Near East. The government thus awarded contracts for segments and subsidized the cable-laying process. In 1860, as we have already seen, the cable across the Red Sea, in which Siemens was involved, had failed.

Siemens had already begun in the 1850s to consider building a telegraph connection between England and India by way of Prussia, Russia, and Persia. This was a bold undertaking, not just because of the immense distance of some 11,000 kilometers, but also because it meant bringing several governments on board with the project. However, the Siemens brothers already had local branches and good relations with most of the countries affected by the line. This was a joint effort that involved Werner, William, and Carl equally.

William mainly managed negotiations with the English government and with the Reuters news agency, which already controlled a connection between England and Prussia and also played a significant role as a major potential user. In 1868, the brothers founded the Indo-European Telegraph Company in London as a joint venture of Siemens & Halske and Siemens Brothers. It proved difficult to raise the necessary capital, so that the two Siemens companies themselves had to assume one-fifth of the shares. The participating governments delegated representatives to the board of directors.

1870 The Indo-European telegraph line goes into operation. It takes only 28 minutes to send a telegram from London to India – a worldwide sensation.

The Siemens companies' Indo-European telegraph connection was competing primarily with the Red Sea cable that was being laid at the same time. At the end of 1868, William engaged in the *Times* in a controversy that involved fundamental advocates of undersea connections as opposed to land lines.[17] He attempted to refute the argument that the United Kingdom could control a submarine cable more easily than an overland cable, which would have to rely on the good will of foreign governments. The connection to India was built in the years around 1870. William oversaw laying the cable through the Black Sea. Once it got past some initial upsets, the Indo-European telegraph line proved quite fit and remained in operation into the 1930s.

Building the Indo-European landline was not a signal that Siemens intended to get out of the submarine cable business. Rather, the construction of the cable ship *Faraday* in 1873–74 proved that Siemens Brothers still had ambitions in this field. William became involved in designing the ship himself and for the most part designed the cable-laying machinery. A particular concern with the *Faraday*, some 110 meters long, was maneuverability and stability in heavy seas. Once the initial problems had been resolved and the cable market revived, the ship proved its worth. By the time of William's death in 1883, it had already laid four cables across the Atlantic. The *Faraday* served as a model for building other cable ships and remained in operation until 1923, when it was replaced by a successor model.

While the cable business picked up again in the 1870s, it was still not without setbacks. Around 1870, the Germans, French, and Americans launched initiatives to break Pender's monopoly in the North Atlantic with a cable of their own. In 1873 this yielded the Direct United States Telegraph Company – the name indicating that the venture intended to bring the cable on shore not in

1868 In its initial public offering on the European stock markets, the Indo-European Telegraph Company raises 450,000 pounds sterling in capital.

The telegraph compresses time and space – the route of the Indo-European telegraph line, map from 1870

Canada, but directly in the United States. At first, however, this was not a success. In this project, William and Carl were among the driving forces, while Werner urged caution.

A coastal cable in South America, between Rio de Janeiro and Uruguay, was a disastrous experience for Siemens. Following William's negotiations with the Brazilian emperor, Siemens got the order for a new cable in 1873. The venture was as ill-starred as could possibly be imagined; not just one, but two ships were wrecked during the laying process, with many fatalities among the crew. An investigation by the English trade ministry, urged by the Siemens brothers, absolved them of all charges. Siemens paid

1866 John Pender is the personality behind the laying of the first transatlantic cable.

a large amount of money into a fund for the widows and orphans. A third ship finished laying the cable in 1875.

Despite the initial difficulties and an assortment of catastrophes, laying cable across the oceans became routine in the 1870s, though the expense was still great and there was no way to prevent unpleasant surprises. The acquired experience paid off for the three transatlantic cables that Siemens laid. The *Faraday* laid Siemens' first transatlantic cable in 1874–75. In 1879 Siemens was awarded the contract for a French cable that ran directly from Brest to Massachusetts. In 1881–82, the *Faraday* laid two Atlantic cables for the company owned by American rail magnate Jay Gould, who went into competition with Pender for a time.

Siemens became successfully established in the cable business in the 1860s and 1870s. Yet competition from John Pender's powerful group of companies was a Sword of Damocles hanging over all the brothers' efforts. The Direct United States Telegraph Company was not up to handling the price war that Pender launched. By 1877, "Direct" was largely under his control. The Indo-European company and other ventures as well could not avoid making cooperative agreements with him.

The global telegraph network – at least in the time up to William's death – was very expensive to use. That was primarily because the cables' capacity was extremely low. Originally only one message could be transmitted at a time. The introduction of duplex telegraphy, which took a long time, doubled capacity. Input and receiving techniques using machines sped things up further. But that in no way changed the fact that telegraphy remained "the rich man's mail."[18] Transoceanic telegraphy was so expensive that many governments limited its use by their diplomatic missions.

In the medium and long term, the submarine cable network brought about important effects that contemporaries had not

1870s Jay Gould acquires a network of American railroads, giving him control of up to 16,000 kilometers of track in the USA.

Setting the standard for laying submarine cables – the cable steamer *Faraday*, 1874

1857 Werner von Siemens and Carl Frischen develop a duplex telegraphy system that makes it possible to send messages from both ends of a cable.

entirely foreseen.[19] More trade could now be conducted using the order-and-delivery system. Trading centers and trade flows shifted. Governments were better positioned to monitor and control their worldwide missions. News agencies and the press reported more, and much faster, about distant countries and regions. The result was that opinions of the public, which now learned of major events and developments as soon as politicians did, began to increase in importance.

1851 Banker Paul Julius Reuter founds a news bureau in London to transmit stock prices to Paris over the Dover-to-Calais submarine cable.

Versatile and committed – William’s inventive activity pays off

In parallel with his work for the Siemens companies, William also worked as an independent inventor and entrepreneur. After resettling in England, he worked at and with numerous companies in machine construction, the rail sector, electrical engineering, and the textile industry. The sheer diversity of these companies, industries, and tasks is likely to have equipped him with extensive problem-solving skills in various fields of technology. At any rate, his contemporaries lauded the breadth of his technical knowledge and skills as well as his ability to relate theoretical and practical questions to one another.

During the 1840s and 1850s, his thoughts centered on improving energy use in steam engines. The steam engine and other thermal engines converted only a small portion of thermal energy into mechanical work; most escaped unused up the smokestack. For that reason, the brothers Robert and James Stirling had conceived devices as early as 1816 to feed waste heat back into the technical process. But their work attracted little attention and had few technical applications.

In Dundee in 1845, William encountered a hot-air engine that James Stirling had built. After examining the machine, he concluded that it was a better idea to apply the regenerative principle to steam engines. By the mid-1850s he had developed steam engines equipped with heat exchangers; he presented them at the Paris Exposition Universelle and founded an international company to market them. But it turned out that the engines were not

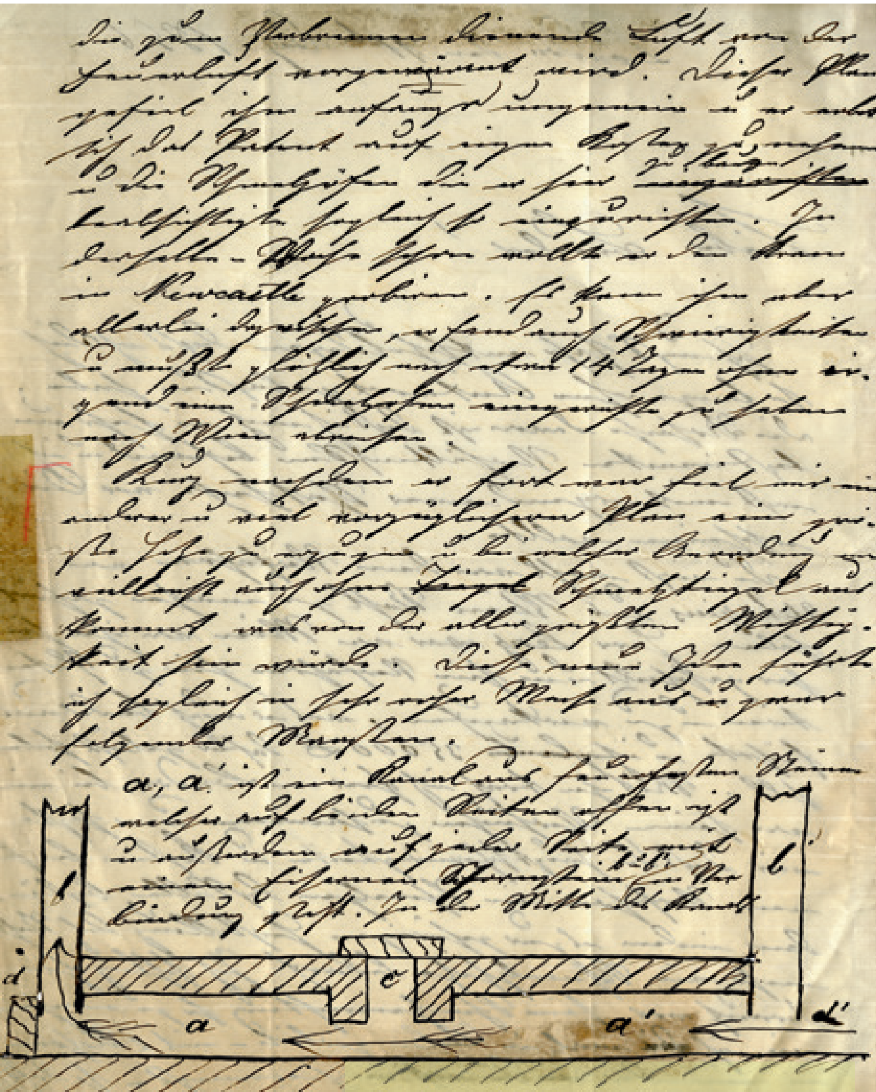
1816 Robert Stirling, a trained theologian, invents a hot air engine that later becomes famed as the Stirling engine. That same year, he is consecrated as a pastor in Scotland.

A congenial partner for inventions – Friedrich Siemens, ca. 1866

really ripe for the market. William's theoretical concepts were defective, and the engines could not withstand the extreme thermal stresses involved. He abandoned development work and the company went out of business.

The steam engine proved to be an extremely difficult field in which to apply the regenerative principle. A far less complicated proposition was the idea that William's younger brother Friedrich came up with – applying the principle to simple furnaces. These worked with two chambers. Waste heat heated one, while the combustion air was conveyed to the furnace through the other. After a certain amount of time, the flow direction was reversed, so that the combustion air was always preheated. This approach saved a considerable amount of energy, and the high temperatures also improved process quality. Friedrich and William quickly recognized

1874 Swiss engineer Anatole Mallet patents the energy-saving compound principle for steam engines.



A strained yet productive exchange of knowledge – letter from Friedrich Siemens about the discovery of the regenerative oven, 1856 that regenerative furnaces were useful for any smelting and combustion process that needed high temperatures.

The basic idea was simple, but putting it into action involved some not inconsiderable technical difficulties. The two chambers and the channels needed fireproof materials that could withstand the high temperatures involved. Properly timed process management had to be found for each application. Friedrich came up with the idea of combining the regenerative furnace with a gas generator, thus sidestepping a number of problems. Though the basic idea for the regenerative furnace came from Friedrich, both brothers were involved in working out the invention. Here they worked sometimes together, sometimes independently. Considerable tensions arose between William and Friedrich in this connection. They quarreled about who deserved credit for what share of

A successful company – a trough furnace at Friedrich Siemens' glass factory in Dresden, ca. 1890 the innovation, about the applications to be pursued, about the furnace design, and about how to divide the market. Ultimately, Friedrich left England in 1863, where he had lived since 1849; he returned to Berlin and built up his own furnace business.

From around 1860 onward, Friedrich concentrated on glass production. Regenerative firing not only saved fuel and time, but also made it possible to maintain a more uniform temperature, with helpful effects on the quality of the glass. Early in the 1860s, Friedrich and William were not the only brothers to experiment with glass production – yet another brother, Hans Siemens, had taken over a small bottle-glass factory in Dresden in 1862. Friedrich and Hans developed the regenerative process for glass troughs independently from one another. The troughs not only had a considerably greater capacity than the pots that had been used previously but were also easier to maintain. After Hans' untimely death, Friedrich took over the factory in 1867. He was able to make the company highly profitable and turned it into Europe's largest maker of bottle glass.

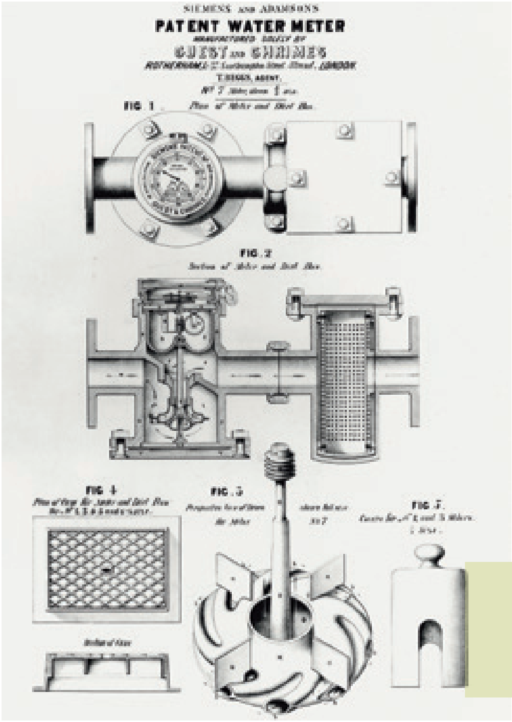
William Siemens' regenerative principle served to save thermal energy. That was certainly of interest to individual businesses. But on top of that, William wondered in general what the situation was with the global energy supply. He determined that coal was the most important primary energy source and concluded that it would remain so. In the 1860s and 1870s, the question of a coal shortage became a major topic in Britain. The government appointed a coal commission, which presented a multi-volume final report. In this connection, William recommended increasing energy efficiency, proposing in particular his regenerative techniques for the purpose. His vision was that the expected growth in consumption could be countered entirely through enhanced efficiency.

1862 Michael Faraday presents a paper before the Royal Institution on using the Siemens regenerative principle for glass production.

Wherever possible, William wanted to use coal not directly, but in a refined form as coal gas or coke. This in itself was nothing new; after all, English cities had been building gas plants and gas networks for lighting since the early 19th century. In the early 1880s, William was still of the opinion that gas light would retain its importance as "the poor man's friend."[20] Electric light could not compete with gas light on price, he said. The praise of gas light was designed for his own benefit because around 1880 Friedrich and William also applied the regenerative principle to gas lamps. But Friedrich did not begin to bring in relevant sales figures until the late 1880s – which was after William's death. William had been convinced that a new market would open up where gas could display its advantages in heating, in addition to lighting. One of his favorite plans was to generate gas directly in coal mines. But the gas companies torpedoed experiments along these lines in Birmingham in the late 1860s.

London's air was often catastrophically bad[21] – a combined consequence of commercial firing systems, private open chimneys, and the burning of low-quality coal. Although there were environmental regulations for commercial burners, private burners were entirely unregulated. As a name for the worst weather conditions, the Londoners coined the term smog, from "smoke" and "fog." According to William, these conditions could be counteracted only by abandoning the direct burning of coal. A furnace he proposed in 1880 worked with the two refined products coal gas and coke, as well as heated air. He was not so foolish as to expect the British to do without an open flame. He did not profit from his furnaces because he had not taken out any patents. The movement to combat smoke gases and the exhibition of associated firing techniques that was held in London yielded no fundamental improvement in conditions. London was still suffering

1952 During the Great Smog of London, tens of thousands of Londoners suffer respiratory problems; thousands die. It is the worst event of its kind in the city's history.



A successful mass-produced product – patent drawing for the Siemens-Adamson water meter, 1851–52

environmental catastrophes from the extreme smog conditions in the mid-20th century.

The fight against waste in the mid-19th century also included the water supply. The old system of a decentralized water supply from groundwater wells ran up against its limit as industrialization and urbanization spread. Groundwater was polluted and dirty, which led to cholera and typhus epidemics. To counteract that, the major cities had, since the first half of the 19th century,

1847 Besides telegraph equipment and water meters, the Telegraphen-Bauanstalt von Siemens & Halske also initially builds signal bell systems for railroads and electrical medical apparatus.

been building water works, where water was purified using sand filters. The plants also supplied process water to industrial establishments. And streets were equipped with hydrants to fight fires better.

Usually these water plants made contracts with their customers that guaranteed delivery of a certain quantity of water. But there were difficulties in measuring that water. Hence there was demand for a water meter that could record water consumption precisely and continuously. The most obvious solution was to insert a turbine or paddlewheel into the water line and connect it to a recording device. That sounds simple, but the difficulty was to design the water meter in such a way as to supply reliable results for several years. Rust, lime, and other deposits usually caused water meters to become inaccurate over time.

Since the mid-1840s, Werner, William, and Johann Georg Halske had been developing various types of water meters in Berlin and London, and steadily improved them. The water meters were series or mass-produced articles that the Berlin workshop was ill-prepared to make. In any event, William reached the conclusion that manufacturing them was too much for Siemens & Halske. Instead, he entered into a contract in 1852 with the English plumbing supplies manufacturer Guest and Chrimes in Rotherham. The water meters that William designed and that the Rotherham company produced were widely accepted by English water works. Up to 1886, the company produced some 130,000 water meters, compared to 88,500 in Berlin.

Improving the urban water supply had its downside. Increasing amounts of water also increased the amount of sewage, and it was easier to carry off solids in open or covered sewers. The situation got worse as the water closet spread. In London, the Thames became a dark, smelly sewer that posed a very substantial threat

1856 The first modern sewer system in continental Europe begins construction in Hamburg. It takes nearly 20 years more before work starts on a city-wide system in Berlin.

to health.[22] Special problems arose because the Thames changes directions at high tide. And London was organized into a great many independent administrative units, impeding a fundamental solution. The mid-19th century saw a boom in proposals to clean up the Thames. One group suggested gathering solid waste matter and carrying it off for agricultural use. Another faction wanted to build large sewers running parallel to the Thames that would open at a few points in the river's lower reaches. Ultimately, this was the project that was accepted, and it was implemented by the mid-1860s. In 1858, William issued his own concept. His plan was to build a canal parallel to the Thames that went out to the sea. The tide would then regularly flush the river. This proposal does not seem to have caught on. At any event, no responses are recorded, and William did not pursue the matter further.

William viewed himself as a mechanical engineer, not an electrical engineer. All the same, he accepted the task of marketing Werner's electrical engineering innovations in England. In the 1870s, electric light was attracting attention, either as a bright arc light sparked between two carbon electrodes or as a more diffuse incandescent light from carbon-filament lamps. In 1879 the British House of Commons appointed a commission to investigate the future of electric light.[23] Its work yielded the Electric Lighting Bill of 1882, which defined the general conditions for electrification. The commission also consulted William as an expert witness. Here he repeated his ideas on the fruitful and mutually complementary competition between gas and electric light. In his comments on electric lighting, he discussed only arc lights. He calculated that 140 lighting districts could supply all of London with electricity, but that not all were suitable for electrification.

All in all, William's attitude toward electrification was cautious, but by no means restrictive. From the late 1870s onward, he in-

1879 Thomas Alva Edison invents a carbon-filament lamp. Over the next decade it becomes one of the first electrical products to be used in private homes.

vestigated whether electric light could substitute for the sun in growing plants and could thus be used in gardening and agriculture. He did most of his experiments on this at his Sherwood estate. He exposed crop plants to different doses of artificial light at various times of day and night, comparing their growth and yields. His results were positive but variable. William was ahead of his time in this work. Today such research is on the rise, exploring the appropriate light spectra and working with energy-saving LED lamps. After a trip to America in 1876, William even floated the possibility of using Niagara Falls for energy.

William and steel – the Siemens-Martin process becomes a true global success

Friedrich and William Siemens fully realized that the regenerative furnace was suitable for universal use and had particular advantages in processes that required high temperatures. Their first thoughts about specific applications were for steel production. Steel was made in a two-stage process. In the first stage (the blast furnace process), pig iron was produced in a blast furnace. In the second stage (refining), the pig iron was made into steel by burning off the excess carbon.

One steelmaking process was called puddling, in which a puddler stirred the pig iron, which had been melted over a coal fire, and thus burned off the excess carbon. William worked to convert the puddling process to a gas fire, and to save energy using the regenerative process. But the focus of his innovative experimentation was on making steel with an open-hearth furnace. Here the charge – the metal to be melted, comprising pig iron, iron ore, and scrap metal plus additives – was contained in a roofed trough. Gas and hot air were fed in from outside, after having been preheated

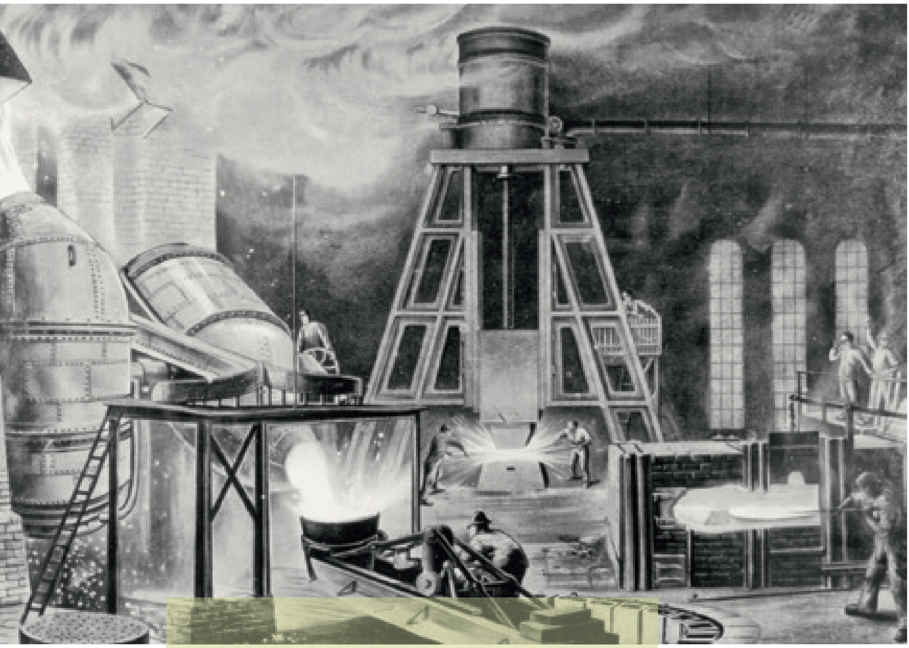
1784 Englishman Henry Cort invents the puddling technique for steel production.

in a chamber. The exhaust gases heated a second chamber at the same time. After a certain amount of time, the flow between the two chambers was reversed, so that high temperatures of between 1,500 and 1,800 degrees Celsius always prevailed. The charge was converted to steel relatively slowly. This offered the opportunity to take samples during the process and make corrections. William was able to find siliceous stones that could cope with the extreme thermal stresses. He arranged for the furnace and the process to be tried out in France and at several English steel mills, but the initial results were unsatisfactory. One reason was that he had set himself the ambitious goal of running the process primarily with iron ore rather than pig iron – in other words, ultimately making the blast furnace superfluous.

In 1863, William entered into an agreement with the company owned by Émile Martin and his son Pierre-Émile Martin for the use of the regenerative furnace. The Martins had a small ironworks in Sireuil, in the Charente region of France.[24] William assisted them in word and deed with refining the hearth, and he sent employees to collaborate in designing it. In the end, the Martins developed a process that made a high-grade steel primarily from pig iron, scrap, and Bessemer waste. Using this steel, they made gun barrels, cast cannons, rolled railroad rails, and forged wagon parts. Because of the Martins' success and activity, the new steel first became widespread in France.

In 1866 the Martins entered into an agreement with William, after which all agreed on how to split up the market. Regardless, in later years there were vehement disputes between the two companies about priority and credit for developing the equipment and the process. The Martins made sure that France spoke of the "Martin process," "Martin steel," and even the "Martin furnace." William Siemens' contribution to developing the process was

1883 The Martins' company in Sireuil, France, is forced to close.



A widespread steel manufacturing process – puddling furnace and Bessemer converters, ca. 1900

largely swept under the rug. The brothers William and Friedrich, German iron smelters, and the Siemens company successfully countered by promoting the term “Siemens-Martin steel;” over time, this is the term that became established internationally.

The Siemens-Martin process, like the competing Bessemer process, suffered from the drawback that at first only certain (acid) kinds of pig iron could be used. During the 1870s and 1880s, it also became possible to refine basic pig iron, and to develop both

1993 The last German Siemens-Martin furnace, in Brandenburg an der Havel, is shut down.

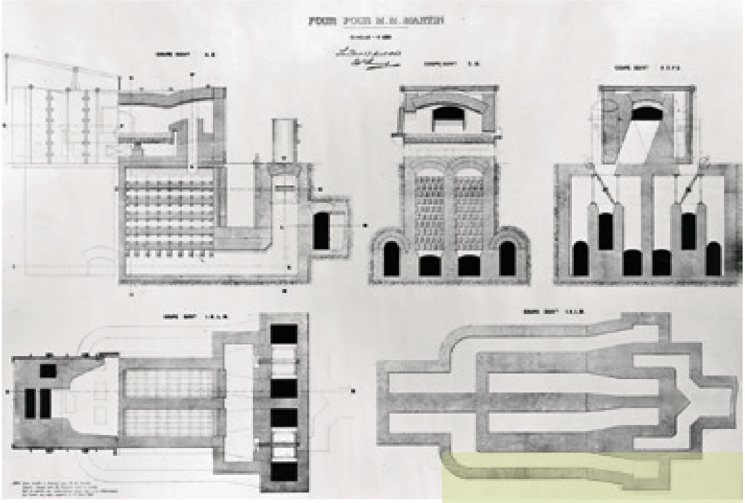
steel mass-production methods into universal processes. That laid the foundation for the Siemens-Martin process to become the world's most important steelmaking method for about a century.

William was involved in promoting the new steel, but he was also developing a "direct process" for making steel directly from iron ore. For this purpose, he developed a rotary furnace that he charged with materials like ground ore, ground coal, and limestone. The developmental work ultimately failed. William could not get around having to add other materials like pig iron to the iron ore in the process. The resulting steel needed additional reworking. Accordingly, in a private letter dating from 1876 he confessed:

> *"My focus is on producing iron in rotary furnaces, and I hope to get good results with time, but so far only rather heavy losses!"*[25]

The process never became cost-effective, but this only became clear over the course of the 1880s, after William's death.

Starting in the late 1860s, steelmaking became William's most important field of activity. He first founded two small steel mills that served primarily for developing the process. In 1870 he took

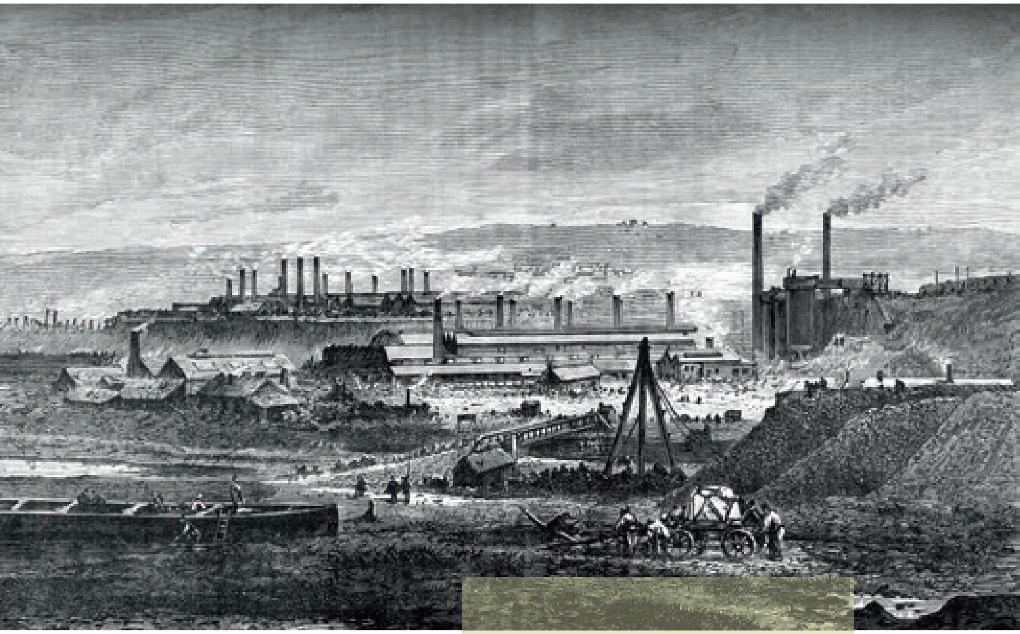


A pioneering joint innovation – Siemens-Martin furnace, 1863 over the Landore steel mill in southern Wales. Members of the Siemens and Gordon families acquired a majority interest and took management positions. The existing plant underwent a substantial expansion. After that expansion, it had three blast furnaces designed by William himself, 16 smelting furnaces for pig iron, 24 gas generators, a number of gas-fired puddling furnaces, Siemens-Martin furnaces, rotary furnaces using the Siemens design, coke ovens, steam generation plants, steam hammers, rolling mills, cranes, and other machinery. The plant owned shares in six mines. In the 1870s Landore employed a workforce of between 1,000 and 2,000 persons, depending on what one includes in the definition.

The company's capital was increased several times. It was ultimately converted to a stock corporation to bring in still more capital. The company consistently ran at a loss, although William often felt he saw silver linings among the clouds. According to estimates, William invested – and lost – a total of 300,000 pounds sterling at Landore. At the time of his death in 1883, Landore was essentially ripe for liquidation. Werner, Carl, and Friedrich rescued the company – out of consideration for the family. Friedrich and Joseph G. Gordon, Lewis's son and William's nephew, took over the management. But they also were unable to achieve a decisive improvement in the business situation. By 1888, it was no longer possible to avert liquidation. The losses accumulated since the company's founding were estimated at half a million pounds. The liquidation process dragged on until 1896.

William's involvement in steel production thus resulted in enormous financial losses, a steel produced in the direct process that was of high quality but not competitive, and the Siemens-Martin process, which became the most important steelmaking process of all and remained so for a century. William never tired,

End of the 19th century Steel production by the direct process, developed by William Siemens, has been largely abandoned.



Ambitious, but with little success –
the Landore Siemens Steel Works, ca. 1880

from the late 1860s onward, of recommending the new steel for numerous applications in his lectures and contributions to debates. Siemens-Martin steel turned out to have particular advantages for ship construction. Ships had hitherto been built from expensive puddle iron, or from economical Bessemer steel that had sometimes led to negative experiences. The Siemens-Martin steel was more expensive, but less material was needed, and the resulting strength was greater. Landore was able to meet the shipbuilders' requirements for a homogeneous material.

1844 The first German ship made of iron is built by Jacobi, Haniel and Huyssen in Ruhrort.

The first tests with Siemens-Martin steel were performed by navies, which had a greater risk propensity and where cost was not the crucial factor. The French Navy led the way. In 1876 the British Navy built two cruisers serving as dispatch vessels, using only Siemens steel supplied by Landore, to get a comparison with ships made of Bessemer steel. When the experiment turned out entirely to the good, the Navy switched to Siemens or Siemens-Martin steel across the board. In commercial shipping, the switch from Bessemer to Siemens-Martin steel took somewhat longer. This was primarily a matter of cost. By the 1880s, the opinion started to become widespread that Siemens-Martin steel was the best-suited material for shipbuilding.

As the 1870s drew to a close, William presented a smelting furnace that worked with an electric arc, similar to the arc in an arc light. He pointed out how the furnace would make it possible to smelt metals economically. He may have been thinking primarily of applications in metallurgical laboratories. At least we find no mention from him about using the furnace for mass-production of metals. Yet after William's death, this was in fact where this furnace came into use – to produce aluminum, magnesium, and finally steel as well.

Another of William's innovations also had the potential for applications that did not come into use until later. Like other researchers before him, Werner von Siemens had realized in 1853 that a metal's resistance changes with temperature. William took advantage of this finding in 1860 to design an electric thermometer that could be used to monitor the temperature in cable tanks. The heart of the 1860 electric thermometer was a copper spiral. William later replaced the copper with platinum, making the instrument usable at very high temperatures as well, like those applied in steel production. Testing by other technicians

1886 Molten-salt electrolysis for the production of aluminum is achieved on an industrial scale.

and scientists revealed that the thermometer had some early-stage problems and did not yield stable results. The main cause was impurities in the platinum, but that was not realized until after William's death. It did not change the fact that this was a principle with a future. Millions of platinum thermometers are in use today.

1783 A process is developed for the industrial extraction of platinum.

Offices and honors – William Siemens as association member

As is still the case today, England had a well-developed culture of associations. These associations were already performing a number of functions in the 19th century. They were centers for social life. They provided recreation and relaxation, but they were also representational. They brought together individuals who had the same interests and promoted discussions about their fields. In this way, the technical and scientific associations made a contribution to technical progress. They were suitable places to explore questions of all kinds in an informal setting, and where applicable, to prepare decisions. Not least of all, membership certified that one belonged to a given group. That might be a social class, or it might be a community brought together by knowledge and skills. Membership in a technical or scientific association signified recognition of one's successful activity as an engineer or scientist.[26]

William Siemens was a member of numerous associations, where he held a variety of offices. As a broad generalization, these associations can be organized into several groups: learned societies, professional societies, industry associations, scientific associations, and finally, clubs. The learned societies were where scientific and technical discussions took place. They arranged regular meetings where lectures were held and discussed. They usually published one or more journals with lectures from their meetings and other articles. They awarded prizes for publications and other achievements, and they financed research projects. They

1856 The Verein Deutscher Ingenieure (VDI)– the Association of German Engineers – is founded in Germany. Ten years later, the VDI initiates the founding of steam-boiler monitoring associations, the forerunners of today's Technischer Überwachungsverein (TÜV) –technical supervisory association.

Membership by recommendation – an admission ticket for a meeting of the Institution of Mechanical Engineers in Leeds, 1859

also appointed commissions to clarify issues involving technology and science.

Most of these institutions also served as professional societies. The professional societies performed an important function in establishing and stabilizing professional groups. Ultimately, it was their acceptance criteria that defined who belonged to a profession and who did not. In the 19th century especially, membership in these institutions carried more prestige than an academic degree. Later on, the professional societies also became involved in training and testing aspiring engineers.

To become a member of a learned or professional society, one needed to first be nominated by a group of members and then voted upon. The associations that William joined in the 1850s were the Institution of Mechanical Engineers and the Institution of

1847 A group of railroad engineers founds the Institution of Mechanical Engineers.

Civil Engineers. In later years he also became a member of the Institution of Naval Architects, the Society of Civil Engineers, and the Chemical Society of London. When the Society of Telegraph Engineers was founded in 1871, William was pulling strings in the background. A particular honor in 1862 was his appointment as a member of the Royal Society, the most tradition-steeped English scientific society.

Industry associations included not just scientists and engineers, but business owners and managers as well. They dealt not only with scientific and technical matters, but with issues of business and social policy. William was particularly involved in the Iron and Steel Institute, founded in 1869. His membership in the Society of Chemical Industry, founded in 1879, was more a passive one.

Scientific societies appealed not only to their own communities, but to a broader audience as well. They regarded it as one of their key tasks to promote technology and science among the British public in general. In addition to professionals, they also accepted lay people as members if those individuals showed an interest and involvement in technology and science. In the late 1840s and the 1850s, William joined a number of these associations: the Society of Arts, the British Association for the Advancement of Science, and – along with his wife, Anne, who joined later – the Royal Institution of Great Britain.

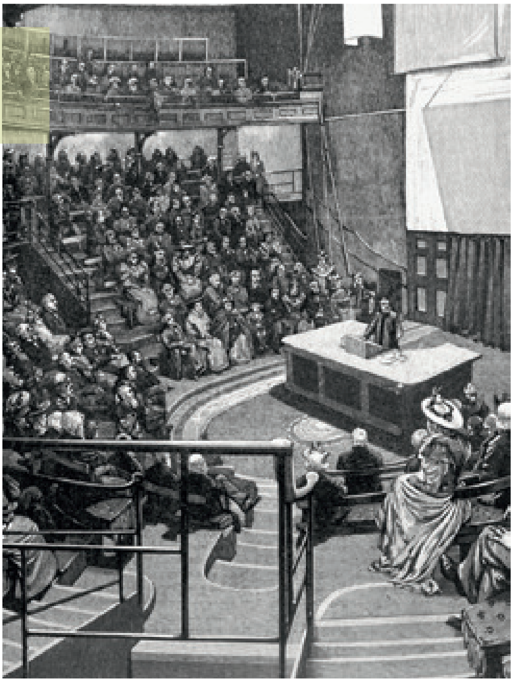
The "clubs" were primarily social organizations, with limited membership. Members came from very different professions, but all from a social position of similar high rank. The clubs often had imposing buildings of their own. Members invited friends to dine with them there. The club buildings also offered facilities for reading, playing games, or simply relaxing. William belonged to the Whitehall Club from 1866 onward, and to the Athenaeum Club from 1871, one of London's premier addresses.[27] The membership

1824 The Athenaeum Club is founded. To date more than 50 of its members have won a Nobel Prize.

of the Athenaeum Club included prime ministers and famous artists, musicians, and scientists.

William's memberships in his various technical and scientific associations show a clear pattern. Starting in the late 1840s, the engineer, still largely unknown, joined a number of organizations – with the support of professional colleagues who held his work in high esteem. In the 1860s he became more and more deeply involved in these associations, elevating his reputation. From the 1870s onward he was among the leading engineers and scientists who came under consideration for any position in such organizations. Although his attitude was hesitant at times, he was ultimately very willing to hold office in these associations and to invest effort in them beyond that as well. He gave numerous lectures and engaged in debates. He served on a number of committees to clarify technical and scientific issues. In cases of dire necessity, he was also willing to step in financially to safeguard the

Open to the lay public too – a meeting of the Royal Institution, undated



organizations' work. The societies honored him in many different ways – by electing him to office, presenting him with awards, having him deliver keynote speeches and addresses for festive occasions, and more. On top of this came honorary doctorates from the Universities of Oxford, Glasgow, Dublin, and Würzburg. In April 1883, the Queen of England knighted him, and he became a "Sir," "in recognition of the service which you have rendered to the cause of Science."[28]

The numerous offices that William held in technical and scientific societies, and his many contributions in the form of lectures and statements, are evidence of the great importance he attached to these institutions and their work. On the other hand, his many offices also gave him an intimate look at the fragmentation of the environment that the societies operated in and the duplication of work that frequently resulted. Those experiences may well have been part of the reason for the initiatives he launched in the second half of the 1870s to create a kind of umbrella organization for these technical and scientific societies or to bring about a closer coordination and collaboration among them. He backed the idea by offering to donate 10,000 pounds sterling for the construction of a shared building under the working title of a "Hall of Applied Sciences." The initiative ultimately came to nothing because the Institution of Civil Engineers, which played a key role among the associations, could not bring itself to lend support.

1844–1883 During this period, William publishes nearly 100 articles on a wide variety of subjects – including mechanical engineering and electrical engineering – in association journals.

A select circle – William's personal network

Personal connections were of great importance for an engineer, scientist, and entrepreneur like William Siemens. They paved the way for the German emigrant technician to enter English society. They helped make the Siemens name familiar in English engineering circles and opened doors for business connections. William is likely to have become acquainted with most of his close English colleagues and good friends through the technical and scientific associations and at the clubs.

As time went on, William established a group of friends in technology and science. What these friends had in common was that they had all conducted fundamental scientific work, but were also interested in technical applications or were actually engineers themselves. They held influential positions in the British engineering world and in science. They thus had a profile that William himself embodied or aspired to. In those days, scientists generally worked on a broad basis, and were not yet as specialized as they would become later. As a rule, William's own fields and those of his friends overlapped to greater or lesser degrees. This made it easier for them to communicate in professional terms and discuss matters as colleagues. The friends often quoted one another and thus promoted the dissemination of the results of their research.

William's friends and colleagues included the physicist John Tyndall, the chemist Edward Frankland, the mathematician William H. Spottiswoode, the engineer Frederick Joseph Bramwell, and the physicist William Thomson. In 1874 Tyndall was president of the British Association, where an address that he delivered sparked attention when he emphasized the social value of science over religion. Here he is likely to have been speaking in terms

1862 William Siemens is nominated for membership in the Royal Society by a group including Michael Faraday, William Thomson, Charles Wheatstone, and James Prescott Joule.

close to William's heart. William worked with Bramwell on such projects as reforming the English Patent Act. Thomson gained a reputation as a specialist in laying cable, and William was able to win him over as a consultant for Siemens' relevant activities. Social contacts for William included not just professional colleagues but also their families. They visited one another and spent holidays together.

In refining and marketing his innovations, William had to rely on collaboration with English entrepreneurs. In particular, he partnered with smaller engineering firms and their owners, who were able to judge his work fairly. Members of the Siemens and Gordon families also invested in the companies he founded. For very large investments, such as laying transoceanic cables and building up the steel mill in Landore, it was necessary to also draw on capital obtained from outside. For the large submarine cables, they formed stock companies, usually with the aid of banks. All in all, William seems to have had little difficulty raising capital for his projects. From the 1860s onward, thanks to the commercial successes of his water meters, regenerative furnaces, and submarine cables, he had it made, thereby enabling him to finance many ventures himself. Thus, his estate at his death still amounted to 380,000 pounds sterling, even though he is estimated to have lost 300,000 pounds on Landore.

Esteemed and appreciated – home and legacy

In 1870 William was able to acquire a rather large property opposite Kensington Gardens, and in 1874 he bought the Sherwood estate as well. Sherwood was not just an oasis for retreat, but also a demonstration site for applications of electricity and a laboratory for William's technical and scientific work. The estate was outfitted

1870 Deutsche Bank, with which Siemens will have an especially close relationship, is founded in Berlin. Georg von Siemens, a cousin of Werner's, is one of the bank's first directors.

A social hub – William Siemens' country house in Sherwood, undated

with a small power plant, equipped with a steam engine. Electricity drove the water pumps, a sawmill, and machines for processing agricultural products. The generated steam also heated the greenhouses. William thus had facilities for his experiments on promoting plant growth with electric light. In the 1880s he added a power station equipped with a gas engine and battery, which provided the house with electric light.

In London and at Sherwood, William and Anne welcomed many guests and organized festive parties. Guests came from a broad range of groups, from close personal friends to members of royal families like the Emperor of Brazil and Crown Prince Wilhelm, who later became German Emperor Wilhelm II. A guest book from

1880 William Siemens presents the results of his experiments on the influence of electric light on plant growth to the Royal Society.

Sherwood that survived for the years 1881 to 1883 gives an insight into the social activities there.[29] Among those who appear in it are William's and Anne's relatives, families with whom William had maintained relationships since the 1850s, including the Löfflers, and William's friends and colleagues from science and technology. The guest book includes no small number of entries praising the Siemens family's hospitality and the beauty of Sherwood.

William Siemens died unexpectedly at age 60 in 1883. Coming home from a meeting of the Royal Institution, he fell, without suffering any serious injury. But a few days later, he felt ill and died suddenly. It was determined that the fall had exacerbated a hitherto undetected heart defect. In view of his life's achievements in science and technology, his death attracted widespread attention. Some 150 obituaries are thought to have appeared in newspapers and journals.

In 1883, Werner took part in the funeral ceremonies for William in London. Looking back, he recalled his impressions:

"Already all the honors which a savant and engineer can obtain in England had been heaped upon William. He was repeatedly president of the foremost scientific and technical societies … The highest recognitions and prizes accorded by these societies were awarded him. The universities of Oxford and Cambridge gave him an honorary doctorate; and he received the honor of knighthood at the hands of the Queen. His death was felt throughout England as a national calamity, and was as such lamented in all the newspapers."[30]

The great figures of British society were buried in Westminster Abbey or commemorated there in some other way. It speaks to how highly William was esteemed that several engineering associations

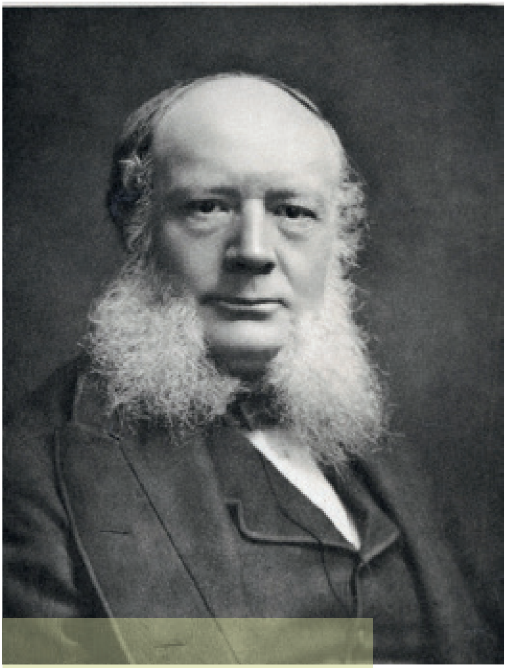
1883 William Siemens' executors are his adopted son Alexander, his nephew Joseph G. Gordon, and Siemens Brothers attorney J. W. Budd.

proposed that he should be laid to rest in the Abbey. By that time, however, there was already a shortage of space in the church, so that those in charge suggested a different honor. Ultimately, the engineering associations donated a decorative memorial window in the Abbey for William and held his funeral there. Friends and colleagues bade William Siemens farewell in an impressively large and grand funeral procession.

After World War II, the window's fate was the subject of extensive misinformation. The tale circulated that the window had been dismantled and put into storage during World War I because of enmity toward Germany. And it was said to have been destroyed by a German aerial bomb in World War II. The true story of the Siemens window is more complex. In 1907, the Abbey decided to remove a number of windows and replace them with others dedicated to kings or abbots. From 1907 onward, this affected windows for British engineers and philosophers, including – in 1926 – William Siemens' window. It was put in storage and survived World War II largely undamaged. The Abbey's chapter offered it to the Institution of Electrical Engineers in 1953, but they declined the offer because they had no proper use for the window. The Abbey then dismantled it and integrated parts of it into tower windows that had been damaged in the war.

William Siemens was the face of Siemens in the United Kingdom in the 19th century. He became an Englishman through and through, and earned an exceptionally high regard in England. He thus deserves huge credit for the Siemens company's image in that country. But the cultural and economic differences between England and Germany also caused tensions and conflicts with the company's German headquarters and with his brother Werner. Here William asserted his ideas about the company's development in a thoroughly obstinate way. He demanded greater independence

1066 An English king (William I) is crowned for the first time at Westminster Abbey. The kings of England have been crowned there ever since.



A respected member of English society:
Sir William Siemens, ca. 1882

for the English subsidiary, and he wanted to become more fully involved in the global transoceanic telegraphy business than his brothers did. These differences ultimately resulted in compromises, though they at least did not cause the Siemens company any harm.

But William was not just the head of the Siemens business in England; he was also an independent engineer who pursued his own technical interests. He was a trained mechanical engineer, but

1871 The Institution of Electrical Engineers is founded, with significant assistance from William Siemens, under the name Society of Telegraph Engineers.

also acquired a distinctly broad range of technical and scientific skills. William worked on innovations his whole life. As is normal in technology, only a small number of them were a success – but these were worthy of attention. He probably earned his greatest profits on water meters and regenerative furnaces. But the most important invention was surely the Siemens-Martin process, to which he made crucial contributions and which dominated steelmaking worldwide for a century. Thus, together with the French cooperating partners who were also involved in the process, not only the name Siemens, but specifically William himself, have remained an integral part of the history of technology long after his death.

Notes

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7 Siemens Historical Institute (SAA = Siemens Archive Record) SAA W712, Wilhelm to Werner Siemens, January 25, 1873
8 SAA W1875, Wilhelm to Werner Siemens, September 2, 1845; W8540, Werner to Wilhelm Siemens, October 9, 1845; SAA W1572, Wilhelm to Werner Siemens, December 22, 1846; SAA W1063, Werner to Wilhelm Siemens, January 3/4, 1847 (quote is here); SAA W1037, Wilhelm to Werner Siemens. January 10, 1847; Werner von Siemens, Recollections, p. 165.
9 SAA W1076, Werner to Wilhelm Siemens, November 29, 1847.
10 Journal of the Society of Telegraph Engineers 5 (1876), pp. 67–69, 71–72, 82-83, 85–86 and 100–102.
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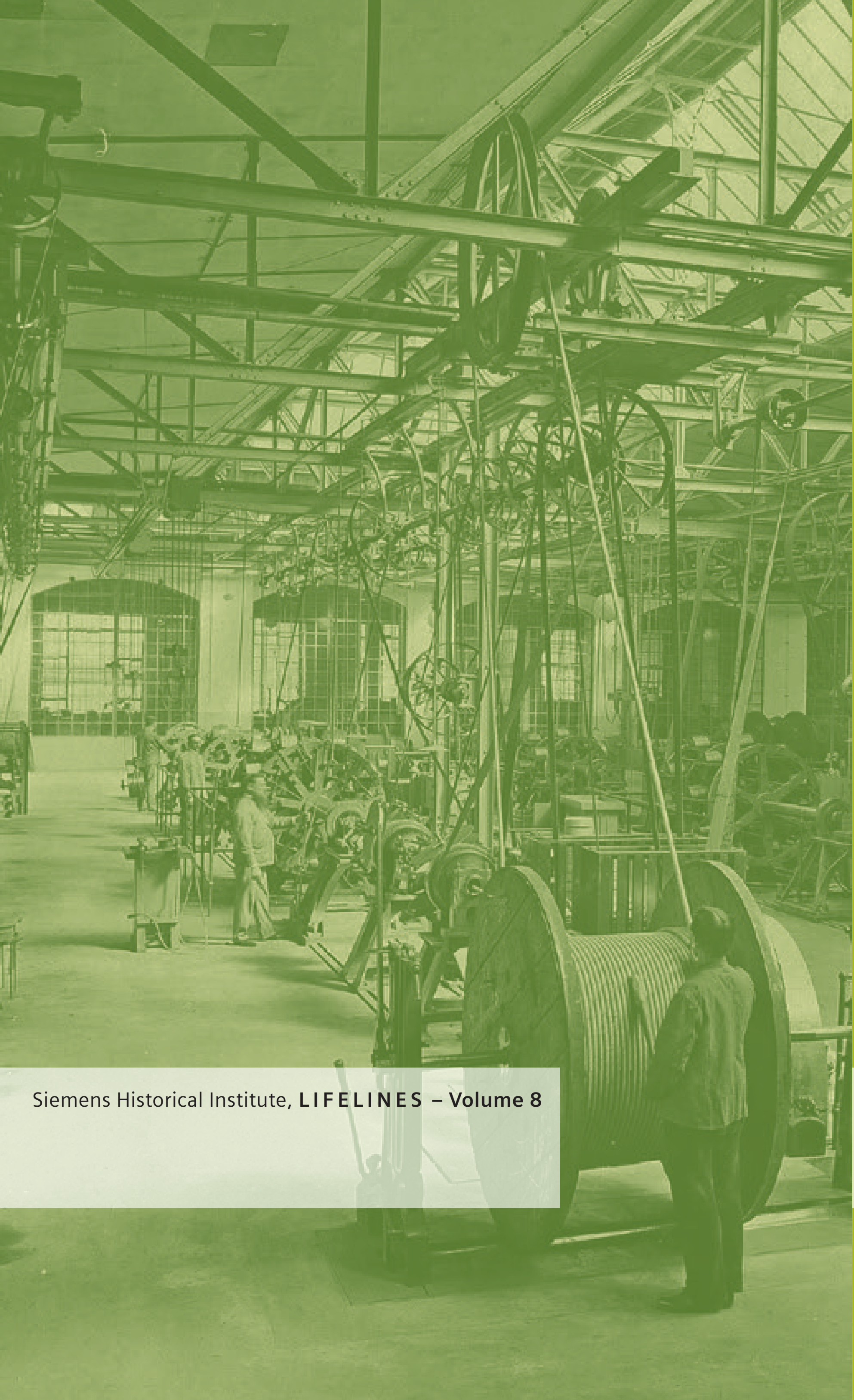

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