WERNER VON SIEMENS

RECOLLECTIONS

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INTRODUCTION

Wilfried Feldenkirchen

Werner von Siemens – Inventor and International Entrepreneur

Werner Siemens (1816–1892) – or Werner von Siemens, as he was known after 1888 – lived in an age of upheaval in every aspect of life. Conditions in those days not only provided the environment that was essential in order for the firm of Siemens & Halske to grow, but were themselves influenced significantly by Werner von Siemens' own work and the business operations of the companies he founded.[1]

The process of industrialization began in Germany while Werner von Siemens was still a child, and accelerated by mid-century. Within a few decades, Germany had been transformed from a still largely agrarian country, with an economy lagging far behind its Western European neighbors, into one of the leading industrialized nations in the world. At first, industrialization was driven mainly by railroad construction and the rapidly expanding manufacturing sector, both in machine construction and in heavy industry. By contrast, the "second industrialization" that began toward the end of the nineteenth century was marked by the expanding use of electricity and the marketing of newfound chemical products. True, before the First World War the value of manufactures and the number of people employed in the "new" electrical equipment and chemical sectors of the economy were still well behind the figures for the "old" industries – despite vigorous growth since the 1890s, the prewar workforce in the electrical industry and in electrical installation was still only about 1.3 percent of the figure in crafts and industry as a whole.

Yet above-average growth rates and obvious development potential already hinted at the role that these industries would play in the future, as technical advances furthered their development. Seemingly endless new applications were discovered for electricity, so that in our time electrical equipment is directly or indirectly connected with every aspect of life, and the growth elasticity of the world's electrical equipment market continues to rise relative to worldwide aggregate output even today.

The electrical industry had its roots in the development of "low-voltage" technology, a term applied in those days to distinguish communications technology from "high-voltage" (power) technology. The first products of the low-voltage technology industry, where production was at first still organized as a craft operation, were the telegraph apparatus, the overhead line, and the cable for long-distance communications. In 1837, the American Samuel Morse built the first telegraph set (which produced a zigzag type of script), in the recognition that neither the existing optical systems (like semaphore) nor Charles Wheatstone's dial telegraph could meet the rising world economy's rapidly increasing demand for information and communications. Here Werner von Siemens, by refining Wheatstone's telegraph, laid the groundwork for all encompassing commercialization.[2] He belongs to the list of outstanding personalities who were responsible for developing electrical engineering[3] away from an experimental pastime into the electrical equipment industry.

Werner von Siemens' own personality and the firm Siemens & Halske that he founded in 1847 – the "stem cell" of today's Siemens AG – early attracted the attention of biographers and of historians of business and technology.[4] Works about Werner von Siemens have hitherto emphasized his outstanding importance for the technical development of the electrical equipment industry – an approach that seems well justified by his pioneering inventions and developments, for example in the dial telegraph and in the "dynamoelectric" principle, to name just the most important innovations. Yet these outstanding technological achievements have somewhat overshadowed his importance as a businessman, even though in his day it was not only his inventions that lent important momentum to the still young science of electrical engineering, but also his activity as an entrepreneur that provided crucial assistance to the development of the electrical equipment industry. Despite his vigorous technical interests, Werner von Siemens worked until his very last years to take over profitable, prestigious enterprises that comprised not just fabrication, but installation and operation as well.

Werner von Siemens was born on December 13, 1816, the fourth of 14 children of the leasehold estate farmer Christian Ferdinand Siemens and his wife Eleonore. In terms of his parents' backgrounds and the household's liberal Protestant ethic, Werner's family would be categorized among the upper levels of the educated middle class. But the family's financial circumstances were in stark contrast to its social status and were exacerbated still further by the persistent agrarian crisis of the 1820s, making it difficult for the children to get a formal education consistent with middle-class aspirations. Werner left his *Gymnasium,* an academically oriented secondary school, as early as 1834, without graduating, and joined the Prussian Army as a pathway toward training as an engineer. Although his schooling, oriented to classical languages, hardly offered much of a recommendation for a career that required a sound knowledge of mathematics, physics, geography and French for the entrance exams, he nevertheless more than measured up – thanks to three months of intensive preparation and a spot of good luck. Training at the military academy, an institution halfway between a trade school and a scientific university, gave him a background in science and theory that would place him at a distinct advantage over most technicians, whose training was merely empirical and practical. It also provided a solid foundation for his research, which he intensified and pursued systematically after his transfer to Berlin, most especially in electrical engineering.

In 1847, using extremely simple materials – a cigar box, tin-plated sheet iron, a few scraps of plain iron, and a bit of insulated copper wire – he built a dial telegraph that operated reliably and was, thus, far superior to previous equipment. "My telegraph uses only one wire, can be played with keys like a piano, and combines the greatest reliability and such speed that one can telegraph nearly as fast as the keys can be pressed. Yet it is ridiculously simple and quite independent from the strength of the current," he reported to his brother Wilhelm. He entrusted the construction of his new device to a precision-instrument maker named Johann Georg Halske, whom he knew from the Physics Society, an association of ambitious young practitioners and researchers who met at the house of physics professor Gustav Magnus on the Kupfergraben in Berlin. Halske, born in 1814, had settled in Berlin as a precision mechanic, and operated the small workshop of Bötticher & Halske there. He quickly developed an interest in the simple yet reliable system, and enthusiastically set about making mechanical improvements in the apparatus. When Werner's cousin, the magistrate Johann Georg Siemens, provided startup capital of 6,842 thalers, there were no further obstacles in the way to founding a new company.

On October 1, 1847, "Telegraphen-Bauanstalt von Siemens & Halske" (Siemens & Halske Telegraph Construction Company) was formed under a partnership agreement by

1. "Mechanic Halske,"
2. "Artillery Lieutenant Werner Siemens," and
3. "Justizrath Georg Siemens."[5]

On October 12, less than two weeks later, Werner von Siemens and Johann Georg Halske opened their workshop in a building at the rear of Schöneberger Strasse 19 in Berlin. Within a few decades, the small precision-mechanics operation of Siemens & Halske, making mechanical bell systems for railroads, water meters, gutta-percha insulation for wires, and especially electrical telegraphs, would become one of the largest electrical equipment firms in the world. Indeed, it was already operating internationally within a short time after its founding. The company was founded to meet a demand that was not directly determined by the market and was not subject to general economic fluctuations. Until the 1880s, it was the unquestioned leader in Germany, since no competitor could match it in size, capitalization, variety of products, technical knowledge, experience or qualifications.[6]

The speed of this no-red-tape process of launching a company and the way in which it was financed with the help of a well-to-do relative were typical of the early phase of German industrialization. What was less typical is that the company was founded successfully in the midst of the crisis of the late 1840s, a crisis both political and economical – demonstrating quite clearly that, for the moment at least, the new telegraph industry was in a position to operate with a considerable degree of independence from economic conditions. What's more, handcrafting telegraph equipment called for no great capital investment. But the flip side of this extensive independence from economic conditions was a dependence on a few clients: the military administration and, a short time later, the administrations of the state telegraph offices and the railroads.

At first, the new Telegraph Construction Company found that this disadvantage was outweighed by its near-monopoly position as a vendor and by the fact that it could profit from its founder's excellent contacts. Even before the company was founded, Werner von Siemens was in promising negotiations with the Prussian Telegraph Commission, the Anhalt Railway and the Russian Ambassador in Berlin.

So, at its founding, Siemens & Halske already had several almost firm orders; the financial risk seemed low.

By the summer of 1848, the young Telegraph Construction Company had already received its first prestigious major order: a government contract to build a telegraph line more than 500 kilometers long between Berlin and Frankfurt am Main, where the German National Assembly was convening in the aftermath of the revolutionary March uprisings of 1848. This, the longest telegraph line on the European continent at the time, was put up within an extremely short time, so that on March 28, 1849, the election of King Friedrich Wilhelm IV of Prussia as German Emperor was wired to Berlin within the very hour it was announced. It was a technical sensation that attracted attention not just within Germany but – most significantly – from abroad.

But smooth relations with the Prussian telegraph administration did not last long. The first difficulties arose as early as the summer of 1849, as a consequence of disruptions in line service. Finally, by 1851, the Prussian telegraph administration was placing no new orders with Siemens & Halske. The young company went into its first fight for survival, which it overcame only by carefully tapping foreign markets.

The Russian business in particular provided for a new upswing in business in the early 1850s, after Siemens & Halske won the contract in 1851 to build the Russian telegraph network. By the mid-1850s, this system would extend from the Baltic to the Black Sea,[7] and the company had signed special maintenance or "remount" agreements with the Russian government to cover it. These contracts proved a lucrative source of income, especially after Werner von Siemens invented the "Tatar" galvanometer, which soon made it possible to localize malfunctions accurately and thus reduce maintenance expenses. The high repute that Siemens & Halske enjoyed in Russia was particularly reflected in the official appointment of the company as

"Contractors for the Construction and Maintenance of the Imperial Russian Telegraph Lines." To ensure that they could exercise their authority in maintaining the lines, the "officials" employed at Siemens & Halske received the right to wear uniforms with badges of rank.

In 1853, Werner's younger brother Carl, only 24, took over the supervision and management of telegraph installations in Russia. With his ability to solve problems quickly and capably, he soon proved his mettle. In 1855, the Russian business under Carl's management became an autonomous subsidiary with its own assets, and with Carl Siemens still at its head.

During the early years of Siemens & Halske Telegraph Construction Company the nature and scope of orders fluctuated widely. It was barely possible to keep up with the production of telegraph equipment and accessories for large orders, yet underemployment during the intervening slack periods repeatedly threatened the company's survival. This basic problem would remain insoluble as long as the company operated solely or at least primarily in the telegraph industry. Siemens & Halske attempted to counter with an early form of diversification. When the Russian contracts began falling off at the end of the 1850s, the Berlin plant began building water meters – developed under the guidance of another younger brother, Wilhelm, and patented by him – for the English market. Thus, the company was able to maintain and offer employment for its core staff of highly skilled workers even when orders were few. It was able to maintain an almost constant workforce of about 150 from the first expansion up to the mid-1860s, and only a few of these were unskilled assistants.

In addition to the Russian business, operations in England became a second important mainstay of the Telegraph Construction Company. Here Wilhelm Siemens – who was later naturalized as Charles William Siemens and eventually knighted as Sir William – became involved in the production and laying of undersea telegraph cables and achieved the difficult feat of breaking into the highly evolved English telegraph market, where private operating companies competed with one another.[8] The London office, which became an independent business in 1858, was especially successful in the cable business, thanks to Wilhelm's good contacts among engineers and government officials. So, in 1863, the company decided to build its own cable factory near Woolwich in order to shake off its dependence on suppliers' quality and prices.

In 1865, the London business was reorganized and renamed Siemens Brothers after Halske left the company. A highlight of operations was the construction of the Indo-European Telegraph line linking London and Calcutta. The line remained in operation until 1931 as one of the world's fastest, most reliable and most profitable telegraph systems. Another triumph was laying large transatlantic cables from the *Faraday*, a cable steamer designed by Werner and Wilhelm Siemens. Stretches of bad weather, false rumors and sabotage by competitors made laying the cable a test of nerves for all involved, and Carl Siemens later said, "I can consider those five years as equal to at least ten years taken off my life. I was mentally and physically at the end of my tether."

In 1883, Siemens & Halske opened an Austrian branch in Vienna with its own production capability. Attempts to establish offices in Belgium and France failed, not least of all because of politics. Werner von Siemens' last project before his death was founding an office in America. In 1892, the year he died, Siemens & Halske of Berlin, joined together with two American partners to found Siemens & Halske Electric Co. of America, a company that concentrated on building dynamos, railroad engines and their accessories. But it suffered from serious internal disputes among management from the very start, and Siemens & Halske shed its holding only a few years after the company was founded.[9] The business did not perform terribly well and finally had to be discontinued entirely after a fire destroyed a large portion of the plant.

These examples show that worldwide business operations were an important part of the corporate culture from the very start. Few businessmen of that era moved as resolutely into foreign markets as Werner von Siemens and his brothers. With their inventions and business projects, they sought global success from the outset and, thus, were well ahead of their time. Certainly one of the reasons behind this international orientation lay in the exceptional characteristics of the still young electrical equipment industry in the middle of the nineteenth century. If only to protect their patents, electrical companies, like chemical companies, were interested in becoming a presence abroad at an early stage, while the drop in Prussian government orders in the early 1850s added to the pressure to become really successful abroad, as a matter of economic survival. But another source of the company's international involvement lay in the Siemens brothers' personalities, their philosophies and political convictions. In this connection, the 71-year-old Werner wrote to his brother Carl:

"From my young days it has always been my ambition to build an enterprise of world standing in the style of the Fuggers, which would give not only me but my successors power and authority in the world and also provide the means to a better life for my brothers and sisters and close relatives. [...] I view business only secondarily as a way of making money; for me, rather, it is an empire that I have founded, and that I would like to leave to my descendants undiminished, so that they may continue to work in it."

These words reveal another deciding factor in Werner von Siemens' corporate policies: his focus on his family and the obligation he felt to provide for his closest family members – initially his brothers and sisters, and later his children. This view of his own role provides an understanding of his intensely familial and personal style of doing business, as well as his efforts to include family members in a joint enterprise. Yet despite the successes in Germany and abroad, relations between Werner and his brothers Carl and Wilhelm were not free from tensions. Differences of opinion on corporate policy sometimes led the brothers into vehement arguments that peaked when both Wilhelm and Carl accused Werner of unprofessional management: they were suffering from what they saw as the inflexible operating methods of the Berlin plant and Werner's patriarchal attitude. Nevertheless, Werner von Siemens continued to assert his policy concept of a combined business managed out of Berlin until 1880, maintaining ascendancy over his brothers in management – not least of all because the business was based on his capital, and the brothers needed his help since their own sideline businesses had not been very successful.

Werner von Siemens' management style is sometimes called "liberal patriarchalism" in the literature, but a more accurate term might be "social-welfare patriarchalism" – because his attitudes favoring general social welfare were combined with considerations of corporate policy. The company's hierarchical structure could not be touched, and unconditional loyalty and strict maintenance of labor harmony were requirements, but the reward – as Werner himself expressed it – was the happy, independent cooperation of all employees for the promotion of their interests. His business approach was conditioned by the belief that social problems had to be solved through concessions, because the livelihood of everyone working in a company depended on everyone else. Combining the employees' best interest with the objectives of the company – that was the maxim that guided Werner von Siemens in his numerous social policy initiatives as well. He was far ahead of his time, for example, in the "inventory bonus" he first paid out in 1866, the ancestor of today's annual employee profit-sharing bonuses. As early as 1872, he founded the first company retirement program with a "pension, widows' and orphans' fund" – more than a decade before the government-regulated retirement and survivors' pension plan was founded. The fund also served as a way of strengthening staff loyalty to the company. Werner von Siemens himself once called this mixture of entrepreneurial calculation and patriarchal responsibility a "healthy egoism."

What made it possible to carry out his social-policy ideas was the company's financial success, thanks to Werner's own forward-looking, innovative inventions. With these he earned Siemens & Halske Telegraph Construction Company a reputation as a pioneer in electrical engineering. In 1866, he achieved what is probably his most important contribution to electrical engineering, when he built on Michael Faraday's work to discover the dynamo-electric principle, thus achieving the breakthrough that enabled electricity to be used as a power source.

Werner von Siemens' report to the Berlin Academy of Sciences on January 17, 1867, entitled "Über die Umwandlung von Arbeitskraft in elektrischen Strom ohne Anwendung permanenter Magnete" (Of the Conversion of Mechanical Energy into Electric Current without Permanent Magnets), established his credentials not only as a researcher who sought to track down the sources of the phenomena he observed, but also as an engineer and farsighted entrepreneur, who from his experiences with the experimental machine he himself had built derived a prediction: "Technology now has the means to generate electric current of unlimited power cheaply and conveniently wherever work is available. This fact will be of considerable significance in many technological fields."

He put his expectations of his invention even more precisely in a letter he wrote to Wilhelm in England on December 4, 1866: "If the design is carried out correctly, the effects must be colossal. The matter is very capable of expansion, and may open up a new era in electromagnetism. [...] It will make magneto-electricity very cheap, while lighting, electroplating, and so forth – even small electromagnetic machines that obtain their power from larger ones – will become possible and useful." By that time, Werner von Siemens had already recognized the principal applications of power engineering and had named the fields that would become widespread by the time of his death. A few examples to show how rapidly this development advanced: In 1879, Siemens & Halske introduced the world's first electric railroad at the trade exposition in Berlin. The first electric street lighting followed in Berlin's Kaisergalerie. In 1880, came the first electric elevator in Mannheim and, in 1881, the world's first electric tram line in Berlin-Lichterfelde. There were no limits to the general public and private spread of electricity. In 1892, Siemens & Halske alone was building 1,000 dynamos a year and generating sales of nearly 20 million marks. The company had 6,500 employees worldwide, 4,775 of them in Germany.

As Werner von Siemens' own expectations (quoted above) about the dynamo machine also show, only one side of his work tends to be illuminated in the variety of publications that mainly emphasize his outstanding importance to the technical development of the electrical industry. It needs to be pointed out that he not only lent significant impetus to the then young field of electrical engineering through his inventions, but as a businessman, played a crucial role in the industry's advancement as well, even though for his own part he always claimed to see himself as a researcher and inventor, and had no particular sympathy or esteem for the business profession or, as he called them, the "money people."[10] Yet Werner von Siemens' success as an entrepreneur lay not simply in his ability to formulate fundamental technical discoveries, but rather in that as a researcher and a businessman, he was able to provide an intermeshed vision that extended all the way from an invention to marketable products and systems solutions. In this, he laid the foundations of a way for Siemens to view its business, in a tradition that continues even today: it might be called finding both technical and business applications for electricity in a universal sense, with an involvement in almost every field of electrical engineering and a presence in virtually every regional market in the world. Nevertheless, in the 1970s the company relinquished the principle of working in every field of electrical engineering and electronics. The difficult market conditions in the recent past have led the company to address the advancing integration of the world economy with a further concentration on its core operations and an optimization of its business portfolio.

It does not detract from Werner von Siemens' towering significance if one notes that in advanced age, his increasingly conservative, cautious and rather risk-averse business policies favored the rise of competitors and caused a relative weakening of Siemens & Halske's position in the 1880s. One contributing factor in this change was that Siemens & Halske's business policy aimed more for technical than commercial optimization, and its cautious expansion was based not least of all on the founding family's interests and financial capacity. Despite its technical leadership, in the 1880s Siemens & Halske, as a family firm with a relatively small capital base, could no longer compete in every sector with stock corporations like AEG. Since its inception, the electrical industry had had a tendency toward large-scale operations, and during this period the large capital demands of energy technology amplified that tendency still further.

In international operations, Werner von Siemens' aversion to delegating tasks and his severe distrust of anyone not belonging to the family became an increasingly serious handicap. Not until the last decade before the turn of the century did Siemens & Halske's corporate policy begin slowly to change, not least of all in response to the industry's changing operating conditions. One sign of the new direction was the transformation to a stock corporation, initiated in 1890 and completed in 1897 with significant cooperation from Deutsche Bank. In 1890, Werner von Siemens officially left the firm when it changed its form to a limited partnership, but he continued to exercise a defining influence. Only after his death in 1892 did the second generation of entrepreneurs – his sons Wilhelm and Arnold under the executive oversight of his brother Carl – set the course for Siemens & Halske to quickly make up for the gap that had opened between it and its competitors.

One hundred sixty years has passed since Siemens & Halske was founded. That time has seen immense political, social, economic and technical advances and changes. The company that Werner von Siemens and Johann Georg Halske founded still exists today, albeit with a different corporate structure. Siemens is thus one of the few corporate groups that has far exceeded what a study by the *Harvard Business Review*[11] found was the average lifespan for companies in Western Europe and the United States – 20 years. That study listed several characteristics that all long-lived companies seem to share and that might help explain their survival:

- A conservative financial policy
- A strong ability to learn, so as to adapt to the changing environment
- Openness and tolerance for new ideas
- Most importantly, a clearly marked, strong corporate culture
- And finally, a repertoire of visions that define the company's strategic orientation.

On the basis of these success factors, it is possible to identify central values in operation at Siemens that go back to Werner von Siemens. His entrepreneurial spirit still influences the strategy and policies of Siemens AG today. The following core elements of the company's corporate culture have been present right from the start:

- A high level of technical accomplishment
- A consistent flow of innovations
- Personnel and social policies in keeping with the times
- Internationalism – or what Werner von Siemens called "a world enterprise like that of the Fuggers"
- Solidity/long-term corporate strategy
- A conservative financial and investment policy.

These elements have changed very little in the 160 years since the company was founded. This is why it is so fascinating to study the historic roots of the company, and the inventive power and outstanding achievements of its founder, Werner von Siemens.

Conventions Used in this Edition

Werner von Siemens wrote his *Recollections* during the last three years of his life, from the summer of 1889 to the summer of 1892. The book was published in December 1892, shortly before his death. In the foreword, he noted he was motivated by the intention of preventing his efforts and achievements from "later being misjudged and falsely interpreted." He also hoped that his writings "would be instructive and stimulating for young people [...] and they could see that a young man without an inheritance and influential patrons, even without the right educational background, can rise in life and achieve something useful through his work alone."

In a highly attractive and lively style, Werner von Siemens set down a thrilling report of his event-filled life, during which he traveled to many countries and met with countless personalities of his day. His *Recollections* are not only an important document about the pioneering age of modern technology but also a valuable personal testimony about daily life and culture in the 19th century. They bring alive the conditions of life and work in an age when technological progress was changing human lives at a breathtaking pace and to a degree previously unimaginable. Werner von Siemens, whose inventions and application of innovative technologies made a decisive contribution to this development, regrets at the end of his *Recollections* "that it is not granted to me to continue working on the full development of the age of science." At the very end, he sums up with the words: "my life was beautiful."

While working on his *Recollections*, Werner von Siemens was told by a critic who had been given texts for correcting that the language and style he had used were too nonchalant and not refined enough. Siemens replied: "For me, the correct style of my recollections is less important than the fact that they reflect me, my feelings and my thoughts without adornment. [...] It is writing in a nightshirt and slippers, and it should also remain so; it shouldn't be a clumsy attempt at a carefully groomed and stylized official language!" The goal of the newly revised English edition is to keep the original and lively character of the *Recollections* in their author's spirit. This book is based on the 19th German edition of the *Recollections*, published in 2004 by Piper Verlag of Munich.

When the first edition of the *Recollections* came out in 1892, it immediately attracted considerable attention. Just one year later, the book was translated by William Chatterton Coupland and published by Asher & Co. in London. By 1986, the *Recollections* had gone through 18 editions in Germany. In the 16th edition, which appeared in 1956, Werner von Siemens' original text was for the first time accompanied by extensive footnotes, contemporary documents and illustrations. These supplementary elements were retained in the second English edition, which was published in 1966 by Percy Lund Humphries & Co. in London and by Prestel in Munich, as well as in the following two German editions. This English edition – the third – is based on the revised 19th German edition of 2004. Werner von Siemens' texts were editorially reworked from the 18th edition, the footnotes were brought up to date, and the layout was enhanced with additional illustrations. The current edition also contains an appendix written by Werner von Siemens as a supplement to his *Recollections*, in which he primarily discusses his later scientific and technical work. This appendix appeared in the first edition, but was omitted – for unknown reasons – in some of the later editions, including the second English edition.

The first edition of 1892 serves as the basis of the text presented here. This new English edition followed certain conventions: Spelling has been modernized to ease readability, while phonetics and grammar reflect the first edition. Special contemporary terms, such as used by the military, are also oriented to the first edition. Obvious errors have been corrected.

The footnotes, which have been revised and updated from the 19th edition, are provided to clarify the historical background of the main texts. The footnotes include explanations of facts, brief biographical information and more extensive comments on the technical developments discussed in the original text. Explanations necessary for understanding the text are placed in the margins beside the relevant passage. Terms which are explained more extensively in the appendix notes are printed in small capitals. In addition, the appendix also contains a genealogy of Werner von Siemens' parents, siblings and children. A chronology with biographical information about Werner von Siemens includes key facts and data from the life of the company founder. The index has been reorganized and lists places, names and subject matter. The bibliography has also been newly compiled and provides a more extensive listing of literature about Werner von Siemens and his work.

Notes

1 Wilfried Feldenkirchen, *Werner von Siemens: Inventor and International Entrepreneur,* Columbus, Ohio, 1994; Wilfried Feldenkirchen, *Siemens – From Workshop to Global Player,* Munich and Zurich, 2000.

2 The dial telegraph invented by Werner von Siemens – which no longer operated on a clockwork principle, but used a synchronously controlled signal between sender and receiver activated with a Wagner-Neefs key – was a fundamentally new solution for the electrical transmission of communications.

3 The term *electrical engineering*, which was intended to convey the idea of technical applications in the field of electricity, was coined by Werner von Siemens at the founding of the Electrotechnical Society in 1879.

4 Richard Ehrenberg, *Die Unternehmungen der Brüder Siemens,* Vol. 1: *Bis zum Jahre 1870,* Jena, 1906; Conrad Matschoss, *Werner von Siemens: Ein kurzgefaßtes Lebensbild nebst einer Auswahl seiner Briefe,* 2 vols., Berlin, 1916; Georg Siemens, *History of the House of Siemens,* 2 vols., Freiburg and Munich, 1957; Sigfrid von Weiher, *Werner von Siemens – A Life in the Service of Science, Technology and Industry,* Göttingen, 1975; Sigfrid von Weiher and Herbert Goetzeler, *The Siemens Company – Its Historical Role in the Progress of Electrical Engineering 1847–1980,* 2nd ed., Berlin and Munich, 1984.

5 Company founding charter of October 1, 1847 (Siemens Corporate Archives).

6 Jürgen Kocka, "Siemens und der aufhaltsame Aufstieg der AEG," In *Tradition*, vol. 17 (1972), 10.

7 Wilfried Feldenkirchen, "Die Firma Siemens im Russischen Reich vor 1914," In … *das einzige Land in Europa, das eine große Zukunft vor sich hat: Deutsche Unternehmen und Unternehmer im Russischen Reich im 19. und frühen 20. Jahrhundert,* ed. Dittmar Dahlmann and Carmen Scheide, Veröffentlichungen des Instituts für Kultur und Geschichte der Deutschen im östlichen Europa, vol. 8, 167–188, Essen, 1998.

8 Sigfrid von Weiher, "Die englischen Siemens-Werke und das

Siemens-Überseegeschäft in der zweiten Hälfte des 19. Jahrhunderts," *Schriften zur Wirtschafts- und Sozialgeschichte,* ed. Wolfram Fischer, vol. 38, 38ff., Berlin, 1990.

9 For the origins of the business with America, see Wilfried Feldenkirchen, "Die Anfänge des Amerikageschäfts von Siemens," In *Wirtschaft – Gesellschaft – Unternehmen: Festschrift für Hans Pohl,* ed. Wilfried Feldenkirchen, Frauke Schönert-Röhlk and Günter Schulz, 2 vols., Vierteljahrschrift für Sozial- und Wirtschaftsgeschichte, vol. 120 a/b, 876–900, Stuttgart, 1995.

10 Werner von Siemens established from the very beginning that the company primarily wanted to operate factories but not pursue venture activities, and justified this business principle in a letter to his brother William on November 11, 1876: "Products and services are the solid foundation of lasting business, while venture enterprises are fruitful only when the opportunities are especially favorable. A pure venture enterprise blooms [...] therefore only for a short while. A manufacturing and supply business can last for generations, and that is more to my taste."

11 Arie de Geus, "The Living Company," In *Harvard Business Review* (March/April 1997), 59.

PREFACE

Harzburg, June 1889

"The days of our life are threescore years and ten, or even by reason of strength fourscore years" – that is a serious admonition to one who is approaching the mean point between these limits, and who still has much to do! Speaking generally, we may indeed console ourselves with the thought that others will do what we ourselves have not been able to accomplish, that the world accordingly will be no permanent loser; but there are certain tasks in regard to which this consolation is of no avail, since the performance of them *can* devolve upon no other. Into this category falls the autobiographical narrative which I have promised my family and my friends.

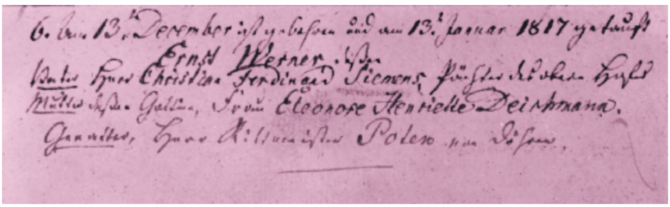
Werner von Siemens' country home in Harzburg. On the balcony: Werner and his second wife, Antonie. Undated.

I confess that the proposed undertaking has weighed heavily on my mind, being fully conscious as I am of possessing the talent neither of the historian nor of the man of letters, and having always had a more lively interest in the present and the future than in the past. Furthermore I do not have a good memory for names and dates, and not a few events of my tolerably changeful existence are utterly beyond recall. On the other hand, however, I am desirous of being my own chronicler, in order to preclude the possibility of future misunderstanding and misinterpretation of my endeavors and actions, and I have an idea also that it will be instructive and stimulating to the coming generation to be shown plainly how a young man, without inherited resources and influential supporters, nay, even without proper preliminary culture, may, solely through his own industry, rise and do something useful in the world. I shall not expend much thought on literary form, but shall jot down my recollections just as they occur to me, being only anxious that my statements may be clear and truthful, and my impressions and feelings faithfully reproduced. I shall, however, at the same time try to indicate those inner and outer forces which have borne me through weal and woe to the desired goals, and which have made my evening of life an easy and sunny one.

Here in my secluded villa at Harzburg I hope to find the necessary calm for such a retrospect, for amid the scenes of my active labors, in Berlin and Charlottenburg, I am too much beset by the demands of the hour to be able without interruption to devote any considerable time to reflection on my own past.

CHILDHOOD AND YOUTH

My earliest recollection is of an act of juvenile heroism, which perhaps imprinted itself so indelibly on my mind on account of its striking effect on the development of my



Werner von Siemens' birth recorded in the Lenthe church register.

character. My parents lived till I was eight in Lenthe, near Hanover, where I was born, and where my father farmed the estate (Obergut) of a Herr von Lenthe. I must have been about five years of age when, while I was playing one day in my father's room, sister Mathilde, my senior by three years, was led in, weeping copiously. She had been on her way to

The Lenthe estate near Hanover, where Werner von Siemens was born on December 13, 1816.

The vicarage in Lenthe. Drawing by Anton Scheuritzel.

the parsonage for her knitting lesson, but a dangerous gander, she complained, had barred her entrance into the parsonage yard, and had repeatedly snapped at her. Accordingly she stoutly refused, despite all her mother's coaxing, to repair to her lesson without a companion. My father, too, could not succeed in shaking her determination. At last he gave me his stick, which was considerably bigger than I was, saying: "Then Werner shall go with you, and I hope he has more courage than you have." At first that appeared to me somewhat questionable, as my father dismissed me with the injunction: "If the gander comes, just go toward him bravely and hit him soundly with the stick, then he will run away!" And so it turned out. When we reached the yard gate, the gander ran toward us with outstretched neck and terrible hissing. My sister turned tail, shrieking, and I was strongly tempted to follow suit, but I trusted my father's counsel and encountered the monster, with eyes shut indeed, but hitting out doughtily with the stick to left and right. And lo, fear seized the gander, and he returned cackling noisily to the flock of geese that had also taken to flight.

It is curious what a deep and lasting impression this first victory made on my childish mind. Even now, after well-

Christian Ferdinand Siemens (1787–1840), Werner von Siemens' father. Undated.

nigh 70 years, all the persons and surroundings associated with this important event stand clearly before my eyes. With it too is connected the only remembrance that remains to me of the appearance of my parents in their younger years; and numberless times in difficult situations the victory over the gander has unconsciously stimulated me, not to yield to threatening dangers, but to overcome them by a bold confrontation.

My father came of a family which had lived since the Thirty Years' War on the northern slope of the Harz mountains, and engaged for the most part in agriculture and forestry. An old family legend, which it is true is rejected as unproven by recent historians, runs that some venerable ancestor came to North Germany during the Thirty Years' War with the troops of Tilly, was present at the storming of Magdeburg, then married a citizen's daughter whom he had snatched from the flames, and settled in the Harz region. As is proved by the existence of a reliable genealogical tree, somewhat rare in middle-class families, the Siemens family has always shown a certain cohesiveness. In recent times the gathering taking place every five years in some place in the Harz mountains, as well as an institution founded in 1876, have contributed to the solidarity of a family now very widely distributed.

My father was very proud of his family, as were most of the Siemens, and often told us children of its members who had in some way or other distinguished themselves. Of these celebrities, except for my grandfather with his fifteen

The Wasserleben estate near Wernigerode. Drawing by Anton Scheuritzel. From 1777 to 1805, Werner von Siemens' grandfather had a leasehold on the estate from the Count of Stolberg-Wernigerode.

children, my father being the youngest, I remember only a military councilor, who held a position of authority in the council of the free town of Goslar at the time when the town lost its immediate connection with the empire. My grandfather had rented the estate of Reichsfreiherr von Grote, consisting of the manors Schauen and Wasserleben at the foot of the northern part of the Harz mountains. Wasserleben was my father's birthplace. Of the stories which my father loved to recount to us children, two have remained vivid in memory.

About 120 years ago, the petty court (Duodezhof) of Reichsfreiherr von Grote was startled by the intimation that King Frederick II of Prussia was about to trespass on the imperial-baronial domain in his march from Halberstadt to Goslar. The old baron awaited his powerful neighbor in befitting manner along with his only son, at the head of his customary contingent to the Imperial Army, consisting of two men, and accompanied by his vassals – my grandfather and his sons, all on horseback.

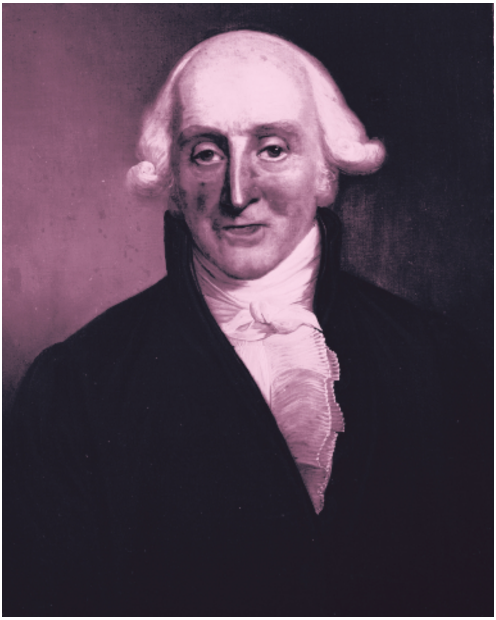
As Old Fritz with his mounted escort approached the boundary, the imperial baron rode a few paces to meet

The Schauen estate near Wernigerode. Drawing by Anton Scheuritzel. From 1762 to 1792, Werner's grandfather Johann Georg Heinrich Siemens held a leasehold and local magistracy here. The house is where Johann Georg Heinrich's son Christian Ferdinand was born on July 31, 1787.

him, and in due form bade him welcome "in his territorio." The king, in whose memory perhaps the existence of this neighboring realm had grown somewhat dim, appeared surprised at the greeting, returned the compliment, however, in proper form, and turning to his retinue remarked: "Messieurs, voilà deux souverains qui se rencontrent!" This caricature of old imperial glory has always remained in my memory, and very early kindled in us children the longing for future national unity and greatness.

There was another event of even greater importance for the miniature state of Grote than the foregoing. My father had four* sisters, one of whom, Sabine, was very amiable and beautiful: excellences which the young baron was not slow to perceive, and who accordingly offered her his heart and hand. The attitude the old Freiherr adopted in this crisis is unknown to me; but the young gentleman met with a decided rebuff from my grandfather. The latter was unwilling that his daughter should enter a family where she would not be treated as an equal, holding tenaciously to the opinion of his time, that bliss and blessing can only spring from a union of like and like. He forbade his daughter all

** Werner's father, Christian Ferdinand Siemens, had eight sisters, only five of whom reached adulthood.*



Johann Georg Heinrich Siemens (1735–1805), Werner von Siemens' grandfather. Undated.

further dealings with the young nobleman, and resolved to facilitate the same by removing her from under the parental roof. But the young folk evidently were seized by the spirit of the new era, and on the morning of the arranged departure my grandfather received the dire intelligence that the young baron had carried off his daughter the previous night. Whereupon there was great excitement and hot pursuit of the flown birds by my grandfather and his five grown-up sons. The trail of the fugitives was followed to Blankenburg and there ended in the church. When entrance had been effected the young couple was found stationed at the altar, where the pastor had just pronounced the nuptial blessing!

How the family drama developed immediately thereafter it is no longer in my ability to say. Unhappily, after a few blissful married years the young husband died without leaving any progeny. The barony of Schauen thereupon passed to collateral relations, together with the obligation to pay to Aunt Sabine for nearly half a century the statutory imperial-baronial widow's pension. While a young artillery officer, I often visited the amiable and sprightly old lady at Kölleda in Thuringia, whither she had retired. "Aunt Grote" was still beautiful even in her old age, and formed at that time the acknowledged center of our family. For us young people she possessed an almost irresistible charm, and it was a real delight to hear her speak of the persons and scenes of her early life.

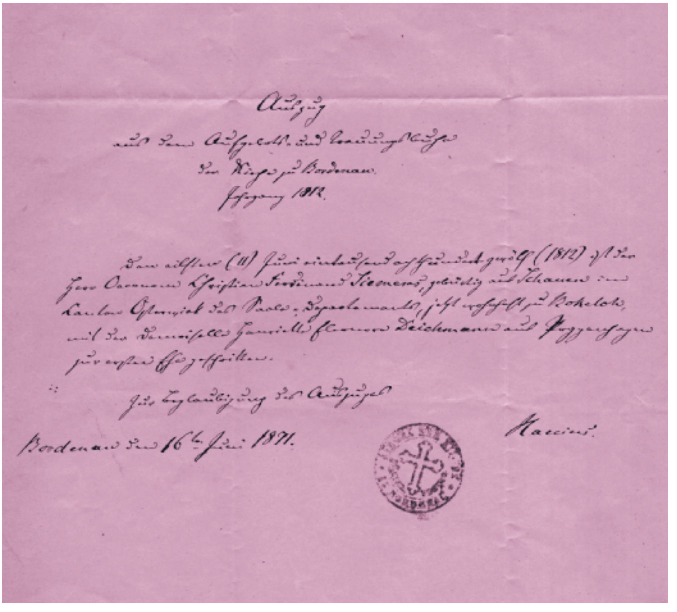
My father was a clever, well-educated man. He had attended the grammar school at Ilfeld in the Harz, and afterward the University of Göttingen, in order to prepare himself thoroughly for his chosen vocation as agriculturist. He belonged with heart and soul to that section of young Germany which, growing up amid the storms of the great French Revolution, was enthusiastic for freedom and a united fatherland. Once, in Cassel, he had almost fallen into the clutches of Napoleon's myrmidons, when taking part in the weak attempts of certain visionary youths who still strove to offer resistance after the prostration of Prussia. On his father's death he went to councilor (Amtsrat) Deichmann at Poggenhagen, near Hanover, for practical training in agriculture. There he quickly fell in love with the Amtsrat's eldest daughter, my beloved mother, Eleonore Deichmann, and his youth notwithstanding – he had hardly attained the age of 25 – married her after obtaining the lease of the Lenthe estate for farming. For twelve* years my parents enjoyed a happy life in Lenthe. Unfortunately, however, the political condition of Germany and especially of Hanover, then again under English rule, was very depressing to a man like my father. The English princes, who then kept court at the Hanoverian capital, troubled themselves but little about the welfare of the country, which they regarded chiefly as a hunting ground. The game laws were in consequence very strict, so that it was a common remark that in Hanover to kill a stag was more criminal than to kill a man! A charge of damaging game, through the use of unlawful means for protecting his property, was the cause of my father leaving Hanover and seeking a new home in Mecklenburg.

** The family lived in Lenthe for just ten years, from 1813 to 1823.*

The Lenthe estate (Obergut) is situated on a wooded ridge, the Benthe mountain, which joins on to the extended Deister range. The stags and wild boars, preserved for the royal chase and secure in their inviolability, visited the Lenthe fields in large herds with unmistakable predilec-

The Poggenhagen estate in 1988. Werner von Siemens' maternal grandfather, local magistrate Ludwig August Deichmann (1768 – 1819), had the leasehold on the main house of the Poggenhagen manor near Neustadt am Rübenberge. Here Werner's mother Eleonore spent her childhood.

tion. Although the entire village exerted itself to protect the crops by a nocturnal chain of guards, yet the game issuing forth en masse often annihilated in a few hours hopes based on the work of a whole year. In a severe winter, when wood and field failed to afford the animals sufficient sustenance, they frequently foraged in complete herds in the villages themselves. One morning, the bailiff announced to my father that a herd of deer had got within the farm enclosure; the gate had been shut, and he wanted to know what should be done with the animals. My father gave orders that they should be driven into a stable, and sent an express messenger to the Royal Supreme Court Hunting Bureau in Hanover with a notice of what had happened and the inquiry whether it pleased that the deer should be sent to Hanover. That, however, turned out to be a most unlucky business for him! After a very short interval there appeared on the scene an imposing commission of investigation, which liberated the



The marriage of Christian Ferdinand Siemens and Eleonore Henriette Deichmann (1792 – 1839) in 1812. Extract from the Bordenau church register, transcribed in 1871.

stags, and after a criminal inquiry of several days arrived at the conclusion that violence had been offered to the creatures, inasmuch as they had been driven into the stall against their will! And my father had to think himself lucky that he got off with a heavy fine.

This is a brief account of the then condition of the "Royal Hanoverian Province of Great Britain," as my dear countrymen were pleased with a certain pride to call their country. But even in the other German lands the state of things was not much better, in spite of the French Revolution and the glorious War of Liberation. It were well if the relatively fortunate youth of the present day now and again compared their own condition with the woes and often hopeless cares of their fathers, as a prophylactic against pessimistic ideas and fancies. The freer surroundings which my father sought he really found in the principality of Ratzeburg appertaining to Mecklenburg-Strelitz, where he obtained a lease of

The farmhouse of the Menzendorf estate near Schönberg in Mecklenburg, 1910. Werner's brothers Friedrich, Carl, Franz, Walter and Otto and his sister Sophie were born here.

THE GRAND-DUCAL DOMAIN OF MENZENDORF for a lengthy period. Apart from domains and peasant villages, in this heavenly little place there was only a single nobleman's estate. It is true the peasants on the domains were still bound to services appertaining to socage tenure, but in the years immediately following our arrival these were abolished, and the holdings of the peasants were freed from all burdens and even from almost all imposts.

The childhood years of my brothers and sisters were happy ones in Menzendorf, growing up among the village youth tolerably free and unrestrained. At first we older children – my sister Mathilde, my younger brothers Hans and Ferdinand, and I – roamed unhindered through the woods. Our instruction was undertaken by my grandmother, who lived with us after her husband's death. She taught us reading and writing and exercised our memories by compelling us to learn by heart innumerable poems. Father and mother were too occupied with their economic cares, and the latter also with the rapidly increasing flock of my younger brothers and sisters, to be able to concern

View of the town of Menzendorf, around 1910. The young Werner lived in Menzendorf from age 7 to 16. His father leased the Menzendorf estate from 1823 to 1840.

themselves much with our education. My father was a thoroughly good-hearted but also hot-tempered man, who punished unfailingly if any of us did not do our duty, were untruthful or guilty of a dishonorable action. Fear of our father's wrath and affection for our mother, whose sorrow we never occasioned intentionally, kept our little band, otherwise somewhat unruly, in good order. The care of the elder for the younger children was prescribed as a primary duty. In fact it reached so far that the seniors were punished with their juniors, if the latter ever rendered themselves liable to punishment. The said burden weighed especially upon me as the eldest, and awakened and confirmed in me at a very early age the feeling of obligation to care for my more youthful brothers and sisters. Accordingly, I assumed the right to set the penal law in motion in respect of my juniors, which not infrequently led to counter-coalitions and violent combats. These, however, were always fought out without invoking the intervention of our parents. I call to mind an incident of that time, which I will relate, as it is characteristic of our youthful life.

Ferdinand Siemens (1820 – 1893). Undated.

It was the habit of my brother Hans and myself to assail, and not in vain, crows and birds of prey with self-fabricated cross-bows in the use of which we attained great proficiency. One day, a dispute having arisen in connection with the chase, I took the liberty of exercising the right of the stronger. My brother declared this to be base, and demanded that the dispute should be settled by a duel, in which my superior strength would give me no advantage. I found that equitable, and we proceeded to a crossbow duel, correct according to the rules which we had learned from occasional stories of my father of his student life. Ten paces were measured off, and at my word of command "Now!" we both discharged at one another our feathered arrows with knitting needles for heads. Brother Hans had aimed well. His arrow hit the tip of my nose and penetrated under the skin. Our joint outcry brought our father on the scene, who pulled out the arrow and thereupon prepared to chastise the delinquent by taking out his pipestem. This conflicted with my feeling of rectitude. I stepped between my father and Hans and said: "Father, it isn't Hans's fault, we have been fighting a duel." I still can see the puzzled face of my father, who in justice could not punish an activity which he had engaged in himself and considered honorable. He quietly replaced the pipestem in the bowl, adding only: "In future leave such nonsense alone."

Hans Siemens (1818–1867). Undated.

When my sister and I outgrew the tuition of grandmother Deichmann – née von Scheiter, as she never forgot to sign herself – my father undertook our instruction for six months. The outline of universal history and ethnography, which he dictated to us, was spirited and original, and formed the foundation of my later knowledge. When I had reached the age of eleven my sister was sent to a boarding school at Ratzeburg, while I attended the grammar school in Schönberg, the market town neighboring Menzendorf. In fine weather I had to cover a distance of something like three miles on foot. In wet weather the pathways were impassable, and I rode to school on a pony. This, and my habit of always being a match for practical jokes, soon led to chronic feuds with the town scholars, through whose midst I generally had to force a way, lance (i.e., beanpole) in hand. This tourney, in which the farm lads of my village sometimes assisted me, continued for a whole year. It certainly contributed a good deal to strengthening my powers of action, though it yielded only very indifferent scientific results.

A decisive turning point in my life occurred at Easter 1829, when my father engaged a private tutor. The choice was an exceedingly fortunate one. Sponholz, candidate of theology, was still a young man. He was highly cultured, but in bad odor with his spiritual superiors, his theology being too rationalistic, too little positive, as one would say nowadays.

He contrived, even in the first weeks, to obtain a power over us semisavage youths which is mysterious to me to this day. He never punished us, hardly ever uttered a word of blame, frequently shared in our games, however, and through the medium of play even had the knack of calling forth our good qualities and repressing our bad ones. His teaching was stimulating and encouraging in the highest degree. He understood how to set up really attainable goals for our labors, and strengthened our energies and our ambition by his delight at the attainment of the proposed goal, which he himself frankly shared with us. Thus he succeeded in a very few weeks in making out of unruly lazy boys the most eager and industrious scholars, whom he had not to urge to work, but rather to keep from attempting too much.

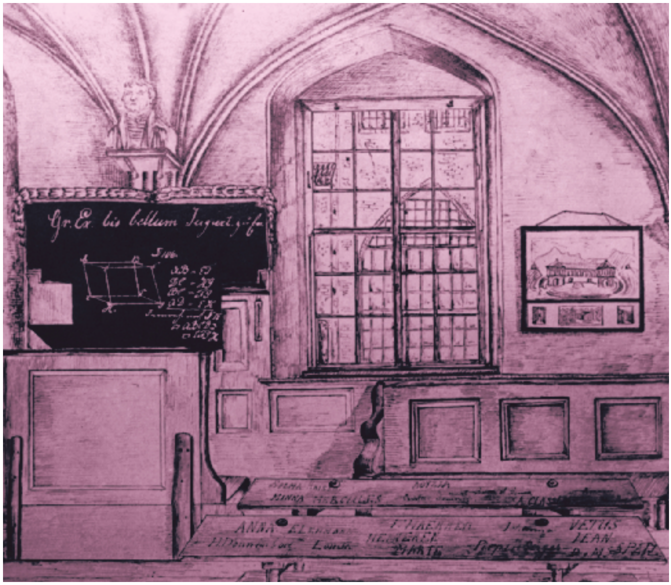
In me, especially, he awakened an inextinguishable feeling of delight in useful work and the ambitious desire actually to perform it. An important expedient employed by him for this purpose was his stories. If late in the evening our heads began to nod over our work, he would beckon us to him on the leather sofa where he used to sit beside our worktable, and while we clung to him paint us pictures of our own future. These either represented us at the heights of civil life, which we had scaled through industry and moral fitness, and which enabled us to lessen the cares of our parents – very considerable in that time of great agricultural difficulty – or depicted our wretched fate, if we relaxed in our efforts, and were unable to resist temptation to evil.

Unfortunately, this happiest period of my boyhood did not last long, not even a full year. Sponholz often had attacks of deep melancholy, which probably arose in part from his mistaken theological calling and career, in part from causes which were unintelligible to us children. During one such attack he left the house on a dark winter's night, gun in hand, and after a prolonged search was found in a remote part of the estate with a shattered skull. Our grief at the loss of our beloved friend and teacher was boundless.

The "Bürgerschule" in Schönberg. Undated. Werner von Siemens attended this school from June 1828 to Easter 1829.

My own love and gratitude to him I have retained to the present day.

Sponholz's successor was an elderly gentleman who had for years filled the office of private tutor in noblemen's families. He was in almost all respects the reverse of his predecessor. His educational system was of a wholly formal character. He required that before all things we should be docile and mannerly. He was especially averse to anything boisterous. We had to be attentive and do our tasks at the prescribed times, accompany him with decorum in our walks, and not disturb him out of school hours. The poor man was sickly, and after two years died of consumption in our house. He certainly did not exert a stimulating and molding influence, and had it not been for the previous training of Sponholz, whose effect was enduring, the two years would have been pretty well thrown away, at least as far as my brother Hans and I were concerned. As for me, the desire to do my duty and to learn thoroughly had become



A classroom in the St. Catherine's School in Lübeck, the secondary school attended by Werner von Siemens and his brothers.

so engrained, thanks to Sponholz, that far from my ardor being dampened I rather set the pace for my tutor. Years later, the thought has often given me a pang that I so often robbed the poor sick man of his needed rest by remaining after the end of lessons for hours together at my desk, quietly ignoring all the little devices he employed to be rid of me.

On the death of our second tutor, my father determined to send brother Hans and myself to the Lübeck grammar school, the so-called St. Catherine's School, and carried out the plan after my confirmation in the parish church at Lübsee. As a result of the entrance examination I was put in the upper, and my brother in the lower, fourth form. We were placed in no regular boardinghouse, but lodged with a Lübeck citizen who at the same time boarded us. My father had such an unbounded faith in my trustworthiness that he also gave me custody of my somewhat giddy brother, whose lawless nature had again come to the surface, as is evident from the nickname given him by the school, "mad Hans."

St. Catherine's School, Lübeck, consisted of the grammar school proper and the city school, both under the same headmaster and having similar classes as far as the fourth form of the grammar school. The latter at that time enjoyed considerable scholastic repute. The instruction was mainly confined to the dead languages. The teaching in mathematics was extremely defective and did not satisfy me; in this subject I was put into a higher class, although up to that time I had only worked at mathematics by myself, as neither of my tutors knew anything of it. The ancient languages on the other hand gave me a great deal of trouble, through lack of thorough grounding. Much as the study of the classics interested and excited me, the acquisition of the grammatical rules, which offered no material for thought and positive knowledge, was distasteful to me. In the two following years, I conscientiously worked myself up to the highest form, perceived, however, that I should never find satisfaction in the study of ancient languages, and resolved to devote myself to architectural engineering, at that time the only technical branch. Accordingly, in the fifth form I dropped the study of Greek, and instead took private lessons in mathematics and land surveying, in order to prepare myself for entrance into the Bau-Academy at Berlin. On further inquiry, however, it unhappily appeared that the course at the Academy was too expensive (at a time of ever-increasing difficulty in agriculture, when the selling price of wheat was a florin per bushel) to allow of my imposing so great a sacrifice upon my parents, having regard to the interests of my younger brothers and sisters.

Werner to Carl, December 25, 1887

. . . From my young days it has always been my ambition to found an enterprise of world standing comparable to that of the Fuggers [ed. note: German family dynasty of the late Middle Ages], which would give not only me but my successors power and authority in the world and also provide the means to a better life for my brothers and sisters and close relatives. This sentiment originated from our tutor Sponholz, who goaded us lazy youngsters to energetic diligence by stories in which we regularly saw ourselves in a position to eliminate all the troubles of our parents at one go. This feeling remained with me and was reinforced by the turn of fate which placed on me the responsibility for the care of my younger brothers and sisters . . .

The schoolyard of the St. Catherine's School in Lübeck. Drawing by Anton Scheuritzel.

In these straits I found relief in the advice of my preceptor in land surveying, Freiherr von Bülzingslöwen, lieutenant in the Lübeck contingent, who had formerly served in the Prussian Artillery. He advised me to join the Corps of Engineers, where I should have the opportunity of acquiring the same knowledge as a student of the Academy of Architecture. When I confided this plan to my father, he at once consented, giving an additional important reason in its favor, the truth of which has been clearly demonstrated by recent German history. He said: "The present condition of things in Germany cannot possibly last. A time will come when everything will be turned topsy-turvy. The only fixed point in Germany is, however, the state of Frederick the Great and the Prussian Army, and in such times it is always better to be hammer than anvil." Accordingly, at Easter 1834, in my seventeenth* year, I left the grammar school, and repaired with a very moderate supply of money in my pocket to Berlin, in order to place myself among the hammers of the future.

** Werner von Siemens was already 18 at Easter 1834.*

MILITARY SERVICE

When the painful leave-taking of the old home, of my deeply loved but overburdened and ailing mother, and my numerous brothers and sisters affectionately clinging to me had been accomplished, my father took me to Schwerin, and from there I embarked on my pilgrimage. After I had crossed the Prussian frontier and found myself on a straight and dusty road in the midst of a treeless and barren sandy plain, I was overcome by a feeling of terrible loneliness, which was intensified by the melancholy contrast between the landscape and the scenery with which I was familiar. Before my departure, a deputation of the most respected peasants of the place had presented itself to my father with the petition not to send “so good a lad” to that famine-stricken land Prussia; I should always find plenty to eat at home! The peasants would hardly credit my father that beyond the desolate sandy borders there lay also fertile land in Prussia. Despite my firm resolve to seek my advancement in the world through my own efforts, it did indeed for a moment seem as if the peasants were right and I was wending my way toward a sorry future. It was therefore some consolation when I met in my journeying a cheery and cultivated young man, who, like me, was tramping knapsack on back toward Berlin. He was no stranger there, and proposed that I should go with him to his inn, which he greatly praised.

It was the buttonmaker’s inn in which I took up quarters for my first night in Berlin. The host soon perceived that I did not belong to his regular patrons, and accorded me his goodwill. He protected me from the tricks of the young buttonmakers, and assisted me on the following day to discover the address of a distant relative, Lieutenant von Huet, who belonged to the Horse Artillery of the Guards. Cousin Huet received me kindly, but was seized in mortal terror when he heard I had put up at the buttonmaker's inn. He at once gave orders to his servant to fetch my knapsack from the inn and to engage a room for me in a small hotel in the new Friedrichstrasse. He also offered, after the necessary improvement of my toilet, to proceed with me to General von Rauch, the chief of the Corps of Engineers, and to inform him of my desire.

The general strongly dissuaded me, since, as so many cadets were already waiting for their call to the Artillery and Engineering School, I could not hope to gain entry in less than four or five years. He advised me to try the Artillery, whose cadets attended the same school as the engineers and who had considerably better prospects. I accordingly made up my mind to try my luck in the Artillery, and as there was no question of joining the Guards, I obtained an introduction from Lieutenant von Huet's father, colonel on the retired list, to Colonel von Scharnhorst, commander of the 3rd Artillery Brigade, and proceeded blithe of heart to Magdeburg.

Ludwig Siemens (1819–1892), known as Louis. Undated.

The colonel – a son of the celebrated organizer of the Prussian Army – also made sundry difficulties at first, remarking that applications for cadetships were very numerous, and that of the fifteen young men who had already offered themselves, he could take only the four who should pass out top in the examination. Finally, however, he acceded to my request, and promised to admit me to the examination, provided His Majesty the King was pleased to allow me, although a foreigner, to enter the army of Prussia. My frank, resolute bearing evidently took his fancy; but most influential perhaps was the fact that he saw from my papers that my mother was a Deichmann of Poggenhagen, which adjoined his father's estate.

As the entrance examination was not to take place till the end of October, I still had three months for preparation. I therefore moved to Rhoden on the northern slope of the Harz, where a brother of my father owned some property, and there spent a few weeks with my relations, of whom the two pretty and amiable grown-up daughters in particular made a great impression upon me; I willingly allowed them to exercise their refining influence on their young and still somewhat unpolished cousin. Then I went with my cousin Louis Siemens, my junior by a few years, to Halberstadt, where I prepared myself in good earnest for the entrance examination.

The syllabus of the examination placed in my hands by Colonel von Scharnhorst caused me a good deal of uneasiness. In addition to mathematics were history, geography and French especially required, and at the Lübeck grammar school these subjects had only been taught in a very superficial manner. I could scarcely hope to make good my deficiencies in a couple of months. There was still wanting my discharge from the Mecklenburg military service, which my father would have to purchase, and the permission of the King to enter the Prussian

Your Most Gracious Grand-Duke and Lord!

I most humbly beg Your Royal Highness to permit my second son, Ernst Werner Siemens, seventeen years old, to enter the Prussian engineer or artillery service and will myself accept any condition which Your Highness may wish to impose.
My son, who is not without talent, has studied with great diligence to become a mathematician and it is quite impossible for me to procure for him a suitable education in any other way. When he presents himself on the first of October next he is required to produce permission from his Sovereign. I venture to state that if his wish is not fulfilled he has no prospect of following his chosen career and irreplaceable years would be lost. I can only hope, therefore, for the gracious permission of Your Royal Highness.
Your Royal Highness's most humble servant

C. F. Siemens,
Tenant of Menzendorf

Menzendorf, September 1, 1834

Army. It was with a heavy heart, therefore, that toward the middle of October I marched to Magdeburg, where I was disappointed at not finding the expected letter from home along with the necessary papers. When, nevertheless, at the prescribed hour I was just about to start for the examination, to my great and joyful surprise I was met by my father, who had himself driven over to Magdeburg in a light conveyance, in order to deliver the papers into my hands by the right time, as the post in those days was far from expeditious.

The examination took a favorable course for me from the commencement, and beyond my expectation. In mathematics I was decidedly ahead of my fourteen competitors. In history I had luck, and got off tolerably well. In modern languages I was certainly weaker than the others, but my better knowledge of the ancient languages made up for it. The outlook was worse in geography; I soon perceived that most of them knew more of the subject than I did. But here I was favored by a particularly lucky coincidence. The examiner was a certain Captain Meinicke, who had the reputation of being a very learned and at the same time original man. He passed for a great connoisseur of Tokay wine, as I afterward learned, and that was perhaps the reason for his curiosity regarding the location of Tokay. No one knew, whereupon he waxed very wrath. When my turn came last of all, by good hap it occurred to me that Tokay wine had once been prescribed for my invalid mother, and that it had also borne the name of Hungarian wine. At my answer "In Hungary, Captain!" his face brightened up, and with the exclamation "But, gentlemen, you must surely know Tokay wine!" he gave me the highest mark in geography.

So I was one of the fortunate four who passed out top in the examination, but I still had to wait four anxious weeks for the royal permission to enter the army, and when at the end of November it arrived, I could not immediately be admitted, because I had only been born on December 13, 1816, and so had not yet reached my seventeenth* year. I was, however, allowed a special drill sergeant, who vigorously drilled me in civilian dress in the cathedral square.

* *The author means his 18th birthday.*

My performance soon gained the approval of the strict bombardier, although there was one point which almost drove him to despair. I had extremely curly light-brown hair, which absolutely refused to conform to military regulations. These required that the hair should lie evenly on the temples. On inspection day the captain had expressed displeasure at the disorderly hair of the recruit, and as a result every conceivable means was tried to conceal in a measure this military blemish. The sediment of a favorite Magdeburg beer seemed to be most effective. I was obliged to order many a bottle for the purpose, as unfortunately only the sediment could be of any use to me. After repeated applications I succeeded in rendering my hair tolerably smooth, but after an interval it showed symptoms of revolt, and, usually on parade, to the horror of the bombardier, certain rebellious locks persisted in protruding from the even layer.

Despite the great exertions, and the rough and apparently harsh treatment at the hands of the drill sergeant, I still look back with pleasure to my time as a recruit. The roughness is sheer habit and does not spring from intention to inflict pain. It therefore does not go very deep; on the contrary it has something refreshing and stimulating about it, especially if combined with humor, as has almost always been the case with the models of military harshness known to fame. The service over, the incivility is forgotten and the feeling of comradeship is again uppermost. The feeling of comradeship which pervades the entire Prussian Army from king to recruit renders endurable the strict discipline, the toils and hardships reaching often to the extreme limits of endurance, and constitutes its cementing bond in good times and bad. It will, accordingly, often be very hard for the military veteran to feel comfortable in civil life; he misses therein the toughness and the good fellowship.

After six months' drill came the great event of advancement to the rank of bombardier. It was an elevating feeling now to be the superior of hundreds and thousands and to be duly saluted by every private. Then followed the transfer to the Horse Artillery, then the interesting artillery practice, in which for the first time I became aware of my technical abilities, since what most found hard to comprehend appeared to me a matter of course. Lastly, in the autumn of 1835, I received the longed-for order to attend the united school of artillery and engineers in Berlin, and therewith the fulfillment of my ardent desire to have an opportunity to learn something useful.

The three years which, from the autumn of 1835 to the summer of 1838, I spent at the Berlin ARTILLERY AND ENGINEERING SCHOOL I reckon to be the happiest of my life. The social life with young people of the same age and with the same aims, the common study under the guidance

The Royal Artillery and Engineering School in Berlin, around 1829. Here Werner von Siemens acquired a thorough scientific and technical training, 1835 – 1838.

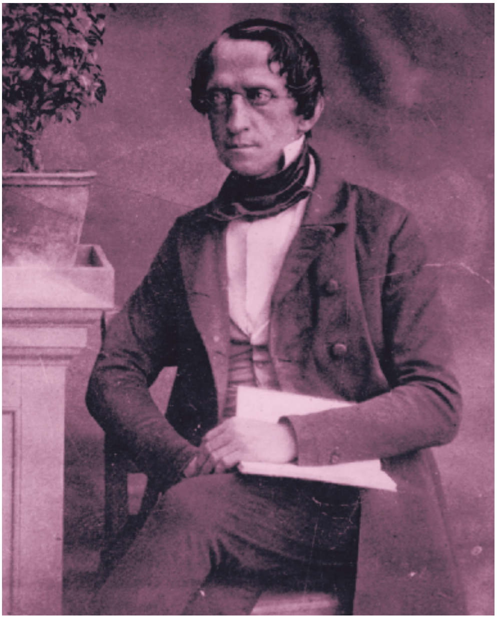
of able teachers, of whom I will mention only the mathematician Ohm, the physicist Magnus, and the chemist Erdmann, and whose instruction opened to me a world new and full of interest, made this time one of extraordinary enjoyment. In addition, I found in one of my comrades in the brigade, William Meyer, a real friend, with whom till his death I was united by the bond of the closest and completest friendship. I had before, at the Lübeck grammar school, entered on the first stage of such an intimate friendly alliance, and imagined I had found in a fellow pupil a genuine friend, but when I called upon him one day he gave orders to say he was not at home, although I was perfectly sure that he was in the house and concealing himself from me. That appeared to me such an unpardonable breach of proper friendship that I severed the tie with intense pain, and could never again bring myself to treat him as a friend.

I got to know William Meyer when the Horse Artillery was stationed at Burg, whither he had been ordered before me. He had a far from imposing figure, was in no respect distinguished or talented, but possessed a clear understanding, and pleased me from the first by his straightforward, unaffected nature, and his unimpeachable sincerity and trustworthiness. We chummed together at the school, lived and studied together, had the same quarters then and thenceforward, whenever circumstances allowed of it. Our conspicuous friendship and the circumstance that I revolted against the "tyranny of the ensigns," which led to a duel with the senior of

Lieutenant's commission

Whereas His Royal Majesty of Prussia, our most gracious King and Lord, has graciously decided to promote the Ensign in the 3rd Artillery Brigade, Ernst Werner Siemens, to Second Lieutenant and to appoint him to the aforesaid Brigade; so the All-Highest does the same herewith and by virtue of this Commission so that he may serve His Royal Majesty and His Royal House faithfully, devotedly and obediently, may do and perform his duty in a manner befitting his rank faithfully and diligently by day and night, may bear himself bravely and honourably in all circumstances, in times of war, but otherwise shall enjoy all prerogatives and rights associated with his rank. In witness whereof the All-Highest has authorized this Commission to be impressed with His Seal.

Thus effected and given
Berlin, September 29, 1837



Carl Himly (1811–1885), Professor of Physics at Göttingen, Professor of Chemistry at Kiel from 1846 onward. Undated.

my room, in which Meyer acted as my second, had the curious result that in almost all the duels which occurred in the first year at the school, Meyer and I were chosen as seconds of the opposing parties.

These duels were only in a few instances followed by dangerous consequences, and had a very useful effect in that they tended to preserve a polite tone in social intercourse.

Our year was the first in which the cadets were admitted in limited numbers after a pretty stiff entrance examination, and were then ordered to the school on completion of their year of service. Before that, no difference was made between the rank of commissioned and noncommissioned, and it was then often only after the lapse of several years of service, which in part had to be spent in barracks, that the ablest or perhaps the best recommended were ordered to the school. The somewhat unpolished tone which had clung to the young fellows through prolonged intercourse with unrefined comrades was most effectively and quickly corrected by means of the duels.

My three years at the military school passed without any important events. Although I suffered much from attacks of intermittent fever, and once was obliged to lie several months in hospital on account of an injury to the shin, yet I contrived to pass successfully the three examinations – the ensign, the army officer and finally the artillery officer examination, although without special distinction. I had with unremitting endeavor crammed the required matter into my head in order afterward to forget it as quickly again, but had devoted all my spare time to my favorite sciences, mathematics, physics and chemistry. The fondness for these sciences has remained all through my life, and has been the root of my subsequent achievements. Great was the joy when, the school course completed, I received four weeks' leave to visit my home along with my friend Meyer. My brothers and sisters, whose number had risen to ten, and even my parents, hardly recognized me.

The whole village rejoiced with them on the return of the "Muschü," the traditional title of the sons of "the Manor." There were really touching meetings with the worthy people of our own and the neighboring villages, who for the rest had great respect for the Prussian officers, in whom certainly they perceived no signs of Prussia's starving condition.

My elder sister, Mathilde, was just celebrating her marriage to Professor Carl Himly from Göttingen, who remained a dear friend of mine until his death. Hans and Ferdinand had become farmers. My third younger brother, William, was at the school at Lübeck and was destined for

Carl Himly and his wife Mathilde, née Siemens (1814 – 1878), with their children. Undated.

Friedrich Siemens (1826–1904), around 1866.

commerce. The next two, Friedrich and Carl, likewise attended the Lübeck School, where they boarded with a younger brother of my mother, Ferdinand Deichmann, a merchant.

That William was to be a businessman didn't at all please me. At that time I shared the aversion of Prussian officers to the mercantile class, while William's somewhat reserved but intelligent nature and his clear understanding particularly attracted me. I accordingly begged my parents to let him accompany me to my future garrison town, Magdeburg, that he might attend the highly esteemed School of Trade and Commerce in that city. My parents consented, and so we took him with us to Magdeburg, where I installed him in a small boardinghouse, having myself to spend the first year in barracks according to the regulations.

At the end of this year, which I had to devote entirely to strict military service, friend Meyer and I took up our quarters in the town, and I brought William, now sixteen years of age, to reside with me. I took a paternal delight in watching his rapid development, and helped him with his school tasks in my leisure hours. I also induced him to give up the unsatisfactory lessons in mathematics at the school and to learn English instead. This turned out very important for his future career. I myself gave him mathematical instruction every morning from

Note by the Section Commander concerning Werner von Siemens:

… He combines excellent moral qualities with commendable zeal and good scientific knowledge …

From the conduct reports of the officers of the 3rd Artillery Brigade, 1839

Carl von Siemens (1829–1906), around 1860.

5:00 to 7:00, and was rewarded by the particularly good examination he afterward passed in that subject. For my part, this tuition was of great utility, and it also made it easier for me to resist the temptations of an officer's life, as well as stimulating me energetically to continue my scientific studies.

Unhappily, this fraternal intercourse was much troubled by the increasingly ominous communications from my father regarding the health of our beloved mother. On July 8, 1839, she succumbed to her malady, leaving my father, himself ailing, in a very doleful condition, weighed down with sorrow and serious material cares, together with numerous children still to be educated. I forgo the description of the poignant grief at my mother's loss. The love for her was the strong tie that held the family together, and the fear of distressing her always formed for us children the most effective guarantee for our good behavior.

I received a brief leave to visit our home and my mother's grave. Unhappily, the enfeebled health of my father inspired me with but little confidence in the duration of a regular family life, favorable to the prosperity and development of the younger members. The correctness of my foreboding was only too soon confirmed. Barely six months later, on January 16, 1840, we also lost our father.

On the death of our parents, guardians for the younger children were appointed by the court of ward, and the management of the domain of Menzendorf was entrusted to my

Wilhelm (Sir William) Siemens (1823 – 1883), around 1847.

brothers Hans and Ferdinand. My youngest sister, Sophie, was adopted by uncle Deichmann in Lübeck, while the youngest brothers, Walter and Otto, remained for the present under my grandmother's care in Menzendorf.

The scientific-technical studies to which I now devoted myself with increased ardor almost had very serious consequences in the following summer. I had heard that my cousin, the Hanoverian artillery officer A. Siemens, had made some successful experiments with friction tubes, which were intended to be used for the firing of cannon in place of the hand fuses then exclusively employed. The importance of this discovery was evident to me, and I resolved myself to make experiments in this direction. As the flammable materials employed did not act with sufficient certainty, in the absence of better implements I stirred up together an aqueous solution of phosphorus and chlorate of potash in a pomatum bowl with a very thick bottom, and as I had to go to the drill ground, placed the bowl, carefully covered, in a cool window corner.

When I returned and looked with some anxiety for my dangerous preparation, to my satisfaction I found it still in the same corner. But on carefully taking it up and barely touching the match standing in the paste, which had served to stir up the mixture, a violent explosion took place, which hurled the shako from my head and shattered all the windowpanes, together with their frames. The entire upper part of the porcelain bowl was scattered about the room in the form of fine powder, while its stout bottom was wedged firmly into the windowsill.

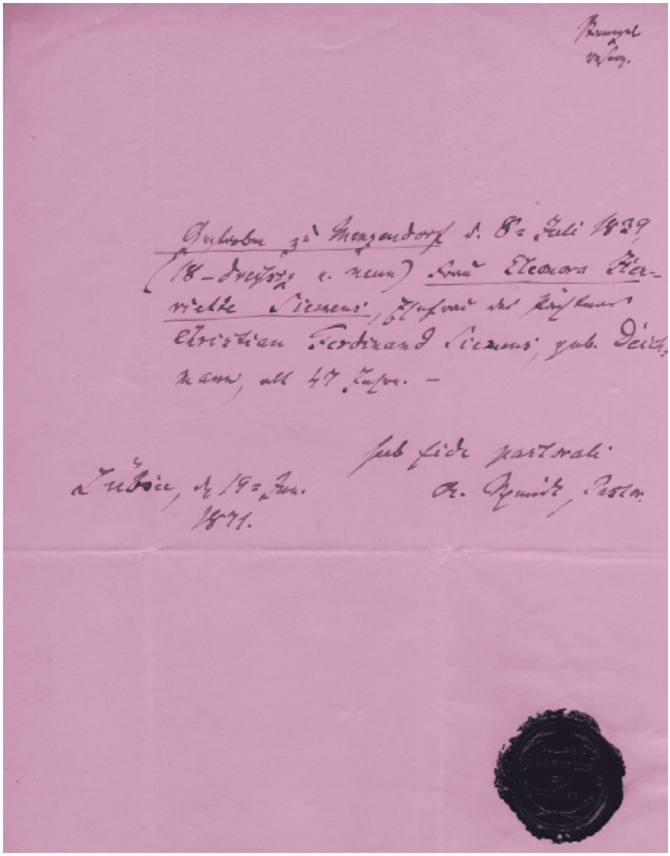
The cause of this altogether unexpected explosion turned out to be this: that my man on cleaning the room had placed the vessel in the oven, and let it dry there a few hours before putting it back in its place. Strange to say, I was not visibly wounded, though the violent pressure of the air had so contused the skin of my left hand that the forefinger and thumb were covered by a large hematocystis. Unfortunately, however, the drum of my right ear was fractured, which I immediately

I hereby request and authorize Lieutenant Werner Siemens of the 3rd Artillery Brigade of the Royal Prussian Army in Berlin to take over my rights and obligations with respect to his 3 brothers, August Friedrich Siemens, Carl Heinrich Siemens, Ferdinand Walter Siemens, who have been handed over to him for his special supervision and for their further education so that he may arrange what is necessary for the education of these persons committed to my charge, direct their occupations and give the necessary permission for any holiday travel and generally undertake the care of these his brothers according to the obligations which I myself would perform if I were personally in Berlin. I hereby give my full approval in advance to anything which Lieutenant W. Siemens may do in this respect.

J. G. Ekengren as legally appointed guardian of the children of the late tenant Siemens of the domain of Menzendorf

Warsaw, November 10, 1845

A copy of the death certificate of Eleonore Henriette Siemens, née Deichmann, dated July 8, 1839.

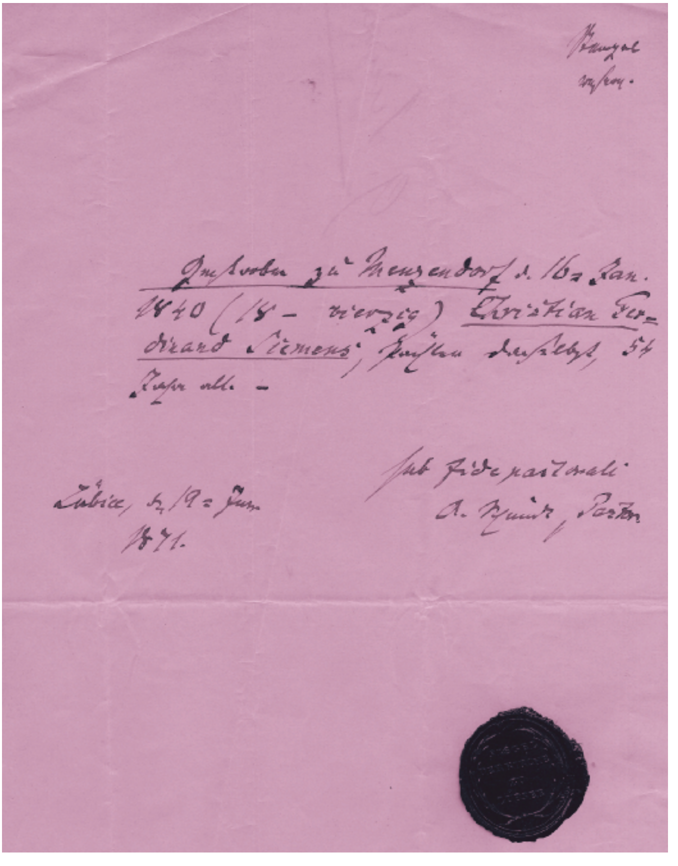

Gestorben zu Menzendorf d. 8. Juli 1839 (18-dreißig u. neun) Frau Eleonora Henriette Siemens, Ehefrau des Pächters Christian Ferdinand Siemens, geb. Deichmann, alt 47 Jahre. –

Lübeck, d. 19. Jan. 1871.

sub fide pastorali
A. Schmidt, Pastor

Werner von Siemens to the committee of the Wittenberg Guild
Charlottenburg, December 22, 1886

Dear Sirs,
Your letter of the 16th inst. gave me great pleasure and I thank you for it sincerely.
I have always had the happiest recollections of the year which I spent in your town as a young artillery officer. It was there, while enjoying the life of cheerful comradeship, that I first felt I might aspire to greater achievements than were offered by military service in peace time . . . My grateful thanks are therefore due to the good Mrs. Knoke and for the friendly intercession of her amiable daughter, for without their kindly indulgence as regards the dire consequences of my chemical experiments, I should probably never have had the opportunity to put my ideas into practice and . . . I would myself probably now be a pensioned military man, having stuck at the rank of major . . .



Gestorben zu Menzendorf d. 16. Jan. 1840 (18-vierzig) Christian Ferdinand Siemens, Pächter daselbst, 54 Jahre alt. –

Lübeck, d. 19. Jan. 1871.

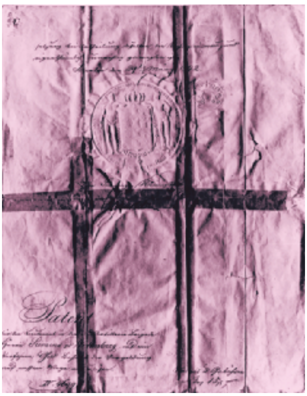
Sub fide pastorali
A. Schmidt, Pastor

A copy of the death certificate of Christian Ferdinand Siemens, dated January 16, 1840.

perceived when I found that I was able to blow out the air through both ears; the drum of the left ear had been burst the year before during artillery practice. In consequence, I was for the moment quite deaf and had heard no sound, when suddenly the door of my room opened and I saw the whole anteroom full of horror-stricken people. The report had immediately spread that one of the two officers resident in the lodgings had shot himself.

In consequence of this mishap, I have long suffered some difficulty in hearing and still suffer, from time to

A Daniell cell.



Werner von Siemens received his first (Prussian) patent in 1842 for his method of galvanoplastic gilding and silvering.

time, whenever the closed rents in the tympana chance to open.

In the autumn of 1840, I was transferred to Wittenberg, where I had to enjoy for a year the dubious pleasures of life in a small garrison town. All the more eagerly did I continue my scientific studies. In that year, Jacobi's discovery was made known in Germany: the precipitation of copper in a metallic form by means of the galvanic current from a solution of the sulfate. This process interested me to a high degree, as it evidently was the key to a whole class of hitherto unknown phenomena. As I succeeded well with the copper precipitates, I tried also to precipitate other metals in the same way, but with only moderate success, owing to my limited means and apparatus.

My studies were interrupted by an event which in its consequences had an important influence on my future career. The frequent squabbles in the smaller garrison towns between the members of different branches of the service had led to a duel between an infantry officer and an artillery officer with whom I was on friendly terms. I had to act as the latter's second. Although the duel terminated with only an insignificant wound sustained by the infantry officer, for certain reasons it came to be taken notice of and to be dealt with by a court-martial. The statutory punishments for dueling in Prussia were at that time draconian in their severity, but precisely on that account were almost always mitigated by an early pardon. In fact, by the court-martial held in Magdeburg, the principals were condemned to ten and the seconds to five years' confinement in the fortress.

I was condemned to confinement in the citadel of Magdeburg and had to report there on confirmation of the sentence. The prospect of being shut up for at least half a year without occupation was not pleasant, but I consoled myself with the thought that I should have a good deal of leisure time for my studies. In order to make good use of this time I sought out a chemist's shop on my way to the citadel, and provided myself with the necessary means for pursuing my experiments in electrolysis. A friendly young fellow in the shop promised not only to smuggle these articles into the citadel, but also to execute promptly future orders, and conscientiously kept his promise.

Accordingly, I set up a small laboratory in my barred but roomy cell and was quite content with my situation. Fortune favored me in my work. I remembered that some time ago I had tried experiments with my brother-in-law Himly in Göttingen for the production of pictures according to the process made known a little while before by Daguerre, and that hyposulfite of soda employed in these experiments had dissolved otherwise insoluble salts of gold and silver. I determined therefore to proceed on these lines, and to test the applicability of such solutions for electrolysis. To my unspeakable joy the experiments succeeded in a surprising manner. I believe it was one of the happiest moments of my life when a German silver teaspoon, which I had dipped into a beaker filled with a solution of hyposulfite of gold and connected with the zinc pole of A DANIELL CELL, while the copper pole was connected with a louis d'or as anode, changed in a few minutes into a golden spoon of the finest and purest luster.

Galvanic gilding and plating was then, at least in Germany, still quite new and naturally caused a sensation in the circle of my comrades and acquaintances. I almost immediately

Patent application filed by Lieutenant of Artillery Siemens.

The undersigned respectfully submits a request to the Ministry for the issue of a patent relating to the use of certain gold salts discovered by him, not previously employed for technical purposes, and especially for the deposition of gold in coherent plates from solutions of the same by means of galvanic current . . .

Wittenberg, January 8, 1842

concluded a bargain with a Magdeburg jeweler who had heard of the marvel and visited me in the citadel, whereby I sold him the right of making use of my process for forty louis d'or, which supplied me with the required means for making further experiments.

In the meantime, a month of my confinement had elapsed, and I imagined I should have at least a few more months quietly to continue my work. I improved my apparatus and lodged a petition for a patent, whereupon with surprising rapidity a Prussian patent for five years was granted me. But the officer of the guard unexpectedly appeared and, much to my consternation, I must confess, handed me a royal order in council announcing my pardon. It was really hard to be so suddenly torn from my successful activity. According to the regulations, I was obliged to leave the citadel the same day, and had neither an abode into which I could put my effects and apparatus nor any idea whither I should be ordered.

I therefore drew up a petition to the commander of the fortress, in which I begged to be allowed to occupy my cell for a few more days, in order that I might arrange my affairs and finish my experiments. I came off badly by that, however! Toward midnight I was awakened by the entrance of the officer of the guard, who communicated to me that he had received orders to turn me out of the citadel at once. The commander had regarded it as a sign of ingratitude for the royal favor extended to me that I desired a prolongation of my imprisonment. Accordingly, about midnight I was conducted out of the citadel with my effects and had to get lodgings in the town.

Luckily, I was not sent to Wittenberg again, but received an order to go to the pyrotechnic factory at Spandau. My discovery had in the eyes of my superiors doubtless made me appear less qualified for active service! The fireworks factory was a relic of the old days when "gunnery" (Konstablertum) was still an art of which the manufacture of fireworks was held to be the crown. My interest in the activity assigned to me was great; in good spirits I repaired to Spandau and took possession of the rooms in the citadel allotted to the manufacture of pyrotechnics.

My new occupation was in fact very interesting, and I devoted myself to it with the greater eagerness, as a large order had arrived for a quantity of fireworks intended to be let off on the birthday of the Russian Empress in the park of Prince Charles at Glienicke, near Potsdam. Owing to the progress of chemistry, means were afforded at that time for the production of very beautiful colored flames unknown to the old gunners. My fireworks on the Havel Lake at Glienicke brought me therefore much honor and recognition, especially on account of the splendor of their colors. I was asked to the prince's table, and received an invitation to engage the young Prince Frederick Charles in a sailing match, as the sailing boat in which I had come from Spandau to Glienicke had distinguished itself by its excellent speed. I had the honor of beating the future victor of famous battles, who even then impressed me to a high degree by his resolute, energetic character, or his "smartness," as one now expresses it.

With the letting off of these fireworks my command of the pyrotechnic factory came to an end, and to my delight I was ordered to Berlin for service in the ordnance department. Through this transfer my greatest wish was fulfilled, to obtain time and opportunity for further scientific studies and for increasing my technical knowledge.

But there were also other reasons which made this change welcome. After my parents' death, the duty devolved upon me of providing for my younger brothers and sisters, of whom my youngest brother, Otto, was at the time of our mother's death only in his third year. It is true the farming of the domains still

Werner to William, January 21, 1842

. . . [I] hasten to send you in reply a belated Christmas present, namely a job in an engineering works in Magdeburg . . . I believe that thereby you will be able to learn a great deal in two years . . .

The artillery workshop in Berlin. Werner von Siemens lived in a room here from 1842 to 1846, sharing it after his parents' death with his brothers Carl, Walter, Friedrich, and sometimes Ferdinand.

remained in the hands of the family for a number of years, but the times continued to be extremely bad for agriculture, so that the slight profits made from farming by my brothers Hans and Ferdinand did not suffice for the education of the children. I was therefore obliged to look out for some way of earning money in order to fulfill my obligations as senior of the family, and that appeared to me to be easier in Berlin than elsewhere.

My brother William had meanwhile completed his course at the Magdeburg School, and at my suggestion had gone for a year to Göttingen, to sister Mathilde, in order to further his scientific studies. After that, he entered the Count Stolberg engineering works in Magdeburg as an apprentice. He there devoted himself with great energy to practical engineering, which just then was undergoing rapid development in Germany in consequence of the introduction of railways.

I kept up a frequent correspondence with William, and got him to communicate to me the problems which exercised

Agreement
Berlin, November 18, 1842

Between W.-Siemens, Lieutenant in the Royal Prussian Artillery, and the manufacturers of German silver, J. Henniger & Co., the following is agreed and settled. § 1 J. Henniger & Co. with W. Siemens will establish on their joint account a works for the deposition of metal by galvanic means (coating of all metals with others from their solutions by means of galvanic current). The process patented by W. Siemens on 29 March of this year, i.e. the solution of gold for the purpose of gold plating by galvanic means, will be employed.

his constructive faculty. One such problem was the precise regulation of steam engines, which were assisted by wind or water mills. William's plan did not satisfy me, and I proposed to employ as regulative principle a heavy, freely swinging circular pendulum, which, connected with the engine to be regulated by a differential mechanism, might effect an absolutely uniform rotation, instead of diminishing the irregularities by the only means then known, the very imperfect regulator of Watt. To this suggestion was due the construction of the differential governor, to which I shall return in due course.

Otto Siemens (1836 – 1871). Undated.

In Berlin, my efforts to earn money by my inventions were soon attended with success, although I was very much hampered as a military officer by being considerably restricted in the choice of devices for initiating business undertakings. I succeeded in concluding an agreement with the German silver manufacturer J. Henniger, by which in return for a share in the profits I agreed to set up an establishment for him for gilding and plating in accordance with my patent. Thus arose the first establishment of its kind in Germany. In England, a Mr. Elkington had already started a similar establishment, employing another process, now in general use – viz. depositing from gold and silver cyanides – which was soon widely extended.

In the negotiations with regard to the Berlin plan and the fitting up of the establishment I was materially assisted by my brother William, who had paid me a holiday visit, and who succeeded at the same time in inducing a Berlin

A view of Berlin from the tower of the French Church at the Gendarmenmarkt, around 1850.

engineering firm to adopt the differential governor. As he clearly showed talent for such negotiations and himself wanted to get to know England, we agreed that he should try to utilize my inventions in that country and for this purpose obtain a longer leave of absence from his factory. I certainly could not afford him considerable means for his journey, and I have often wondered how in spite of this he attained his end. With excellent judgment he went straight to our competitor Elkington, who at first cut him short with the remark that we had no right to use our process in England, as his patent gave him the exclusive right to employ electric currents, produced by electric batteries or by induction, for depositing gold and silver. William had sufficient presence of mind to reply that we employed thermoelectric currents, and therefore did not infringe his patent. In fact I at once succeeded in making a thermoelectric battery, consisting of pairs of bars of iron and German silver, with which we could very well precipitate gold and silver from hyposulfite solutions. As a consequence, William succeeded in selling our English patent to Elkington for £ 1,500. This in our then circumstances was a colossal sum, which put an end for some time to our financial difficulties.

On his return from England, William reentered his Magdeburg factory, but soon found he had lost his relish for such small undertakings, after becoming acquainted with the large scale of English industrial operations and acquiring a taste for English life. He accordingly proposed to settle in England, and as I approved of the project, we took out a patent there for the jointly elaborated differential governor, in order to facilitate its introduction into England.

I had meanwhile made two more discoveries which William was likewise to try to turn to account there. The prosecution of my experiments in electrolysis had led me also to attempt to get good deposits of nickel from a solution of the double salt of sulfate of nickel and sulfate of ammonia. This nickelizing appeared to be of special importance for engraved copper plate, which, provided with a coating of nickel, allowed of a far larger number of impressions, without the fineness of the engraving being blunted by the nickelizing. To derive benefit from this process I had made a compact with a Berlin house, from which I expected considerable profit. Unluckily, however, the galvanic deposition of iron from the corresponding iron solution was discovered soon afterward. This had the great advantage over nickel coating that it could be easily renewed when worn out, in that the iron could be liberated again by dilute sulfuric acid and the plate then coated afresh with iron. This made my nickelizing worthless for this purpose. A few years later, it was again discovered and made known by Professor Böttger, but has only in recent times been much employed in industrial operations.

The second discovery consisted in the application of the zinc printing to a rotating fly press, which process had just then come to be known. With the help of a skillful mechanician, the watchmaker Leonhardt,

Werner to William, March 11, 1845

… He [an American journalist] was particularly intrigued by the small presses (especially their output) and thought that they would be widely acclaimed in America, for every well-to-do American would consider such a handsome press an indispensable ornament for his drawing-room …

Werner von Siemens as a second lieutenant in the Prussian Artillery, around 1842.

I had prepared a model of such a press, which very satisfactorily executed the necessary operations for producing lithographic impressions from a cylindrical zinc plate. But it subsequently turned out, on its employment on a large scale by William in England, that zinc printing allowed of no rapid repetition of impressions. After about 150 to 200 impressions the work had to be interrupted for a pretty long time, or else an obliteration of the reprint on the cylinder took place.

When my brother met with these difficulties in England, I obtained six weeks' leave and visited him in London, where he had rented a small place for our experiments in a narrow lane in the City near the Mansion House. Despite the most strenuous efforts, however, we could not succeed in overcoming the difficulties. We succeeded, indeed, in obtaining reimpressions from even century-old prints by a regenerating process – by continuous heating, if I remember rightly, in a solution of salts of barium – and our process, to which we had given the grand name "ANASTATIC PRINTING," accordingly excited much attention in England and contributed to making William known there; but it soon became clear to us that speculative inventions are a very uncertain affair and only in very rare cases lead to good results, unless supported by thorough knowledge and ample means.

For me personally the journey to England proved very stimulating, and at the same time gave a more earnest and critical direction to my further endeavors, leading me to look rather at the solidity of my foundations than at the hoped for result. This was still more confirmed by my return journey through Paris, where in the then flourishing period of the reign of Louis Philippe the first great French Industrial Exhibition was taking place.

Unfortunately, my stay in Paris was disturbed by an unpleasant incident. I had intended to decide in Brussels whether I should return by way of Paris or by the direct route, and had arranged therefore with William that he should send to Paris any money required to supplement my traveling budget, if I should write him to that effect from Brussels. When I decided therefore to make the journey to Paris, I enclosed with the request for money my Paris address and entrusted the letter to the landlord of my hotel.

Arriving in Paris after a two-day journey, perched on the top of an omnibus of the *messageries générales,** I found the city filled to overflowing as a result of the Exhibition and only succeeded with difficulty in obtaining a small garret room on the eighth floor of the *hôtel des messageries générales,* in which it was only possible to stand upright if the window, which served also as a roof, were placed horizontally. As my cash had as a result of the extra traveling been reduced to a minimum, I could not think of a change of residence until the expected remittance had arrived. Almost a fortnight passed, however. A young Berliner who had come to Paris for the Exhibition found himself in the same plight. We had to study the art of living in Paris without money very thoroughly, and being entirely without acquaintances or other sources of assistance found ourselves at last in a very uncomfortable position. Finally we resolved simultaneously to employ our remaining resources in dispatching letters to London and Berlin, as at that time only prepaid letters were accepted. At the post office it turned out, however, that my ready money was not quite sufficient for the purpose. The young Berliner – Schwarzlose was his name – magnanimously came to my assistance, but was

* *With a postal coach.*

then obliged to forgo the dispatch of his own missive, his funds being now exhausted.

This magnanimity found its reward, for on the same evening the eagerly awaited money letter from my brother arrived, instead of after the lapse of a week, as I had feared. The postage for the Brussels letter had been embezzled by the boots of the hotel; the post office authorities had therefore not dispatched the letter, but had written to the addressee that if he desired to have it he must remit the postage. Only after my brother had done this, and had received the letter containing my address, could he let me have the truly "necessary."

Our distress was accordingly relieved, but the Paris trip was rendered useless, for my leave was now at an end. As compensation, I had had practical experience of what lack of money really means. Of Paris itself I saw little except the streets in which I tramped away my hunger.

Back in Berlin, I reflected very seriously on the aims I had lately been pursuing, and saw clearly that the pursuit of discoveries, by which I had allowed myself to be carried away following the facility of my first success, would if continued probably be my own and my brother's ruin. I accordingly got rid of all my inventions, even selling my share in the manufactory set up in Berlin, and devoted myself again with heart and soul to serious scientific study. I attended courses at the Berlin University, but soon perceived to my dismay from the lectures of the celebrated mathematician Jacobi that my previous train-

Rudolf Clausius (1822–1888), co-founder of the Physics Society. Undated.

ing was insufficient to enable me to follow him all the way. To my great regret this imperfect schooling in scientific study has always kept me back and crippled my efforts. All the more grateful am I to some of my earlier teachers, among whom I must specially mention the physicists Magnus, Dove and Riess, for the friendly reception they gave me into their highly interesting circles. I also owe many thanks to the younger Berlin physicists, who allowed me to take part in founding the Physics Society. That was a wonderfully stimulating association of talented young scientists, who subsequently almost without exception became celebrated by their achievements. I need mention the names only of Du Bois-Reymond, Brücke, Helmholtz, Clausius, Wiedemann, Ludwig, Beetz and Knoblauch. Association and cooperation with these young men, distinguished by talent and earnest endeavor, strengthened my preference for scientific study and labors, and kindled in me the determination to be in future the votary of pure science alone.

Gustav Magnus (1802–1870). Magnus introduced Werner von Siemens into the society and presented Werner's discovery of the dynamo-electric principle (1866) to the Prussian Academy of Sciences in January 1867. Undated.

But circumstances were stronger than my will, and the native impulse never to let acquired knowledge lie idle, but as far as possible to make some use of it, led me ever and again back to technology. And so it has been all my life. My affection has always been given to pure science as such, but my labors and achievements have been for the most part in the domain of applied science.

This technical turn was especially favored and supported by the Polytechnic Society, to which as a young officer I zealously devoted myself. I took an active part in its pro-

Heinrich Wilhelm Dove (1803–1879). Undated.

ceedings, and in the answering of the questions deposited in the query box. The answering and discussing of these soon formed a part of my regular activity and proved a good schooling for me. My scientific study stood me in good stead, and it became clear to me that technical progress is only to be attained by the diffusion of scientific knowledge among technicians.

At that time there still existed an unbridged gulf between pure and applied science. The meritorious Beuth, who should without doubt be regarded as the founder of technical science in North Germany, had indeed in the Berlin Industrial Institute erected an institution which was especially designed for the diffusion of scientific knowledge among young technicians. The existence of this institute, out of which arose the Industrial Academy and finally the Technical College in Charlottenburg, was, however, too short to raise the level of education of the craftsmen of the period.

Prussia was at that time still a purely military and bureaucratic state. Only in its official class was culture to be found, and it is doubtless mainly owing to this circumstance that even at the present day the semblance of an official title is regarded and striven for as an external mark of a cultured and respected man. Of the economic body only agriculturists, from whom the military class as well as the bureaucracy was almost without exception recruited, had a respectable status in the eyes of the latter. In this country, wasted and impoverished by a century of wars, there no longer existed a well-to-do bourgeoisie to act as a counterpoise in culture and property

to the military and official class. It must, however, be added that this state of things was in part attributable to the fact that the representatives of science, always highly respected in Prussia under the rule of the farseeing Hohenzollerns, did not consider it compatible with their dignity to manifest a personal interest in technical progress. The same may be said in respect of sculpture and its like, whose representatives regarded – and in part, I believe, still regard – it beneath their dignity to employ a part of their creative power for the elevation of commercial art.

The house belonging to the physicist Gustav Magnus at Kupfergraben 7 in Berlin. In 1843, at this location, Magnus set up the Physics Colloquium, the forerunner of the Physics Society founded in 1854. Here Werner von Siemens found important inspiration for new ideas and became acquainted with Johann Georg Halske.

Through my activity in the Polytechnic Society I arrived at the conviction that scientific knowledge and scientific methods of investigation are capable of developing the industrial arts to a degree far beyond anything that can be foreseen. It had the further advantage of making me personally acquainted with Berlin manufacturers, and of affording me an insight into the achievements and defects of the industry of the time. My advice was often sought by manufacturers, and I thereby became acquainted with the contrivances employed and the modes of working. It became clear to me that the industrial arts cannot advance by sudden leaps, as has often been possible in science as a result of the fruitful ideas of a few remarkable men. A technical invention only achieves value and importance if industrial art itself has so far progressed that the invention is a practical one and supplies a need. Hence one so often sees the most considerable inventions lying idle for decades, until all at once their great importance is recognized, their hour having arrived.

Of the scientific-technical questions which at that time especially occupied me, and at the same time gave rise to my first literary labors, the first owed its origin to a letter from my brother William concerning an interesting engine which he had seen at work in Dundee. From a rather brief account it appeared that this engine was not driven by steam but by heated air. This idea interested me exceedingly, since it appeared to afford a foundation for an advantageous transformation of the whole art of engine construction. In a paper entitled "Über die Anwendung der erhitzten Luft als Triebkraft" (On the Employment of Heated Air as a Motive Power) contributed in 1845 to *Dingler's Polytechnic Journal*,* I described the theory of such AIR ENGINES, and gave also a sketch of the construction of such a one as I conceived to be practicable.

My theory was based entirely on the principle of the conservation of energy, which had been advanced by Mayer and worked out mathematically by Helmholtz in his celebrated memoir "Über die Erhaltung der Kraft" (On the Conservation of Energy), originally read before the Physics Society. Later on, my brothers William and Friedrich occupied themselves a good deal with these engines, and constructed them in various forms. Unfortunately, however, they too had to undergo the common experience of

** A periodical founded by pharmacist and manufacturer Johann Gottfried Dingler (1778–1855) in 1820. It reported on inventions, first primarily in the crafts and agriculture and later from all fields of technology. For example, it maintained a register of all English patents. The* Polytechnisches Journal, *or* Dinglers polytechnisches Journal *after 1874, was published until 1931.*

The co-founders of the subsequent Berlin Physics Society, 1842. Standing, from left: Gustav Karsten, Wilhelm Heintz, Karl Hermann Knoblauch. Seated in the middle, between Ernst Wilhelm von Brücke and Wilhelm von Beetz, is Emil Du Bois-Reymond.

finding that engineering had by no means advanced far enough to allow of the discovery being utilized with advantage. Only small engines could be constructed on the basis of the above principle so as to work well for any length of time; for large ones the right material for the heating apparatus was and still is wanting.

In the same year, I printed in Dingler's journal a description of the differential governor mentioned earlier, to which in collaboration with my brother William I had tried to give the most varied forms.

Another question, which had already occupied me for a long time, was that of the exact measurement of the velocity of projectiles. The watchmaker Leonhardt, known as a skilled mechanician and in the employ of the Artillery Commission, had constructed a clock which turned an indicator with great velocity when the latter was electromagnetically connected with the clockwork.

The coupling and uncoupling of the indicator by the flying shot was attended, however, with great difficulties, which in spite of our efforts could not be quite overcome. This led me to the idea of the employment of the electric spark for the measurement of velocity. In a paper published in Poggendorff's *Annalen*,* "Anwendung des elektrischen Funkens zur Geschwindigkeitsmessung" (Application of the Electric Spark to the Measurement of Velocity), I demonstrated the possibility of accurately measuring the velocity of projectiles at every stage of their progress by means of a rapidly rotating polished steel cylinder, on which incident electric sparks could leave a distinct mark. This paper also

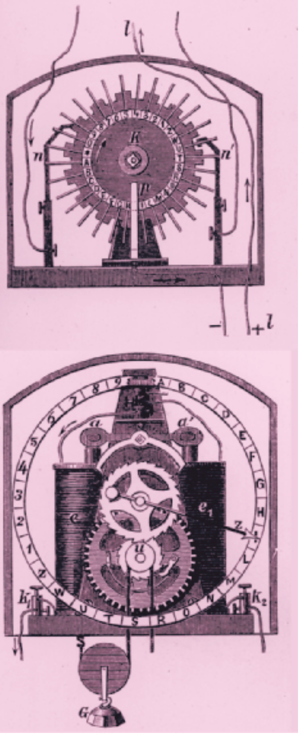
* Annalen der Physik, *founded in 1799, was published in 160 volumes from 1824 until his death by the physicist Johann Christian Poggendorff (1796–1877) as* Annalen der Physik und Chemie; *it has been published since 1877 as* Annalen der Physik *once again.*

contained the plan, executed by me only many years later, of ascertaining by the same method the velocity of electricity itself in its conductors.

My interest in electrical experiments was most vividly stimulated by participating in the work of Leonhardt, who was at the same time occupied with experiments, which the military staff had caused to be instituted, with regard to the substitution of electric for OPTIC TELEGRAPHY. In the house of Hofrat SOLTMANN, father of a close friend of mine, I had had the opportunity of seeing the model of a WHEATSTONE dial telegraph, and had taken part in the attempts to bring it into operation between the house and an establishment for producing artificial mineral waters at the end of the large garden. These, however, never succeeded, and I soon perceived the cause of the failures. They were traceable to the principle on which the apparatus was constructed, which required the turning of a handle with such regularity that the impulses of current produced had always sufficient strength to keep the clockwork of the receiving apparatus in motion. This was not attainable with any certainty even if the entire apparatus was working in the same room, and was altogether impossible where an important part of the current was lost through the imperfect insulation of the conductors.

Leonhardt, trying at the instance of the commission to remedy this defect, caused the impulses to be produced by clockwork, i.e., at quite regular intervals, which was certainly an improvement but which still, with the varying loss of current, did not suffice. This made it apparent to me that the problem was most completely to be solved by converting the dial telegraphs into self-acting machines, each of which would automatically break and make the circuit. If two or more such electrical machines were connected to *a single* electrical circuit, a fresh impulse could only be given when *all* the inserted apparatus had completed its stroke, and thus had again closed the circuit. This proved subsequently to be a very fruitful principle for innumerable electrotechnical applications. All the self-acting alarms or bells employed at the present time are based on automatic interruption after a completed stroke, first introduced as described above.

The construction of these self-interrupting DIAL TELEGRAPHS I entrusted to a young mechanician named HALSKE, with whom I had become acquainted through the Physics Society, and who at that time managed a small mechanical workshop, the business firm being known as Boetticher & Halske. As Halske at first entertained doubts whether my apparatus would work, I myself set up a couple of automatic telegraphs, composed of cigar boxes, tin plate, a few pieces of iron, and some insulated copper wire, which worked with perfect certainty. This unexpected result filled Halske with so much enthusiasm – for a design capable of success notwithstanding such defective materials – that he gave himself up with the greatest eagerness to the construction of the first apparatus, and even declared himself ready to withdraw from his firm and in conjunction with me to devote himself entirely to telegraphy.



A Wheatstone dial telegraph. Top: the transmitter; bottom: the receiver.

This success, as well as the growing responsibility for my younger brothers and sisters, matured my resolution to relinquish military service and by means of telegraphy, whose great importance I clearly perceived, create for myself a new vocation, which should also afford me the means of fulfilling the duties I had undertaken toward my younger brothers. I was therefore intent on the preparation of my new telegraph, which was to form the bridge to the new career, when an event occurred which threatened to throw all my plans to the winds.

It was a time of great religious and political stir all over Europe. This first found expression in Germany in the free religious movement which ran counter both to Catholicism

Characterization of Johann Georg Halske by Werner von Siemens at the end of his Mémoire sur la télégraphie électrique *(présenté à l'Académie des Sciences le 15 avril 1850)*

... Il va sans dire, au reste, que ces appareils, malgré la simplicité de leur principe, exigent, en leur qualité de machines à mouvement propre, un constructeur habile, intelligent et soigneux. Qu'il me soit permis, à cette occasion, de faire mes remerciments publics à mon collaborateur M. J. Halske, de Berlin, à l'admirable talent duquel je dois attribuer la plus grande partie des succès dont mes efforts, dans cette belle branche de la physique appliquée, ont peut-être été couronnés.

and to the rigid Protestantism then in the ascendant. JOHANNES RONGE had come to Berlin, and held public lectures in the Tivoli Gardens, which were attended by all the world and excited great enthusiasm. The younger officers and officials in particular, then almost without exception liberally inclined, raved about Johannes Ronge.

Just as this adulation of Ronge was at its height, I, along with all the officers of the Artillery workshop – nine in number – happened to take a stroll after working hours in the Tiergarten. We found many people assembled "UNDER THE TENTS," listening to lively speeches, in which all those of like mind were called upon to support Johannes Ronge against the obscurantists. The speeches were good, and were perhaps the more persuasive and captivating as people in Prussia were not then accustomed to public speaking.

When, therefore, on leaving, a sheet already almost filled with names partly known to me was presented for my signature, I did not hesitate to add mine. The other officers, some considerably my seniors, followed my example without exception. No one dreamed for a moment of doing anything wrong. Each thought it only common honesty openly to avow his conviction.

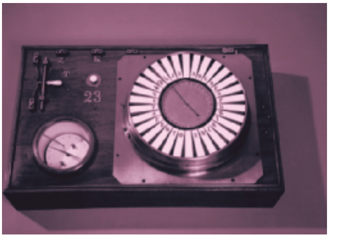
But great was my alarm when at breakfast on the following morning I happened to glance at the *Vossische Zeitung,* and found a leading article entitled "Protest gegen Reaktion und Muckertum" (Protest against Reaction and Religious Cant), and at the head of the subscribed names my own, followed by those of my comrades.

When, soon after – half an hour before the commencement of work – I appeared in the laboratory yard, I found my comrades all assembled in a state of great excitement. We feared we had committed a grave military offense. In this supposition we were soon strengthened by the appearance of the commandant of the workshops, an excellent and extremely amiable man, who declared to us in great excitement that we had by our action ruined ourselves and him likewise.

Johann Georg Halske (1814 – 1890), around 1855.

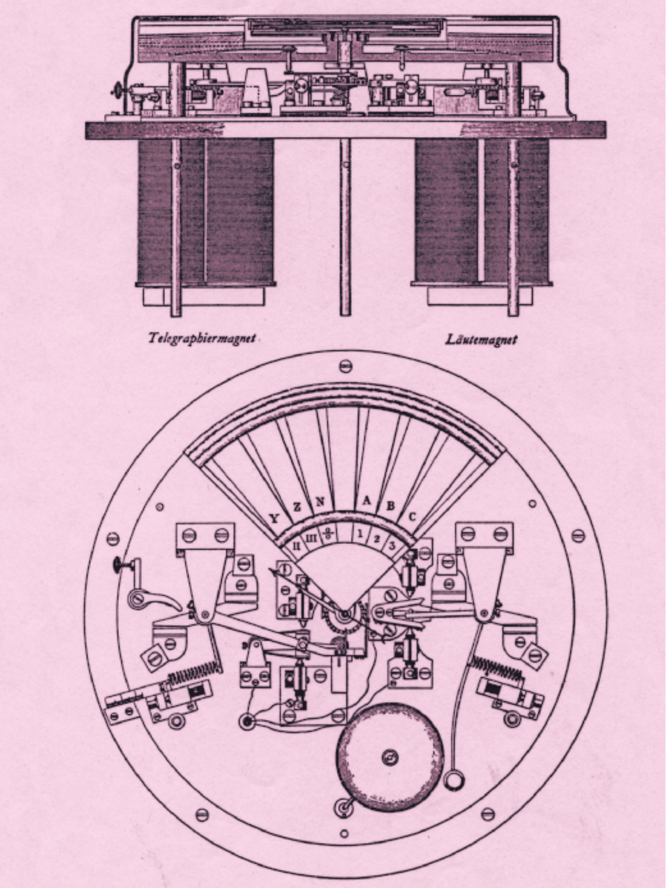
Some anxious days passed. Then it was announced that the inspector of the workshops, General von Jenichen, had to communicate to us an order in council. The order in council reprimanded us very severely indeed, but was more gracious than we had ventured to hope. The general addressed us in a long speech in which he set before us the impropriety and blameworthiness of our conduct. I was awaiting with some curiosity the conclusion of this speech, as I had taken the waters at Kissingen for a month with the general, who was a highly cultured and very humane man, and as I knew well that his opinions were not altogether different from those subscribed to by us. "You know," said the general in conclusion, directing a look toward me, "that I am of the opinion that every man, and particularly every officer, should always express his opinion openly. You have, however, not considered that openly and publicly are worldwide different things!"

We soon learned that as punishment we were all to be sent back to our brigade – or our regiment, as it is now again called.



Werner von Siemens' dial telegraph of 1847. The pointer, which traveled uniformly in both the transmitter and the receiver, was held at the desired letters by pressing the keys, and thus transmitted the message.

For me this was an almost insupportably hard blow, upsetting all my future plans, and making it impossible for me to go on providing for my younger brothers. The problem was to find a way to prevent this removal. That was only to be attained by an important military discovery, which should necessitate my presence in Berlin. Telegraphy, in which I was specially interested, could not perform this service, for only few then believed in its great future, and my projects were still undeveloped.



Siemens dial telegraph, 1847.
An extract from the patent drawing.

By good luck, the idea of guncotton occurred to me. This had been discovered a little while before by Professor Schönbein in Basle, but had not yet been brought into use. It appeared to me beyond question that it could be so improved as to be made available for military purposes. I therefore went immediately to my old teacher Erdmann, professor of chemistry at the Royal Veterinary School, told him of my trouble, and begged permission to institute experiments with guncotton in his laboratory. This he willingly granted, and I went eagerly to work.

Berlin, August 2
(Private communication)
Yesterday evening after 8:00 here in the Tiergarten without any previous announcement an assembly of Protestant friends was held, at which the following declaration was made, discussed and signed: "Freedom of conscience and instruction is recognized as the basis of true, human culture and the sole guarantee of its continuance. It is up to us in our day and age to put this hard-fought-for right into practice. Religion … is a matter for the individual … the undersigned are resolved to defend these precious possessions by all legal means within their power and undertake to protest publicly against any coercion." [About 170 signatures, among others]: W. Siemens, Lieutenant, Müller, First Lieutenant of Artillery, Th[eodor] Fontane.
Supplement to the Berlinische Nachrichten von Staats- u. gelehrten Sachen *(Spenersche), August 7, 1845*

I had the idea that by employing stronger nitric acid and by more careful washing and neutralizing, a better and less easily decomposable product could be obtained. All the experiments, however, came to nothing, though I used extremely concentrated fuming nitric acid; a greasy, easily destructible product was always the result. My stock of extremely concentrated nitric acid having run short, I once tried the effect of adding some concentrated sulfuric acid in order to strengthen it, and to my astonishment got a guncotton with altogether different properties. After washing, it became white and firm like the unchanged guncotton and exploded very energetically. I was overjoyed, and till late at night made a considerable quantity of such guncotton and placed it in the drying stove of the laboratory.

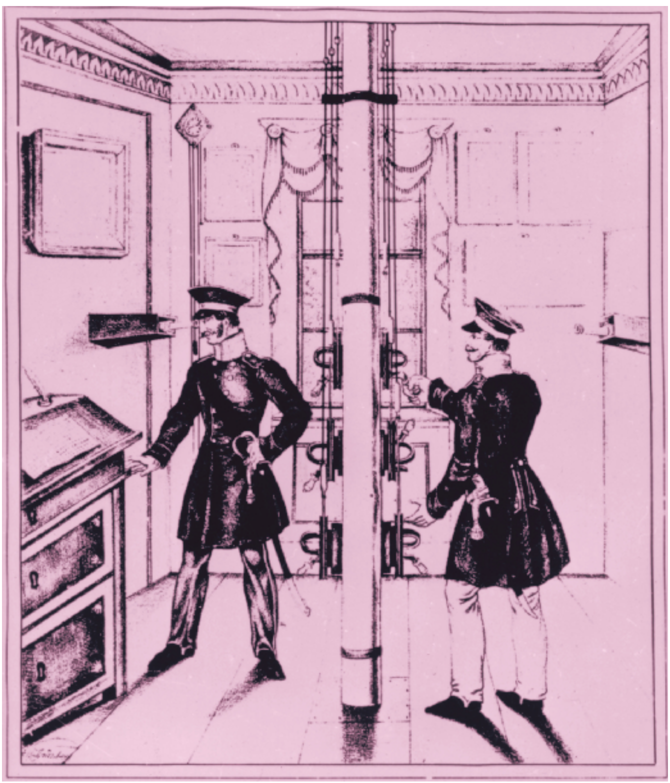
When after a brief sleep I went again to the laboratory early in the morning, I found the professor standing mournfully among ruins in the middle of the room. On heating the drying stove, the guncotton had exploded and destroyed the stove. A glance made this clear to me and showed the perfect success of my experiments. The professor, with whom in my joy I tried to waltz around the room, seemed at first to think I had gone wrong in the head. It cost me some trouble to set his mind at rest, and to induce him to resume the experiment at once. About eleven o'clock I had packed a goodly quantity of faultless guncotton, and sent it with a formal explanatory letter to the war minister.

The result was glorious. The minister of war instituted a shooting trial in his large gardens, and, as it went off brilliantly, immediately induced the heads of the ministry to make a regular trial with pistols. On the very same day, I received an

Station 2 of the optical telegraph in Berlin-Dahlem, with the telegraph room next to it. One official, looking through a telescope, spotted the characters signaled by the nearest station, and a second official transmitted the characters to the signalmen on the roof by way of levers. If the weather was good, this technique made it possible to send a message from Berlin to the Rhine within two hours.

official order direct from the minister to repair to the powder manufactory at Spandau, which had already been instructed to place everything required at my disposal, to institute experiments on a larger scale. It is seldom, I fancy, that a memorandum to the war office has been so quickly acted upon! Of my returning to the brigade there was no more talk. I was soon the only one of my brothers in misfortune who had not been obliged to leave Berlin.

The experiments on a large scale, which were made under my direction in the powder factory at Spandau, did not lead to the result expected in the first glowing moments, viz. that guncotton would generally supersede gunpowder. It is



The Berlin Justizrat *Johann Georg Siemens (1805–1879). Undated.*

true the trials with small arms as well as with cannon yielded excellent results; it appeared, however, that guncotton was not a sufficiently fixed combination, since it gradually decomposed in the dry state, and also would occasionally go off by itself. Moreover, its effectiveness depended on the degree of compression of the guncotton and on the mode of its ignition. My report therefore ran that the guncotton produced according to my method, by means of a mixture of nitric and sulfuric acid, possessed excellent properties as a blasting material, and seemed well suited to take the place of blasting powder for military purposes, but that it could not in general be substituted for gunpowder, as it presented no sufficiently stable chemical combination, and its action was not constant enough.

I had already sent in this report when Professor Otto in Brunswick discovered anew and published my method of preparation of serviceable guncotton. My earlier action in the matter and my report to the war office remained of course secret, and Otto therefore must rightly be held the discoverer of serviceable guncotton, since he was the first to make public the method of its production. It has often been so with me. It appears at first sight hard and unjust that anyone may by earlier publication appropriate the honor of a discovery or invention which another, who has

… Because of his excellent knowledge of engineering and the natural sciences and his talent for invention he is capable of higher achievements in the technical field …

From the conduct reports, note by a brigadier, 1846, on Werner von Siemens long worked at it with ardor and success, would only make known after the most thorough testing. On the other hand, however, it must be admitted that some definite rule must be established in regard to priority, since for science and the world it is not the person, but the thing itself and its publication, that is of importance.

This great length of copper wire is coated by means of one single machine which has been constructed by Mr. Siemens and a Mr. Halske conjunctively. It consists of a horizontal cylinder, with a moveable piston; a chamber at the end of this cylinder is pierced with sixteen holes, eight of which are through the bottom, and of the same diameter as the wire itself; the remaining eight are through the top side, exactly opposite to those in the bottom, and are of the intended diameter of the coated wire. Eight separate wires are pointed through the bottom holes; the cylinder is moderately heated, and filled with the gutta-percha composition, whereupon the piston is urged forward, and, in forcing the semifluid substance through the eight larger holes, it carries with it the coated wires with remarkable velocity, the wire itself being impelled by virtue of adhesion to the gutta-percha which surrounds it.

The Mechanics' Magazine,
London, February 3, 1849

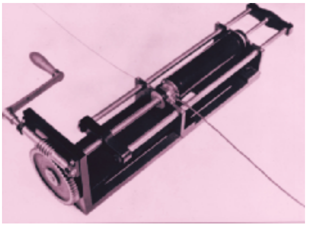
After the danger of removal from Berlin had in this manner been successfully averted, I was able to devote myself with a tranquil mind to telegraphy. I sent General O'Etzel, the chief of the optical telegraph department under the immediate direction of the staff, a memorandum on the condition of telegraphy and the improvement to be expected therein. In consequence of this I was ordered to place myself at the service of the staff commission, which was deliberating on the introduction of electrical instead of optical telegraphs. I succeeded in gaining the confidence of the general and his son-in-law, Professor Dove, in so high a degree that the commission almost always assented to my proposals and entrusted me with their execution.

It was then regarded as altogether out of the question that a telegraph wire easy of access, attached to posts, could be really serviceable, since it was imagined the public would destroy it. Accordingly, wherever on the European continent it was desired to introduce electric telegraphs, experiments were first made with subterranean conductors. The best known were those of Professor Jacobi in St. Petersburg; he had tried resin, glass tubes, and india rubber as insulators, but had obtained no permanently satisfactory results. The

Berlin commission likewise had begun such experiments, which, however, yielded just as unsatisfactory a durable insulation.

By chance my brother William in London had sent me as curiosity a sample of a substance which had recently appeared on the English market, GUTTA-PERCHA. The remarkable properties of this material, of becoming plastic in the heated state and when cooled of being a good insulator of electricity, aroused my attention. I covered some

A view through the entrance toward the first Siemens & Halske workshop at Schöneberger Strasse 19 in Berlin. Undated. Werner von Siemens lived on the ground floor, the workshop was on the next floor, and Halske lived on the floor above that.

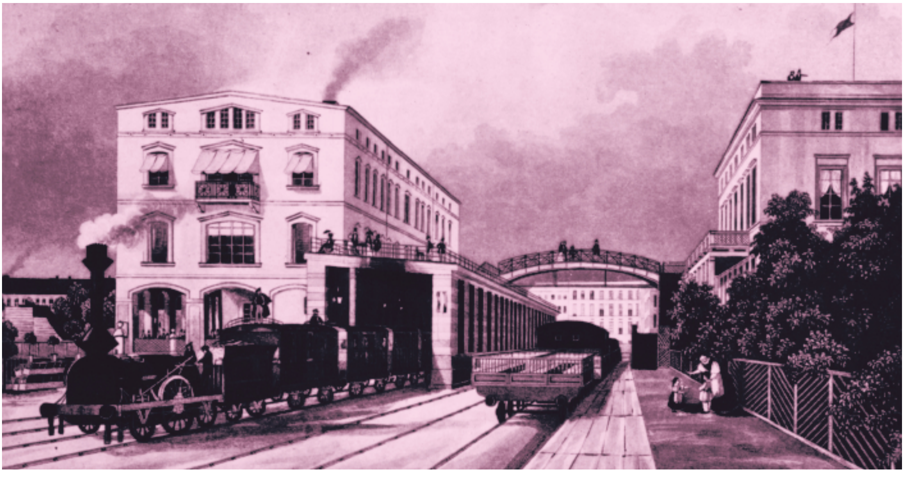


pieces of wire with the heated material, and found that they were thoroughly insulated. At my suggestion the commission gave orders for more considerable experiments with such wires insulated by gutta-percha, which were begun in the summer of 1846 and continued in 1847. In samples placed on the track of the Anhalt Railway in 1846, the gutta-percha was rolled around the wire. It turned out, however, that the seam thereof became loosened in the course of time. I accordingly constructed a screw press, by which the heated gutta-percha was cohesively pressed around the copper wire under the application of a high pressure. The conducting wires, coated by the help of a sampler press constructed by Halske, proved to be well insulated and permanently retained their insulation.

A model of the first gutta-percha press, from 1847.

In the summer of 1847, the first long subterranean wire from Berlin to Grossbeeren was laid, by me, with such insulated wires. As it stood the test perfectly, the question of the insulation of subterranean wires by the employment of gutta-percha and my press appeared now to be successfully solved. In fact, since that time not only the subterranean

The Berlin – Potsdam Railway, 1838.
In 1847 the Prussian military administration organized a competition along this route among the new electric telegraphs. Werner von Siemens won with his dial telegraph.



Werner to William, December 14, 1846

. . . I have now practically decided to make a career of telegraphy, whether in or out of the army. Telegraphy will become an important branch of scientific technology in its own right and I feel the call to further its organization since I am convinced that it is still in its early childhood . . .

The undersigned witness that from today's date J. G. Halske relinquishes his interest in the jointly run workshop; F. M. Boetticher will continue the business in the manner as hitherto, taking over all assets and liabilities, whereas J. G. Halske has established a workshop in the Schöneberger Strasse 19 for electromagnetic telegraphs and similar apparatus.

Berlin, October 1, 1847
F. M. Boetticher J. G. Halske
Vossische Zeitung,
October 19, 1847

land lines but also the submarine cable lines have almost without exception been insulated in this manner.

The commission had under consideration the employment both of the wires coated with gutta-percha by pressing and also my dial and printing telegraph in the telegraph system about to be introduced into Prussia.

The resolution to devote myself entirely to the development of telegraphy was now fixed. Accordingly, in the autumn of 1847 I induced the mechanician J. G. Halske, with whom our common labors had bound me closely, to hand over his business to his partner and to start a telegraph factory, into which I reserved to myself the right of entry on my discharge from the army. Since Halske like myself lacked available resources, we had recourse to my cousin, Georg Siemens, a barrister residing in Berlin, who lent us 6,000 thalers* for the erection of a small workshop on condition of a share in the profit for six years. The workshop was opened on October 12, 1847,** in the rear part of a house in the Schöneberger Strasse – where Halske and I also took rooms – and grew rapidly and without the aid of outside capital into the world-renowned establishment of Siemens & Halske in Berlin, with branches in many of the chief cities of Europe.

I had put aside the enticing prospect of rising, by virtue of my dominating position in the telegraph commission, to be the head of the future Prussian state telegraphs, as a position of dependence was not congenial to me, and I had the conviction I should be of more service to myself and the

** To be exact, 6,842 thalers and 20 silbergroschen, i. e., £ 1,005.*

*** The articles of association of Siemens & Halske date from October 1, 1847.*

Johann Georg Halske and his wife, around 1847.

world if I obtained my full independence. But I resolved not to renounce military service, and therewith my place on the military commission, before the latter had completely accomplished its task, and a definite settlement of the future telegraph system had been arrived at.

I urged in the commission that the PUBLIC should also be allowed the use of the telegraph lines, which met with considerable opposition in military circles. The great celerity and certainty with which my new patented dial and printing telegraphs worked on the overhead line between Berlin and Potsdam and on the underground line between Berlin and Grossbeeren – performances with which those of the old semaphores** were not to be compared –

*** A signal pole with several movable arms whose angles can be changed to send signals.*

The experiments which the State has just instigated here as to the most practicable means of introducing electromagnetic telegraphs are going very satisfactorily … so that it is probable that all State telegraphs to be installed will be of this kind … The tests are being carried out by Lieutenant Siemens, whose new, patented, electromagnetic telegraph system finds the highest approbation and in the forthcoming competition with all other usual systems for the purpose of determining the most suitable one for the Prussian State Telegraphs will no doubt prove victorious, as it is the simplest, most reliable, most highly perfected and withal the cheapest …

Bremer Zeitung,
December 19, 1847

contributed, however, in no small degree to produce an opinion more favorable to the public interest. The report of the astonishingly favorable results of these experiments went the round of the higher circles in Berlin, and brought me a command from the Princess of Prussia to give a lecture in Potsdam on electric telegraphy to her son, later Crown Prince Frederick William and Emperor Frederick. This lecture, accompanied by experiments on the Berlin – Potsdam line, and a memorandum connected therewith, in which I enlarged upon the great future in store for telegraphy, supposing it to be made the common property of the people, no doubt considerably assisted in winning over the higher circles.

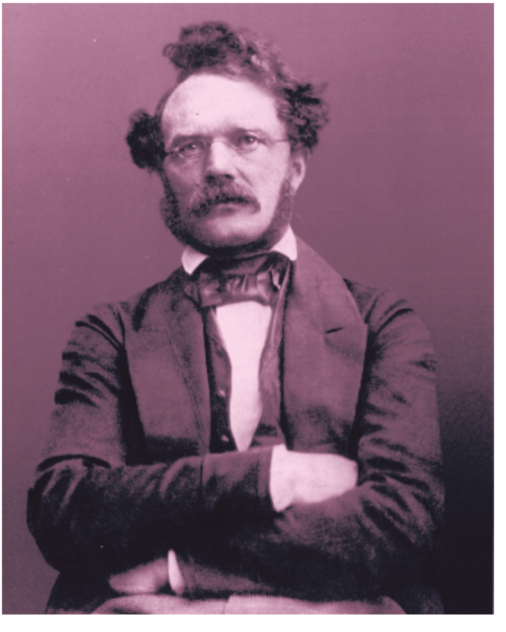
At my instigation, the commission instituted a public competition for March 1848, and settled the conditions to be satisfied in regard to the telegraphic communications and apparatus. Prizes were assigned to the winners, who were also to have the reversion of consequent orders. I had a pretty safe expectation of obtaining victory with my own proposals in this competition, which opened on March 15, 1848, when on the 18 the competition as well as the commission itself came to an abrupt end.*

** But the interruption can only have been very transient, since by the beginning of June 1848 the (Prussian) Ministry of State received a detailed report from the commission on the results of its activities, prompting the king to issue a decree on July 24, 1848, calling for the immediate installation of an electromagnetic connection between Berlin and Frankfurt am Main, and between Berlin and Cologne and as far as the Belgian border.*
After a publication from 1899.

1848

Plunged in my own interesting labors, I had found little time to give heed to the wild commotion which, since the February revolution in Paris, was spreading all over Germany. With elemental force the mighty stream of political excitement rushed onward, tearing down all the feeble dikes which the existing powers aimlessly and without plan opposed to it. Discontent with the prevailing state of things, the hopeless feeling that they could not be changed without violent subversion, penetrated the entire German people and extended to the upper strata of the civil and even the military administration of Prussia. The political and national claptrap, the emptiness of which was only revealed by subsequent events, still exerted its full influence upon the masses, and its diffusion was materially assisted by the unusually fine summer weather which prevailed throughout Germany during the whole of that time.

Werner von Siemens at the time of the company's founding in 1847.



The streets of Berlin were continually flooded by excited crowds, discussing the most exaggerated reports of the progress of the movement, and eagerly listening to agitators who spread them further and called for action. The police seemed to have disappeared from the town, and the military, which did its duty

Werner to William, March 11, 1848

. . . I would cry "Vive la France" with you with enthusiasm if we were still lucky enough to belong even morally to the proletariat! Still, never mind, we are making tremendous progress. Such an emotional upheaval, such an eagerness to break all unworthy fetters and barriers must produce good results! No doubt, in North Germany the fight will be hard. Here phlegm and indifference are still too prevalent, yet the Press, which is already free in half of Germany, is bound to do the rest! . . .

with thorough fidelity, hardly made itself really noticed. Then came the overwhelming news of the victory of the revolution in Dresden and Vienna, closely followed by the shooting of the sentry at the Bank, and finally the misunderstanding at the Castle Square. This drove even the quieter citizens, who had formed themselves into a mediating national guard, to the revolutionary side. I saw from my windows how a division of this citizen guard came in great excitement from the Castle Square and threw their scarves and staves on the square in front of the Anhalt Gate with the cry "Treachery! The military have fired upon us!" In a few hours the streets were covered with barricades, the sentries were attacked and in part overpowered, and the struggle with the garrison, which for the most part confined itself to defense, and without exception remained true to their flag, quickly extended over a large part of the town.

I, myself, owing to my being seconded to a special commission, was out of touch with the active army and awaited with beating heart the issue of the unhappy struggle. Then on the following day appeared the royal proclamation, which restored peace. On the forenoon of March 19, the citizens crowded to the Castle Square to thank the King for his proclamation. I could no longer stay at home and accordingly mingled with them in civil dress. I found the whole square filled with a vast throng, which on all sides gave lively expression to its joy at the peace proclamation. But soon the scene changed. Long processions came, bringing the fallen to the Castle Square, in order, as was said, that the King might see for himself what havoc his soldiers had wrought. Then followed the terrible scene on the balcony of the castle, when the Queen fainted away as her eyes caught

Berlin, Alexanderplatz, the night of March 18 – 19, 1848.

sight of the bloodstained dead heaped at her feet. There came fresh processions with corpses, and as the King no longer responded to the shout for his appearance, the excited throng prepared to burst open the castle gates, to confront him with the dead in the same way.

It was a critical moment, for to a certainty the struggle would have been renewed in the Castle Yard, where a battalion had been stationed, a struggle the outcome of which, as the rest of the military had left the town by royal order, would have been exceedingly doubtful had not a savior appeared in the person of young Prince Lichnowsky. From a table placed in the middle of the Castle Square he addressed the crowd in a loud audible voice. He said His Majesty the King had in his great goodness and grace put an end to the struggle, in that he had withdrawn all the military and had entrusted himself entirely to the protection of the citizens. All demands would be granted, and they should now go quietly home. The speech manifestly made an impression. To the question from the

Werner to William, March 20, 1848

I hasten, dear brother, to send you my first greeting from a free country! What a change in 2 days! The two shots fired by mistake on the Castle Square have brought Germany a whole generation forward at one bound. Outside my window the Civic Guard of my district is just falling in. The rest of the military is withdrawing from the town with funeral music, as the people demand. It was a frightening but beautiful night. The bright full moon was encircled by a brilliant halo, all windows were shining brightly wherever the fight was not raging. In the streets no sad or anxious face, only a terrible earnestness in the features of all the people, including the women, combined with belligerence and the humor so characteristic of the Berliners even in the most serious situations. On that fearful night I solemnly made my apologies to the Berliners for the bad opinion which I previously had of them! I listened with tears in my eyes to the sound, powerful logic of people from the lowest classes and I have become convinced that no nation can be more ripe for freedom. You should have seen how courageously they all rushed on when the word went around: "Here they come – Forward brothers!" If only we had weapons, was the general cry, it would soon be over, but even without them we will win. And just think, during the whole revolution not a single street lamp was broken, not a single piece of private property touched! All the houses stood open and the crowd surged through them up and down stairs but not a thing was stolen. Can one now not be proud to be called a German?…

people whether everything was really granted he answered – "Yes, everything, gentlemen!" "Smoking too?" sounded another voice. "Yes, smoking too" was the answer. "In the Tiergarten also?" – was further enquired. "Yes, you may smoke in the Tiergarten also, gentlemen." That was decisive. "Well, then, we can go home" was the general exclamation, and in a short time the cheered-up multitude left the square. The presence of mind with which the young prince – probably on his own responsibility – conceded the liberty of smoking in the public streets and the Tiergarten possibly averted more serious mischief.

This scene in the Castle Square produced in me an indelible impression. It showed with such unmistakable plainness the perilous fickleness of an excited multitude and the impossibility of predicting its actions. It taught me also that it is not usually the large and weighty questions that agitate the masses, but petty grievances long felt as oppressive by everybody. The prohibition of smoking in the streets and particularly in the Tiergarten, with the constant petty warfare with gendarmes and watchmen connected with it, formed in fact about the only hardship really comprehended by the great mass of the Berlin populace, and for which it in truth contended.

With the victory of the Revolution in Berlin, all serious activity was put a stop to for a time. The whole governmental machine seemed out of gear. The telegraph commission without being abolished or even suspended had simply ceased to do anything. I owe it to the energy of my friend Halske that our workshop quietly continued its activity during the hard times that ensued and manufactured telegraphic apparatus, although there was an entire lack of orders. Personally I was in a difficult position, as my official activity had ceased without any other being assigned me, and on the other hand it did not do to request my discharge at a time when it was generally assumed that a foreign war was imminent.

Then, again, as so often in my life, an event occurred which gave it a new and ultimately favorable direction.

In Schleswig-Holstein the uprising against the Danes had been accomplished successfully. A powerful impulse was thereby given to the desire for national unity, and free corps were formed throughout Germany to render aid to the brothers contending against foreign oppressors in the extreme north. On the other side, the Danes made preparations for reconquering the land, and the Copenhagen newspapers with one accord called upon the government to punish the center of the revolutionary movement, the town of Kiel, by a bombardment.

My brother-in-law, Himly, had in the previous year been called to Kiel as professor of chemistry, and resided close by the harbor. Sister Mathilde wrote me in great anxiety and almost envisaged her house in ruins, since it was particularly exposed to any assaults by the Danish men-of-war. The Friedrichsort marine battery, as the small fortress at the entrance to Kiel harbor was then called, was still in Danish hands; the entrance to the harbor stood perfectly open therefore to the Danish fleet.

This led me to the then entirely novel idea of defending the harbor by submarine mines fired by electricity. My wires insulated with gutta-percha offered a means of exploding such mines at the right moment in safety from the shore. I communicated this plan to my brother-in-law, who took it up enthusiastically and immediately submitted it to the provisional government for the defense of the country. The latter gave its approval and dispatched a special emissary to the Prussian government, with a request to grant me permission to execute the plan. My authorized employment or even mere leave of absence for this warlike purpose was opposed, however, on the ground that peace still reigned between Prussia and Denmark. But it was intimated to me that I should receive the desired permission if, as was expected, circumstances changed.

I employed this waiting time in making preparations. Large and particularly strong canvas bags rendered watertight by caoutchouc were got ready, each capable of holding about five hundredweight of powder. Further, wires insulated in great haste and exploding contrivances were prepared, and the galvanic batteries necessary for firing were procured. When the departmental chief at the war office, General von Reyher, in whose anteroom I daily waited for the decision, at last made it known that he had just been appointed minister and that, war having been resolved against Denmark, he granted me the desired leave of absence as the first act of hostilities against that country, my preparations were almost completed, and on the same evening I left for Kiel.

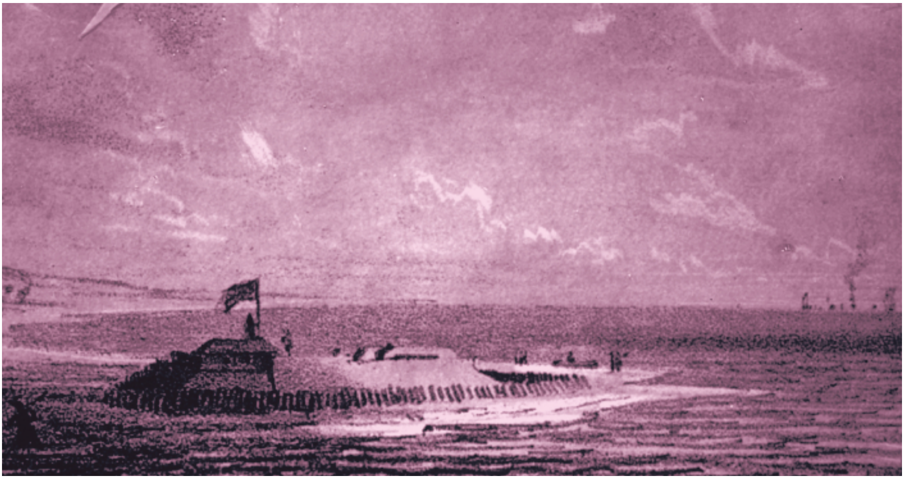
In Altona, where great excitement prevailed, my brother-in-law, Himly, already awaited me; a special locomotive took us to Kiel. The news of the declaration of war by Prussia had already become known, but was still considerably doubted. My appearance in Prussian uniform was rightly taken as evidence of the longed-for fact and all the way to Kiel and in the town itself excited unbounded joy.

In Kiel my brother-in-law had meanwhile made all the preparations in order to proceed quickly with the laying of the mines, as the appearance of the Danish fleet was expected daily. A shipload of powder had already arrived from Rendsburg, and a number of large casks stood ready, well calked and pitched, in order to be used provisionally instead of the still unfinished caoutchouc bags. These casks were filled with powder as quickly as possible, provided with fuses, and anchored in the rather narrow channel in front of the bathing establishment in such a way that they were buoyed twenty feet under the surface of the water. The firing wires were carried to two covered points on the shore, and the course of the current so disposed that a mine must explode if contact was made at both points simultaneously. At both observation points upright rods were set up and the instruction given that contact must be made if a hostile ship took up its position in the direct line of the rods, and had to remain closed until the ship had again completely removed itself from the said-direct line. If contact of both right lines were made at any moment simultaneously, the ship would be exactly over the mines. By experiments with small mines and boats it was ascertained that this exploding arrangement acted with perfect certainty.

In the meantime, the battle of Bau had been fought, in which the Schleswig-Holstein gymnasts and the German free lances had been vanquished by the Danes and in part made prisoners. It is remarkable how quickly and potently the national hatred and the bellicose passions of the otherwise peaceful Schleswig-Holsteiners were now inflamed. This was strikingly exhibited in the temper of the women. A characteristic instance came immediately under my own observation.

At a social gathering a beautiful and amiable young girl made me explain to her the construction of the mines laid down for the protection of the town and the method of firing them. When she learned that in a successful case the whole ship would be blown into the air and the entire crew destroyed, she excitedly asked me if I believed that there were people who could perpetrate such an atrocity, and with the pressure of a finger annihilate hundreds of human lives. When I affirmed this and endeavored to excuse it by the necessity of war, she turned indignantly away and obviously avoided me from that moment. When I again met her shortly afterward in society, the battle of Bau had meanwhile been fought; Wrangel was on the point of marching into Schleswig-Holstein with the Prussian troops, and the fever of war had taken possession of the public mind. To my surprise, as soon as she caught sight of me, my fair foe came straight up to me and asked whether my mines were still in order. I said "Yes" and added that I cherished the hope of soon being able to show their effectiveness on an enemy's ship, for it was said that a Danish fleet was on the way for the bombardment of Kiel. I intended by this means to again kindle her wrath, which had shown her to such advantage. But to my surprise she said, her countenance charged with hatred: "Oh, it would give me infinite pleasure if a couple of hundred of those monsters were to be seen sprawling in the air!" Her fiancé had been wounded at Bau and taken prisoner, and was according to rumor being badly treated by the Danes, along with the other captives aboard the warship *Droning Maria*. Hence this sudden reversal of her sentiments!

It really was said at the time that it had been resolved in Copenhagen to bombard Kiel, even before it was occupied by German troops. I was indeed somewhat anxious about the town, for the channel proved on precise investigation to be broader for ships of moderate size than was originally supposed. The Danish fleet could also quietly drop anchor at Friedrichsort and effect the bombardment at their leisure by means of gunboats. I considered it therefore of extreme importance that the Friedrichsort fort should not remain in Danish hands. It was said to be occupied by only a small number of disabled soldiers; its capture accordingly did not appear difficult.



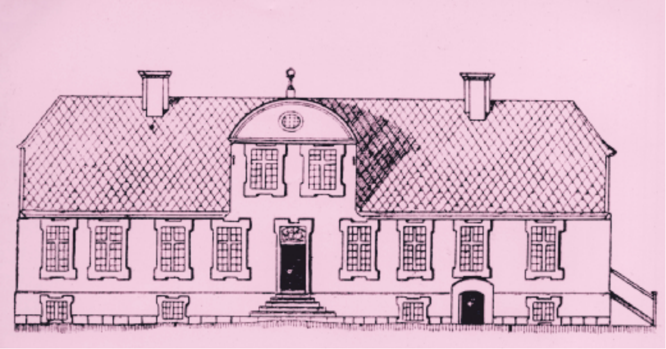
The Danish sea battery at Friedrichsort. Undated drawing.

I expressed my opinion to the newly nominated commander of Kiel, a Hanoverian major. He entirely agreed with me, for he had also received news that a Danish squadron was in fact on the way to occupy Friedrichsort. He only lamented that he was without men, and therefore unable to do anything. When I mentioned the Kiel civic guard, who certainly would be willing, he doubted this indeed, but offered to have the drum beat and the civic guard informed of my proposal. The latter turned out in respectable numbers, and I tried to prove to them that it was absolutely necessary for the protection of the life and property of the citizens of Kiel to occupy Friedrichsort, which today would be quite easy, but tomorrow perhaps no longer so.

My speech took effect. After a brief consultation, the civic guard declared itself ready to take possession of the fort in the coming night if I would undertake their command, to which I of course willingly consented. Accordingly, with the help of the commander of the town, who it is true had no men but a tolerably well-filled magazine at his disposal, an expeditionary force of 150 men was hastily formed from the civic guard, supplemented by a reserve of 50 men.

Toward midnight we were on the way to Holtenau, whence the storming of the fort was to be attempted. My troops marched noiselessly and bravely on to the drawbridge, which luckily had been let down, and with loud hurrahs we took possession of the fort. Resistance of any kind whatever, alas, was not perceptible. I set up my headquarters in the Commander's house, and soon the garrison, consisting of six old gunners and sergeants, altogether forgotten by the Danes as it seemed, was brought captive before us. The fellows were placed temporarily under arrest and on the following day transported to Kiel as the first prisoners of war; they were born Schleswig-Holsteiners, who obviously were glad enough to obtain their discharge from the Danish Army in this manner.

At daybreak I received the intelligence that a Danish man-of-war was lying in the roads, and soon afterward a spy was brought in who had been signaling to it from the ramparts. A trembling old man was brought before me, pinioned by powerful arms. On hearing the case, it appeared that he was the garrison chaplain, who, having found it too noisy in the otherwise quiet old fort, had therefore been giving the accustomed signal for a boat to the fishermen of Laboe, a village on the other side of the harbor entrance.



The old Commander's House at the fortress of Friedrichsort. A front view, around 1848.

The Danish warship remained quietly at anchor, sent a boat to Laboe, and on its return went again to sea. I had hoisted on the fort a huge black, red and gold flag and manned the walls, so that the ship might carry the news to Copenhagen that the Friedrichsort marine battery was occupied by German troops, as was soon to be read in the Danish papers.

There now began a right cheery life in the fort. My citizen troops did their duty conscientiously. On organizing the service, to my surprise, I found among the men members of well-known noble families of Schleswig-Holstein and respected citizens of the town of Kiel. They all, however, submitted implicitly to the command of a young Prussian Artillery officer of their own selection. I had the ramparts cleared, the embrasures repaired, and the old cannons placed on such platforms as remained. The powder magazine was put in order and a stove for making the balls red-hot erected by Kiel artisans. I was especially assisted in this work by my man Hemp (who without orders had followed me from Berlin), an intelligent, able fellow, who subsequently accompanied me in all my telegraphic undertakings and finally became chief engineer of the Indo-European telegraph line, which position he occupied till last year. With his help the men serving a gun were hastily trained, so that on the third day after the occupation we could essay a first shot, which announced far and wide the military occupation of Friedrichsort.

On the following days we had many visits from Kiel. Not only the commander of the town and even a member of the provincial government paid us a visit, but the wives and relations of the civic guard also came in great numbers, in order to be personally assured of the welfare of their friends. After the lapse of a week, however, my forces began perceptibly to shrink, as the wives in their visitings convincingly proved to their husbands that they were indispensable at home. I could not shut my eyes to the consideration that it would be impossible to retain in Friedrichsort for any length of time the citizens, who could only with difficulty be absent from their private business. On the other hand, Holstein was still entirely without regular troops, and the feeble remnants of the Schleswig-Holstein force alone opposed the Danes, who were again advancing into North Schleswig.

I therefore had the choice either of abandoning my conquest or of procuring an equivalent for the civic guard. The peasant youth of the Provostry – the district over against the fort forming the south shore of Kiel harbor – appeared to me particularly suitable for supplying this substitute. Accordingly, accompanied by a small body of the guard, I went with drum and flag first to Schönberg, the chief place of the Provostry, called the elders of the village together, and represented to them that it was altogether essential for their own safety that they should offer their grown-up sons for the occupation of the fort. Then arose a long and difficult negotiation with the farmers and their wives, who placed themselves behind their lords and took a leading part in the conversation. The people were of the opinion that if "the gentlemen," viz. the government, considered it necessary that their sons should march, they could give orders to that effect: Then one would know what one had to do. If the Danes actually invaded their land, the Provostry, then they would certainly defend it, even without orders, but "in det Butenland up de annere Sid det Waters," into the outland on the other side of the water, they would not voluntarily go.

As the peasantry with loud approval of the female chorus remained immovable, I became angry. I declared to them in the Low German tongue, which I had not forgotten from my boyhood days, that they were stupid asses and craven poltroons, and told them that the women in Germany had more courage than the men here. In proof thereof I read to them from a newspaper the statement that a female company had already been formed in Bavaria to protect the land

. . . On the 13 [of April] the Prussian Artillery Lieutenant Siemens called for volunteers to occupy Friedrichsort; this was immediately carried out by 150 men of the civic guard.

Berlinische Nachrichten von Staats- und gelehrten Sachen (Spenersche), *April 20, 1848*

against the Danes, as the men of that land had not the courage to do it. I would wait till they came, and defend the fort with them!

That had the desired effect. As I was on the point of departing with my little troop there came a deputation of the elder peasants and begged me to wait a little, they would think the matter over again, for they didn't like the idea that the women should defend their country. I declared my willingness, but required that the village should furnish at least 50 men, otherwise it would be no good. We were thereupon well fed, and an hour later there stood in fact 50 young men ready to go with us, followed by vehicles laden to the utmost with all sorts of provisions, "that their youngsters might not have to starve in the fort," as the mayor's wife explained to me. Thus we proceeded from village to village with like result, and late in the evening I marched back to the fort with 150 stout peasant lads and a whole caravan of supplies.

I thereupon discharged the civic guard with the exception of a sprinkling of volunteers, who were willing to assist me in the direction and drilling of my peasant corps, and I had the pleasure of seeing a thoroughly serviceable troop turned out in a short space of time.

Arms, ammunition, and military insignia I obtained from the ever helpful commander of the town, whose name unfortunately has escaped my memory.* My corps of volunteers was recognized by the provisional government, and also received the usual pay. In the military training of the folk my aforementioned man Hemp, whom I named chief of the artillery, again rendered me signal service. The cannons were certainly old and bad, but a short 24-pounder and a howitzer were still serviceable; the Danish blockade ship, which no longer left the harbor roads, seemed some-

** Major Hans Joachim von Sachau (1791 – 1848), Commander of the Fifth Rifle Battalion in 1848.*

what to respect the red-hot balls, which we always sent her when she came within range.

One morning, we were alarmed by the announcement that three large Danish men-of-war were lying in the roads. It seemed indeed as if an attack on the fort were intended, which, considering its bad condition and equipment, would have had everything in its favor. The weakest point of the fort was the entry-gate opening on the inner harbor. The drawbridge was out of repair, the moat was dry, and only the outlines of the ravelin protecting the entry remained. As meanwhile my brother-in-law, Himly, had partially replaced the casks temporarily employed for the mines by the india-rubber bags that had arrived from Berlin, I ordered one of these now superfluous casks to be towed to Friedrichsort, in order to be there used as fougade for the defense of the fort gate. The day before the alarm I had had a deep pit dug in the middle of the old ravelin and the cask lowered therein. As night had come on before this work was finished, the pit remained open and was guarded by a sentry. When next morning the alarm occurred, I commissioned my brother Friedrich – who, as my brothers William and Carl were to do subsequently, had followed me to Kiel and Friedrichsort – to prepare the firing communication, to enable the mine to be exploded in case of an attempted storming of the ramparts. The ships had now really approached within range. My three serviceable cannons were manned and the oven for heating the balls was fully active. I prohibited firing, however, before the ships forced the entrance. The rest of the men I had collected in the fortress yard to distribute them and exhort them to bravery, when suddenly in front of the fort gate arose a vast sheet of flame. I felt a violent compression succeeded by a violent expansion of the chest; the first sensation was accompanied by the clatter of broken windowpanes, and the second by the elevation of the tiles of all the roofs to a height of about a foot and their subsequent fall with a dreadful din.

> ***Report of May 6, 1848, from Lieutenant Colonel Meyer to General von Wrangel on the defense of Eckernförde harbor:***
>
> *Finally, I feel I must draw attention to the excellent qualities of Lieutenant Siemens of the Royal Prussian Artillery. He displayed remarkable ingenuity in creating much out of little, and his circumspection and knowledge of the district and people are such that it is highly desirable that he should retain his present post for a prolonged period.*

Of course it could only be the mine whose explosion had produced the mischief. I thought at once of my poor brother Fritz. I ran to the gate to look after him, but before I reached it he met me uninjured. He had prepared the mine, set up the battery on the terreplein, connected the one igniting wire with the one pole of the battery and fastened the other to the branch of a tree to have it ready to hand, and was about to announce this when the explosion occurred and the atmospheric pressure hurled him down from the rampart into the interior of the fort. The rather violent wind had shaken the second firing wire from the tree, causing it just to fall on the other pole of the battery, so producing the explosion.

With the sentry, who was standing on the breastwork of the ravelin when the explosion occurred, it had fared worse. I found him on the other side of the pit lying on the ground, apparently dead, beside him his gun buried half a barrel length in the earth, bayonet forward. The powerful draft caused by the mine exploding in the open pit had evidently caught the man up and hurled him over the crater of the mine. Fortunately, however, he had clutched his gun convulsively, and thereby the blow in falling was mitigated. The man came to his senses again after the lapse of an hour; he bled indeed from mouth, nose and ears, and then became blue over the whole body, but was otherwise uninjured and after a few days again fit for service. The Kiel military doctor, who had hurried to Friedrichsort on the announcement of the appearance of the Danish squadron, and was crossing the drawbridge at the moment of the explosion, was more seriously injured. He was thrown with his vehicle into the rampart moat and had received a few contusions.

The cook too, who was just carrying a bowl of soup up the steps of the ground floor and was thrown down by the explosion, was severely scalded.

Extremely remarkable were the mechanical effects which the explosion produced over a wide radius. It must be considered as a shot from an open earth-formed tube with a charge of five hundredweight of powder. In the entire fort no space of any extent remained closed. Either the atmospheric pressure had pushed in the doors or walls, or where they resisted the ensuing vacuum had burst them asunder. Even in the village of Laboe and in Holtenau the windowpanes were broken. The differential pressure in the interior of the fort must have amounted to at least one atmosphere, otherwise it could not have produced such an effect at so great a distance.

When I returned to the place where I had left my troop, I found it deserted, and feared that the people in their first terror had dispersed and crept away. To my delight, however, I soon saw that they had all betaken themselves to their assigned places. They had imagined that a Danish bomb had struck and the attack had begun.

The Danish ships had, however, determined to proceed no further, returned to the outer roads, and soon abandoned these also with the exception of the blockade ship. In the Copenhagen newspapers it was shortly afterward reported that one of the submarine mines, with which the harbor of Kiel was paved, had accidentally exploded and destroyed the fort. Indeed the view from the ships must have been rather astonishing. The red tiles of all the buildings of the fort protruded over the low ramparts, and rendered them particularly conspicuous. Immediately after the explosion, however, all the tiles had fallen down, and no houses were any longer visible.

That the Danes had acquired considerable respect for the mines is proved by the fact that in spite of the notorious weakness of the artillery defense of Kiel harbor during both Schleswig-Holstein wars, no Danish ship ventured into it. Although these first submarine mines never came into action, nonetheless they accordingly played a very important part. I may therefore with justice complain that later military writers have completely ignored this first harbor defense with the help of submarine mines, carried out in view of the whole world and at the time much talked about. Even German military writers have subsequently ascribed the invention to Professor Jacobi in St. Petersburg, although his experiments at Kronstadt were carried out many years later, and he himself never dreamed of disputing my claim to the invention and its first employment in war.

On the History of the Torpedo

The evening edition of the National Zeitung *of July 23 contains an article: "Torpedoes and their employment in naval warfare," which begins with the statement "It is indisputable that the credit for the first use of mines in naval warfare belongs to the Russians, etc." As I have repeatedly come across this statement and it has even found its way into military literature I would request that the following correction be published: Submarine mines with electrical detonation were first used in 1848 on an extensive scale and in a successful manner for the defense of Kiel harbor and are therefore a German and not a Russian invention.*
. . . In the spring of 1848 . . . the appearance of a Danish fleet in Kiel harbor was generally expected . . . My brother-in-law, Professor of Chemistry C. Himly, first had the idea of preventing the feared entry of the Danish fleet by means of mines to be laid in the navigable water . . .
Seebad Westerland (Sylt),
July 27, 1877
Dr. Werner Siemens

National Zeitung, *July 30, 1877*

When, after conclusion of peace, the mines were fished up and lifted, the powder in the caoutchouc bags was found still dry as dust, despite the two years' soaking in seawater. It is thus not to be doubted that, had occasion offered, the mines would have done their duty.

Soon after the explosion in Friedrichsort just described, the main body of the Prussian Army under Wrangel entered Schleswig-Holstein. A little later I received a direct dispatch from headquarters, in which I was commended for the harbor defense by submarine mines and for the occupation of the Friedrichsort marine battery. I was therein further apprised that a company of one of the recently formed Schleswig-Holstein battalions under Lieutenant Krohn would undertake the permanent occupation of the fort, and

Army Order No. 840
H. Q. Flensburg, June 25, 1848

To W. Siemens, Royal Lieutenant in the 3rd Artillery Brigade . . . I wish to express my appreciation of your efforts to put Friedrichsort in a state of defense and also of the arrangements you have made to render the entry of enemy ships into Kiel harbor more difficult and I hope that you will do what you can with the somewhat inadequate means available . . .

The Army Commander Wrangel

was charged to march at a precisely appointed time with my peasant corps to the mouth of the Schlei, to cross it at a suitable place, and urge the population of the province of Angeln to seize Danish fugitives, who would there show themselves after an intended battle near Schleswig.

After being relieved by the Schleswig-Holstein company, I marched at the appointed time to Missunde, crossed the Schlei at daybreak, and led my briskly marching troop toward Flensburg. At that early hour we already heard the roaring of the cannons near Schleswig. The population comported itself very calmly, and did not seem at all inclined to let itself be disturbed from its repose. No Danes were to be seen; we heard, however, in the evening from villagers that the Danish Army had been defeated and was retreating by way of Flensburg, pursued by the Prussians. In the neighborhood of Flensburg this report was confirmed; the Prussian advance guard had already occupied the town.

As I had no further orders for my free corps, and did not feel myself warranted in retaining the men any longer, after the fort, for whose defense they had been recruited, was occupied by the military, I dismissed them to their homes, to which they hurried with all speed, and went myself to Flensburg to deliver my report. That, however, proved extremely difficult as the greatest confusion still prevailed in that town. The streets were completely barricaded with all sorts of vehicles, and no military or civil authority was discoverable. At last in the throng I stumbled upon Captain von Zastrow, well known to me in Berlin, to whom I imparted my difficulty. He told me that he had received the command of a newly formed Schleswig-Holstein corps, and had orders to march with it to Tondern on the following day. He was very much in want of officers, however, and proposed that I should join him, and undertake the command of the battery. He would set everything right formally with the commander-in-chief and also take in charge my report to the same. This proposal particularly pleased me, as it would have been anything but agreeable to me to have been removed just then from the seat of war to peace quarters in Berlin. I therefore wrote my report detailing the execution of my orders, and announced that I had discharged the volunteer peasantry and in the absence of further instructions was about to undertake provisionally the command that had been offered me of a Schleswig-Holstein battery.

Accordingly, on the following day I rode at the head of the battery assigned me over the barren ridges of the "sea-girt" land toward Tondern. The joy, however, was not to last long. On arrival the commander handed me a dispatch brought from headquarters by estafet performance, according to which I was to report myself at once to the commander-in-chief. As a result of this I requisitioned a vehicle, and toward midnight arrived again in Flensburg, and reported myself at once at headquarters. I was shown into a large room of the first hotel in Flensburg and there found seated at a long table a number of officers of all ranks and of every arm of the service. On the sofa at the narrow end of the table sat two young princes, while General Wrangel occupied the first place next to the sofa at the end of one of the long sides. When I had delivered my report the General rose, and with him the whole assemblage, as it was contrary to etiquette to be seated while the commander-in-chief stood.

The General expressed astonishment at my being there, as it was only a few hours since he had made out the order for my attendance. When I explained that I had turned back immediately at the conclusion of the march, he thought I must be very tired and should drink a cup of tea. At his express order I had to seat myself at his place and take a cup of tea, while the rest of the company to my great embarrassment remained standing. I gained the impression that the commander-in-chief wished to use the opportunity to show that he honored merit without respect of rank, and to give at the same time a little exercise in etiquette. In the ensuing conversation the General expressed his acknowledgments for the protection of Kiel harbor by submarine mines, as well as for the occupation of the fort of Friedrichsort. Further, he said it would now be necessary to make the protection of Kiel harbor as strong as possible, and also to secure the harbor of Eckernförde by submarine mines, as he had the intention of entering Jutland with his whole army. When I replied that the Eckernförde harbor was too open and its channel too broad for resting its defense on mines, and that a few well-placed batteries could do this with greater certainty, a long discussion arose in the company with regard to the supposed superiority of marine artillery to land batteries, in which I took leave to observe that a battery of eight 24-pounders well placed and protected by an earth wall, using red-hot balls, might engage the largest man-of-war. In all the history of war, the assertion that a land battery might be razed by a few broadsides from a man-of-war had not been proved, and no wooden ship could long withstand a fire of red-hot balls.

The final outcome of this audience was that the defense of the harbors of Kiel and Eckernförde was formally entrusted to me. I was nominated commander of Friedrichsort and received an open order to the commander of the fortress of Rendsburg, in which the latter was directed to comply with my requisitions of guns, ammunition, and men for Friedrichsort and the batteries to be set up at the harbor of Eckernförde. This order was duly complied with in Rendsburg – it is true, with some reluctance, as the fortress itself was very inadequately equipped for defense. Friedrichsort was now provided with serviceable cannon, and put as far as possible into a state of defense. In Eckernförde I erected a large battery for heavy 12- and short 24-pounders on the level shore, somewhat eastward of the town, and a howitzer battery on the hilly land on the northern shore of the harbor.

Neither Friedrichsort nor Eckernförde came into serious action in this campaign, but in the following year the batteries set up by me at Eckernförde acquired renown by their victorious struggle with a Danish squadron, in which the line-of-battle ship *Christian VIII* was set on fire and the frigate *Gefion* rendered *hors de combat* and captured.

After the completion of the fortification of Friedrichsort and the batteries at Eckernförde, my activity began to be somewhat monotonous. It was mainly confined to the watching of the enemy's blockade ship lying before Friedrichsort, and the control of the shipping passing the harbor entrance. The military commander of Kiel had forbidden the departure of trading vessels without special permission, and had given the Friedrichsort marine battery orders to prevent it by force in case of need. This led to a small military engagement, which brought a little variety into our monotonous life.

One evening I crossed the entrance of the harbor in the commander's boat to visit the Laboe battery, which I had erected on the opposite shore, when a Dutch bark in full sail came toward me, with the manifest intention of leaving the harbor without giving the prescribed notification. I called to the captain to lie to and report himself, otherwise he would be fired on by the fort. The Dutchman and his wife, who appeared to compose the whole crew, did not, however, take my warning in earnest, on the contrary declaring they were not going to trouble themselves about the prohibition. While this negotiation was taking place there was a flash, however, from the fort rampart, and a warning shot fell into the water close in front of the ship, as prescribed by the regulations. Nevertheless, the ship continued its course under full sail. Now followed from the fort, as well as from

The Christian VIII, *a Danish ship of the line, explodes after taking a hit from the sea batteries set up by Werner von Siemens in 1849 (illustration from* Leipziger Zeitung, *vol. 1, 1849).*

the Laboe battery, shot on shot, to which was soon added sharp fire from a military sentry stationed on the shore. But the doughty Dutchman was not to be diverted from his object, and, successfully clearing the harbor mouth, he disappeared in the darkness of the night that had meanwhile come down.

Fishermen who had been sent out found the ship on the following morning anchored outside the harbor entrance, and the crew busily engaged in making good the harm caused in particular by the musketballs. The bravery of the Dutchman was very simply explained by the fact that he had lashed the helm when he actually heard the balls whistling, and had prudently retired with his wife below the waterline, where both were completely protected. I myself with my boat's crew was entirely at the mercy of the balls, and could afterward boast at any rate that I had once withstood an artillery fire without flinching! For the rest, I must confess that the hissing of the balls whizzing past did not excite in me precisely pleasurable sensations.

Finally, in the latter part of summer, the Danish blockade ship too brought us another interesting interruption of the monotonous existence in the fort.

I received from headquarters the communication that the free corps under the command of the Bavarian Major von der Tann would attempt a night attack on the blockade ship, and also the order to support this undertaking with all the resources of the fort. Soon after, von der Tann, with his adjutant, a Count Bernstorff, presented himself to me, and took up his quarters in Friedrichsort. The free corps collected at Holtenau, where also the boat squadron which was to undertake the night attack was organized. The day before, a parade of the free company took place in the fort yard, which did not inspire me with much confidence in the success of the venturesome enterprise. The men were not, perhaps, wanting in courage, but in discipline and calm resolution. Von der Tann and his adjutant endeavored in vain to convert the wild confusion into military order.

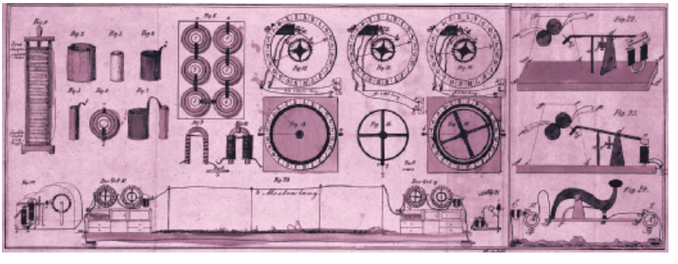
The plan of the surprise proceeded from a man who had formerly held some subordinate post in the Danish Navy. He was a Hercules, who had got his huge limbs into a gold-embroidered admiral's uniform of his own fancy, and incited the men with loud-sounding voice to courageous deeds. Thus he asked the fellows standing in rank and file what they would do when they had got on board and were confronted by the Danes. One declared he would stab the nearest man, another found it more fitting to knock him down, and so on. The "Admiral" listened quietly, then stretched himself to his full height and asked with flashing eyes and gestures appertaining thereto: "Do you know what I shall do? – I shall take the two nearest Danes and grind them to powder against one another!" That sort of thing did not exactly inspire confidence in future heroic deeds.

The boat squadron was to pass the fort about half past eleven at night in the utmost stillness and without lights, and then proceed to the blockade ship for the attack, when a signal given from the fort testified that the hostile ship was maintaining its wonted quiet. The signal was duly given; it was, however, about one o'clock before the first boats had reached the fort. Then nearly two hours passed without anything happening, and at last the whole party returned without any order and with loud din. The "Admiral" had at first not been able to find the blockade ship, then he declared he had observed that the ship was alarmed, and was provided with boarding nettings, so that clearly the planned attack had been betrayed. With cries of treachery the expedition returned to Holtenau, and soon afterward disbanded itself. On the following morning the ship lay in its accustomed place, and with the strongest telescopes no special armature against the threatened attack was to be observed.

As von der Tann confided to me, the undertaking had collapsed through want of discipline and too free resort to stimulating potations, and he himself had lost the desire to make a further attempt. I was heartily sorry for the able and amiable Bavarian officer in this fiasco. Von der Tann remained my guest in the fort for several days, and I have in later years often remembered that agreeable time with pleasure, whenever the fame of the deeds of "General von der Tann" reached me. With my official appointment as commander of Friedrichsort, and the charge to provide for the defense of the harbor of Eckernförde by the installation of batteries, my position had lost the somewhat adventurous character that had thus far clung to it. It had, however, also lost by that a great part of the charm which it had hitherto possessed for me. Particularly after I had fulfilled my tasks, and the commencement of the peace negotiations rendered further warlike activity very improbable, the longing for the resumption of my scientific-technical activity in Berlin took possession of me with ever growing strength.

THE FIRST TELEGRAPH LINES

In the meantime, great changes had taken place there. The military commission for the introduction of electric telegraphs had been formally dissolved and telegraphy placed under the newly created Ministry of Commerce. Assessor NOTTEBOHM, who had already occupied an administrative post in the telegraph commission, had been appointed as head of this department. The resolution was taken to follow



A contemporary dial telegraph and Morse telegraph set, around 1849. 1: Voltaic pile, 2–7: various parts of a Daniel cell, 8: galvanic battery, 9: electromagnet, 10: electromagnet with coils, 11: armature for 10, 12: dial telegraph with circuit open, 13: dial telegraph with circuit closed, 14: circuit open again after closing, 15–18: marker, 19–21: functional diagram of the dial telegraph, 22–23: transmitter of the Morse telegraph, 24: key of the Morse telegraph.

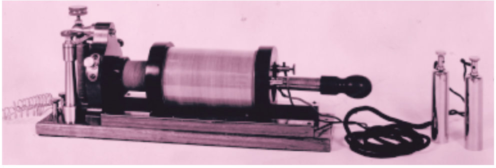
the course adopted by the late commission, and first to construct in all haste a subterranean line from Berlin to Frankfurt am Main, where the German National Assembly was holding its sittings. In consequence of this, an inquiry was addressed to me whether I was disposed to direct the construction of this line according to the proposals made by me to the commission. In the event of my acceptance, my command from the war office would be transferred to the Ministry of Commerce. Although a position under Assessor Nottebohm was not particularly agreeable to me, I nevertheless accepted the call, since it set me free from the present monotonous military life in the little fort, and gave me an opportunity of bringing my proposals into practical execution on a large scale.

In Berlin, I found Halske already busily engaged on work for the line about to be constructed. It had been determined to lay the line completely underground, as it was feared that wires aboveground would, in that time of great political excitement, be destroyed. The wires, insulated by a coating of gutta-percha, were to be laid without external protection in the railway embankment in a trench a foot and a half deep. My proposed protection of the communications by means of envelopes of iron wires, iron tubes, or clay channels was not approved on account of the great expense. A contract had already been signed with the Berlin india-rubber factory of Fonrobert & Pruckner for the further construction of subterranean wires. This was the same factory to which I had transferred my model for the covering of copper wires with gutta-percha, and which had already manufactured the experimental line from Berlin to Grossbeeren with a press made according to that model. I had to confine myself to providing for the best possible insulation of the wires. Considerable difficulties stood in the way, however, inasmuch as, owing to the sudden great demand for gutta-percha, the best sort for insulation was soon off the market.

To cope with this impediment to the rapid progress required of the work, it was resolved to make use of the recent English invention of vulcanizing the gutta-percha, i.e., mixing it with sulfur, whereby even with inferior kinds of gutta-percha the insulation of the conductors as well as their power of resisting external injuries was increased. Unfortunately the vulcanization turned out afterward to be a mistake, as the sulfur combined with the copper of the conductor and the adjacent layers of gutta-percha gradually became coppery and capable of conduction. To this circumstance was it mainly ascribable that the wires, though perfectly insulated at the time of their being laid down, had already lost a part of their insulation. Particular care was taken in testing the wires in the factory. For this purpose Halske manufactured galvanometers which far excelled in sensitiveness all known up to that time. In testings with these sensitive galvanometers I observed for the first time in the year 1847 the surprising phenomenon that, even in a perfectly insulated wire lying in water, on interposing a battery a short current occurred, which was succeeded on removal of the battery by an equally strong current in the opposite direction. This was the first observation of the electrostatic charge by galvanic chains. I was at first inclined to see in this a phenomenon of polarization, since at that time the galvanometer was not considered capable of indicating the passage of static electricity. The phenomena on longer, well-insulated lines, however, soon made it quite obvious to me that it was a case of ELECTROSTATIC CHARGE and not of polarization.

The first difficulty, the finding of defective insulating points in a long piece of the conducting wire, I was able to overcome in the following manner. The dry wire coated with gutta-percha was drawn through a vessel filled with water and insulated in respect to the earth, while the second coil of thin covered wire, which surrounded the electromagnet of a Neef hammer, was interposed between the insulated copper wire and the earth. If now a workman standing in communication with the earth dipped a finger into the water of the insulated vessel, he felt electrical shocks at the moment at which a defective piece of the wire enveloped by gutta-percha was immersed. In this way I succeeded in detecting all the small defects of insulation discoverable in no other way, and after their removal in obtaining conductors with extremely good insulation.

With regard to the modification of the Neef hammer just described, the following observation may here find a place. I had already made this modification in the year 1844 and given it the name of voltaic inductor. It even then afforded me the opportunity of observing the therapeutic effect of the variable currents induced in the second coil of such a



Sled inductor built to Emil Du Bois-Reymond's design by Johann Georg Halske, 1846. One of the first medical apparatus to apply electric current for therapeutic purposes. Moving the outer spool and a soft-iron core made it possible to set the voltage on a precisely engraved scale. Current was applied using the terminals at the left, and the electrode handles were connected to the terminals at the right.

VOLTAIC INDUCTOR. At that time, my brother Friedrich was suffering a good deal of rheumatic toothache, which had affected his otherwise perfectly sound teeth and refused to yield to any prescribed remedy. The experiments with my new voltaic inductor led me to hit upon the idea of trying whether the variable currents produced by it could not remove the intolerable pain, or at least diminish it, if conducted through the roots of the teeth. This was actually the case with a particularly painful front tooth. The pain was at the first moment intense, but then quite suddenly ceased.

With the great force of will which at all times characterized my brother Friedrich, he at once proceeded to send alternating currents through all the roots, and thereby obtained such relief from pain as he had not experienced for weeks. Unfortunately, however, on the second day the pains returned. By repeated application of electricity their cessation was again effected, but the ensuing painless period became shorter, and at last the remedial agency altogether failed. This first attempt within my knowledge to employ galvanism for therapeutic purposes inspired me with a certain distrust of this particular application of the electric current. It appeared as if its action were only temporarily, not permanently, curative.

The ensuing autumn of 1848 was to me an exceedingly interesting and exciting one. The line to Frankfurt am Main, where the German Parliament held its sittings and the vicar-general of the empire had his residence, was for political reasons to be completed as quickly as possible. This was, however, rendered difficult on the one hand by the disturbed political condition of affairs, on the other by altogether unexpected phenomena, which manifested themselves in the underground conductors. My friend Halske, to whom had been consigned the fitting of the finished parts of the line with signaling apparatus, was the first to encounter these phenomena while I was engaged upon the line between Eisenach and Frankfurt. It had been resolved to carry the latter aboveground, as the railway was still in course of construction, the land having only been acquired in part.

> *… The difficulties and complications in negotiation entailed by the present constitution of Germany in order to take a large and useful installation even through some German principalities and the free townships are well illustrated by the fact that in connection with the electromagnetic telegraph line from Berlin to Cologne and Frankfurt am Main no less than 9 public treaties and one private treaty (with the Thuringian Railway Company) were necessary, namely treaties with Hanover, Brunswick, Schaumburg-Lippe, the Electorate of Hesse, the Grand Duchy of Hesse, Frankfurt am Main, Anhalt-Dessau and Köthen, the Grand Duchy of Sachsen-Weimar, Sachsen-Coburg-Gotha …*
>
> Königl. Privilegierte Berlinische Zeitung, *January 10, 1849*

Halske found first of all that with shorter lines our self-interrupting dial telegraphs acted with much greater speed than corresponded to the resistance of the line. When communication between Berlin and Köthen had been established, a distance of about 20 German miles (95 English miles), the sending apparatus ran with double velocity while the receiving apparatus stopped altogether. The better the lines were insulated, the earlier this, at the time inexplicable, phenomenon occurred. This induced Halske deliberately to impair the insulation of the line by the addition of artificial watery bypasses.

The aboveground construction likewise encountered unexpected difficulties. Where the land for the future railway had not yet been purchased, the owners would not permit the erection of the posts. This opposition was encountered especially in the non-Prussian parts, Hesse-Cassel and Hesse-Darmstadt, when the antagonism between the government of Prussia and the administration of the empire had become considerably more acute after the restoration of order in Berlin in consequence of the entrance of the army returning from Schleswig-Holstein. I only succeeded in carrying out my task by obtaining an open order from the vicar-general of the empire, Archduke John. Technical difficulties also made their appearance. The line was con-

Porcelain insulator for the Berlin – Frankfurt am Main Telegraph Line, 1849.

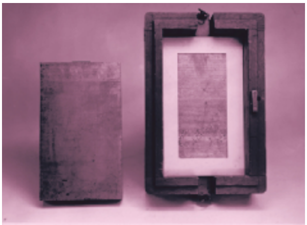


Plate-type lightning conductors *for the Berlin – Frankfurt am Main Telegraph Line, 1849.*

structed of copper wire, as suitable iron wires were not then to be had in Germany, and moreover were still regarded with a certain mistrust. The unfortunate experiences which we had had the foregoing year in the case of the Berlin – Potsdam line, which despite the application of all sorts of insulating media proved so badly insulated in rainy weather that the proper service of the apparatus was constantly disturbed, had led me to make use of bell-shaped insulators of porcelain. These possessed the great advantage that the inner surface of the bell always remained dry even in rainy weather, whereby the insulation was secured under all circumstances. In fact I succeeded in this way in producing an almost perfect insulation. Unfortunately I did not at the time think it necessary to solder the ends of the copper wire then in use, close coiling seeming to me sufficient. This afterward turned out to be an error. In calm weather the apparatus acted very well, but with a strong wind the resistance of the conductor was so remarkably variable that the apparatus refused to work. Only subsequent soldering of all the joints put an end to this trouble.

The atmospheric electricity also proved very disturbing. In passing from level to high land, currents of varying direction often traversed the communications and impeded the working of the apparatus. A late-autumn storm caused widespread destruction, which led me to construct lightning conductors for the protection of the lines and apparatus. In order to ascertain the most efficient form of lightning conductors, I set up between two parallel wires spikes, balls, and plates at equal intervals from one another, and observed the sparks, caused by the discharge of a large battery of Leyden jars, which passed between these three adjacent lightning conductors.

It appeared that very weak discharges took their course solely through the spikes, while stronger ones passed mainly between the balls, and very strong ones were carried off in a large number of sparks almost entirely through the plates. For actual lightning, therefore, roughened metallic plates placed nearly opposite one another proved particularly effective. The influence of the northern lights also frequently made itself perceptible, and at times in a very disturbing degree, especially in the underground line running mainly from east to west. Thus, during the great aurora in the autumn of 1848, communication was interrupted for days between Berlin and Köthen on account of violent and rapidly changing currents. This was the first observation of the connection between earth currents, magnetic disturbance, and the aurora borealis.

When the underground line had been extended to Erfurt, Halske's watery bypasses were no longer sufficient. But meanwhile I had become convinced that the peculiar behavior of the underground wires could only be ascribed to the electrostatic charge already observed at the testings in the factory – the wire forming the inner, the damp soil the outer, coating of a Leyden jar. Conclusive evidence was the fact that the quantity of electricity contained in a perfectly insulated conductor, measured by the deflection of a freely oscillating magnetic needle, was definitely related both to the electromotive force of the interposed galvanic battery and to the length of the wire; further, that the electric tension of the charge in a closed conductor corresponded to the electric tension occurring at every point of the circuit according to Ohm's law.

The construction of a telegraph line between Berlin and Hamburg has been in the offing for a considerable time, but so far nothing has come of it because the authorities here would not accept the demand of the Hamburg business community that the line should also be available for private use. Military events in the Duchies which have rendered rapid communication between north and south essential now appear to have led to agreement to the effect that the line will be taken not only to Hamburg but as far as Rendsburg … The local government in Rendsburg and the central authority in Frankfurt will thus soon be able to communicate with one another via Berlin with lightning speed.

National Zeitung, *April 11, 1849*

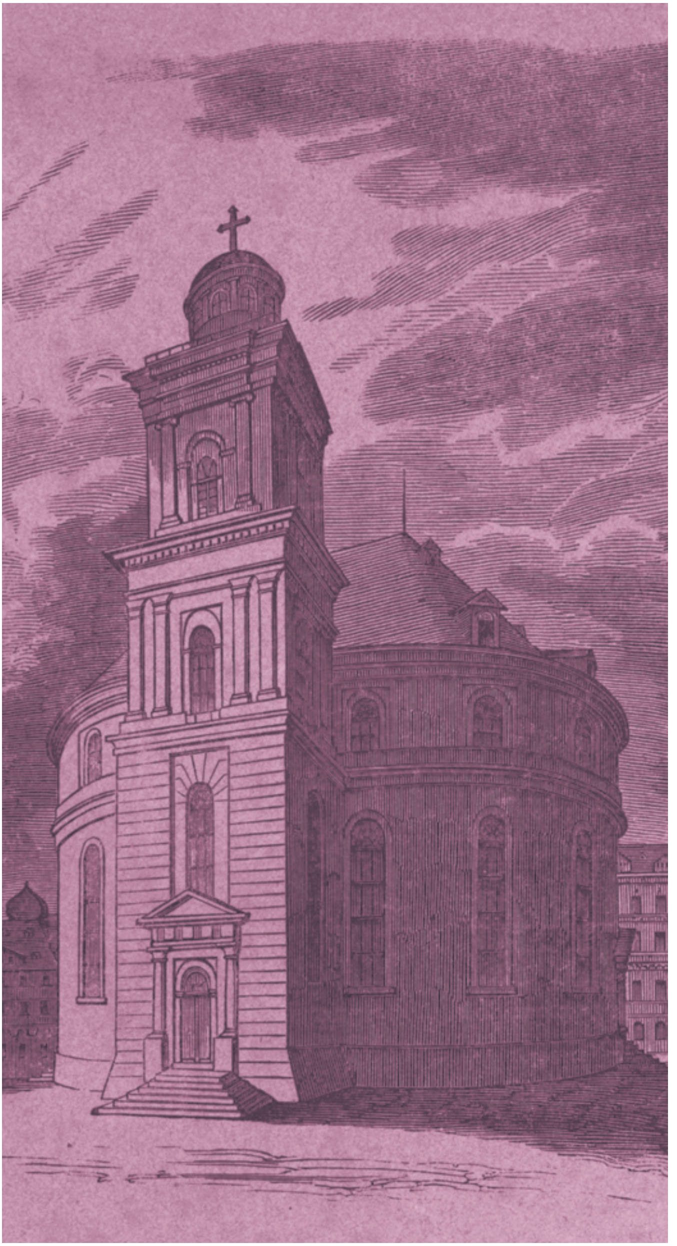
In this way and in spite of the present unfavorable conditions, the Prussian administration has already completed 245 Prussian miles at a cost of about 400,000 thalers and in less than 12 months connecting Berlin with Frankfurt (Main), Aix-la-Chapelle, Hamburg, and Stettin. Before the end of this year . . . the connection between Berlin and Oderberg will be completed, thus by arrangement with the Imperial Austrian Telegraphs connecting Berlin with Vienna and the Adriatic Sea.

From Polytechnisches Journal, *1849, 151 – 153*

This having been perceived, the impediments to signaling on long underground lines could be, if not removed entirely, yet rendered innocuous for practical purposes by suitable contrivances. These were the application of bypasses in the form of metallic resistances without self-induction, and automatic translation by which several closed pieces of line were united into a single large line.

My theory of the electrostatic charge of closed as well as of open circuits, however, found but little acceptance at first even in scientific circles, since it was opposed to the ideas prevailing at the time. Altogether it is not easy at the present day, when one can hardly conceive how a civilized man can live without railways and telegraphs, to carry oneself back in imagination to that time, with a view to understanding the difficulties which we then encountered in things now regarded as a matter of course. Conceptions and aids which are today familiar to every schoolboy could at that time often be obtained only by effort and hard work.

I had the satisfaction of seeing the first long telegraph line – first not merely in Germany but in Europe – already at work in the winter of 1849, so that the election of an Emperor, which took place in Frankfurt, was by its help known at the same hour in Berlin. This favorable result led to the determination of the Prussian government to construct at once a line from Berlin to Cologne and the Prussian frontier at Verviers, and after that others to Hamburg and Breslau. All these lines were for safety's sake to be underground, according to the system of the Berlin – Eisenach line, although in this unmistakable defects had already made themselves manifest. As these defects were mainly owing to the facility with which the wires were injured by



The Paulskirche in Frankfurt, where the German Parliament met in 1848. To make sure it would be informed quickly about the body's decisions, the Prussian government engaged the then Lieutenant Werner Siemens to build a telegraph line as fast as possible from Berlin to Frankfurt am Main – the first extended electric telegraph line in Germany.

Werner von Siemens (R) and his friend William Meyer (1816–1868) (L) in the 1840s.

workmen, and here and there also by rats, mice and moles, through being deposited only one and a half to two feet below the surface in the mostly loose sand of the railway embankments, it was determined to bury the wires $2^1/_2$ to 3 feet deep; but even then on account of the cost there was to be no external protection.

I had declared myself ready to undertake also the superintendence of the construction of the line to Cologne and Verviers, provided I received further military leave of absence and provided my friend William Meyer, who had always faithfully aided me in my work in his free time and was therefore thoroughly competent, was ordered to assist me. Both conditions were satisfied, and accordingly in the spring of 1849* we began the construction of the line simultaneously at several points. Meyer had considerable organizing talent, and was particularly adept at managing works in which many forces had to cooperate harmoniously.

** Correctly, the fall of 1848.*

Difficulties arose at the rivers Elbe and Rhine, where the active navigation caused me to fear injuries to the wires by dragging anchors. This danger was particularly great in crossing the Rhine, as the conducting wires were for almost the whole breadth of the river threatened by anchors and fishing tackle. An envelope of iron wire, which was employed in the case of the Elbe and in crossing smaller rivers, appeared insufficient for the Rhine, as the tackle of the sailors and fishermen, provided with sharp points, could

Werner von Siemens as an artillery officer, around 1843.

penetrate through the wire covering and injure the insulated conductors within, and as a cable could not be made strong enough to resist the dragging anchors of large ships. I had, therefore, made specially for the Rhine a chain of wrought-iron tubes, in the cavities of which the insulated wires were placed, while a strong chain cable, supported by a series of heavy ships' anchors, was destined to protect the tube chain from the dragging anchors of ships passing down the river. This first large subaqueous line with its external protection has stood the test very well. When many years later, after the building of the fixed railway bridge, it was taken up again, a number of ships' anchors were found suspended from the protecting chain, which the sailors had had to cut in order to free their ships. The chain had thus done its duty.

An extremely difficult and instructive piece of work was the construction of the line from Cologne via Aix-la-Chapelle to Verviers in Belgium, where the junction with the overhead line from Brussels to Verviers, which had meanwhile been put in hand, was to be made. Here were several tunnels to be passed through, in which the conducting wires had to be protected by iron tubes attached to the tunnel walls. In large portions of the railway embankment the trench for bedding the wire had to be made by blasting with powder.

During the construction of the line I got to know the entrepreneur of the pigeon post between Cologne and

Brussels, a Mr. Reuter, whose useful and profitable business appeared to be hopelessly destroyed by the laying of the electric telegraph. When Mrs. Reuter, who accompanied her husband on his journeys, was lamenting over this destruction of their business, I gave the couple the advice to go to London, and there set up a dispatch-forwarding bureau, such as had just been established in Berlin by a Mr. Wolff, with the cooperation of my cousin the aforementioned law counselor Siemens. The Reuters followed my advice with remarkable success. Reuter's telegraph agency in London and its founder, the rich Baron Reuter, have today a worldwide reputation.

When the junction of the meanwhile completed Belgian telegraph line with the Prussian had been effected at Verviers, I received an invitation to Brussels, to give a lecture before King Leopold on electric telegraphy. I found the whole royal family assembled in the Brussels palace, and delivered a long lecture accompanied by experiments, which they followed with close attention and quick understanding, as was evidenced by the intense discussion which followed.

The final decision concerning the turn I should give to my future life had now to be made. The military authorities had only with reluctance granted the extension of my order for service with the Ministry of Commerce, and had emphatically declared that an extension of the same would not be granted. I had the choice either of stepping back into active military service, or of going over to government telegraphy, in which my position as managing engineer was assured, or lastly of renouncing every position of public service, and devoting myself entirely to private scientific and technical activity.

I decided in favor of the last. To return to military garrison service, after the exciting and successfully active life which I had behind me, I should have found altogether impossible. The civil service did not at all content me. There was wanting in it the feeling of comradeship, which mitigates and renders endurable the oppressive differences of rank and power; there was wanting in it also the candor, which reconciles one even with the bluntness, which is traditional in the army. My brief experience of the civil service gave me sufficient grounds for the formation of this opinion. As long as my superiors understood nothing of telegraphy, they let me work entirely unchecked, and limited their intervention and instructions to questions of financial importance. That soon changed in the degree in which my immediate superior in office, "Assessor," afterward "Baurat" Nottebohm, acquired knowledge of the subject during the progress of the work. People were assigned to me of whom I could make no use, technical arrangements ordered which I knew to be bad – in short, frictions and differences occurred which marred the pleasure in my work.

Again, the weakness of the insulated conducting wires, lying unprotected in the loose soil of the railway embankments, already began to show itself with increasing distinctness. Faults in the insulation made their appearance and were discovered and removed only with difficulty; breakage of the wires without loss of insulation occurred, which often only lasted a few hours, and whose position therefore was difficult to determine. The search for and repairing of these defects were commonly entrusted to inexperienced people, who cut the line in numberless places to confine the fault within limits, and by unskillful diggings and joinings paved the way for new defects, which were then again attributed to me and the system. Notwithstanding, new undertakings of the same

Werner to William, June 9, 1849

. . . taken all together the mechanical workshops in Berlin do not have as many workmen as we have now and, of the former, not a third would be of any use to us, as Halske rightly will only employ the very best . . .

General Inspectorate of Artillery Berlin, June 16, 1849

. . . As regards the resignation of Second Lieutenant Siemens of the 3rd Artillery Brigade I notice that contrary to standing orders he has addressed his request to his company commander instead of to the brigadier.

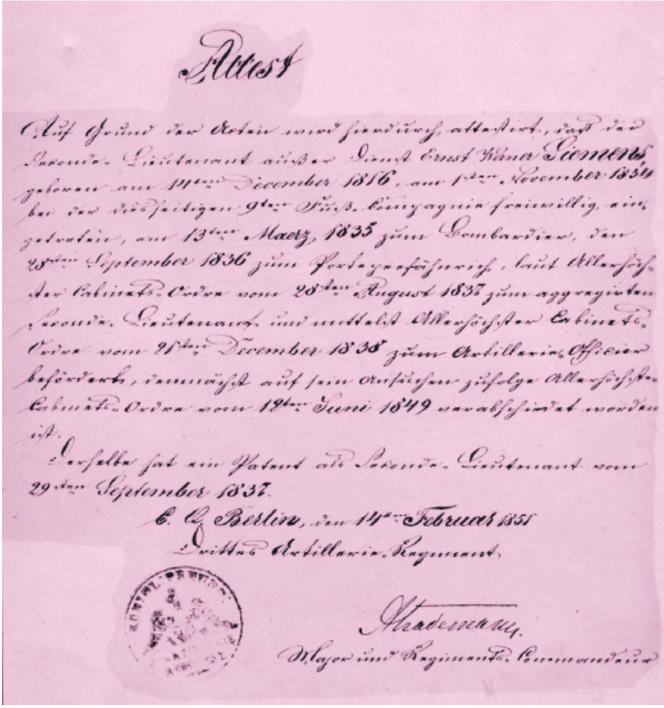
[signed] W. Adalbert
II. Artillery Inspectorate

description were entered upon with an almost blind confidence. It may perhaps have been the political circumstances of the time which called for the rapid construction of a telegraphic network to embrace the whole country, even at the risk of its not being of long duration. The external protection of the conductors by iron tubes proposed by me, as in crossing the Rhine, or by sheathing with iron wires, for the manufacture of which a Cologne firm had at my instigation already made preparations, was declared to be too dear and not readily producible; the provisional character of the first attempts was maintained.

On the other hand, the factory for telegraphic apparatus, which I had founded along with my friend Halske, and into which I had reserved the right of entry, had already under his excellent management obtained considerable recognition by reason of its remarkable achievements. The great importance of electric telegraphy for practical life was perceived, and the managers of railways in particular began to increase the efficiency of the lines and the security of their working by laying down telegraph wires for intelligence and signals. In connection with this an abundance of interesting scientific and technical problems cropped up, which I felt a vocation to solve. My choice therefore could not be a matter of doubt. In June 1849, I requested my discharge from the military service, and soon afterward also resigned my office as technical manager of the Prussian state telegraphs. The latter post was offered at my suggestion to my friend William Meyer, who threw up his commission at the same time as myself. With the then bad arrangements for promotion, I had in the fourteen years of my military service become the senior of rather more than half of the second lieutenants, and received therefore, according to

… the results [of experiments with gutta-percha] on the new line have been so successful that not only for all the telegraph lines so far planned in Prussia but also for those of other nations … use has been made of the notable advance accomplished here and experts have been sent to Berlin to obtain precise information as to the experience obtained…

National Zeitung, *October 30, 1849*



Attest

Auf Grund der Akten wird hierdurch attestirt, daß der Seconde-Lieutenant außer Dienst Ernst Werner Siemens, geboren am 14ten December 1816, am 1sten November 1834 bei der diesseitigen 9ten Fuß-Compagnie freiwillig eingetreten, am 13ten Maerz 1835 zum Bombardier, den 28sten September 1836 zum Portepeefähnrich, laut Allerhöchster Cabinets-Ordre vom 28sten August 1837 zum aggregirten Seconde-Lieutenant und mittelst Allerhöchster Cabinets-Ordre vom 25sten December 1838 zum Artillerie-Offizier befördert, demnächst auf sein Ansuchen zufolge Allerhöchster Cabinets-Ordre vom 19ten Juni 1849 verabschiedet worden ist.

Derselbe hat ein Patent als Seconde-Lieutenant vom 29sten September 1837.

C. Q. Berlin, den 14ten Februar 1851
Drittes Artillerie-Regiment.

Major und Regiments-Commandeur

Werner von Siemens' discharge from the military, 1851.

custom, my discharge as first lieutenant "with the permission to wear officer's uniform with the regulation insignia for those placed on the retired list." I declined the pension due to me for my more than twelve years' service as officer, as I felt in good health and would not hand in the required invalid certificate.

Attached to the acceptance of my request for discharge was a reprimand for a formal error in my petition. The political reaction had then become so strong that the German sentiments shown by me in the Danish war had become a reproach in governing circles. In spite of the final small result of my military service I look back with a certain satisfaction to my military period. My most agreeable youthful recollections are connected with it, it paved my

American Electromagnetic Telegraph

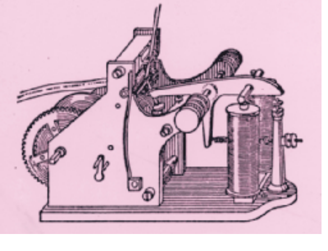
The undersigned, of New York, United States of North America, herewith takes the liberty of respectfully informing the honorable merchants, railway companies and all those being interested in quick communication that he has arrived in Hamburg and is ready to enter into contracts for the construction and installation of electromagnetic telegraphs according to the American method. The American system is without any doubt the best so far invented, it is economic as to costs and safe as to success and can be applied by day and night as well as in all weathers. Any offers are requested c/o Messrs Möring & Co., Hamburg, whose names the undersigned is so free as to mention as a reference.
Hamburg, June 30, 1847
William Robinson

William Robinson's advertisement concerning the introduction of Morse's system, from Hamburg newspapers of June 30, 1847

way through life, and through the success I had achieved gave me self-confidence for aiming at higher goals.

Although my activity and aims were not materially changed by withdrawal from all official duties, yet my life acquired in consequence a more settled direction, henceforth dependent entirely on my own exertions. It lay with me now by good work to raise to the utmost the business which already bore my name, and to obtain recognition in the world as a man of science and as technician. Although my inclinations drew me always to purely scientific investigation, yet I perceived that I must first of all turn my whole energies to technical work, as its results alone could procure me the means and opportunity for scientific work – and did in fact procure them.

Almost without exception my scientific and inventive activity in this busy period was prescribed for me by technical requirements. Thus the then very surprising and disturbing phenomena of electrical charges in underground conductors required thorough study. Further, it was necessary to establish a system for the determination of the situation of faults in the conduction and insulation of underground wires by measuring currents at the ends of the wires. The uncertainty of the measurements of currents led to the necessity of



Morse relief writer, 1853.

replacing them by measurements of resistance, and thereby to the setting up of fixed reproducible standards of resistance and scales of resistance. For this purpose the methods and instruments for current and resistance measurements had also to be improved and adapted for technical use – in short, a whole series of scientific problems had cropped up, the solution of which was called for by technical needs.

I devoted myself with special predilection to these problems, so far as my demands for the technical undertakings of the business permitted, and was therein very effectively supported by the constructive art and mechanical talent of my partner, Halske. This is especially true of the numerous improvements of the telegraphic contrivances and accessories which date from that time, and which, thanks to their solid and accurate elaboration in our workshop under Halske's guidance, were rapidly adopted in technical telegraphy. The great influence which the firm of Siemens & Halske has exercised in the development of telegraphy is mainly to be ascribed to the circumstance that in their work the executive hand has been that of the accurate mechanician and no longer, as formerly, of the clockmaker.

For publication in scientific and technical journals there was then no time; even patents were taken out only in rare cases. There was then no German patent right, and in Prussia patents, given almost arbitrarily for from three to five years, were therefore without practical value. For this reason the inventions and improvements proceeding from us at that time lack in the majority of cases the attestation of their origin by publication or patent.

A conspicuous illustration of this occurred a few years ago. There turned up somebody in the United States who asserted that he was the inventor of underground conductors, especially of those insulated by gutta-percha, and who tried after the lapse of more than a quarter of a century to obtain a patent for the same, which threatened considerable loss to the large American telegraph company. The company sent a special commission headed by their director, "General" Eckert, to Berlin, to search for verification by printed publications that in 1846 I had already introduced wires with gutta-percha insulation. To their written inquiry I was obliged to reply that nothing was to be found in print on the subject, but that the official records of the Staff Commission and of the subsequent Telegraph Board contained proof complete.

This, however, did not suffice for the lawsuit. The Americans chose another very practical way to procure printed information on the subject. They advertised in several German papers that they would pay a considerable sum for a description, printed in 1847, of the underground telegraph lines laid on the track of the Anhalt railway. That succeeded. After a few days there arrived from different places in Germany newspaper clippings with the desired description. The commission congratulated me as the undoubted inventor of the gutta-percha conductors and traveled home.

The proposed publication of the results, however, never materialized, because, it is said, in the meantime a compromise with the reputed inventor had brought greater profit to the company.

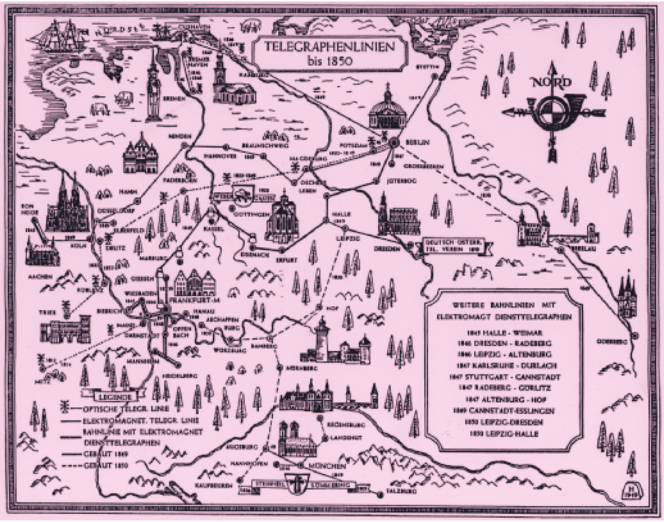
In Germany, after the construction of the lines to Frankfurt am Main and Cologne, the system of underground

Post Office, Berlin, June 28, 1884

The Post Office has the honor to reply to your kind letter No. 15487 of 21 of this month as follows:
As Dr. W. Siemens has already been informed in a letter of April 11, 1874, from Privy Councilor Elsasser, it can be proved from our records that in September 1847 copper wires insulated with gutta-percha were in fact laid for purposes of telegraphy on the Berlin – Anhalt railway under the direction of the then Artillery Officer Mr. W. Siemens and to the instructions of the Commission responsible for electric telegraphs in Prussia.
It is also confirmed that our records include a report dated September 7, 1847, from the above-mentioned Commission to the Prussian Ministry of Finance in which, as the result of tests carried out under the direction of the then Lieutenant Siemens, the use of gutta-percha is strongly recommended as effective insulation for telegraph wires laid in the ground …

Johann Georg Halske to Werner Siemens, March 17, 1852

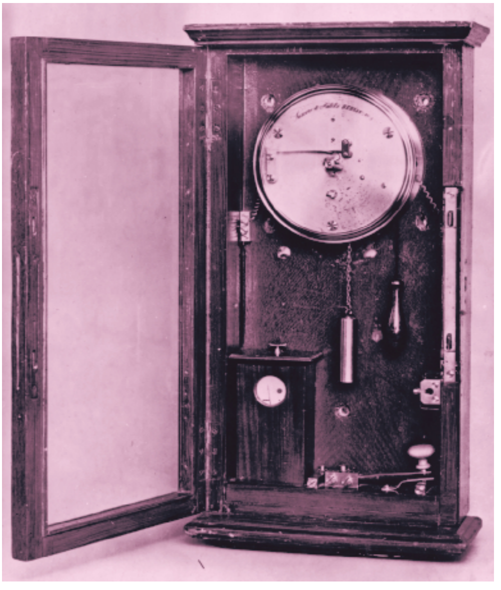
… The rats like the lead wire even better than the gutta-percha, as actually happened on the Hamburg railway – 7 inches all eaten in 8 days. I myself put it in …



Telegraph lines up to 1850.

communications had become the fashion. Not only were the government telegraph lines from Berlin to Hamburg, Breslau, Königsberg and Dresden constructed underground with unprotected wires, buried at a depth of two feet, but even the railways preferred to lay such underground lines, although the indications of the speedy destruction of these lines increased daily. In particular the destructive action of rats and mice became more evident – especially on the first lines, which were laid in the sandy railway embankments one and a half to two feet deep. The wires laid over two feet deep were indeed at first exposed to no such destruction, but subsequently it occurred even to them.

I then believed that a coating of lead would completely cope with this evil. To coat the wires with lead I proceeded at first in the following manner. Leaden tubes were straightened out, then a hempen band was blown through them by means of a bellows, and with its help the conducting wire insulated by gutta-percha was drawn into the tube. Thereupon the tube was passed through a drawplate, in order to effect a firm attachment to the insulated layer of the



An electric fire alarm by Siemens & Halske, 1851–1852. The Berlin fire alarm network made the world's first use of underground cables.

conductor. We afterward succeeded in pressing the leaden tube directly around the insulated wire, when the lead had exactly acquired a certain temperature and permanently retained it. The difficulty of continually controlling this temperature I overcame by a thermoelectric arrangement.

Such conductors, surrounded by lead casing, were frequently furnished by Halske and myself at the beginning of the eighteen-fifties, among others, for the telegraphic system which we set up for the police service and the fire brigade of Berlin. These lead lines acted quite satisfactorily for many years. They were then gradually replaced by cable conductors, yet lead conductors have remained in excellent condition to the present day, after a lapse of 40 years. Only where the lead has come in contact with decaying matter in the soil, whereby the formation of acetate and carbonate of lead is facilitated, is it liable to rapid destruction.

... It is known that at the time when the fire brigade was formed, a plan was devised for connecting the various fire stations in the Capital by means of electric telegraphs which would also eliminate the noise caused by fire alarms at night ...
The carrying out of the plan has been entrusted to the well-known engineer Siemens, who already has a high reputation in connection with earlier work of this kind and has submitted two proposals to the Government ...

National Zeitung, *June 26, 1851*

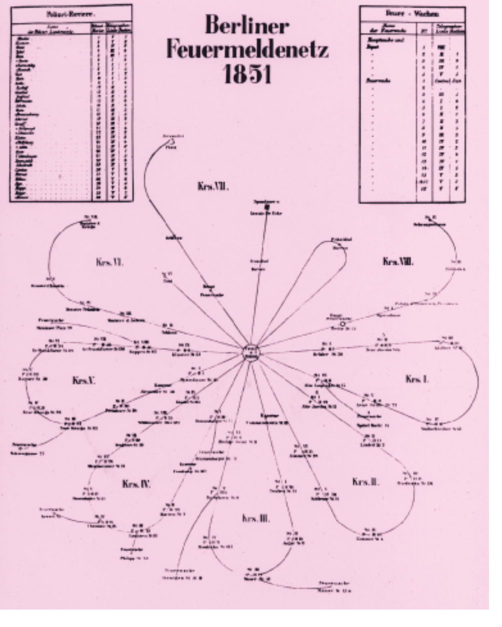
The police and FIRE-BRIGADE TELEGRAPH just mentioned was intended to unite fifty stations in different parts of Berlin with the central office of the police department and the central office of the fire brigade, so that the report of fire might be simultaneously communicated to all stations, while the police reports were only to be received and comprehended at the central police bureau. Our arrangement solved this interesting problem very satisfactorily and worked well and accurately for over twenty years, but then was succeeded by the simpler Morse system.

MORSE's writing telegraph first became known in Germany through a Mr. Robinson, who, in the year 1850,* gave exhibitions with it in Hamburg. The simplicity of Morse's apparatus, the relative facility of acquiring the alphabet, and the pride which fills everyone who has learned to use it and which causes him to become an apostle of the system, have in a short time ousted all dial and older letter-printing apparatus.

** Robinson had already presented Morse's writing telegraph in Hamburg in 1847.*

Halske and I at once perceived this superiority of the Morse telegraph, resting on manual dexterity, and made it our task therefore to improve and perfect the system as far as possible mechanically.

We gave the apparatus good wheelworks with automatic regulation of the velocity, a reliable magnetic system, sure contacts and commutators, improved the relays, and introduced a complete system of translation. This consisted in an arrangement whereby all the currents circulating in a telegraphic circuit were automatically transferred to a neighboring circuit provided with its own battery, so that the whole line was divided into several separate closed circuits; but yet without the assistance of the telegraph clerks of the intermediate stations communication could be directly held between the terminal stations.



The Berlin fire alarm network, 1851.

Such a system of translation

The first trademark of Siemens & Halske, from the 1850s.

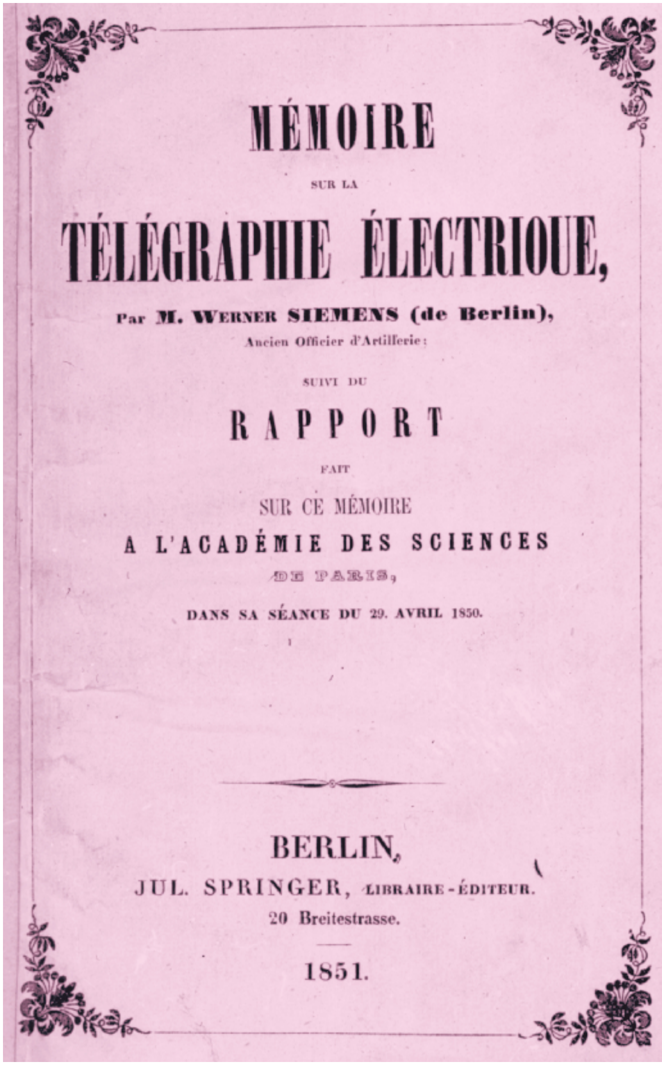
I had elaborated as early as 1847 for my dial and printing telegraphs, and had laid before the Staff Commission an apparatus constructed by myself for this purpose, the so-called GO-BETWEEN (RELAY). However, translation first attained its full importance through the application to the Morse apparatus; it came into use for the first time on the Berlin – Vienna line, which was provided in Breslau and Oderberg with translation stations. It may here be mentioned that the contrivance was subsequently very considerably improved by Professor Dr. STEINHEIL, the then Director of the Austrian telegraphs, by fitting an automatic contact to the wheelwork of the writing apparatus.

The railway companies remained faithful longest to the dial telegraphs with automatic interruption. In this system, however, we had ourselves brought a competitor into the field, who subsequently got in our way a good deal. Dr. Kramer, schoolmaster in Nordhausen, had on his part submitted to the Telegraph Commission a small Wheatstone dial telegraph, which he had had made by a clockmaker. The Kramer apparatus did not by a long way accomplish as much as my self-interrupting dial telegraph, and was therefore rejected by the commission.

The good-hearted General von O'Etzel and I myself felt compassion for the poor man, since he had employed all his savings on the construction of the apparatus; and, as there were no means at the disposal of the commission for the indulgence of such feelings, I consented to buy his apparatus for five hundred thalers. Only six months later, Kramer reappeared with a new apparatus, in which he had made use of my system, with an added modification for employing a clockwork to keep the indicator in motion mechanically. The patent office of that time saw no objection in the appropriation of automatic interruption to granting him likewise a patent. These Kramer dial telegraphs, running automatically like our own, worked just as well and reliably as ours despite their light clockmaker construction, and therefore did us great harm.

On entering the business, my time was entirely claimed by constructive work for the factory, and by the laying down of numerous railway telegraph lines undertaken by my firm. Nevertheless, in the winter of 1849 – 1850 I found a period of leisure, which I employed in putting together for publication my experiences on telegraphic communication and apparatus. In April 1850, I laid my work, with the title *Mémoire sur la télégraphie électrique,* before the Paris Academy of Sciences. This had been rendered possible for me through a lucky accident, which enabled me to meet in Paris my friend Du Bois-Reymond, who intended to present a work of his own to the Academy, and gave me his friendly assistance for the remodeling in French of my essay. I still remember with great satisfaction the stimulating, and to me extremely interesting and instructive, time of this four-week sojourn in Paris, my stay with friend Du Bois, and the exchange of ideas with the most celebrated Paris savants. Pouillet and Regnault were among the members of the committee appointed by the Academy for considering my work. The report on my memoir was read by Regnault at a sitting of the Academy, to which Du Bois and I had received formal invitations. Leverrier appeared as opposer, and defended the electrochemical telegraph of bain, which had likewise been presented to the Academy. The presiding *secrétaire perpétuel,* Arago, however, cut short Leverrier's opposition by moving the thanks of the Academy for the memoir and its reception in the *Savants étrangers.*

This public testing of my literary firstborn in the telegraphic domain by famous members of the first scientific tribunal in the world produced a deep and very stimulating impression upon me. Many reasons can be offered against such an official trial of scientific and technical perfor-



MÉMOIRE

SUR LA

TÉLÉGRAPHIE ÉLECTRIQUE,

Par M. Werner SIEMENS (de Berlin),

Ancien Officier d'Artillerie:

SUIVI DU

RAPPORT

FAIT

SUR CE MÉMOIRE

A L'ACADÉMIE DES SCIENCES

DE PARIS,

DANS SA SÉANCE DU 29. AVRIL 1850.

BERLIN,

JUL. SPRINGER, LIBRAIRE-ÉDITEUR.

20 Breitestrasse.

1851.

Mémoire sur la télégraphie électrique, 1851.

mances, which supplies a kind of hallmark and may easily be very injurious to the free unfolding of science; it is indeed only admissible under full control by the publicity of the *séances,* but can then be very useful and stimulating.

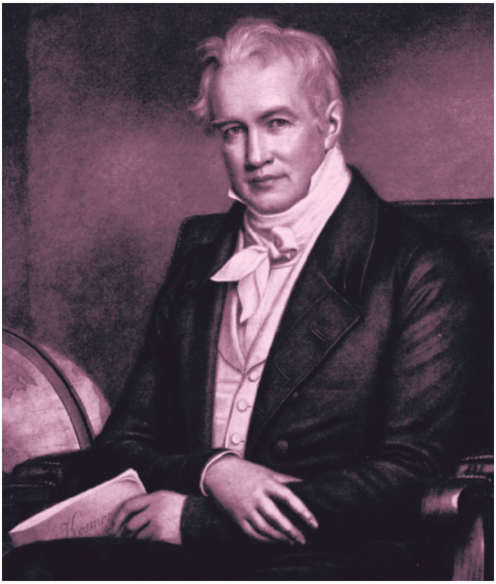
Emil Du Bois-Reymond (1818–1896). Undated.

Through the admission of my memoir into the *Savants étrangers,* and another essay published the same year in Poggendorff's *Annalen,* "Über elektrische Leitungen und Apparate" (On Electric Lines and Apparatus),* which reproduced entire the contents of the memoir so far as they had reference to underground electrical lines, my priority in respect of various scientific and technical achievements has been placed beyond dispute. Nevertheless, unwarranted claims to certain of them were subsequently raised in divers quarters. This leads me to make here a few remarks on the need for an international literary tribunal, which has in recent times come to be felt with increasing acuteness. It must first of all be granted that in the course of the last decades it has become ever more difficult, nay, almost impossible, completely to survey the vast mass of material contained in scientific and technological publications, in many different languages, moreover. It is also natural that those who are entirely absorbed in their own special work, but especially those who actively cooperate in furthering the development of the technical application of physical science, find but little leisure to make a thorough study of the doings of others working on the same or on related lines, even if masters of the several languages, and that in general they have also little inclination to turn their attention to the past. As an

** The title of the essay should properly be "Über telegraphische Leitungen und Apparate" (On Telegraph Lines and Apparatus).*

Mr. Siemens ... has now returned from his journey to England, France and Belgium, which he had been invited to visit in connection with the application of electric telegraphs with underground wires as first proposed by him ... His system has met with great approbation in England, France and Belgium and will be introduced there as soon as circumstances permit ...

National Zeitung, *May 22, 1850*



ALEXANDER VON HUMBOLDT *(1769 – 1859). After Werner von Siemens was elected a foreign member of the French Academy of Sciences, Humboldt sent him personal congratulations and visited him in Schöneberger Strasse, where Siemens and Halske both lived.*

example of this I might point to the most highly gifted and copiously inventive physicist of any age, FARADAY. He got to know the insulation with pressed gutta-percha only many years after its invention, when it began to be employed in England for submarine cables, the external protection of the insulated conductor being secured by surrounding the latter with iron wires. The surprising phenomena of electrical charges, which Faraday observed in these cables, induced him to publish an essay on the subject. When Du Bois-Reymond, however, sent him without further comment a copy of my memoir presented to the French Academy, Faraday did not lose any time in following up his first work with another, in which he cited the relevant sections of my treatise, and made the declaration that the priority both of the observation and also of the explanation of the phenomena belonged to me. Other English writers, such as Wheatstone, Jenkin and many others, have certainly not troubled to give heed either to this declaration of Faraday's or to any of my other publications.

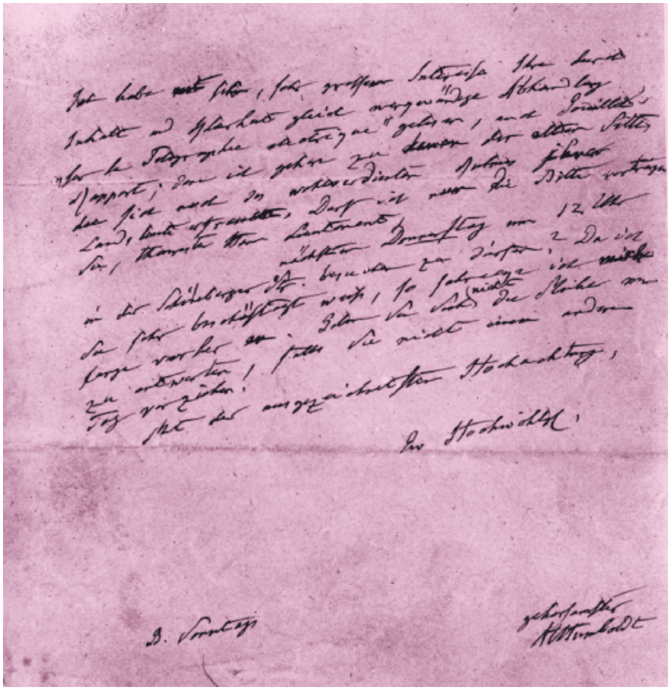
In Germany the good custom formerly prevailed of always prefacing the description of one's own scientific or technical discoveries and inventions by a description of the achievements of predecessors in the same department, thereby giving the progress about to be described its place in the historic evolution – a custom which, unfortunately, has never been observed in other countries in a similarly conscientious way. Hence it has hitherto been the peculiar glory of the Germans to recognize more than other nations the services of foreigners, and always to connect their own achievements with those of their precursors. This has been facilitated by the knowledge, more diffused in Germany than in other countries, of foreign languages; but, even apart from that, German science has always regarded it as a point of honor to practice literary justice equally toward natives and foreigners, and let us hope that this will be so also in the future, and that we shall thereby be spared the literary piracy which unhappily threatens to become prevalent even among ourselves.

As, however, the practice has recently come into vogue of leaving each individual to settle and defend his own real or supposed claims, this being too laborious for others, I intend to follow it in these pages. At the end of each period I shall accordingly give a summary of technical developments, important in my judgment, where the priority of discovery, invention, or first application demonstrably appertains to me. That in so doing I may here and there repeat what has been already adduced in another connection will certainly be unavoidable. Should I now and then make mistakes and pay insufficient regard to the claims of others, I must hope for the indulgence of the reader.

I shall be able to review with great brevity the period terminating with the publication of my *Mémoire sur la télégraphie électrique* and the corresponding paper in Poggendorff's *Annalen,* as the most important particulars have been interwoven in the general narrative, and have thus already received detailed consideration.

When, in the year 1842, I applied for my first Prussian patent, no process of galvanic gilding or silvering was known in Germany.

I had experimented with all the gold and silver salts known to me, and besides the hyposulfites had also found the cyanides suitable. The patent, however, was only granted me for the former, as in the meantime Elkington's English



Letter from Alexander von Humboldt to Werner von Siemens, ca. 1850.

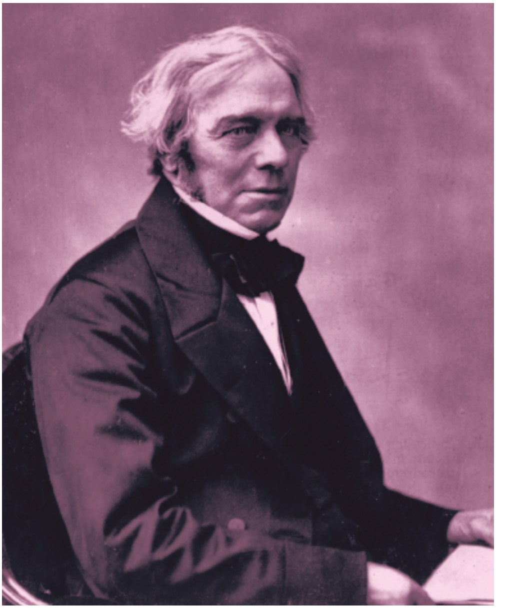
Alexander von Humboldt to Werner Siemens, ca. 1850

I have read with very, very great interest your treatise "sur la Télégraphie électrique," which is remarkable both for its contents and its clarity, also Pouillet's report, since I belong to those of the old school who still take pleasure in the well-deserved fame of their countrymen.
May I now, my dear Lieutenant, ask to be allowed to visit you in the Schöneberger Strasse next Thursday at 12:00? As I know that you are very busy please do not trouble to reply unless another day would suit you better.

With the greatest respect,
Yours most obediently,
A. v. Humboldt

patent for the employment of the cyanide salts had become known. Notwithstanding the beautiful gold and silver precipitates obtainable from hyposulfite salts, the cyanide salts have in the long run kept the field, their solutions being more constant.

The problem proposed to my brother William – to construct a regulator which should so exactly regulate a steam engine connected with a waterwheel that the waterwheel should always perform its full work, but the



Michael Faraday (1791–1867), around 1847. At one of his famous public Friday lectures, the great English researcher presented the 22-year-old William Siemens and his new "anastatic" printing method – related to our photocopy process of today – to the scientifically minded English public.

steam engine yield the required excess of working power – led me to the idea of the so-called differential regulator. It consisted in employing a freely oscillating circular pendulum for the production of a perfectly uniform rotation, thereby causing the turning of a screw, while the engine to be regulated turned a movable nut on the screw in the same direction. The nut must then move right or left on the screw as long as it turns quicker or slower than the screw, and can thus perfectly regulate the pace of the engine, immediately ceasing to move when the velocity of the engine is precisely equal to that of the circular pendulum. The differential regulator (or "chronometric governor," as brother William, who elaborated it practically and mainly perfected it, afterward called it in England), constructed on this principle, has certainly not been largely introduced into practical engineering. It is neither as simple nor as cheap as the Watt regulator, which in later years has been considerably improved, but the differential movement, which we carried out in the most varied forms, has proved an exceedingly fertile element of construction.

My preoccupation with the problem of the exact MEASUREMENT OF THE VELOCITY of projectiles, imperfectly solved by Leonhardt's ingenious clock, caused me to perceive that only a method in which no masses had to be set in motion and brought to rest could lead to the goal. Thus I came to employ the electric spark for the solution of the problem. My proposal consisted in causing electric sparks to pass onto a rapidly and uniformly rotating polished-steel cylinder from a fine point approximated as far as possible to its periphery, and in calculating, from the interval between the marks produced by these sparks and the known number of revolutions of the cylinder, the velocity of the ball, which at particular stages of its career produced the sparks. This method of measuring velocity, by the help of marks which an electric spark brands on polished steel or sprinkles on sooty steel surfaces, has maintained its ground, and is still today employed especially for measuring the velocity of projectiles in large and small gun barrels.

The suggestion for storing up the unemployed heat of one operation for use in the succeeding operation, derived from my brother William's description of the Stirling hot-air engine which I received in the year 1845, interested me in a very high degree. It appeared to me to open the way into a yet unknown vast domain of technical science. It occurred at a time when the idea, pervading and governing the physical science of this age, of the causal connection of all natural forces, unconsciously swayed men's minds, until it soon after became common scientific property through Mayer and Helmholtz. The principle of the circulation of heat equivalent of work already found clear expression in my paper "On the Employment of Heated Air as a Motive Power," whose publication was occasioned by Stirling's engine. I consider the chief value of this essay, however, to have been that it incited my brothers William and Friedrich to their later pioneer efforts in the province of thermal economy.

In my first dial telegraph of 1846 I consequentially carried out the principle of the automatic interruption of the electric current both for the apparatus itself and also for the alarm. The principle essentially consisted in increasing, according to requirement, the stroke of the well-known Neef hammer by the insertion of a movable contact, the so-called

Wilhelm (later, Sir William) Siemens, around 1847. Wilhelm had been in England since 1842, and would make it his second home some years later.

slide. My dial and type-printing telegraphs, depending on this principle, were distinguished from the then well-known Wheatstone telegraphs by being automatic machines, running isochronally with one another, until one apparatus was mechanically stopped by the depression of a key on the particular letter, whereupon all the others likewise stopped at the same letter, and this letter was printed off by the type printer. The description of these instruments, as of most of my further inventions and improvements of telegraphic conductors and apparatus down to the year 1850, is contained in my *Mémoire sur la télégraphie électrique* communicated to the Paris Academy. I content myself here with a concise summary of the most important scientific and technical improvements, the priority of which is secured to me by that publication:

Introduction of the automatic breaking of the electric current at the end of every movement of the armature through a predetermined distance. Or one may put it thus: increase of the movement of the Neef hammer by a mechanism answering to the slide of the steam engine. All automatic electric alarms without clockwork and many other constructions rest on this principle.

Production of the synchronous action of two or more electric machines by allowing a fresh impulse to take place only when all the automatic contact breakers are again closed, i.e., the armature movement of all the apparatus inserted in the circuit is completed.

Manufacture of insulated conductors for subterranean or submarine telegraphs by coating wires with gutta-percha.

Construction of machines which press the seamless gutta-percha around the wires to be insulated.

Discovery of the phenomena of the charge in insulated subterranean or submarine conductors, and establishment of the law of the charge for open and closed circuits.

Establishment of the methods, measurements, and formulae for determining the place of faulty conduction and insulation in subterranean circuits.

The underground wires, both those without external protection and those with an armature of lead, had meanwhile continued to come into use even beyond the confines of Germany; among other states Russia had adopted the system and connected St. Petersburg and Moscow by a subterranean wire. In Prussia, however, the deterioration, which had occurred in the first lines soon after their construction, continued to make uninterrupted progress. The causes which contributed to this and finally led to the complete destruction of the lines have already been mentioned. The almost morbid endeavor, called forth by political exigencies, to set up as quickly as possible and at the least cost a subterranean system of communication embracing the whole country, had prevented the provision of the wires with an armature and a sufficiently deep embedding to secure them from injury at the hands of workmen and from the attacks of rodents. The attempt to replace the wires thus rendered useless by others coated with lead proved fruitless, as the rodents gnawed to pieces even the protective lead covering. Further, there was lacking a properly trained staff to keep the extended network of wire in good order, and to remedy defects without deranging the whole system. In consequence of unskillful searches and tinkering with faults, numerous soldered joints came into existence, which were insulated in a very primitive fashion by patching with heated gutta-percha, and thus gave rise to new faults. It was therefore to be feared that the subterranean lines would, in a short time, become quite unserviceable.

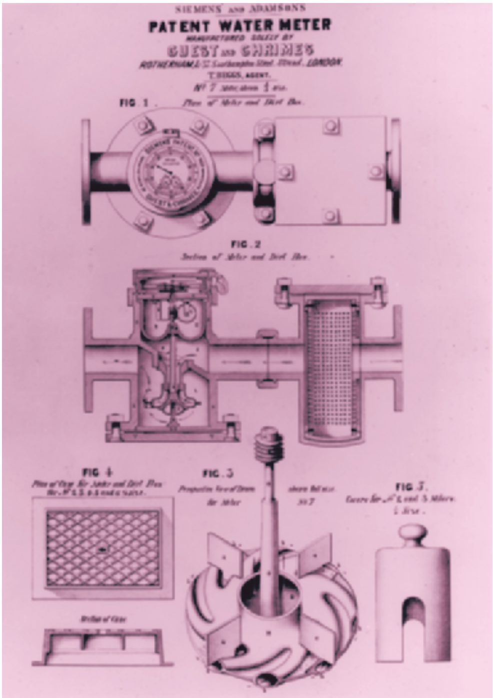
This sad state of things moved me to write a pamphlet entitled "Kurze Darstellung der an den preußischen Telegraphenlinien mit unterirdischen Leitungen gemachten Erfahrungen" (Short Account of the Experience gained with Underground Conductors on the Prussian Telegraph Lines), in which I pointed out the existing risks and made proposals for improvements in dealing with the lines. At the same time, the pamphlet energetically disclaimed responsibility, which on all sides was then sought to be fastened upon me, for the collapse of the system which I had suggested. It was only to be expected that the publication of this pamphlet would lead to differences with the directorate of the Prussian state telegraphs. In fact, for several years communication of any kind whatsoever with myself and with my firm ceased entirely. All orders were withdrawn from us, and our special constructions handed over to other manufacturers as models. This constituted a severe crisis for our young establishment, which had rapidly risen to be a factory with some hundred workmen. Luckily, as the railways themselves were not then state property, railway telegraphy furnished an independent market for our manufactures. The breach with the government telegraph management, however, had a good deal to do with our turning our attention abroad, leading us to seek a market there for our products, as well as opportunities for larger undertakings.

As my younger brothers played a very important part in the foreign undertakings of my firm, which I shall now have to report, it will be as well to cast a retrospective glance at

From Werner von Siemens: "Short Account of the Experience gained with Underground Conductors on the Prussian Telegraph Lines,"

1851, in Scientific & Technical Papers of Werner von Siemens, *vol. II.* Technical Papers, *London, 1895, 75–95*

The object of this paper has been to show that the unfavourable results which have been experienced with the first laid underground wires in Prussia are not a consequence of the system employed, but are mostly due to faults in the laying and in the administration afterwards owing to want to experience and unfavourable circumstances.

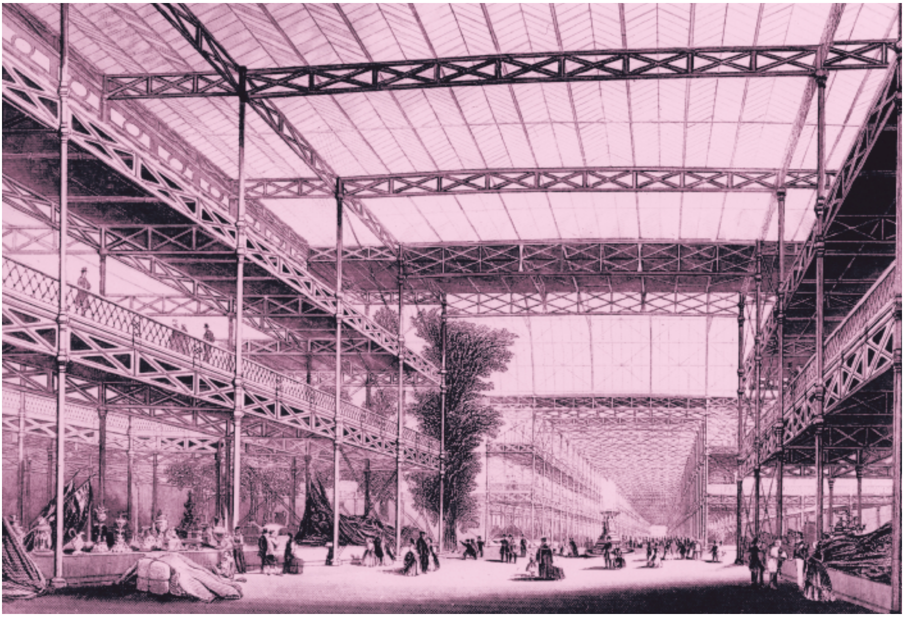


Water meter, 1851.

the doings of my family and especially of my brothers during the period of my life just described.

The life of my brother William has been narrated at considerable length, and with the conscientious use of all the sources accessible to him, by a well-known English writer, Dr. William Pole. In what follows I need therefore only touch upon such events of his life as had immediate relation to my own. First, I will here remark that I stood during the whole of his life in active correspondence and lively companionship with William, to our great mutual gain. We communicated to each other all the more important events of our lives, as well as new plans and aims; discussed our diverging views, and almost always, if not in our letters, then at our meetings, which usually took place twice a year, came to a friendly understanding. The circumstance that I had paid more attention to natural sciences, and William to industrial arts and practical engineering, led to each allowing to the other a certain authority in his own subjects, whereby our collaboration was considerably facilitated. That we were not jealous of one another, but rather rejoiced when the one could further the recognition of the other in his respective country, strengthened and assured our good understanding.

After the dissolution in 1846 of our commercial partnership for carrying out our inventions, William had entered an English machine factory of repute as engineer, with the



The Crystal Palace, built for the London Great Exhibition of 1851.

object in the first place of securing a maintenance. But "the cat can't give up mousing," as a German proverb says; it was not long before he too was again buried in his inventions. The difference between us, however, was that I confined myself to the solution of the numerous problems which telegraphy and in general the application of electrical theory to practical life brought me; William, on the other hand, tried by preference to solve difficult problems of thermodynamics. In particular, he had set himself the task of overcoming the difficulties which Stirling had encountered at Dundee in elaborating his hot-air engine, by introducing the heat regenerator for the steam engine. The experiments with these regenerating steam engines, regenerating evaporators, and condensers, for years

Werner to William, June 9, 1849

You will soon be getting telegraphs which, by English standards, will be immensely superior to the present ones, in exactly the same manner as mine were in theory to their predecessors. Still, practice is the true source of knowledge!...

The certificate awarding Siemens & Halske the Council Medal at the London Great Exhibition, 1851.

claimed his time and means, without procuring for his constructions a general introduction into technical practice. On the other hand, he succeeded in practically solving a problem on which I had also long worked in Berlin with incomplete success, namely the WATER-METER QUESTION. The patented Siemens-Adamson reaction water meters for many years commanded the market and brought William good profits. Then they were superseded by the Berlin construction of the stroke or whirlpool meter, which was at once adopted by William himself. The good progress which the manufacture of telegraphic and other electrical apparatus made in our Berlin factory, and the great recognition which our constructions on all sides enjoyed, suggested the opening of a business connection between William and the firm of Siemens & Halske. He undertook at first to act as an agent for obtaining orders in England, and very cleverly contrived to turn the attention of English technicians to the achievements of the Berlin firm. This was especially furthered by the first Great Exhibition, which took place in London in the summer of 1851. Siemens & Halske sent specimens in abundance; their exhibits found universal approval and procured for the firm the highest distinction – the Council medal.

My brothers Hans and Ferdinand had remained faithful to their agricultural calling. After giving up the farming of the Menzendorf domain they had come to Berlin, whither all the brothers with the exception of William had betaken themselves, and the two soon succeeded in obtaining suitable positions on East Prussian estates.

Friedrich had at a very early age gone to sea from Lübeck and had for some years made a number of long voyages in Lübeck sailing ships. This had indeed somewhat cooled his originally invincible inclination for seafaring, and he wrote me one day that he would like to learn something. I bade him therefore come to Berlin, to prepare him by private instruction for attending a naval school. He devoted himself to his studies with great eagerness and success, and soon showed great interest in my own aims and experiments. The new mental life finally interested him in such a degree that the inclination for a sailor's life, whose seamy side he had got to know well, was incapable of withstanding the new impressions. Added to this was the fact that the total change in dress, living and climate had brought on rheumatic sufferings, which he only slowly got the better of. Henceforth he assisted me in my technical work, and was strenuously bent on filling the great gaps which the seaman's life had made in his knowledge.

The next in order, brother Carl, had, like Friedrich, spent the first years after the death of our parents with our uncle Deichmann in Lübeck, and had then completed his schooling in Berlin. There from an early stage he took part in my work, and became my faithful and ever reliable assistant in my first technical undertakings, in particular helping me in laying down the first underground wires.

I have already related that my brothers William, Friedrich and Carl followed me in 1848 to Kiel and Friedrichsort. The powerful national feeling that had been aroused everywhere in Germany left them no peace at home. To William I entrusted the construction and command of the

Werner to Carl, October 11, 1851

As you have no doubt already tramped about the streets of London quite a lot, perhaps you could just turn your mind to the dirt on them. Loebell wants some information about the hand brooms used there which are said to have the advantage of not scratching the dirt out of the joints between the paving-stones… Perhaps you could also ask about price and effectiveness of the mechanical street sweepers…

Werner to Carl, July 24, 1852

. . . You must not think much about making a lot of money just yet, but rather of laying a firm foundation for the future . . . We, too, began with a few men in a modest living room . . . Once an establishment gets going it gains a certain vitality . . . unless it is completely deprived of nourishment. For you this is assured . . . since our experience and progress are yours also.

battery which I had caused to be erected in Laboe opposite the Friedrichsort fort, while Friedrich and Carl entered the service of the newly formed Schleswig-Holstein Army as volunteers, and remained in the service till the conclusion of the armistice. On this occasion we arranged that Friedrich should continue his technical education in England under William's guidance. Carl entered a chemical factory in Berlin, which, however, he soon left in order to assist me in laying down and repairing the telegraph lines. In the year 1851, he was together with Friedrich the representative of the Berlin factory at the London Universal Exhibition, and carried on with ability the business negotiations which resulted therefrom. A branch in Paris, which we next founded under his management, did not indeed bring the hoped for fruits, but contributed much to his social and business training.

Of the two youngest brothers, Walter had come from Lübeck to Berlin at the same time as Carl and attended school there. Otto I placed in a grammar school at Halle, as my time was too much taken up to allow of my personally superintending his education.

Of our two sisters, the elder, Mathilde, married to Professor Himly in Kiel, was already the happy mother of a troop of pretty children. She has always honestly shared with me the care of the younger brothers and sister, and sought as far as possible to compensate them for the maternal love so early withdrawn from them. My youngest sister, Sophie, had on the death of our parents been adopted, as already mentioned, by our uncle Deichmann in Lübeck. At the beginning of the fifties, Deichmann resolved to emigrate with his family to North America. The reasons which had occasioned this resolution were chiefly political. After the suppression of the revolution in Germany and Austria, after the surrender of Schleswig-Holstein and the deep humiliation of Prussia, a feeling of despair rapidly spread throughout Germany.

The power of Russia appeared then so gigantic that the prophecy of Napoleon at St. Helena that in fifty years Europe would become either republican or Cossack seemed already practically fulfilled. Although I myself was also deeply depressed by the turn things were taking in the political world, I could not subscribe to so pessimistic a view. I therefore not only rejected the pressing invitation of my uncle to accompany him to America, but also tried to prevent any of my brothers and sisters from participating in the emigration. In particular, I refused my consent to the departure of my sister Sophie, in which I was strongly supported by her legal guardian, Herr Ekengren. Unfortunately, however, we had no power to detain Sophie, as she had been formally adopted by my uncle.

In these straits Cupid came to our help. A young lawyer in Lübeck, Dr. Crome, had observed with pleasure the young girl growing up near him, and was only awaiting the dawn of womanhood to present himself as a suitor. The dire news of the intended emigration prematurely ripened his resolution. He begged the hand of the maiden of sixteen, and shortly before the departure of the adoptive parents the wedding was celebrated. We older members of the family have not repented having favored this step. The young husband is said indeed, in the early days of the marriage, to have been terribly tormented by jealousy because the young wife kept certain drawers of her cabinet carefully locked, even eagerly endeavoring on his unlooked for entrance to conceal certain articles on which her attention was engaged. But then, on his impetuous demand, she tearfully confessed to him that it was the new dress of her favorite doll, for the completion of which the hasty wedding had left her no time!

The Crome family. Undated. Sophie Crome, née Siemens (1834–1922), and her husband Johann Paul Friedrich Crome (1821–1883), with four of their children.

It deserves to be remarked that the native characteristics of my brothers, as revealed in their earliest youth, have been faithfully preserved to an advanced age, and have given a well-defined direction to their career. This holds good especially of my three brothers William, Friedrich, and Carl, with whom a common life and aims have most united me.

William had even as a child an abstracted, perhaps somewhat reserved, nature. He clung with great affection to his relatives, but would never let them see it. From earliest youth he was ambitious and a little inclined to jealousy. When the tenderness of mother, grandmother, brothers and sisters was competed for by his brother Fritz, who was the next after him, a deep resentment against the little rival manifested itself – a feeling which I fancy was never wholly extinguished in him, in spite of all the fraternal affection and help bestowed so abundantly in later years. He possessed an extremely clear understanding and a quick power of apprehension, could always follow with great ease the train of thought of others, as well as grasp and give life to the spirit of what he had acquired. The good pupil developed with perfect consistency into the logical, methodical thinker, the able engineer and man of business. His great success in England he owes chiefly to his peculiar power of appropriating easily and quickly from the storehouse of German science what was of practical value for the moment; and also to the further gift of having this scientific knowledge ever ready, and of always immediately discovering in

The Siemens brothers and sisters, around 1850: L to R: Hans, Walter, Mathilde, Friedrich, Werner and his friend William Meyer.

the technical questions with which he was confronted the fulcrum where the scientific lever should be applied for their furtherance or solution. No doubt he was assisted essentially by the circumstance that he came to England at a time when scientific culture was only represented there sporadically, although then in a remarkable degree, and when active cooperation between science and practice was as rare as in Germany. So he succeeded not only in accomplishing good work himself but also, by taking an active and energetic part in the highly developed life of scientific and technical institutions in England, in deserving well of the world of science, and at the same time in rendering a lasting service to English industry.

Almost diametrically opposite were the mental qualities of his successor in the series of surviving members of the family. Friedrich was not a good learner. It has always been difficult for him to follow another's train of thought to the end. On the other hand, he was from childhood a remark-

Machine à Vapeur Régénérée de M. William Siemens.

C'est une de ces natures bonnes et douces qu'on est heureux de rencontrer ici bas, qui imposent presque forcément la sympathie et l'affection; auxquelles s'applique dans toute sa vérité le vieux proverbe allemand: stilles Wasser ist tief, . . . parce que sous les dehors les plus calmes elles cachent une intelligence éminemment active et féconde.

From Cosmos, Revue encyclopédique hebdomadaire des progrès des sciences, *vol. 7, Paris, 1855*

ably good observer, and had the gift of stringing his observations together well, and of making himself intelligible. Really to understand and appropriate the thoughts of others, he had to discover them or think them out for himself afterward. This characteristic of steady, spontaneous, uninfluenced thinking and self-training gave him a peculiarly meditative air and his performances a pronounced originality. Friedrich is the born inventor, to whose brooding mind the novel conception first presents itself in obscure, nebulous form, and who thereupon with restless energy and untiring industry tests the foundation of the conception, filling up at the same time any gaps in his knowledge, and finally either rejecting his idea as false or impracticable, or elaborating it into a serviceable and then almost always original invention. At the same time, Friedrich was never a diplomat, and just as little a man of business, carefully weighing his words and actions. He went and is still going everywhere his straight road, biased only by his innate friendly and benevolent disposition, a road which usually leads him to the desired goal, since he always considers it well and follows it to the end with the greatest energy.

I should call the next brother, CARL, the most normally constituted of us all. He was always to be depended upon, faithful and conscientious, a good pupil, an affectionate, attached brother. His clear eye and generally cultivated understanding made him an excellent man of business and, with his large technical knowledge and excellent tact, an admirable conductor of business undertakings. Carl was the true connecting link between us four brothers, who indeed differed radically from one another, but were

Seven Siemens brothers and sister, 1851. Standing (L to R): Friedrich, Hans; seated (L to R): Otto, William, Sophie, Werner, Walter.

bound together for lifelong common work by an all subduing fraternal love.

Not to leave myself out in this family characterization, I will only remark that I possessed a fair share of the good and bad qualities of my three brothers just described, but that these qualities were much repressed in outward manifestation through my particular line of activity. To perform my duty and do good work has always been my strenuous endeavor. To find recognition has been indeed gratifying to me, but it has always been repulsive to me to push myself in any way, or to be made the subject of an ovation. Perhaps my constant endeavor "to be, rather than to seem," and to have my merits first discovered by others, was only a peculiar form of vanity. I shall try as far as possible to avoid it in these pages.

THE RUSSIAN UNDERTAKINGS

The year 1852 formed a decided turning point in my personal as well as in my business life.

At the beginning of that year, I made my first journey to Russia. The business connection of my firm with the Russian government had been opened as early as 1849 through the medium of Captain von LÜDERS, who was making a circular tour through Europe, having been entrusted by his government with the task of ascertaining the best system of electric telegraphs. He then proposed our system for the line to be constructed from St. Petersburg to Moscow. Orders were given to Siemens & Halske only for apparatus – dial telegraphs and measuring instruments – as the Russian government took upon itself the construction of the underground wires. Negotiations having reference to further orders now required my presence in St. Petersburg.

My journey lay by way of Königsberg, which I had long ardently desired to visit, without having been able to make up my mind to undertake the journey. It was there that DRUMANN, the well-known historian, resided, who had married a daughter of my uncle Mehlis in Clausthal,

Wilhelm Drumann (1786 – 1861), Königsberg historian and father of Mathilde, Werner von Siemens' first wife. Undated.

The well-known inventor of electromagnetic telegraph apparatus, Lieutenant Siemens, has been called to St. Petersburg to undertake the construction of telegraph lines throughout the Russian Empire…

National Zeitung,
December 20, 1851

and was accordingly my kinsman by marriage. In the year 1844, Frau Drumann had, on a journey to Clausthal, looked me up in Berlin, and spent a few days there with her youngest daughter, MATHILDE. I made myself useful to the ladies during the time as cicerone, and passed some very agreeable and exhilarating days in their company. The return journey was also to have been by way of Berlin, and I was looking forward to the renewed meeting with my amiable cousin and her handsome and clever daughter. The pleasure was unfortunately destined to be marred by a very sad event.

Frau Drumann arrived ill in Berlin, and died in the hotel a few days after, of inflammation of the lungs. I was the only relative, the only acquaintance even, of the family in Berlin, and had therefore to fulfill all the duties of the head of family. My compassion was put to a hard test by the intense grief of the poor lonely girl. The speedy arrival of the deceased's brother, councilor Mehlis of Hanover, and of his wife indeed made easier for me the difficult and altogether unwonted task which had fallen to my lot, yet the image of the sorrow-laden girl, helplessly clinging to me, would not leave my mind. Eight years had since passed, in which our correspondence, lively at first, had gradually ceased. My brother Ferdinand had meanwhile become engaged to Mathilde's elder sister, and with the assistance of

Mathilde Drumann (1786–1861). Undated.

Professor Drumann had purchased the estate of Piontken in East Prussia. But when he was on the point of bringing home his bride, she fell ill of a chronic lung disease, to which, notwithstanding the excellent nursing of her only sister, she succumbed after several years of acute suffering. The time had now come for me to fulfill a long cherished wish, without departing from an early-formed resolution – to marry only when my own resources permitted it. Halske had managed well. We had bought extensive premises in Berlin, at Markgrafenstrasse 94, at the back of which a fine roomy workshop had been erected, while the front part, recently enlarged, yielded us excellent dwelling accommodation. For the wedding, then, there was only lacking the bride, and I was able soon after my arrival in Königsberg, on my mother's birthday – the January 11, 1852 – to put the long-deferred question to Mathilde Drumann, whose reply made me an accepted and happy lover.

My business affairs did not allow of a long stay in Königsberg, as I was expected on January 20 in Riga, where we had to establish telegraphic communication with the port town of Bolderaa, which was to be effected by means of a steel-wire cable spanning the broad Düna.

At that time, posting was the only mode of traveling in Russia. This was very well organized on the main roads, that is to say, considering the circumstances. At a distance of on average twenty to thirty versts – a verst is a little more than a kilometer – substantial houses with stabling were erected on the post roads, in which shelter and horses were to be had, if they were free, and if the traveler was in possession of a government order to the postmasters, directing them to furnish horses for a prescribed journey on payment of the regulation fare. If possessed of such an order – called *podoroshna* – the traveler, supposing he had no private carriage, obtained a small four-wheeled peasant's cart, without springs, covering or other luxury, drawn by three usually not bad horses, of which the middle one was harnessed in

Ferdinand Siemens. Undated. Werner's brother owned a manor from September 1, 1850, at Piontken, near Angerburg in East Prussia. He became betrothed to Sophie Drumann in 1850, but she died in 1851.

shafts, and the two outer ones were yoked so that they faced somewhat to the right and left respectively. In a proper *troika* the stronger middle horse has to trot, while the side horses keep pace with a gallop to right or left. The traveler has usually for seat his traveling trunk or a bundle of straw – and then, good speed, and away at a gallop, which only ceases at the next station, if flying report has vaunted the traveler's liberality in the matter of tips. Such a post journey requires experience. It is necessary to sit on the trunk quite loosely and bent well forward, so that one's own spine may form a spring to protect the brain from the violent jolts of the wheels on the usually indifferent roads. If this precaution be omitted, violent headaches are the infallible result. However, one pretty quickly accustoms oneself to this mode of traveling, which also has its charms, and soon even learns to sleep quite soundly in the rocking position, coping instinctively with all the unevenness of the road by judicious countermovements. When two travelers make use of such a *telega,* they usually lash themselves together by a girdle, in order that their oscillations may be so regulated as to prevent their knocking their heads together. For the rest, I have found that telega traveling can be very well borne, if it is not overdone. Certainly it is said that these journeys have often been fatal to couriers, who have had to sit day and night for weeks together in their telegas.

The telega journey was agreeable and interesting enough as far as Riga. But there, regular winter weather had set in, and the further journey could only be made in sledges. The Russian *kibitkas* are low and rather short sledges, which for longer journeys are completely closed with matting. The inner space is separated from the driver's box by a wall of matting, in which two small windows are fixed, which admit light sparingly to the interior. A mat flap at each side of the sledge renders possible the rather difficult matter of getting in and out.

Werner to William, December 18, 1851

. . . The house has been bought for 40,000 thalers. Rebuilding and installation work will cost about another 10,000 thalers . . . We hope to be able to start moving in by Easter. There is no lack of space as less than a fifth is being used and extensions can be made to right and left by purchase . . . Try to make some arrangement for our apparatus to be used in England without thinking too much of direct profit. We now need the moral effect to impress Nottebohm . . .

As I traveled for the first time into Russia proper, knowing no Russian, I had to look about in Riga for a traveling companion. In a newspaper advertisement such a person turned up, who possessed a kibitka and spoke German and Russian perfectly. As appeared when we were already on the road, this was an elderly merchant's wife from Riga, who sought in this way to subsidize her annual business trip to St. Petersburg. She had packed the sledge so full of straw and bedding that one could only lie down in it, and then had the mat covering close over one's face. It had become bitterly cold, and the nearer we got to our goal the stronger became the dry, keen northeast wind, which with 18 degrees below zero Réaumur mocked at the warmest wrapping. Then I learned in Russian fashion to drink hot tea in great quantities, as soon as a station was reached, for only in that way could any warmth be obtained.

When on the third morning we had reached the Narva station, we fell victims to a little stratagem which was often and in the most varied forms practiced by the postmasters. The postmaster declared with the greatest assurance that it was of no use to travel further, as at the stations before St. Petersburg all the horses had been appropriated for a great imperial bear hunt. Apparently touched by the loud

The courtyard of the Siemens & Halske factory at Markgrafenstrasse 94 in Berlin, around 1880.

lamentations of my Russian companion, he finally offered to give us a pair of particularly powerful horses, which would bring us the same evening to St. Petersburg. The bargain was struck, and the crafty Russian imagined that he had by the fiction of the bear hunt secured the whole fare to St. Petersburg. Our subsequent adventures, however, foiled his scheme.

Our driver was a young fellow without fur and warm foot rug. That he often stopped seemed to us intelligible, as he evidently needed a warm drink to avoid being frozen. At last, however, he failed to return at all. I had to struggle out of the kibitka, which, owing to my double furs, which nevertheless did not prevent a rather severe numbness, was attended with difficulty. I then found our *iswoshtchik* in a hut hard by, brandy glass in hand, which the rather suspicious-looking Jewish proprietor of the hut kept eagerly filling. When I drove the man back to the sledge with the necessary physical admonitions, I observed unmistakable signs of a deeper understanding between him and the tavernkeeper who accompanied us. It came to me by no means as a surprise therefore when, soon after resuming the journey, my traveling companion suddenly uttered a loud cry, and called to me that her traveling trunk had just fallen from the sledge. She had immediately noticed the loss, as the trunk was fastened beside the driver on the box in such a way as to block the one small window. It was very difficult in our confined position to make the driver stop. At last I achieved this by breaking the second small window, laid hold of him and threw him down from his seat. The trunk was luckily found again; the rope, which served to fasten it, had undoubtedly been cut.

It soon became pretty clear that the driver was dead drunk, as he repeatedly drove us into the roadside ditches. At last there remained nothing else for me to do but to mount the box, and take the reins from the driver's hands. He very soon after fell soundly asleep, and neither scolding nor cuffing availed to revive him. I, for my part, soon felt my feet becoming numb, and when I tried to change the reins found that both my hands had become quite frozen

Friedrich to William, August 31, 1852

… On Saturday Halske gave a magnificent ball for the workers in the Work Hall of the new house, which was thus inaugurated. Werner's furniture was used to decorate the ballroom.

Entry by Werner von Siemens in the complaints book of the Post Passenger Room, Laugszargen

Having left Tilsit at 7:00 a.m. by Special Post we stopped halfway as the horses were exhausted and refused to go any further. The postillion was kindly given other horses but the delay was such that the station was not reached until 11:00. I shall probably miss the 12:00 Post to St. Petersburg and will have to take a Special Post. I request that those responsible should be reprimanded and ask for redress on account of such unwarranted treatment.

Laugszargen, January 19, 1852

W. Siemens, owner of a telegraph construction firm in Berlin, Schöneberger Strasse 19.

The office building of Siemens & Halske at Markgrafenstrasse 94 in Berlin, 1896.

and immovable. It was still possible for me to drive the sledge once more into the ditch, and to pull off my gloves with my teeth. With the sudden halt the driver had fallen from the box, and lay like a corpse at my feet. I could therefore quite easily perform two useful actions, viz. wash his head with snow and thereby also thaw my own hands. It was a good while before I felt the life return into them. Soon after, the driver also began to show signs of life, in that he made grimaces and presently began to wail and implore forgiveness. So in the darkness of the night we were able to continue on our way by walking beside the sledge, and finally reached Krasnoye-Selo, where we took up our quarters with the postmaster. Our complaint against the post-keeper in Narva and in respect of the iswoshtchik he settled next morning in a very curt fashion. He required from us the stipulated fare to St. Petersburg, then gave the iswosht-

A Troika of the Russian express mail service.

chik a sound thrashing with his own hands until his strength was exhausted, and sent him back with this in lieu of any payment to his master, while he drove us himself with his own horses on to St. Petersburg.

In St. Petersburg I was received in a very friendly manner by the merchant Heyse, an uncle of the poet Paul Heyse. I had first made the acquaintance of the Heyse family in Magdeburg, where, during my period of service as recruit, I had received much maternal sympathy and kindliness in the house of the widow of school director Heyse, distinguished as pedagogue and as author of a German grammar. The St. Petersburg Heyse, a son of the school director, had in his younger years gone to Russia, and had there raised himself to be a partner in one of the most respected commercial houses. The exchange with the amiable, and still thoroughly German, family was made easy by Heyse's procuring a lodging for me in a hotel near his own residence on KADETTENLINIE (Cadet line) on the island of Wasili-Ostrov.

St. Petersburg, with its grand site, its broad streets and large squares, and especially with its mighty river, the many-armed Neva, made a powerful impression on me. This was strengthened by the strangeness of the life of the people and the peculiar mixture of large palaces with small houses, for the most part entirely built of wood, in the broad interminable streets. The active sleighing, which in winter takes up the streets and almost entirely excludes the carriage traffic, also produces a peculiar effect on the foreigner seeing St. Petersburg for the first time. The inability to understand the language, and to decipher a single inscription on street corners and shops, gives one also a feeling of forlornness and dependence, which it is difficult to shake off. All the more cheering on the other hand is the social intercourse with one's compatriots, the extremely developed hospitable family life in the large foreign colony of St. Petersburg, especially the German, to which it is no mean advantage that the Baltic provinces of Russia have completely preserved their German nationality in the cultivated classes. The higher government posts were at that time for the most part filled by Germans from the Baltic provinces. This facilitated the progress both socially and commercially of a German coming to St. Petersburg. It was much in my favor that as a result of introductions from Berlin the scientific circles were thrown open to me. I received a cordial welcome from the most celebrated representatives of Russo-German science, of whom I will mention only the academicians Kupffer, Lenz, Jacobi and von Baer.

Unfortunately the agreeable, and from the point of view of business undertakings advantageous, intercourse was seriously interrupted. One day, I felt extremely unwell. In vain I sought recovery in Russian baths and similar self-prescribed remedies, and finally by an emetic which

Werner to William, August 4, 1853

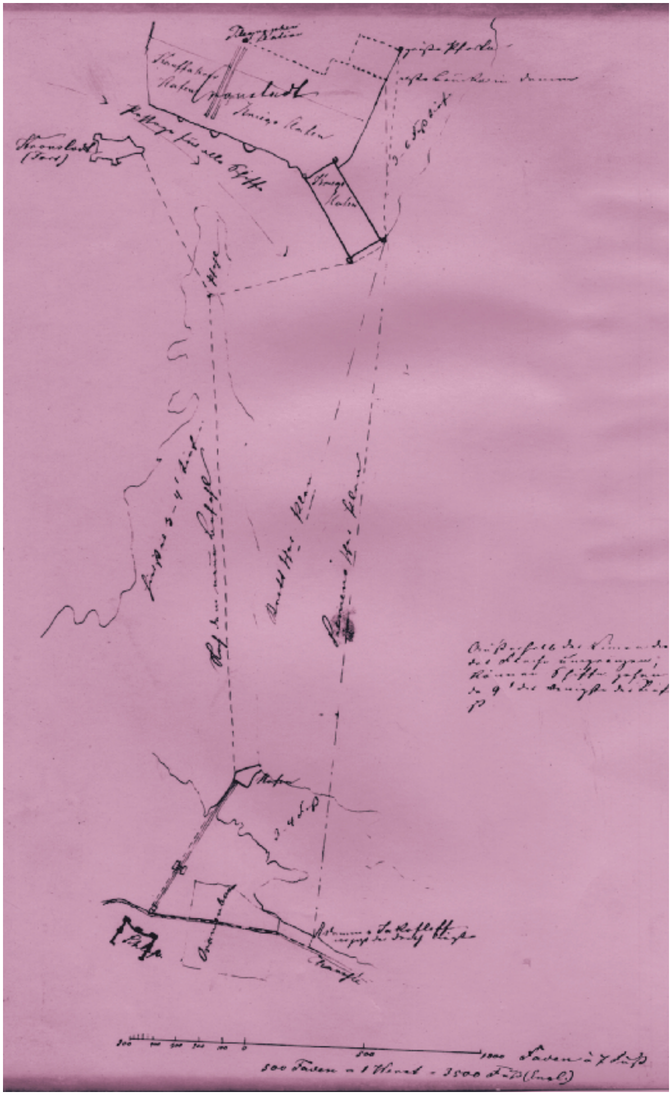
. . . In St. Petersburg I have obtained a contract for the line from St. Petersburg to Kronstadt (for 80,000 roubles) and have to complete it by the end of the summer . . . Here we will have to lay the cable in dredged trenches to protect it against drifting ice. It will be best to do this . . . before the ice gets very thick . . . It would be very difficult to place and transport one enormous drum on sledges and I consider it preferable to reel up the cable in 3 to 5 pieces and to joint them on the ice . . .

Kronstadt (an illustration from Das heutige Russland, *ed. H. v. Lankenau and L. v. d. Oelsnitz, Leipzig, 1876–1877).*

I was able to procure. After the unspeakably painful night which ensued, I fortunately received a visit from friend Heyse, who perceived the seriousness of my illness and sent his doctor to me. I had caught the measles, which were then raging in St. Petersburg. Severe inflammation of the kidneys followed, which chained me for some months to a sickbed, and from the consequences of which I long had to suffer.

Apart from this personal mishap, the results of my journey were very favorable for the development of our business relations. We obtained the commission to lay an underground line from St. Petersburg to Oranienbaum, with a cable junction to Kronstadt.

The construction of the Kronstadt line, and the necessity of organizing new representation for our firm in Russia, led me again to St. Petersburg in the summer of 1852. I found there in a German merchant of the first guild, Mr. Kapherr, a very suitable representative, who has contributed much by his activity and adroitness to the favorable results of our Russian undertakings; and I was able to come



Sketch by Carl von Siemens for laying the first undersea cable from Oranienbaum to Kronstadt, 1854.

into a closer relationship with the department of public ways and communications, which was responsible for the construction and management of telegraph lines.

Werner von Siemens and Mathilde Drumann in the year they were betrothed, 1852.

My marriage to Mathilde Drumann was celebrated on October 1, 1852, in Königsberg. After a short stay in Berlin, we traveled to the Rhine and then to Paris, where my brothers William and Carl also happened to be just then. After the anxious years devoted to strenuous work, I there enjoyed in full measure my young married bliss, enhanced by the companionship of my brothers. The sorrowful years spent nursing her beloved sister had much tried my wife. All the more delightful was it to me to perceive how her

Carl von Siemens, around 1855.

newfound happiness from day to day restored her earlier youthful freshness. This also made me young again, and obliterated the traces of excessive labor and prolonged sickness.

Alas, this sunshine in my life did not last long. Soon after her second confinement, Mathilde began to ail. The germs of the terrible disease of which her sister had died, and which she had probably received during the long self-sacrificing period of nursing, now began to mature. A year and a half's residence in Reichenhall, Meran, and other spas appeared to have restored her, but it was not for long. After a union of thirteen years, in which she bore me two sons and two daughters, she died after long and painful suffering.

When, in the spring of 1853, the construction of a railway telegraph from Warsaw to the Prussian frontier was entrusted to us, we offered my brother Carl, who had returned to London at the beginning of that year after the shipwreck of our Paris plans, the opportunity to undertake the direction both of this construction and also of the further expected works in Russia. Carl declared himself ready, and subsequently executed these in part very difficult tasks so satisfactorily that we considered our decision to entrust him, despite his youth, with such important works as a very happy one. We owe it mainly to his

Werner to William, May 10, 1853

. . . In addition, the embassy here has received orders from Warsaw not to visa Carl's passport and my own. The devil knows what sort of intrigue is behind it . . . My stomach is also very upset and a diet of water-gruel does not give one much energy! . . .

energy and ability that the Russian business now grew so rapidly and to such proportions.

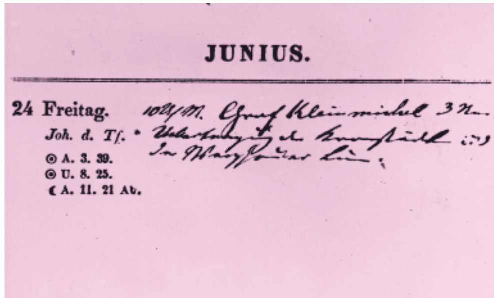
The Emperor Nicholas was then on the throne, and under him the most powerful man in the empire was Count Kleinmichel, chief of the Ministry of Public Ways and Communications. I had up till then not come into personal contact with this man so feared throughout Russia, as negotiations had been carried on through the above mentioned Colonel von Lüders, with whom personally I was on friendly terms. When, however, the latter was taken ill and obliged to take the cure at German spas in the spring of 1853, I was summoned by Count Kleinmichel to St. Petersburg for a conference on telegraph matters, just when I was expecting to accompany my brother Carl to Warsaw. I accordingly applied as usual at the Russian embassy for a visa for my passport. To my astonishment, in spite of repeated reminders, I failed to obtain the visa. When I complained of this to the ambassador himself, he told me that by order of the St. Petersburg secret police the visa could not be given. As no reason was given for the refusal, nothing was left to me but to write to Count Kleinmichel that I could not comply with his request, the visa for my passport having been refused. It then lasted no longer than the exchange of couriers between Berlin and St. Petersburg before an official from the Embassy handed me the *visé* passport with many excuses, and the explanation that a misunderstanding had occurred.

Pyotr Andreyevich, Count Kleinmichel (1793–1869), confidant of Czar Nicholas I, with responsibility for decisions about all telegraph projects.

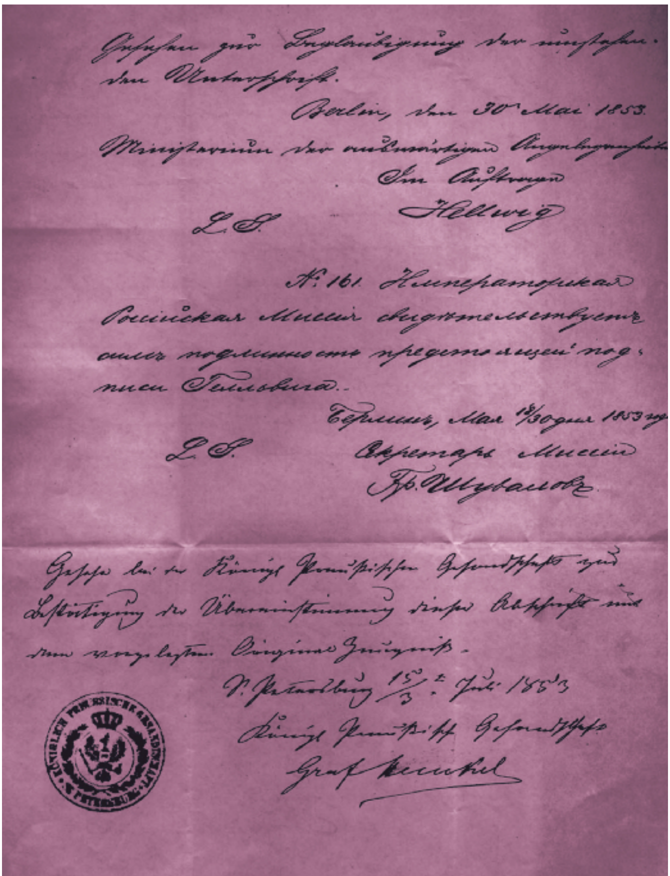
When, however, a few days later on the journey to Warsaw I had reached the Russian frontier station, I soon found that despite the alleged misunderstanding I still belonged to the class of suspects. My effects were searched, after all the other travelers had been passed, with a minuteness which far exceeded all expectation. Every piece of paper whether written on or not was retained, and it was finally declared to me that, in consideration of the excellent result of the search so far, I should be spared an equally thorough personal visitation if I handed over all my letters and gave my word of honor that I carried nothing else about me printed or written. On my declaring that I should return, as such a treatment did not suit me, it was signified to me that I must now go on with my luggage to Warsaw and there await a further decision. I was in fact a Russian state prisoner!

On arriving in Warsaw, I complained bitterly of the treatment to which I had been subjected to General Aureggio, who as director of the Warsaw – Vienna Railway had concluded the contract for the construction of the railway telegraphs with my firm. The General promised to lay my case before the then Governor of Poland, Prince Paskewich. To his question whether I had done, written, or said anything which could have rendered me politically suspect, I could only answer that I had once replied to a Russian state counselor, on his repeated offer to procure for me a decoration for my services to Russia, that this would afford me less satisfaction than an order to construct further telegraph lines for Russia. The Governor had laughed heartily when the General communicated to him the confession of my sin, and bade him tell me that he would in my place have thought just the same. I at once received all my things back and a passport to St. Petersburg. After being a short time with my brother Carl, who had meanwhile followed me to Warsaw, I accordingly continued my journey.

On arrival in St. Petersburg, after a six days' journey in an extremely uncomfortable stagecoach, I immediately repaired to Count Kleinmichel, who, as I had already heard in Warsaw, had on his own responsibility issued the order to give me the passport. The count listened to my report in a quite friendly manner, and took a look at the testimonials in regard to the works hitherto executed by



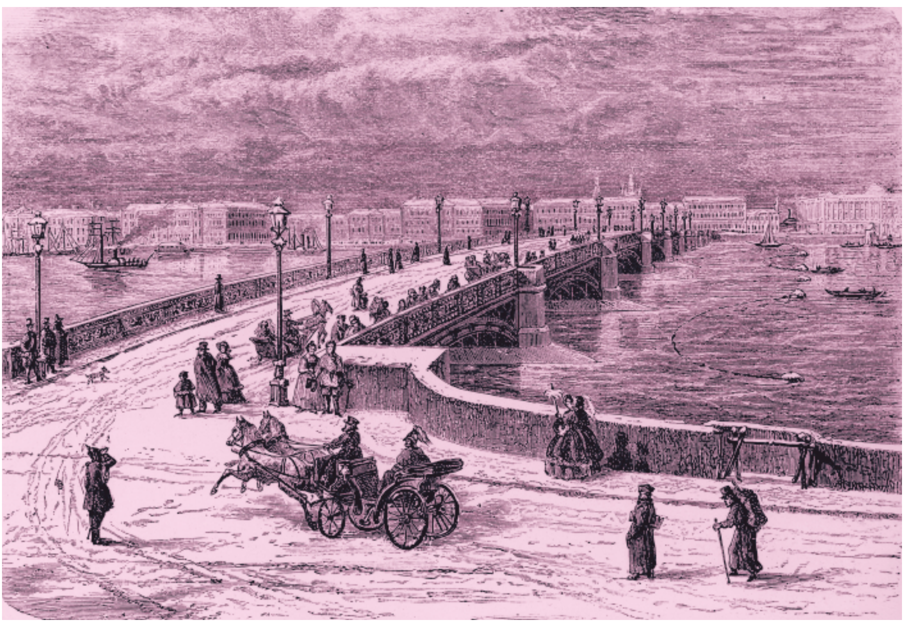
Werner von Siemens' own calendar entry, St. Petersburg, June 24, 1853: "10:00…/ Count Kleinmichel 3 hours. Contract for Kronstadt and Warsaw lines."



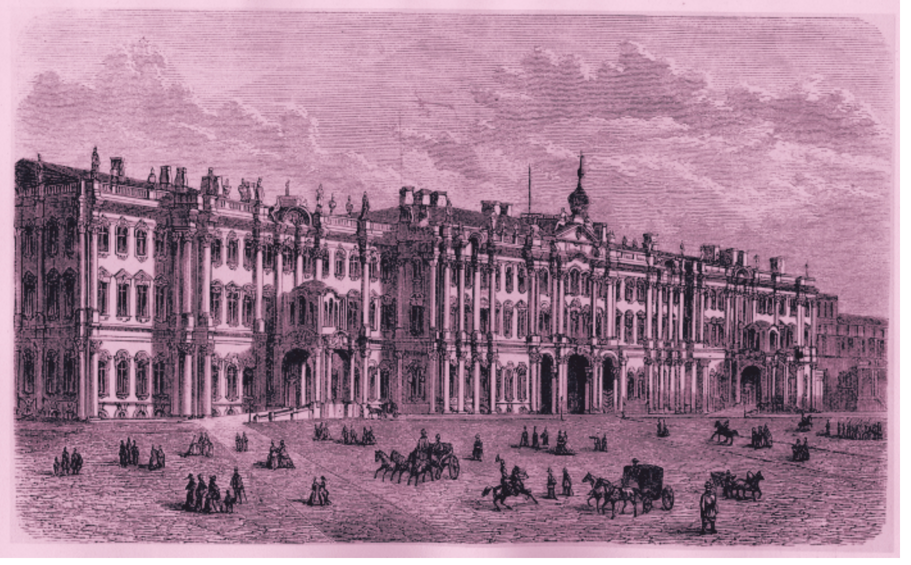
A police attestation of good conduct for Werner von Siemens, issued by Police Chief Hinkeldey for a trip to Russia, 1853.

us which I laid before him. At the treatment which I had suffered he was manifestly very indignant. When, in a very favorable testimonial from the president of the Berlin police, Hinkeldey, in regard to the police telegraphs laid down by us he found the concluding remark that, politically, I was altogether free from suspicion, he bade me go with this testimonial to the chief of the secret police, General Dubbelt. "Tell the General," were his words, "I command him to read the testimonial, and then bring it back to me immediately; I shall show it to the Emperor!"

This injunction placed me in rather an awkward predicament. Fortunately a Warsaw business friend had given me an introduction to one of the higher officials in the dreaded department of the St. Petersburg secret police. I therefore went first to this gentleman, and requested to be advised how I should proceed, in order to do the count's bidding and yet not give offense. From him I learned that it was a



The Nicholas Bridge in St. Petersburg, around 1850.



The Winter Palace in St. Petersburg (illustration from Das heutige Russland, *ed. H. v. Lankenau and L. v. d. Oelsnitz, Leipzig, 1876–1877).*

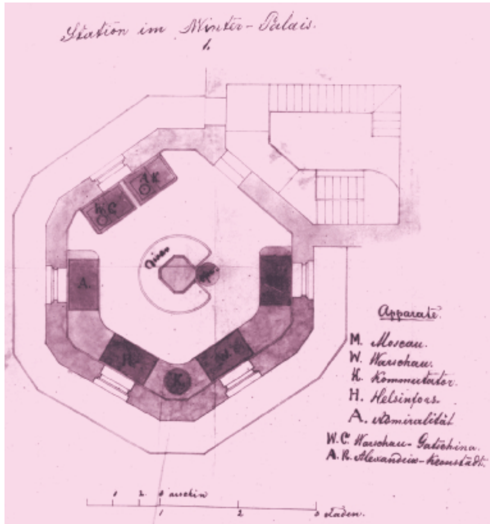
report from Copenhagen, in which I was described as a dangerous character, on terms of intimacy with the democratic professors of Kiel, that had occasioned the refusal of the passport. Evidently it was Danish gratitude for the mines in Kiel harbor and the construction of the Eckernförde batteries which had certainly rendered the Danes rather uncomfortable. Both the chief of the police, who in solemn audience received my testimonial and thereupon assured me of his special satisfaction and his constant readiness to help me in my undertakings, and also Count Kleinmichel himself were perfectly satisfied by these explanations.

I have related this interesting episode from my life in Russia at such length because it gives a good picture of the state of things and official relations in the realm of the Czar at that time, and because it has been of great service to our business transactions. Count Kleinmichel's power was then so great that, as long as the Emperor Nicholas lived, no one ventured to resist it. The count had acquired confidence in me, and afterward bestowed the same in a very marked degree on my brother Carl. To his powerful protection alone did we owe it that we were enabled successfully to execute the great works which he entrusted to us.

Count Kleinmichel did not conceal from me that he would have liked to retain me permanently in Russia for the execution of his further plans. As I could not accede to that, I announced to him, when at the end of July I took my leave, the impending arrival of my brother, who had great experience in the construction of lines and would be able to execute his orders better than I could myself. A few days after my departure Carl arrived in St. Petersburg. When he presented himself to the count, the latter was surprised at his youthful appearance, and showed himself in consequence much annoyed. However, he gave him the order to propose an arrangement whereby the wire of the telegraph in course of construction between Oranienbaum and Kronstadt might be conducted into the turret room of the imperial Winter Palace, hitherto the terminal station of the optical telegraph to Warsaw, without disturbing the Emperor's dwelling place.

When brother Carl looked carefully at the proud palace with its turreted projection, wherein the optical telegraph bureau was situated, he noticed that no gutter ran down in one corner of the tower, as was the case in the others. On perceiving this he immediately returned to the count, who, annoyed at his supposed fussiness, inquired rather roughly what else he wanted. Carl at once communicated his plan of placing in the vacant corner of the tower a similar pipe to that which existed in the others, and of conveying therein the insulated telegraph wires. This made a great impression on the count. He inveighed against his officers, who could suggest nothing better than knocking out grooves in the masonry; "and now," so he expressed himself, "there comes a beardless young man, and sees at first glance how easily the thing is to be done." Thus Carl succeeded on his very first appearance in gaining the favor of the count, who from this moment onward accorded him an authority in which he placed as implicit a confidence as in my own. In this he was not disappointed.

In the autumn of 1853, Carl completed the Kronstadt cable line to Count Kleinmichel's perfect satisfaction. This was the first submarine telegraph line in the world which has remained permanently serviceable. The gutta-percha conductors employed, protected by iron wires, have stood the test admirably. At the same time as the laying down of the line, its maintenance, the so-called remount, was also contracted for by us for a period of six years. During the whole of this time the wire was only once seriously injured by ships' anchors, and after the lapse of the six years was handed over to the government in a faultless condition. It has remained in active use to the present time, and affords therefore a good proof of the durability of well-constructed submarine cables.

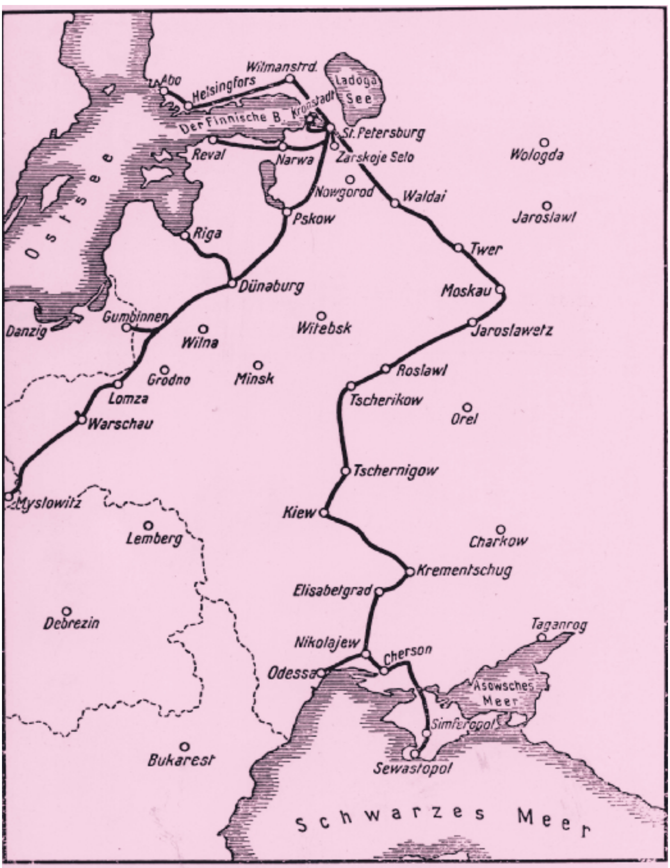


Optical telegraph stations at the Winter Palace in St. Petersburg. Undated drawing.

In the spring of 1854, the Crimean War broke out. We received in consequence the commission to construct as quickly as possible an overhead telegraph line along the high road from Warsaw to St. Petersburg, or rather to Gatshina, which was already connected with St. Petersburg by an underground wire. Accordingly, in April 1854 I traveled to Warsaw and there organized a working column, which began the construction of the line from Warsaw under the command of Captain Beelitz, a former comrade of mine who had entered the service of our firm. I then went to

St. Petersburg and there, together with Carl, organized a second column, which under his command worked toward that of Beelitz from Gatshina. Thus the line, about 1,100 versts* long, was completed in a few months, to the great astonishment of the Russians, who were unaccustomed to quick and well-organized work. When the two columns met halfway at Dünaburg, and the translation station of that place correctly performed its functions after the surmounting of a few difficulties, Carl was able to announce to Count Kleinmichel the completion of the line at the promised time.

** verst = about two-thirds of a mile*



The Russian state telegraph network. Built by Siemens & Halske, 1852–1855.

The count was much astonished at this intelligence, and would not quite believe in its correctness. He at once repaired to the station in the telegraph tower of the Winter Palace, and himself addressed a question to the chief of the Warsaw station. His doubts were only removed when he had received an instantaneous reply, and, astonished in the highest degree, he announced the happy event to the Emperor.

The success of the Warsaw–St. Petersburg line strengthened the Russian government in its resolve to cover the whole empire with a network of electric telegraphs. The speedy construction of a line from Moscow to Kiev was entrusted to us. Between the former town and St. Petersburg an underground line was already in operation, as mentioned before. Then in quick succession lines were ordered from Kiev to Odessa, from St. Petersburg to Reval, from Kowno to the Prussian frontier, from St. Petersburg to Helsingfors; after overcoming infinite difficulties these were all completed in the years 1854 and 1855, and were of great utility to the Russian Empire in the Crimean War raging at the time.

By means of the telegraphs Russia was put in speedy communication with Berlin and the west of Europe; in the interior of the empire the movement of troops and material could be regulated with their help, and the central government could everywhere promptly make and improve its arrangements.

Herr Siemens (originator of underground telegraphy and owner of a telegraph construction firm here) has for some time been very actively engaged in the erection of State telegraphs in Russia. He is shortly going to Warsaw and then to St. Petersburg where his presence is required in connection with this work. The telegraph line from St. Petersburg to Moscow was completed two years ago. At present, preparations are being made for a telegraph line from St. Petersburg to Warsaw. A line is also to be run from the first-named capital to Kronstadt which, because of the many islands and waterways, entails very many difficulties. The idea is to make St. Petersburg the central point for all telegraph routes in Russia and also to connect the various parts of the city by telegraph in the manner of Berlin …

National Zeitung,
September 28, 1853

Werner to Carl, November 3, 1853

… When it thaws they (the telegraph poles) all fall down again. And things are even much worse in Russia! There it is sometimes impossible to transport materials over the bridgeless rivers or streams for weeks at a time … We have 6 to 8 large rivers to cross …

Carl to Werner, November 8, 1854

Today things have changed greatly and in spite of my thick hide my head is fairly swimming. The following jobs have been agreed with the count and are as good as certain.

1. *Construction of the line from Kiev to Odessa at a price of 219,484 roubles to be finished by May 1st.*
2. *Maintenance of this line for 12 years at 52,404 roubles (annually) with surveillance.*
3. *Construction of the line from St. Petersburg to Helsingfors for 115,515 roubles, by May 1st; however, this is not vital.*
4. *Maintenance as above at 53,000 roubles.*
5. *Maintenance of the Moscow line at 53,000 roubles.*

Everything had to be accepted whether possible or not; but we will want a lot of good men for it: [William] Meyer! Things are now getting too much for me. I would have to stay permanently in St. Petersburg as otherwise Kapherr will get too presumptuous and spoil things.

September 5, Berlin

In the morning of the first inst. there were once more stored, on the platform of Potsdam Station in Berlin, 800 hundredweights of telegraph wire which had been sent from Westphalia and ordered by Messrs. Siemens & Halske for the Russian telegraph lines.

Wochenblatt für den Kreis Altena, *No. 36, September 9, 1854*

One may form an idea of the difficulties which beset the construction of these lines when it is borne in mind that all the materials, with the sole exception of the wooden telegraph poles, which were procurable in Russia, had to be obtained from Berlin and western Germany, that there were then no railways in Russia other than those from the Prussian frontier to Warsaw and from St. Petersburg to Moscow, and that all the roads and means of transport were occupied to an unusual degree by the war transports. In addition to this, the marine transport of heavy materials from German to Russian ports was impeded by the blockade of the latter. With great difficulty two ships from Lübeck, laden with iron wire for Russian ports, escaped capture by English cruisers by taking refuge in Memel, whence their cargo was forwarded overland.

The Berlin firm had enough to do in procuring the materials, preparing the apparatus, and organizing the transports, and was therefore only in a slight degree able directly to assist my brother Carl, on whose shoulders the whole burden of the construction of the line rested. Carl's chief assistants in the execution of these works were my former serving-man Hemp, who had rendered such effective aid in Schleswig-Holstein, and the

The first Siemens & Halske construction office in St. Petersburg, 1853.

Captain Beelitz alluded to above. I myself was indispensable in Berlin, where meanwhile the construction of railway lines continued uninterruptedly, and was obliged to content myself with repeatedly journeying to St. Petersburg to superintend organizing work and maintain the connection between the centers of our activity.

In the spring of 1855, I repaired to St. Petersburg for a somewhat longer stay in company with my friend William Meyer – who meanwhile had resigned his post in the Prussian government telegraph department, and had become chief engineer and confidential clerk for the firm of Siemens & Halske – in order to introduce in our office there an organization answering the rapidly growing requirements. We had already nearly finished our work and were thinking seriously of our return when I was suddenly

… Trois grandes lignes de télégraphie électrique relient Saint Pétersbourg 1° avec Mariopoul en Pologne sur la frontière prussienne …; 2° à Moscou, avec embranchements l'un sur Kiew, … l'autre sur Perekoff en Crimée et Odessa; 3° avec la Finlande … le monopole de la construction et de l'installation des appareils a été concédé pour une somme d'environ dix millions à M. Siemens de Berlin. Cet habile ingénieur, que rien ne genait dans l'exécution de ses plans, a pu mettre en évidence toutes les ressources de son esprit si inventif.

From Cosmos, Revue encyclopédique hebdomadaire des progrès des sciences*, vol. 6, Paris, 1855* called up at midnight and taken almost by force to Count Kleinmichel's assistant, General von Guerhardt. The latter imparted to me that the Emperor had ordered the immediate construction of a telegraph line to the Crimea up to the fortress of Sebastopol, and the count wished to have an estimate and the date of completion by 7:00 the next morning. My doubts in regard to the difficulty of procuring and transporting materials on the only open road from Berlin to Perekop and Sebastopol, as well as to the impossibility of constructing a line to the seat of war itself, when all the ways and means of transport were required by the military, were overborne by that all conquering phrase in Russia "The Emperor wills it!" And in fact the magic formula held good in this case also. The line was made.

When after working the whole night I came to the General punctually at 7:00, I learned that the latter had already been summoned to the count two hours before, and had not yet returned. Soon after 8:00 he came and communicated to me that Count Kleinmichel had told the Emperor, who had ordered the report by 6:00, that I would carry out the construction from Nikolaiev to Perekop in six weeks, that from Perekop to Sebastopol in ten weeks, and at the same price as the line from Kiev to Odessa. I declared both to be impossible. The transport of the wire and apparatus alone from Berlin to Nikolaiev on roads destroyed by military transport would take at least two months. The expenses would also as a matter of course be much higher, and at the seat of war the work would be almost impossible for civilians and especially for foreigners. All that, however, was of no avail and was hardly listened to. The Emperor had spoken! In the course of the day I received an official letter communicating that the Emperor desired to express his thanks to us for the services hitherto performed for Russia in its difficult situation, and for the offer of a rapid construction of the required line to the seat of war, but that he trusted we should, in consideration of the difficult war conditions, construct the new line more cheaply than the previous ones.

This was an extremely difficult situation for us. The summer was already half gone, and before the end of it there was no means of getting material to the spot. Moreover, without a heavy river cable it was impossible to cross the broad and swampy Dnieper. And yet the imperial order had to be complied with, so far as humanly possible. The only possibility of effecting a telegraphic communication at least to Perekop, situated on the isthmus uniting the Crimea with the continent, consisted in collecting all the materials remaining over from the construction of the hitherto completed lines, sending them to Nikolaiev, and carrying the line in a circuit of about thirty versts by way of Bereslaw, where a bridge crossed the Dnieper and made the passage practicable without a river cable. The same night in which the communication was made to me, we had accordingly corresponded by telegraph with all the Russian stations and had summoned to the station Captain Beelitz, who luckily was just then in Nikolaiev, to settle the possibility of obtaining telegraph posts. Beelitz answered that he must first consult the Jewish timber merchants, and had sent out messengers to summon them immediately to the station. Then arose a peculiar telegraphic negotiation. Beelitz announced a Jew would undertake the delivery of the poles, but must have fifteen roubles per pole. Answer: "Out with him!" Reply: "Done!" Another offered to do it for ten roubles. Answer: "Out with him too!" Reply: "Done!" A set of others asked six roubles; with these, negotiations were carried on and finally an acceptable offer was obtained, securing timely delivery of the poles.

His Royal Highness the Prince of Prussia [later Emperor Wilhelm I] left for St. Petersburg on the evening of the seventh to convey to Her Majesty the Empress Mother the best wishes of Her Highness's Royal Brothers and Sisters on the occasion of Her Highness's Birthday on the thirteenth of this month. This journey, which had long been intended following the death of His Majesty Emperor Nicholas, has no political purpose whatsoever, but fulfills a long-cherished desire of Her Majesty the Empress Mother for the consolation of the presence of her Royal Brother.

Neue Preussische Zeitung,
July 10, 1855

Werner von Siemens with his first wife, Mathilde, and sons Wilhelm and Arnold, around 1858.

Further, it turned out that there was a reserve of materials in almost sufficient quantity for the line as far as Perekop, and that there was a prospect of obtaining in Odessa thin iron wires for a provisional line. There seemed therefore a possibility of satisfying the imperial will at any rate in essential points. With the request to lower the price "in consideration of the present distressed state of Russia," we so far complied that we offered to execute the necessary circuit by way of Bereslaw at our own expense. In short, the omnipotence of the imperial command again prevailed. The line to Perekop was finished in the required time, and the line to Sebastopol was at least completed early enough for a message to St. Petersburg announcing the probable fall of the fortress.

This construction of a line of about 200 kilometers on a road occupied and rendered impassable by marching troops and transports of war material and into a beleaguered fortress was difficult work, which did great credit to my brother Carl, who conducted it, and to his assistants. Financially, it certainly ran away with a considerable part of the profits obtained through the construction of the other Russian telegraph lines.

I myself, after I had as far as possible made all the preparations for the construction of the line to the seat of war, as ordered by the Emperor, and had become convinced that it was practicable, desired in July to return to Berlin, where my wife was expecting her second confinement. To my great astonishment, however, I could not get my passport back from the police, despite repeated applications. When I complained of this to Count Kleinmichel, he declared that I could not be allowed to depart before the lines in course of construction, and particularly that to Sebastopol, were completed. All my remonstrances were in vain. The count would not withdraw the order, once given, to withhold the visa for my passport, and I was thus for an indefinite time "interned" – as it is called – in St. Petersburg.

Then, luckily for me, the Prince of Prussia came to St. Petersburg to negotiate, as it was said, concerning the neutrality of Prussia in the Crimean War. I determined to use this fortunate circumstance to slip from the semi-imprisonment into which I had fallen. At Peterhof, where the prince had taken up his residence, I called on his first adjutant Count Goltz, explained to him my difficult situation, and begged that the prince would when convenient give me an audience, so that the Russian officials might see that I enjoyed his protection. In his great goodness of heart and affability the prince acceded to my request, and on the very next day I received the official summons of the Prussian embassy to repair to an audience at the Winter Palace. I was awaited by the ambassador and conducted through a series of anterooms, filled with generals and officials of high standing, to the prince, who was surrounded by several grand dukes and highest dignitaries. The prince addressed a few very friendly words to me, mainly to the effect that the posts of the telegraph line we had constructed along the whole way from the Prussian frontier to St. Petersburg had given him the joyful assurance of remaining in constant connection with home, and that he desired to express to me his thanks in person. The result of this audience was more brilliant than I had expected. On the very same day, a police official came and handed me my passport with excuses for the oversight that had been committed.

The Russian government had simultaneously with the contracts for the construction of the lines also concluded

Marie Baroness von Kap-herr (1835–1869), daughter of the Siemens & Halske representative in St. Petersburg, Hermann Christian Baron von Kap-herr (1801–1877). Undated.

remount agreements with us for six to twelve years, which required a large administrative apparatus. We therefore converted our St. Petersburg office into an independent branch establishment under the direction of my brother Carl, whom we at the same time took into the head firm as a partner. We obtained a large building on the island of Wasili–Ostrow, in which the large offices of the maintenance administration were established, and at the same time a workshop was erected for the speedy execution of all repairs. Carl took up his residence there toward the end of 1855, after his marriage to the clever and charming daughter of our previous representative in St. Petersburg, the above-mentioned Mr. Kapherr. Like his father-in-law, Carl now became a Finnish subject, in order to be able to become a merchant of the first guild, and, as such, to have the right of carrying on any kind of business in Russia.

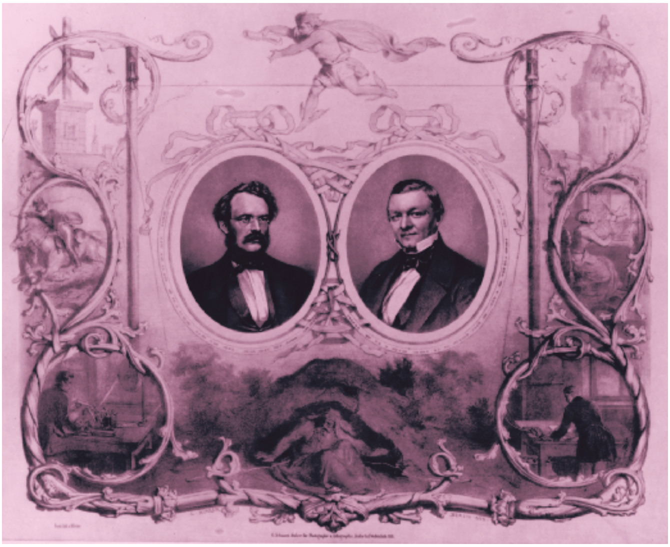
I must mention one other circumstance which was very important for our new St. Petersburg business and rendered it particularly remunerative. Count Kleinmichel had in the beginning entrusted the surveillance of the telegraph lines to the contractors of the turnpike roads, in consideration of a large payment reckoned by the verst. The result, however, was that no, or only a very lax, watch was kept. Accidental or intentional injuries to the lines were generally discovered only after a lapse of several days, and the repairs usually took place only after a long interval and often so defectively that a reliable telegraph service was never to be reckoned

The von Kap-herr family, around 1860. Far right, Carl von Siemens with his wife, Marie. Carl established and managed the Russian branch of Siemens. He was raised to the Russian hereditary nobility in 1895.

upon. At last the count requested us to undertake the surveillance of the lines; he would pay us for the service the hundred roubles per verst which he had hitherto given to the road contractors. In reality a successful watch could not be carried out by us, but only by natives, who would certainly not have kept a better lookout on our behalf than for the government. Nevertheless, we accepted the count's offer on condition that we might carry out the surveillance and the necessary repairs entirely in our own fashion.

As this was agreed, we gave up altogether keeping a guard, properly so called, and contrived instead a mechanical system of control,* which was relatively cheap and yet fully answered the purpose. At intervals of fifty versts we erected a guard hut, into which the wires were conducted. In the hut was placed an alarm and a galvanometer, and these were intercalated into the course of the current in such a way that by watching the movement of the galvanometer

* *The control galvanoscope was known in Russia as the "Tataren" galvanoscope. See Werner von Siemens,* Scientific & Technical Papers, *vol. II, 108 – 114.*



An allegory of the construction of the Russian telegraph lines, 1855.

needle it was possible to see if an electric current was traversing the wire. If the needle stood still for half an hour, the guard had, with the help of a simple mechanism, to telegraph the number of his hut by repeatedly connecting to earth. The telegraph stations between which the connection was interrupted had orders to insert their battery between the conductor and the earth, and received accordingly the reports of all the guard huts on the hind side of the place of interruption, thus learning its situation. To every telegraph station was assigned a mechanic whose duty it was, immediately on the report of an interruption, to take post-horses and travel to the fault. As the order was given to supply our mechanics with post-horses at once and before all other travelers, the fault was nearly always removed in the course of a few hours.

Carl to Werner, late 1858

Even if we were to get no more construction work and were dependent solely on the old surveillance, we would still earn about 80,000 roubles a year … No matter what happens in future here we should in general be well satisfied with the Russian business, since the initial capital investment has already been paid back with a considerable surplus and there is now a new independent concern with its own capital and a guaranteed annual income of 350,000 roubles.

A telegraph office in St. Petersburg, 1878.

In consequence of this arrangement the Russian telegraph lines acted with great accuracy during the period of our management, and interruptions of the service rarely occurred for more than a day, in spite of the enormous length of the lines, and in spite of the desert steppes through which they mostly passed. The contract, almost forced upon us, for the watching of the telegraph lines soon proved very profitable, and amply compensated us for the losses which we had suffered in the construction of many of the lines.

Through the management of the remounts entrusted to us and the continued further constructions of lines, our St. Petersburg business obtained great importance and a unique position in the Russian Empire. We received the official title "Contrahenten für den Bau und die Remonte der Kaiserlich Russischen Telegraphenlinien" (Contractors for the construction and remount of the Imperial Russian telegraph lines), and obtained for our superior servants the right to wear uniforms with badges of rank. The latter was absolutely necessary for the thorough performance of

Uniformed Siemens officials of the Russian "remount."

our tasks, for the Russian public only respects the wearers of uniforms. To obtain this right, I had a number of handsome uniforms designed in Berlin. Instead of the epaulets, which in Russia were reserved for officers, golden chenille of varying thickness, increasing with the rank, was attached to the shoulders. Excellent artists then painted various groups arrayed in such uniforms. The pictures, enclosed in a handsome portfolio, would have made the heart of every admirer and connoisseur of uniforms beat faster. Armed with this portfolio, brother Carl repaired to Count Kleinmichel, explained to him our difficulty, and begged permission for the wearing of a uniform by our officials. The sight of the fine pictures overcame the resistance offered at first by the count; he retained the portfolio to show it to the Emperor, who immediately granted permission for the proposed uniform.

I consider it my duty to meet in this place the often expressed opinion that we could only have concluded these great and, generally speaking, profitable undertakings in Russia with the help of bribes. I can assert that this was never the case. The explanation may perhaps be that the negotiations were always conducted and concluded directly with the supreme government authorities, and that the state of political affairs urgently demanded the speedy construction of the needed telegraphic communications. This, however, does not imply that we have never recompensed the lower officials in the customary fashion of the country for services rendered during the construction of the lines.

SUBMARINE CABLES

Harzburg, June 1890

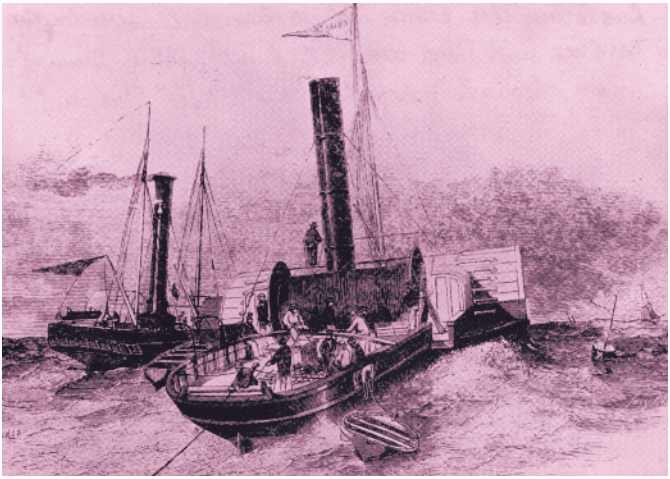
The successful use of copper wires coated with gutta-percha as underground conductors suggested their employment also in submarine telegraphic communication. That sea-water was not in any way injurious to the gutta-percha had been proved in the case of the insulated wires connected with the mines in Kiel harbor, which were quite unchanged after a lapse of two years.

The first attempt to connect two seacoasts by means of gutta-percha conductors had been made as early as 1850 by Mr. Brett, who had obtained a concession for a submarine telegraphic communication between Dover and Calais. As was only to be expected, the unprotected wire laid by him retained its efficiency for not much longer than the time of the actual laying, if indeed it was ever really serviceable. It was replaced in the following year through Messrs. Newall & Gordon by a conductor armed with iron wires, which acted well for some time. This was the commencement of submarine telegraphy, destined speedily to become one of the most important media of communication.

With the perseverance characteristic of the English in prosecuting their undertakings, after this first success the laying of a large number of other cables was at once planned and attempted, before the problem was ripe for a scientific and technical solution. Failures accordingly could not but occur. The laying itself presented no difficulty in the shallow water of the North Sea. The preparation of insulated conductors was undertaken in England by a gutta-percha company, which could not be prevented from employing my coating process, since I had not protected my inventions by a patent. As this company could always make use of the best-quality gutta-percha, owing to its command of the English market, it would have been in a position to turn out remarkably well-insulated conductors, if the electrical testing and control of the workmanship had been carried out with as much care as we had taken. However, at that time scientific knowledge and methods were as little appreciated in English industry as in our own. It was thought enough to make sure that a current traversed the wire, and that the instruments worked satisfactorily. Even much later, my methods for systematically testing the conducting wires were characterized by English engineers as "scientific humbug"! Nevertheless, in 1854, during the Crimean War, the firm of Newell & Co. succeeded in laying an unarmed conducting wire, insulated only by a coating of gutta-percha, from Varna to Balaclava in the Crimea, and with the good fortune that it remained serviceable till the capture of Sebastopol in September 1855, i.e., for about a year.

In this long line of about 600 kilometers, difficulties in the matter of signaling occurred as a result of the electrical capacity of the line, which in spite of my publications in 1850 remained entirely unknown to the English. When the needle telegraphs employed in England refused to do duty on the line, Newall & Co. ordered signaling apparatus from my firm, with which operations could very well be carried on. It was a singular coincidence that, in the two hostile camps of Sebastopol and Balaclava, Berlin apparatus with consecutive numbers of manufacture were at work.

Meanwhile, in September 1855, Mr. Brett, commissioned by the Mediterranean Extension Telegraph Company, had made an attempt to lay a heavy cable with four conductors between the island of Sardinia and the town of Bona in Algeria. He employed for the purpose the same contrivances as in the North Sea, but unfortunately his brake apparatus did not suffice on reaching deep water,



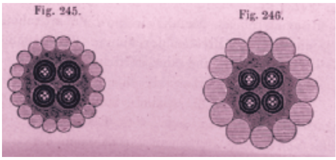
The first undersea cable being laid between Dover and Calais by the steamer Goliath *on August 28, 1850. The line was a copper wire 1.8 millimeters thick, with a gutta-percha sheath applied by the Siemens process. A fisherman destroyed the cable the very next night, not realizing what it was. On September 25, 1851, J. Brett laid a new, heavily armored cable 41 kilometers long, built by Newall & Co. The same company also delivered the Kronstadt cable to Carl Siemens, and engaged Werner von Siemens in 1856 to act as scientific consultant for the Cagliari–Bona cable.*

and in consequence the whole cable rolled to the bottom without the possibility of arresting it. When a second attempt in 1856 also miscarried, he retired from the undertaking, which was then taken up by Newall & Co. The latter contracted with my firm for the delivery of the electric apparatus, and requested me to undertake the electrical testing during and after the laying.

This first laying of a deep-sea cable was both interesting and instructive to me. In Genoa at the beginning of September 1857, with an assistant and the necessary electrical apparatus, I went on board a Sardinian corvette, which was to accompany the expedition and take us to Bona, where the steamship laden with the cable awaited us. It was an interesting group which assembled on board the warship. Besides the English contractors and cable manufacturers, Mr. Newall and Mr. Liddell, there were on board several Italian savants, telegraph officials, and naval officers, among them the learned Admiral Lamarmora, a very amiable and well-

Werner to Carl, June 5, 1856

On the seventh Newall and Gordon are coming from England and William from Paris. An important agreement is envisaged concerning submarine cables, and projects in England and the Colonies . . .

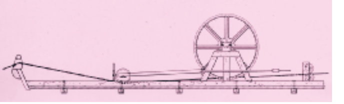


CROSS-SECTION THROUGH THE FIRST DEEP-SEA CABLE *from Cagliari, Sardinia, to Bona, Algeria, 1857. Fig. 245: Deep-sea cable; Fig. 246: Coastal cable.*

instructed officer, brother of the well-known General Lamarmora; in addition there were several French telegraph officials, in particular the well-known engineer Delamarche, who were commissioned by their government to be present at the laying of the cable.

During the passage to the island of Sardinia, which was favored by gloriously calm weather, the party discussed the methods which should be adopted in laying the cable, in order to avoid the failure of previous attempts. Messrs. Newall and Liddell declared that in laying their wire to the Crimea they had found it best to proceed quickly, and let the cable run out without check, so that it would sink slowly to the bottom without any strain. They had indeed as a precaution provided a powerful brake wheel, to regulate the speed of the cable, but that would hardly be necessary if the ship was going fast. This theory of Mr. Liddell was strongly opposed by M. Delamarche, who had been present at the unfortunate attempts of Mr. Brett, and had now adopted the theory that the cable must perforce assume the form of a catenary curve in deep water, and under any circumstances break.

I had originally intended to abstain from interfering in the mechanical part of the proceedings, but it appeared to me so utterly impossible to lay a heavy cable, having a weight in water of at least 2 kilograms, at a depth of more than 3,000 meters (as was the case between Sardinia and Bona), in the manner intended by Messrs. Newall & Liddell, that I spoke very earnestly against the proposal. On the other hand, I could not share the fears of M. Delamarche, and there ensued a warm discussion between Mr. Liddell, M. Delamarche, and myself, in which I expounded the theory which was subsequently universally adopted. It consists in holding back the cable by brake apparatus with a force which corresponds to the weight of a piece of cable in water reaching perpendicularly to the bottom. With a uniform motion of the ship the cable then sinks in a straight line, the inclination of which depends on the ship's speed and the velocity of subsidence of a horizontal piece of cable in the water. If the sinking portion of the cable is not perfectly balanced by the force of the brake, a sliding down of the cable occurs at the same time on the inclined plane formed by itself; it is therefore possible to regulate by the brake the extra amount of cable that is required to lay the cable without strain over the unevenness of the bottom.



The cable brake with dynamometer, designed by Werner von Siemens for the Cagliari – Bona Mediterranean cable in 1857.

This simple theory met with the universal approval of the company. Mr. Newall too came over at last to my view, and requested me to assist him in the preparations for laying the cable in accordance with my theory. It was, however, difficult to do this on the spur of the moment. The brake which, on arrival at Bona, we found on the waiting cable ship proved much too weak for balancing the weight of the cable at great depths. Moreover, the steam power of the ship was too small to overcome the great force with which the cable would endeavor to slide down the inclined plane. Finally, there was no contrivance for measuring this force, and for determining accordingly the amount of the brake action required. I first had a simple DYNAMOMETER constructed by the carpenter, which rendered it possible to ascertain the extent of the actual strain on the cable while it is paid out, by the amount of flexion of a length of the cable stretched over two rollers, between which a third weighted roller rides on the cable. Furthermore, I had the brake wheel strengthened as far as possible, and furnished with strong water boxes. Lastly, I caused the captain of the warship to pass a tow rope from his vessel to the bows of the cable ship, in order to obtain the requisite force for overcoming the backward drag exerted by the cable.

Thus barely provided, we began in the evening* the laying of the cable from Bona. As long as the water was shallow all went well, and my precautions were soon deemed super-

* *Of September 7, 1857*

fluous. After a few hours, when we got into much deeper water, it appeared, however, that the attainable brake force was not sufficient. We paid out too much cable and, when morning dawned, had already used more than a third of the cable, although a fifth of the distance had not been traversed. It was still just possible with the cable end to reach a shallow spot near the island of Sardinia, if the cable could from now on be paid out without any excess whatever. At the request of Mr. Newall I undertook to try this, on condition that the management was entirely left to me. I now loaded the brake with all the weights which were to be found on the ship. Even filled water tubs from the galley were requisitioned. At last the load sufficed, without the brake giving way. We now laid according to the statement of the measurements, without "slack," as the English say, i.e., without using more cable than exactly answered to the length of the seabed. The cable was always pretty near the breaking point, as was proved by the fact that several times one of the thick sheathing wires snapped, whereby the cable ran considerable risk. But by the adoption of prompt measures a fracture of the cable was averted, and when the sun set, and the cable end in the ship was almost reached, my dynamometer luckily indicated shallow water, and we were at the goal.

The joy was general and intense, and even Mr. Liddell congratulated me on the success achieved.

This was the first cable which was successfully laid in deep water, i.e., at a depth of more than 1,000 fathoms.* The laying of such heavy cables with many conductors has since been abandoned for long cable lines in deep water, because the difficulty of laying is too great, and because adjacent conducting wires interfere with one another by induction. This cable laying was for me, therefore, all the more instructive, and certainly also the more exciting and strenuous.

The cable must pass out of the ship's hold, in which it is carefully coiled around a cone, over the brake wheel and

** 1 fathom = usually 6 feet, but the size of the fathom varied historically and was at times as little as 5 feet.*

under the roller of the dynamometer, day and night without any stoppage, which is always dangerous in deep water. Every stoppage is a source of great danger, since the progress of the ship cannot be checked with sufficient celerity. At the same time the brake force must be carefully regulated in proportion to the depth of water, and to the velocity with which the ship is moving, otherwise the cable is either needlessly wasted, or it is strained at the bottom. Furthermore, the electrical quality of the insulated core must be unceasingly tested, in order that the occurrence of a fault in the freshly immersed parts of the cable may be immediately detected. In such a case the laying must be at once suspended, and the last laid portion of the cable taken back again to repair the defect.

The continuous mental strain, and the consciousness that any error committed may occasion the loss of the whole cable, makes the laying of a deep-sea cable a very anxious, and, for a length of time, thoroughly exhausting affair for all concerned, and especially for the leader of the undertaking. Toward the end of the foregoing work, in which I would not allow myself a moment's rest and refreshment, I could only keep myself awake by frequently taking strong black coffee, and required several days to recover my strength.

This cable laying took me for the first time into southern regions. During the whole time we had splendid weather, and I enjoyed to the utmost the charms of the Mediterranean, with its deep blue water, its dazzling white wave crests, and its refreshing air, of which we could never inhale enough, on the beautiful voyage from Genoa to Cagliari, and from there to Bona in Algeria. A surprising sight was afforded by the stout castle of Cagliari, loftily situated and entirely girdled by high-grown aloe bushes in full bloom. On the advice of the friendly captain of the corvette we did not remain in the harbor on account of the fever, but passed the night in the court of the ruined castle. This glorious night under the starry sky of Italy, high above the sea breaking upon the rocky coast in the moonlight, has never faded from my memory.

The electrical testings carried out during the laying showed that the insulation of all the conductors of the cable was imperfect, but on the completion of the line in the following year, in the case of three of them, it satisfied the conditions of the contract, which required only that the loss of current should not exceed a certain percentage. The fourth conductor contained a more serious fault, and the taking over of the cable was therefore refused. However, it was possible by a suitable electrical manipulation – continuous treatment with an exclusively positive current – so far to lessen the defect that the cable had to be taken over.

The theory of cable laying expounded on the above occasion I only made public in the year 1874 through the medium of a paper entitled "Beiträge zur Theorie der Legung und Untersuchung submariner Telegraphenleitungen" (Contributions to the Theory of Laying and Testing Submarine Telegraph Cables), submitted to the Berlin Academy of Sciences. I have preserved among my papers the copy of a letter in which on my return I explained my theory to the aforementioned Mr. Gordon, partner in the firm of Newall & Co. I shall insert this letter here, as it forms the first detailed communication on my theory of cable laying.

Berlin, September 26, 1857

Dear Gordon,

Returning yesterday from my journey, I found your letter of the seventeenth.

First I will give you some particulars from the report made by engineer Viechelmann, who has today returned from Bona.

There is no doubt that wire No. 1 is injured, and that the injury lies in the neighborhood of the African coast, and consists in the wire being in conducting connection with the water. It is not improbable that the defect exists where the shore end is joined to the thinner cable. It has not been possible to determine the precise place, as it is uncertain how much resistance the connection has between the conductor and the water. The place can, however, lie no farther than four German miles from the land, but is probably much nearer.

Through the amount of the charge and by determinations of the resistance in the metallic circuit according to the accompanying sketch (Figure 1) the situation of the fault may be more precisely determined, if you will make the attempt to take up the wire again from Bona. *m* and *n* are the two coils of a differential galvanometer, and *w* a rheostat. By its means resistance is interposed, until the currents through the two coils *m* and *n* are of equal strength and the needle stands at zero. Then the fault *f* lies (electrically) midway, and the distance from the coast can be calculated.

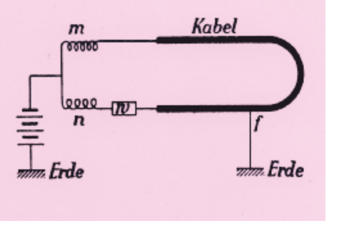


Fig. 1

With well-insulated wires this can be done with perfect exactitude; with badly insulated ones, such as the Bona cable, at any rate approximately correctly. – Mr. Viechelmann has left the apparatus in the customshouse of Marseilles at your disposal. In the telegraph office there lies a letter from Viechelmann to Newall, in which the authority for its delivery is contained.

As regards the theory of cable laying, the following is my view.

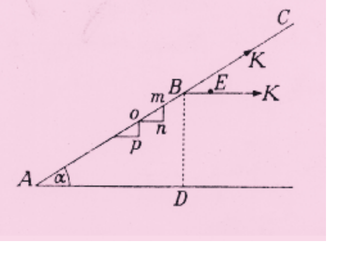


Fig. 2

If *A B* (Figure 2) represents a flexible piece of cable, which is attached to the sky by a weightless wire *B C*, the cable will fall to the ground, without being able to deviate from the straight line in the suspended part, as at every point it falls with equal velocity. *m n, o p* are of equal length. Every point falls with equal velocity, and the new connecting line *n p* must again be a straight one. The active force pulling upon the wire *B C* during the fall is $K = Q^\circ \sin \alpha$, if *Q* is the weight of the suspended cable in the water, or the weight of a piece of cable *B D,* hanging vertically downward, since $A\ B^\circ \sin \alpha = B\ D$.

If the force *K* is less than is necessary for equilibrium, the cable slides back toward *A,* and the terminal velocity is reached, when the friction in the water is equal to the lacking force. If on the contrary *K* is greater than necessary, the cable acquires a velocity toward *B,* consequently the loss, i. e., the difference of the lengths *A B* and *A D,* is picked up again, and the cable places itself in a straight line, thus without loss, on the ground. The angle α is accordingly quite independent of the amount of the force *K.* It simply indicates the proportion of the velocity of sinking to the progressive motion of the ship. For if the cable end *B* instead of being attached to the weightless wire *B C* is carried over a pulley, and the pulley moves with the ship from *B* to *E,* while the cable falls the distance *m n,* and finally if the cable is kept back with the force *K,* there is no change at all in the conditions of equilibrium. If the brake, which detains the cable, is so applied that equilibrium is just attained, thus $K = Q^\circ \sin \alpha$, the cable has no axial velocity whatever; it falls perpendicularly, and there is the loss corresponding to the angle. If *K* is greater, the cable is laid with little or no loss, if *K* is smaller, the loss may be very great. The quicker in the latter case the motion of the ship, the longer does *A B* become, the greater consequently the friction in the water and the smaller the loss. If on the other hand the force *K* becomes greater than is necessary for equilibrium, the loss can easily be made up, and the cable then forms a catenary curve. If the transitions are rapid, the whole velocity, which the cable has acquired after applying the brake on disturbance of the equilibrium, acts in the direction *A B,* and tends to strain the cable. When one considers the great mass of the suspended cable, it is clear that these axial velocities of the cable may easily cause a fracture. The only safe guide is the proportion of the ship's velocity to the velocity of the cable. – Moreover, the ocean currents must be taken into account, especially if they flow in various directions. If the current is everywhere equable, and extends to the bed of the sea, it only produces an additional expenditure of cable. With equilibrium of the force K the cable settles down in the diagonal of the parallelepiped, instead of in the diagonal of the parallelogram, and the cable length bears the same proportion to the distance traversed as the diagonal of the parallelepiped, whose sides are the ship's motion, the depth of water, and the simultaneous velocity of current, bears to the ship's motion. Very violent action on a tightly laid cable may, however, be exerted by variable currents, as the cable has then to resist the pressure of the water in the form of the catenary curve. Lastly, the rising and falling, as well as the lateral, movements of the ship form forces of importance, threatening the fracture of the cable, unless the uncoiling apparatus is very light, or a compensation can be effected whereby the cable may be lengthened or shortened behind the brake, so that no acceleration of the mass takes place. The mechanism [dynamometer] which I propose for determining and regulating the tractive force exerted on the cable is easily calculated as under Figure 3:

I have asked Löffler to calculate a table in accordance with this formula, of which, however, I am not yet in possession, as L. is still in Cologne. e was, as you state, 25 feet, i.e., 8.42 meters. The weight Q was 160 kilograms, according to the statement of Newall's people, who weighed it. You seem in your approximative formula to have taken pounds instead; your values are therefore only about half those I have in my memory. The apparatus was constructed of wood the evening before

$$\cdot \sin\alpha = \frac{Q}{2};\quad K = \frac{Q}{2\sin\alpha}$$

$$\sin\alpha = \frac{b}{ab} = \frac{b}{\sqrt{\frac{e^2}{4} + b^2}}$$

$$= \frac{Q}{2b} \cdot \sqrt{\frac{e^2}{4} + b^2}.$$

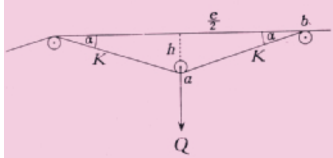


Fig. 3

the laying. Previously, Mr. Liddell seemed not to be in favor of it, and I did not wish to obtrude myself after having made my proposal. In the first night the frame had become warped through the wet, and the place where the height was measured was about 2 feet lower than the other. A trustworthy measurement with an apparatus so crudely and hurriedly made and calculated is therefore out of the question.

That soon after the commencement of the laying much cable was wasted was clear. I therefore at once proposed a stronger loading of the brake, but could not have my way. Undoubtedly there were moments when the cable line was almost straight, although in the ordinary course there was a depression of from 4 to 5 inches, and *one* such moment might have sufficed to break the cable. The brake was also too weak, and I was always in mortal terror lest, with the load of at least 5 hundredweight, which subsequently, when Newall left the matter in my hands, was applied, it should give way. As the cable would have been irrecoverably lost if the brake had given way, it certainly required a prodigious resolution to justify loading it in this manner. It is certain that we strained the cable too severely on the following day. We certainly laid it without any loss whatever, and perhaps already had some catenary curve force in the cable. This was owing to the circumstance that nobody knew how fast the vessel was going. Newall and Liddell thought we were not making 5 knots an hour, whereas in fact we had made $7^1/_2$. As the cable ran off with the velocity of $7^1/_2$ knots, I could only conclude that the waste was still too great for reaching shallow water; was obliged therefore to continue the loading. Thus there were moments when the loading reached quite 6 tons, and the fluctuations were even greater.

That there was no regular log in the ship was a serious misfortune, and might easily have had for its consequence the loss of the cable. The greatest danger in cable laying always consists in the snapping of single wires. That under the circumstances we came off as we did is a real marvel. I should not advise attempting a cable laying in deep water without having previously subjected the wire in its whole length to a maximum strain, never to be exceeded in the actual laying.

I have communicated a plan to Newall how this is very easily to be done. Then faulty weldings will be disclosed by rupture, and one may feel pretty safe afterward. Furthermore, a dynamometer of solid iron must be constructed with an accurate scale, and in such a way that with the maximum loading there still remains a deflection of at least one foot. It is better to make use of a well-made spring than a weight, so that the fluctuations of the apparatus may be as small as possible. It would also be very advisable to carry the wire behind the brake over two fixed and one movable pulley, the latter being pulled down by a weight or better still by a very strong spiral spring. The up-and-down movements of the ship are thereby rendered innocuous.

September 28

As Löffler has not yet returned, I can communicate to you nothing definite in regard to the calculated forces. You are quite right that the assumed forces are not justified by the depths alone. I believe we may go to half the depth for which a cable can support itself with tolerable safety, and to a third with great safety. Up to a fifth of the depth 5 to 10%, and to a third of it 10 to 15% slack may give sufficient safety, if the weather is favorable. At greater depths the loss must be considerably more. Newall's plan of retarding the sinking of the cable by shields is wrong in principle. The cable must sink as quickly as possible on account of the currents. With moderate depths it is more advantageous to take back the slack by somewhat greater loading of the brake. If the depth is greater than $^1/_3$ to $^1/_2$ of the minimum strength of the cable, the sliding back of the cable must be slackened as far as possible by discs attached at right angles to the cable. I believe these are best made of sheet iron. A few large ones are far more effective than many small ones. The attachment can be effected in many ways. One must then proceed as quickly as possible, in order to keep the angle acute. – For the measurement of velocity I am now having an electrical apparatus made which turns a large indicator by the side of the brake. The brake wheel must indicate in the same way, so that at any moment the proportion of the velocity and of the exerted force may be known. The vessel must be well lighted, and the breaking of the wires must especially be kept in view. That the two wire fractures did not entail the loss of the cable was a piece of luck such as seldom occurs. – Altogether, I think you have all reason to be satisfied with the result. I do not consider it difficult to recover the cable end. I likewise consider the repairing of the fourth injured wire feasible, if it is of importance to you. This granted, you have bought the experience and a right theory of laying cheap enough. If you choose to avail yourself of my proposals, you will in future be able to undertake a laying in perfect peace of mind and soon recoup yourself for past losses. With your new brake you should, however, make the experiment of severing the cable with a maximum strain. Mr. Newall told me before the arrival of the *Elba* that he could fracture the cable with his brake, but although on the day of laying we had lengthened the lever of the brake by a half, and had suspended at least twice as many weights as the lever and iron band could reasonably be supposed to stand, yet we had not reached such a force by a long way, apart from the great forces which were exerted during fluctuations and in the first mishap.

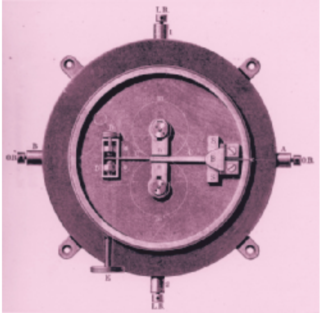
With my own experiments I have unfortunately not succeeded much better than in England. I see, however, that one can certainly signal better in a metallic than in a semi-metallic circuit, and that it is impossible with long lines to signal through more than a single wire. The future belongs therefore to the metallic circuit, and the patent will be remunerative. I see further that our present construction of the induction telegraph acts remarkably well and accurately, and that several submarine translation stations may at pleasure be set up with absolute certainty, that thus, e.g., there may be direct communication between England and India. Your apparatus for Malta – Corfu are dispatched today. I am quite sure that they will do their work well. According to my present experience the inductors might have been smaller and therefore cheaper, but it is better to err on the safe side. Such fine and solid apparatus have never before been turned out in our workshops. The contacts have given the greatest trouble. Platinum burns too quickly with strong primary currents; we were therefore obliged to use everywhere an alloy of gold and platinum, which with thick pieces has its difficulties. Perhaps you will get along with half the inductors on the Malta line (one coil). You will thereby effect a considerable saving, as the great quantity of silk-covered wire is expensive.

I beg you to let me know in good time when and where you wish to have the mechanic, and whether you think one enough. I think you should have plenty of intelligent assistants at your disposal, for any error may be very dangerous even with the best preparation.

I send this letter direct to Birkenhead, where I imagine you still to be, and where William intended to visit you; may I ask you to let William have a look at it?

Would it not be better to defer your Malta line to the winter, when you can more certainly reckon on calm weather? – October is said to be a very dangerous month there, and the atmosphere does not become quieter before December.

With sincere regards, W. Siemens



Polarized relay, *1859.*

The experience I acquired in the laying of the cable between Cagliari and Bona really convinced me, as expressed in the foregoing letter, that submarine cables of the right construction and carefully made could be laid in any depth of water, and then also promised long and certain service. I therefore took especial pains to overcome the existing difficulties. For that purpose it was necessary to establish a systematic supervision of the manufacture of the cable, in order to obtain the certainty that no defect existed in the whole cable stored in the ship's hold. This could only be effected by making the testing instruments sufficiently sensitive for measuring the insulating quality of the gutta-percha itself employed and indicating the same in figures.

When the insulation resistance of the conducting wires coated with this gutta-percha had then in a similar manner been determined in figures, they were faultlessly insulated, provided the measured result agreed with the calculated. If the resistance of the conductor of the complete cable was not greater, and the resistance of the insulator of the same not less than that ascertained by calculation, the cable might be regarded as faultless.

It was not to be expected that such exact testings could be carried out by measuring currents. For determining the position of faults, for which I had as early as 1850 found and published the necessary formulae, the inexact current measurements were also insufficient. It was necessary therefore to have recourse to measurements of resistance, but for that there were still wanting good practical methods of measurement, and especially a fixed standard of resistance. Finally, the knowledge of the physical properties of the jar wires, as I had termed the underground conductors on account of their property of acting as large Leyden jars, was still too undeveloped for planning long submarine lines without risk of failure.

Werner to Carl, July 26, 1857

. . . We shall simply have to establish a small works and a branch in London. Only in this way have we any prospect of getting the submarine lines completely in our hands and finding a market for our apparatus. Newall & Co. and William wish to come in as partners. The firm Siemens, Halske & Co. Without William's direction it would not work and Newall's participation ensures us of his goodwill and thus of the submarine lines almost exclusively made by him. I have promised to take part in the laying between Bona and Sardinia next month and to set up the apparatus . . .

I had been intently occupied with the study of these questions since 1850. My labors belonged to the time when the great investigator Faraday astonished the scientific world with his fundamental discoveries. In Germany, however, many of Faraday's views, particularly those of electrical distribution by molecular induction, obtained but little credence, being incompatible with prevailing theories. This induced me to study, without regard to existing theories, the question of electrostatic induction, which according to my earlier experience was of extreme importance for telegraphy. I finally obtained a complete confirmation of the views of Faraday, for the correctness of which I was fortunate enough to find new proofs. Unhappily being oftentimes interrupted in my labors by my strenuous technical activity, I could not conclude my experiments before the spring of 1857, when I summarized their results in a paper published in Poggendorff's *Annalen,* "Über die elektrostatische Induktion und die Verzögerung des Stromes in Flaschendrähten" (On Electrostatic Induction and Retardation of the Current in Cores).

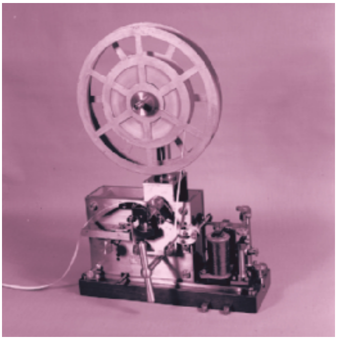
It became clear to me from these experiments that only by employing short intermittent currents was there any prospect of corresponding quickly on longer cable lines. In a paper published in 1857,* "Der Induktions-Schreibtelegraph von Siemens & Halske" (Siemens and Halske's Induction Writer) I described the mechanical expedients for accomplishing this task. They consisted essentially of a magnetically polarized relay, which was so constructed that its armature, when moved by a short impulse of current to the contact, remained attached to this, until a short current in the opposite direction carried it back to the insulated

** The paper was published in 1856.*

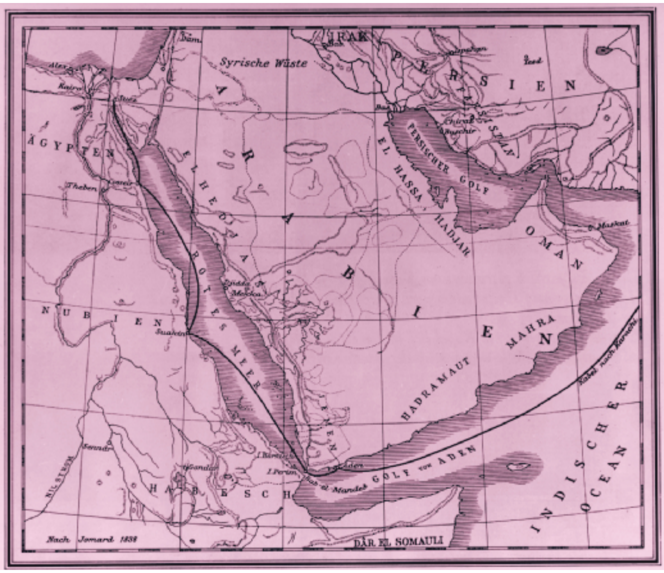
stop. The short intermittent currents were generated in the secondary coil of an inductor by the telegraphic currents being sent through the primary coils of the same. When in the same year – 1857 – Messrs. Newall & Co. laid a cable line from Cagliari to Malta and Corfu, I furnished the stations of this line with such induction writing-telegraphs. A translation station was erected on the island of Malta, which made it possible to correspond by the thin cable direct between Cagliari and Corfu with satisfactory speed. In order to secure the good insulation of this as well as of other lines, which were to be laid in the eastern part of the Mediterranean, my firm undertook the electrical testing of the insulated conductors in the cable works of Messrs. Newall & Co. at Birkenhead. A talented young man, Mr. F. Jenkin, who afterward made a name as an electrician, was assigned me as assistant.

The cable line through the Red Sea and Indian Ocean from Suez to Kurrachee in India (today Karachi, Pakistan), the execution of which had been entrusted to the firm of Newall & Co., brought me a very interesting task. My firm undertook for the latter the electrical supervision of the laying of this cable, as well as the furnishing and setting up of the necessary instruments. The most important of the cable lines laid up to that time, that from Sardinia to Corfu, about 700 nautical miles long, hardly afforded a standard for the construction and working of a line of 3,500 nautical miles in length, such as the proposed cable line to India. According to previous experience, it was possible by intermittent currents to work lines 700 nautical miles in length with safety and sufficient power.

Polarized Morse inker for long undersea lines, *1859.*



There were, accordingly, four or five intermediate stations to be set up between Suez and Kurrachee, which had to be provided with automatic translation, so as to be able to work without troublesome and embarrassing man-



A map of Arabia and the Red Sea, showing the cable line.

ual transference of signals. The fitting up of these translation stations was, however, attended with peculiar difficulties in the case of long submarine lines, as the charge left in the cable produced disturbances when, as on the Corfu line, it was undesirable to telegraph with secondary currents. There were practical reasons moreover, against the latter mode of operating, which consisted especially in the greater complexity of the whole arrangement. I accordingly constructed a new system of signaling apparatus, which was afterward designated the "Red Sea system." In this, not intermittent currents produced by induction, but battery currents of varying direction were employed. The effect of this was that at the end of every word an interruption of the second demagnetizing battery and a discharge of the cable must occur, before the latter was again con-

. . . We learn from a private letter which arrived with the last Levant post that this spring the laying of the submarine telegraph cables in the Red Sea on the route from Suez to Aden, a distance of 1,500 English miles, is to be undertaken with the greatest energy . . .

National Zeitung, *March 30, 1859*

The two cable laying ships Imperatriz *and* Imperador*, festively decorated, after their arrival in the Gulf of Aden on May 28, 1859. The cable, brought on land, ran for about another half mile underground to the station in Aden.*

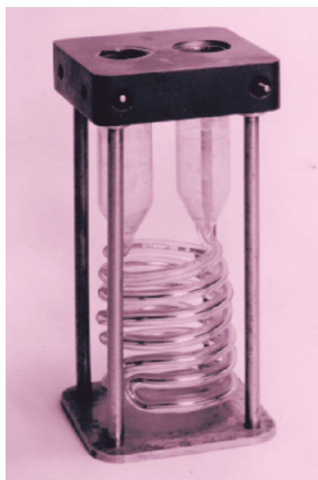
nected with the relay. For this purpose special simple contrivances were made use of, which were described at length in the account of the system which I published in 1859 in the German-Austrian *Telegraphic Journal,* with the title "Apparate für den Betrieb langer Unterseelinien" (Apparatus for Working Long Submarine Cables). In the first part of the line between Suez and Aden, which was laid in the spring of 1859, such translation stations were established at Cosseir and Suakim. They acted in a very reliable and satisfactory manner, so that it was possible to correspond with the Morse key provided with discharging contact as quickly as on land lines, while by excluding translation stations it was only possible to make oneself understood very slowly on the line of 1,400 nautical miles in length.

During my stay in Aden, however, I succeeded by a peculiar expedient in communicating quickly and certainly by the direct line also, and in rendering the intermediate translation stations superfluous. Through the study of the electric properties of underground conductors it had become clear to me that all the secondary currents, which confuse the telegraph signals, could best be avoided if definite amounts of positive and negative electricity in proportion to the capacity of the cable were suddenly sent to the delivering end of the cable, and likewise at the receiving station only definite quantities of electricity were allowed to leave the cable. At first I thought to be able to attain this by the intercalation of a POLARIZING BATTERY, possessing such a large number of elements and so small a surface of electrodes that the quantity of electricity necessary for reversing the battery just sufficed for moving the relay bar. I had brought with me such a polarizing battery of 150 platinum elements, but found that the resistance of the battery did almost as much harm as the polarizing action did good. The fortunate circumstance, however, came to my assistance that the remnant of the cable of 150 nautical miles or so had been submerged from Aden, to be subsequently utilized for the further extension of the line. This was an electric CONDENSER, which could accomplish, without the injurious resistance of the polarizing battery, what I had expected of the latter. I therefore had the more remote end of the cable insulated, when the laying was completed, and used the cable as an earth connection. The result was brilliant beyond expectation. The Morse writing could now not only be received direct from Suez without any difficulty, but to my surprise could also be sent there without lessening the speed of the signaling.

This was the first employment of the condenser in submarine telegraphy, without which it would not have been possible to communicate on the long Atlantic lines with the speed and certainty now permitted by Thomson's mirror galvanometers. Instead of insulated lengths of cable, paper or mica condensers are now made use of, which we did not possess at that time.

As regards the laying itself, I had introduced a systematic method for the control of the electric properties of the cable, which excluded all uncertainties and misunderstandings. A clock was set up at the starting point which automatically insulated the end of the cable at definite intervals of time, then connected it with the earth, and finally with the telegraphic apparatus. The ship could therefore carry out all the mea-

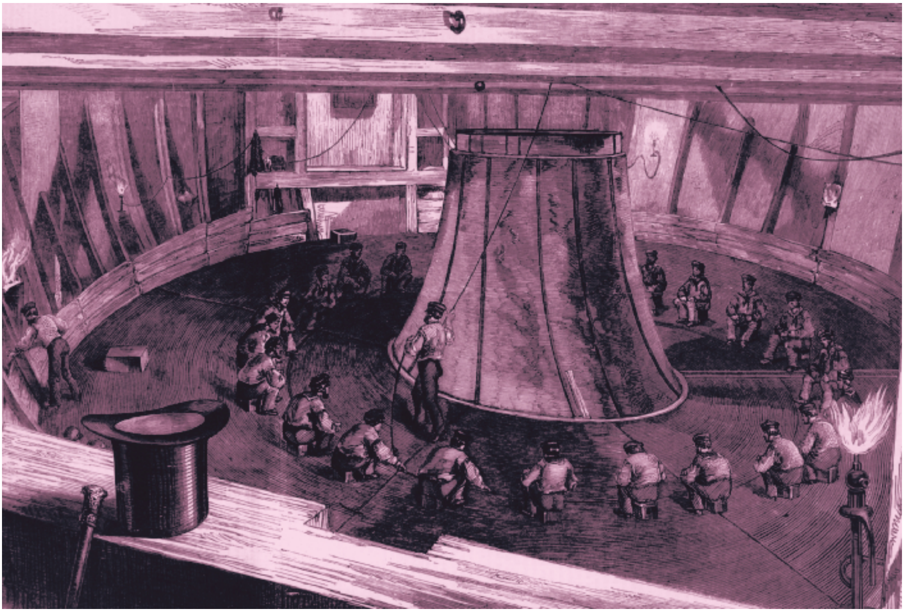
A 1-OHM STANDARD RESISTOR USING MERCURY *(1,063 mm at 0°C).*



Loading cable onto the Agamemnon *in Plymouth Harbor, England, 1858 (illustration from Gerald Garratt,* One Hundred Years of Submarine Cables, *London, 1950).*

surements without the cooperation of the land station, and the same held good of the land station, which continuously telegraphed its measuring results to the vessel, so that the latter possessed the requisite data for calculating according to my formulae the situation of any suddenly occurring fault. This supervising method turned out to be extremely necessary, for the notoriously high temperature of the Red Sea softened the gutta-percha and thereby produced numerous faults. In spite of all the care that had been taken for their removal, it appeared on arriving in Aden that a defect – fortunately considerable, and therefore easily discoverable – existed in the cable, which rendered communication with the preceding station, Suakim, impossible. The determination of the fault from Aden yielded the result that the defect was somewhere in the vicinity, i.e., in the Straits of Bab-el-Mandeb. Although Mr. Newall and his engineers had not much confidence in my determination of the position of the fault, yet the cable was fished up and cut close behind the place I had indicated, whereupon to the general surprise and joy it appeared that the part of the cable connected with Suakim was sound. The fault was situated almost exactly at the calculated place, and was removed after inserting a short piece of new cable.

Through this successful incident the "scientific humbug" had come all at once to honor. Success was rendered possible by my having entirely substituted resistance measurements for current measurements. A fixed standard of the resistance to electrical conductions did not then exist. Jacobi had indeed tried to introduce a purely empirical standard as a general measure of resistance by sending to scientists and mechanicians pieces of copper wire of equal resistance, recommending them to take this resistance generally as unit. But it soon appeared that the resistances varied, and repeated copying magnified the variations by a large percentage. My firm had up to that time taken the resistance of a German mile of copper wire of 1 millimeter diameter as unit, and produced graduated scales of resistance on the basis of this unit. It appeared, however, that the copper itself with the utmost possible purity had essentially different specific resistance, and changed its resistance in the course of time. To adopt the ABSOLUTE UNIT OF WEBER as a fundamental standard was rendered impossible by the then state of electrical measurement, which at the time made agreement on the various productions of this unit unattainable. Under these circumstances I resolved to make pure mercury the basis of a reproducible standard of resistance, and proposed to take the resistance of a mercurial prism of 1 square millimeter in cross section and 1 meter in length at the freezing point of water as the unit of resistance. I shall return to this standard of resistance in the description of my papers on this subject, and shall only remark here that the scales of resistance with the mercury unit, regulated according to the weight system, prepared by my firm, proved extremely use-



Loading a cable onto the Agamemnon. *Undated drawing.*

ful in laying the cable from Suez to Aden, and for the first time made reliable determinations of faults possible.

The cable laying in the Red Sea was also rich in interesting personal experiences for myself. The very day after embarking at Trieste at the beginning of April, I was fortunate enough to witness a splendid zodiacal light in the evening sky. Scientists contended then, and still contend, concerning the cause of this phenomenon. I believe those to be correct who see in the zodiacal light a proof that the air, charged with aqueous vapor and rising in the equatorial zone with increased velocity, forms a high ring above this zone, which is further enhanced by the effect of centrifugal force. The appearance answered to the descriptions one sees in manuals of physics, and lasted about an hour before it became quite extinct.

After an agreeable, calm passage we arrived in splendid weather at Corfu, where we stopped several hours, and had

The Pyramid of Cheops and the Sphinx at Giza. Undated.

time to make acquaintance with the interesting town and its splendid surroundings. At that time the Ionian islands belonged to England. When after a number of years I again visited Corfu, it had meanwhile passed into the hands of the Greeks, and the town appeared to me considerably decayed and poverty-stricken compared with its former appearance. In the finest weather we sailed through the Adriatic and Mediterranean, so rich in historical associations, disembarked at Alexandria and traveled by the recently opened railway to Cairo, where we stopped a few days to give the ship *Agamemnon,* laden with the cable, and which had made the journey around the Cape of Good Hope, the necessary time to arrive in Suez.

I used this opportunity for an inspection of the town, which interested me and my engineers in the highest degree by its rich historical monuments and as the point of junction of

Emil Du Bois-Reymond's letter of recommendation for Werner von Siemens to the physician and zoologist Theodor Bilharz in Cairo
Berlin, March 16, 1859

Dear colleague,
You will certainly be pleased to become acquainted with the bearer of this, our famous mechanician and telegraph constructor, Mr. Werner Siemens, who is ready to go with his staff to the Red Sea in order to lay the cable to Aden.
I recommend him to you not only as a German countryman and scientist, that would scarcely be necessary, but particularly as a friend of mine, who took an active part in the development of my work by the establishment of his great workshops for electromagnetic apparatus; and on the other hand, I ask you as a physician who is experienced in tropical climates to look after him on my behalf, on our behalf, and for Germany's sake. He is used to carrying his projects through without any consideration of his health, and I am afraid he might contract some malignant intermittent fever, heatstroke or dysentery. Deliver him a serious and impressive lecture on this pleasant trilogy and provide him with some reasonable instructions and, if possible, some remedies, though I am afraid he might be inclined to use them to excess . . .

the civilizations of Europe and Asia. When on April 14, we visited the pyramid of Cheops, we had the good fortune to observe on its apex an interesting physical phenomenon, of which I subsequently gave an account in Poggendorff's *Annalen* under the title "Beschreibung ungewöhnlich starker elektrischer Erscheinungen auf der Cheops-Pyramide bei Kairo während des Wehens des Chamsin" (Description of Unusually Strong Electrical Phenomena on the Cheops Pyramid near Cairo during the Blowing of the Chamsin).

During our donkey ride from Cairo to the pyramid there arose an unusually cold desert wind, which was accompanied by a peculiar ruddy color of the horizon. During our ascent or rather our transport by the Arabs, who always encamp by the Giza pyramids, and do not allow the office to be taken from them of carrying or rather throwing the visitors up the steps, each a yard high, the wind assumed a tempestlike force, so that it was to a certain extent difficult to keep oneself upright on the flattened apex of the pyramid. The raised desert dust had now become so thick that it appeared like a white mist, and altogether obscured the view of the ground. It gradually rose higher and higher, and after some time enveloped even the summit on which I was standing with my ten engineers. Then a remarkable hissing noise was heard, which could not have been caused by the wind itself. One of the Arabs called

A depiction of the argument on the Great Pyramid, in 1859.

my attention to the fact that by raising his outstretched finger above his head a sharp singing sound arose, which ceased as soon as he lowered his hand. I found this confirmed when I myself raised a finger above my head; at the same time I noticed a prickling sensation in my finger. That this had to do with an electrical phenomenon appeared from the circumstance that a slight electrical shock was felt when one tried to drink out of a wine bottle. By wrapping a piece of damp paper around it, I transformed such a filled bottle, having a metallically coated neck, into a Leyden jar, which was strongly charged when one held it high above one's head. It was then possible to obtain loud cracking sparks of about 1 centimeter range. This established in an unequivocal manner the electrical properties of the desert wind which had already been observed before by travelers.

In the further course of our experiments I had occasion to prove that electricity can also be serviceable as an effective defensive weapon. The Arabs had at once observed with manifest distrust the flashes darting from our wine bottles. They then held a brief council, and at a signal every one of my companions was laid hold of, to be forcibly transported down again, by the three men who had brought each of them there. I was standing just on the highest point of the pyramid, a large stone cube in the center of the flattened summit, when the sheik of the tribe approached, and communicated to me through our interpreter that the tribe had resolved we should immediately leave the pyramid. On being asked the reason, he replied that we obviously practiced magic, and that might injure the source of their livelihood, the pyramid.

When I refused to comply with his request, he made a dash at my left hand, while I held the right with the well-coated bottle – in a conjuring attitude – high above my head. I had waited for this moment and now lowered the neck of the bottle slowly toward his nose. When I touched it I myself felt a strong concussion, to judge from which the sheik must have received a violent shock. He fell speechless to the ground, and several seconds elapsed, making me somewhat anxious, before with a sudden cry he raised himself, and sprang howling down the steps of the pyramid with gigantic leaps. When the Arabs perceived this, and heard the sheik's continuous cry of "magic," they one and all abandoned their prey and plunged after him. In a few minutes the battle was over, and we were absolute masters of the pyramid. Even Napoleon had not such an easy "victory at the foot of the pyramids" as I had at their summit!

As the blowing of the Chamsin soon ceased, and the sun again brightly illuminated the imperiled pyramid, the Arabs recovered from their terror, and clambered up again so as not to lose the expected *baksheesh*. Even at our peaceful leave-taking, however, they evidently still regarded us with suspicion on account of our magical powers.

Nor were there wanting some small adventures by sea during this cable laying. The weather was thoroughly calm and fine, as is always the case in the Red Sea, where a rainfall is a great rarity; only the enervating heat was inconvenient. My traveling thermometer indicated by day nearly always 100 degrees and by night 102 degrees Fahrenheit, a temperature which with our northern strength is indeed borne tolerably long without difficulty, but which in the long run becomes extremely troublesome. By day, one lives in a perpetual conflict with the sun, from whose rays head and back must be carefully protected. By night, the hoped for cooling is entirely wanting. The splendor of the starry southern heavens with the truly Egyptian darkness of the nights is indeed imposing, but it does not make up for the desired refreshing breeze.

One night, as I was in my test room supervising the insulation of the cable between Cosseir and Suakim, I suddenly heard loud shouting and violent commotion on board. The man at the ship's prow, entrusted with the continuous soundings, had fallen overboard. As the whole deck was well lighted with gas, many of the people busy there could see the man calling lustily for help in the water and throw him life preservers, kept ready everywhere on board. The vessel was stopped and boats put out, which disappeared for an uncomfortably long time in the darkness of the night. At last they returned triumphant. The man had kept himself afloat by swimming, and had been lucky enough not to be seized by any of the numerous sharks which disport themselves in the Red Sea, and which are said to have an especial appetite for white people, while they rarely molest the black. He was trembling violently when brought on board, and had his knife still open in his hand. Questioned as to what had befallen him, he related that he had been surrounded by a number of sharks, but luckily had been able to draw his knife, and defend himself till the boats arrived. We all felt a cold shiver at the vivid description of his perils and combats. Just then the boatswain stepped into the ring which had been formed around the man, and announced to the captain that some of the life preservers, which had been thrown to the unfortunate man had been recovered, and that curiously several of them showed signs of having been pierced with a knife. The man in his ter-

London, June 1. The Red Sea telegraph cable has probably already been laid between Suez and Perim . . . Laying was commenced at Suez . . . From there it was laid to Suakim – 460 miles further. The next section is from Suakim to Perim (540 miles) and from this point we may soon expect telegrams from India and China . . .

National Zeitung, *June 4, 1859*

ror had mistaken the white rings for sharks' bellies – the shark, as is well known, turning on his back when preparing to snap.

The shark plays an important part in the sailor's life in the torrid zone, as he spoils the mariner's refreshing bath. The sailor therefore passionately hates him and tortures the animal with glee, if he succeeds in getting hold of one. I was witness when two powerful sharks, at least twelve feet long, were caught on a small flesh-baited anchor and brought on board. It was rather dangerous to approach them. They had immense strength and so tough a life that even after having been disemboweled they still lashed about with their tails.

When we lay at anchor in the harbor of Suakim, it was strictly forbidden to bathe, as very many sharks were disporting themselves in the neighborhood. One evening after sunset, which is there quickly succeeded by perfect darkness, we were sitting at dinner on deck, as usual, when suddenly "shark" was called by several voices, and at the same time the cry of a man for help was heard. The boats were lowered, and in the light streaming from the ship something could be clearly discerned moving in the water, which was taken for a shark. Several ran for their revolvers, which lay always ready, as it was a common sport to shoot at empty soda-water bottles thrown into the water during the progress of the vessel. Luckily, before the commencement of the cannonade it became apparent that the supposed shark was a sailor who, contrary to the prohibition, was taking a bath, and had been alarmed by his comrades' cry of "shark!"

Arriving at Suakim, we soon received a visit from the highest officials, the Turkish pasha and the governor of the place. They were both extremely dignified figures, who moved with oriental gravity, and carefully avoided all appearance of being astonished at anything. A carpet was spread for them, and chibouk and coffee served. They smoked and drank with dignity, without regarding us who were standing around them. My friend William Meyer, who accompanied the expedition, said "Look, Werner, what a splendid fellow that is with the fine white beard; he might be exhibited in Berlin for money!" To our astonishment the individual in question turned slowly toward us and said, in the purest Berlin dialect: "Oh, you speak German?" On our replying that we were Germans, but were surprised that he could speak German, he answered: "But I am from Berlin. Call upon me!" Then he turned away in a dignified manner, and took no further notice of us. Meyer called upon him next day, and made the acquaintance of a man who was thoroughly sociable when not in Turkish company. He had left Berlin as journeyman tailor and set out from Berlin on his travels 50 years ago, was making for India when he was wrecked in the Red Sea off Suakim, stayed there, became a Mohammedan and finally chief of the town. At the same time he had become a rich man. He showed my friend all his possessions, and was unwilling only, in spite of all requests, to show him his harem, at last earnestly forbidding him to speak about his wives.

When we had finished our business in Aden, I wished to return to Europe with Meyer as quickly as possible by the next steamer of the Peninsular and Oriental Company, the *Alma*. Messrs. Newall and Gordon contemplated doing the same. When the steamer arrived, however, it was quite full, and they refused to take us. Only through an order of the Governor of Aden, procured by Mr. Newall, were we able to carry out our purpose, and then only as deck passengers, no cabins being vacant. We had no objection to this, as during our several months' stay in the Red Sea we had always slept in our clothes on deck, since the heat below was insufferable.

On board we found arrangements of a really luxurious character, and an elegant social life almost to be styled epicurean, which contrasted strongly with our recent existence. Ladies and gentlemen changed their elegant toilets several times a day, and two bands took it in turns to lessen the tedium of the voyage with music. In our ragged garments we appeared very much out of place in this fine circle, and indeed the glances of the ladies that fell upon us betrayed astonishment at such an unseemly addition to the ship's company. Nevertheless, we were presented by the first lieutenant to the highest in rank of the company, the English Ambassador to China, who had just happily succeeded in bringing on the Anglo-French war with China. He graciously gave us an audience, and exchanged a few words with each of us in our mother tongue, being rather proud of his own extensive linguistic acquirements and delighting to display them. At the approach of night each sought his camping place on deck, but our rest was long disturbed by the ladies, who could not make up their minds to return to the stifling cabins.

We had slept only a few hours when we were rudely awakened from our dreams. A violent shock caused the ship to tremble, two others followed still more violent, and when we had sprung up in alarm we felt the ship heeling over. I had luckily not taken off my boots, only laid aside hat and spectacles. When I looked around for these, I perceived my hat already on the way to the sinking ship's side, and involuntarily followed it in the same direction. Wild, terrified, ear-piercing shrieks resounded

This fine vessel, belonging to the Peninsular and Oriental Steamship Company, while on her passage up to Suez, went on shore at about 3:00 a.m. on June 12, on a reef that extends nearly half a mile from a small rock called Moosedgerah, and about two miles and a half from Little Harnish. The Alma *was a ship of 2,200 tons burden, her length 320 feet, and her horse-power 450. Moosedgerah is situated in latitude 14.48 north, longitude 41.54 east. The particulars of the wreck of the* Alma *have been too recently given to need recapitulation here. Our engraving is from a sketch by Mr. T. E. Branthwayt, taken on June 15, on board the Nemesis which, it will be remembered, rendered great assistance to the passengers and crew of the* Alma.

From the newspaper Once a Week, *London, September 3, 1859*

The Alma *is shipwrecked on a coral reef south of the Harnish Islands (illustration from* Once a Week*, London, September 3, 1859).*

on all sides, then a general clatter, as everything on deck was taking its course to the deep. Everybody instinctively made for the higher part of the ship; most were able to reach it. I came off worse, having lost time in my search for hat and spectacles. Already the water streamed over the ship's side, and warned me to think of my own safety. The deck had in a few seconds assumed so oblique a position that it was no longer possible to clamber up it. But necessity gives giant strength. Piling up chairs and tables, I managed to reach a rope, visible in the bright moonlight, which hung down from the elevated part of the ship, and to climb up with its assistance.

Above, I found almost the whole ship's company already assembled, and awaiting with admirable composure the development of the drama. Then women's faint cries for help broke the stillness of the night, and someone called out that there were still many ladies in the already half-flooded cabins. Everybody was ready to assist in rescuing them, but this was very difficult to accomplish, as the smooth deck, lying already at an angle of more than 30 degrees, no longer offered a foothold. My rope now did good service. A seaman, familiar with the ship's structure, let himself down to the entrance to the cabins, and fastened a lady to it, whom we then pulled up. That proceeded too slowly, however, for a large number still waited to be rescued. Accordingly, with the help of further ropes a living chain was soon formed, by which the poor trembling ladies, for the most part surprised in their beds by the water streaming through the open cabin windows, were lifted up from hand to hand. If an impediment occurred anywhere, the word "stop!" was given, and then everybody had to sustain his burden until the furthering process could be continued. During one of these pauses in the moonlight, I beheld in the dripping lady anxiously clinging to me the proud young Creole whom we had admired at a modest distance a few hours before, surrounded by a crowd of adorers which her beauty had attracted.

The rapid sinking of the ship, after striking upon a concealed coral rock, was explained by the circumstance already mentioned – that the cabin windows had all been open, and the water therefore found unimpeded access into the hold. The vessel soon lay entirely on her side, and the great question, on which now the life or death of every living being on it depended, was whether it would assume a position of rest, or capsize and hurl us one and all into the deep.

I erected for myself a little observatory, with the help of which I could note the further inclination of the ship by the position of a particularly brilliant star, and proclaimed from minute to minute the result of my observations. These communications were awaited with great anxiety. The cry "standstill!" was greeted with short joyful murmurs, that of "sunk further!" answered by various doleful exclamations. At last no further sinking was observable, and the paralyzing fear of death gave place to energetic efforts for effecting our safety.

By the light of the moon and the glittering starry sky we could distinctly perceive that we had run upon a large rock, rising at one point tolerably high above the water, and now only a few hundred yards from us. The lifeboats fastened on the leeward side could be lowered without much difficulty, and then in conformity with traditional English seafaring practice the women and children were first taken ashore. That was in truth extremely unpractical, as on the land the poor creatures were in a desperately helpless condition, but the principle had to be rigorously observed.

When at daybreak the turn of William Meyer and myself came, we found the ladies almost without exception in an extremely lamentable plight, as they were very sparingly clad, and for the most part shoeless. The rock, perhaps never before trodden by human foot, was everywhere covered by jagged coral, which drew blood from the unprotected feet. Here help was most needed. I belonged to the lucky ones who possessed boots, and had also saved my pocket knife. I accordingly returned with the next boat to the wreck, and fished out a thick mat of linoleum and another of finer material, with which I then opened a sandal workshop on shore. My friend, who had not been so fortunate as to have saved his boots, was the first to receive a pair of sandals, and then in gratitude undertook to fit the ladies crouching motionless on the ground with similar articles. He still remembered with delight years later the grateful glances from beautiful eyes which this Samaritan service procured him.

But what next? On Whitsunday morning, about 500 persons were sitting on a bare coral rock a couple of acres or so in extent, and about eight leagues out of the usual ships' course. We had, in the fine calm night, in which probably helmsman and lookout had fallen quietly to sleep, run on the notorious coral bank lying to the south of the Harnish Islands, which is given a wide berth by all shipping. We could the less depend on a chance rescue, as the total absence of drinking water rendered long waiting for help impossible. The vessel indeed had not sunk entirely, and we could save provisions of all kinds in sufficient quantity, but the water tank had become filled with seawater, and the distilling apparatus, which was used for producing the necessary freshwater, could not be lifted out of its place. The water still found in the cabins formed therefore our sole supply, on whose sparing use depended the length of time we should be able to continue the struggle for existence.

But yet another serious danger threatened us. The crews of the fine large steamers of the Peninsular and Oriental Company, which then worked the service between Suez and India, consisted almost wholly of natives, as Europeans are not able to stand the climate in the Red Sea for any length of time. Among the 150 persons or thereabouts who formed the *Alma's* crew, there were thus, with the exception of the ship's officers, only three or four Europeans. The captain was ill, and is said to have died from the effects of the excitement soon after the shipwreck. The officers had by their bad management of the vessel lost the men's respect, and could no longer maintain discipline among them. The latter began therefore to mutiny, refused obedience, broke open the travelers' trunks, and behaved rudely to the ladies. In these straits a sort of government came spontaneously into existence. The most active of the younger men, including a number of English officers on their way home from India, took possession of the old muskets with bayonets, which were rather for ornament than for real use in the vessel, and proclaimed martial law. A recalcitrant drunken sailor was knocked down, and on the summit of the rocky eminence a gallows was erected as a sign of our authority. Thither, too, all the recovered provisions were taken, and a guard tent was set up, before which a sentinel patrolled. This had a calming effect and reduced the crew to submission.

It was above all things necessary to obtain protection from the sun, which at this time of year shone vertically down on the island at midday. Accordingly, a certain number began busily to occupy themselves in erecting tents with the help of sails and yards. Further, a kitchen was contrived, and the provisions, especially the water and the stock of beer and wine, were stored safely. In these operations Mr. Gisborne, the leading engineer of the cable laying, was especially prominent, and exercised a sort of dictatorship on the island. Mr. Newall had at break of day immediately gone with one of the three boats which were at our disposal to Mokka, the nearest place on the Arabian coast, to seek assistance. He did not find any there, however – perhaps because the recent bombardment of Djedda by the English had caused a very unfavorable feeling toward Europeans – and therefore proceeded further toward the Straits of Bab-el-Mandeb in the hope of falling in with a vessel. This voyage in a frail open boat was a bold enterprise, but our only hope depended on it. And in reality it succeeded, thanks to a splendid telescope which I had had made for my journey by Steinheil in Munich.

For when the English man-of-war which had left Aden a few days after us to visit the intermediate stations and take off our engineers had passed the Straits of Bab-el-Mandeb in the early morning, our engineer Dr. Esselbach was standing on deck, searching with my telescope the vast unbroken expanse. He descried a white point, which he took to be the sail of a European boat, as the natives use only brown sails.

He called it to the attention of the ship's officers, and lastly of the captain himself, who with my telescope convinced himself of the correctness of the observation, and at once directed his course to the white point. To the great surprise of everybody, this soon developed into the boat of the passenger steamer well known to the seamen, and already in the far distance Mr. Newall was recognized by his striking long white beard.

Meanwhile the life on the coral rock had rolled on as might have been expected. From 9:00 in the morning till 4:00 in the afternoon we were obliged to lie quietly under the roofs of our tents, to enable us the better to resist the glare of the sun and not to excite too great a craving for drink. Then the cooking began, and we dined as well as we could, each of us getting on the first days a small bottle of pale ale, as the water was reserved for the women and children. Wine, which was also to be had, no one could stand; it heated the blood to such a degree that those who tried to drink it got ill. The first two days all went passably well, but then great lassitude and despondency began to set in. Faithful old servants refused to perform small services, even though gold pieces were offered them. Even the sheep and dogs, which had been brought to land, lost all vitality. They pushed with irresistible force under the tent covers, and chose rather to be killed than subjected to the pitiless rays of the sun. The pigs alone excelled the human beings in endurance; they explored the island without ceasing, until they dropped dead in their struggle for existence.

On the third day, a small number of us who still possessed sufficient force and self-control to perform work when the sun was low succeeded in breaking through the outer wall of the ship and obtaining access to the ice room. Certainly there was no longer any ice to be found there, but a moderate quantity still of cold water. This was likewise reserved for the numerous women and children, but everyone who had assisted in the work received as reward a glass of cold fresh water. Many years after, I have often gratefully remembered that refreshing draft when tormented and parched with thirst. When the fourth day passed without prospect of release, dull despair took possession of even the stoutest-hearted. A steamship, whose smoke we descried in the far distance, had gone its way without discovering us. On the following morning the cry was again raised, “steamer in sight!” but the cry this time only awakened feeble hope. Still the smoke came nearer, and the already slumbering vital spirits awoke anew. The ship now approached, now moved off again; hopes began to rise that it was seeking us. Then at last it seemed to perceive our signals, and steered its course straight for the island. No more doubting! Rescue was at hand, and its certainty made the almost dead alive again. We recognized our companion ship in the cable laying and Newall, our savior, on board.

The scenes that were now enacted are never to be forgotten. On the ship all was astir for effecting the landing. Nobody appeared to notice the many-hundred-voiced jubilation that greeted the ship’s crew. The anchor rattled down, and the boats shot into the water. They brought casks full of water, and flat wooden vessels, which were then placed on land and filled by stout sailors’ hands. Mr. Newall had informed them that we were in want of water, and their first thought was to quench our thirst. Everyone made a rush for the large wooden vessels and tried with hollow hand to scoop up the water. But that was a slow affair, and others kept pressing forward. Accordingly, the head was simply lowered and the delicious fluid swallowed in greedy drafts. The beasts too had scented the water and pressed forward with irresistible energy, although they had been lying under the tent covers for days as though dead. A huge ram pushed everybody aside, and plunged its own head into the vessel between that of a fair blonde and a negro, without the latter being at all disturbed. Pictures assuredly never to be forgotten by those who gazed upon them.

As the number of about five hundred passengers and crew was too large to be transported by the small man-of-war, the captain determined to leave the crew on the island under a guard of sailors from the warship, to be kept under strict discipline on account of their mutinous behavior, but to take all the passengers on board and convey them to Aden. So again we arrived in Aden, packed in fearfully close quarters on the deck of the little ship, to find that the telegraphic news of our arrival in Suez had been anxiously awaited. By order of the governor of Aden the next homeward-bound passenger steamer had to take up almost the entire number of the shipwrecked, in spite of its being already overcrowded. But we gladly bore the inconveniences of this passage, and of the further one from Alexandria to Marseilles, and thanked God that we had not met with a tragic end on the lone coral rocks of the Harnish Islands.

Neither in Cairo nor in Alexandria had we leisure to improve our very defective outward appearances. Almost everyone had lost their entire baggage in the shipwreck, and most of us were without funds. Not until Paris, whither we traveled without stopping, was an opportunity afforded for a fresh outfit. We were all obliged to travel by way of Marseilles, as Trieste harbor was blockaded by the French, and the journey through Italy was impossible on account of the war in Lombardy. I had received the news of the declaration of war by France and of the death of Alexander von Humboldt during the cable laying in the Red Sea. The subsequent great political events had also been communicated to us through the cable, so that we had remained well informed of the events of the world.

For the rest, Meyer and I narrowly escaped being left behind in Malta. The captain of the French passenger steamer emphatically declared that he could take no passengers to Marseilles without passports, and that if we had lost our own in the shipwreck we must provide ourselves with

The founders of the Atlantic Telegraph Company, which commissioned the laying of the first transatlantic cable in 1857–1858. After a painting by Daniel Huntington, New York, 1856.

passports in Malta. When the captain presented us to the respective consuls as shipwrecked persons handed over to him in Alexandria, all the rest received consular passports without any difficulty; the Prussian consul alone, a commercial man who had settled there and been entrusted with this office, declared that he possessed no authorization, as we could produce no regular evidence of identity. Only after some stormy scenes did he give in, and we were able to reach the ship just before its departure.

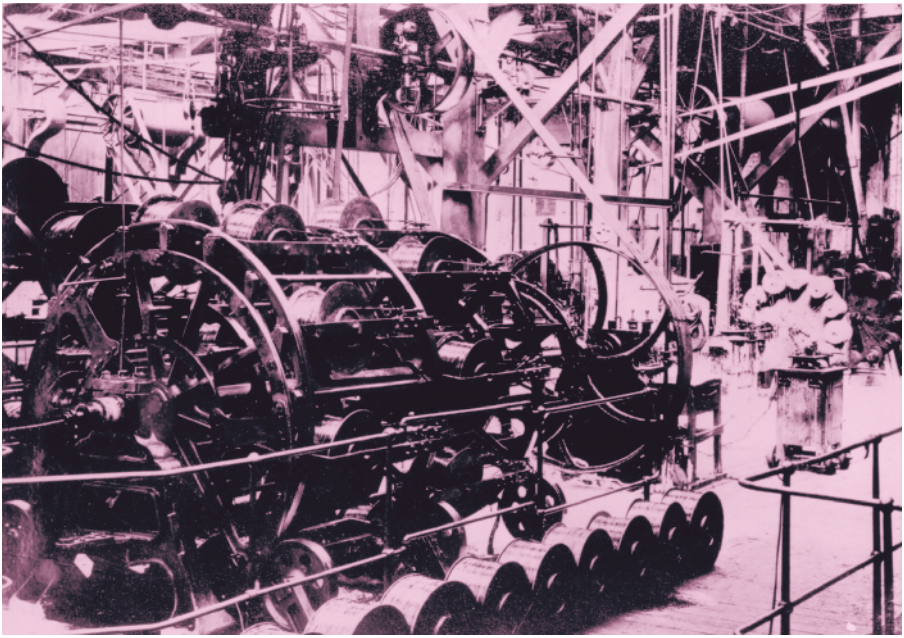
In the following year, the Indian line was extended from Aden to Kurrachee, William Meyer superintending the electrical arrangements. Unfortunately the line did not long remain in a serviceable condition. Defects of insulation, which impeded correspondence, already began to show themselves in the Red Sea cable in the course of the extension of the line to India. Our electricians indeed attempted repairs, whereby all the more serious faults were removed, but new ones constantly made their appearance, and in the following year rendered the whole line unserviceable, since the cable in the Red Sea was held fast at the bottom by coral formations and could not therefore be raised and repaired. This unfortunate failure was mainly due to the circumstance that the contractors had laid the cable not in deep water in the middle of the sea, but in shallow water in the proximity of the intermediate stations near the Nubian coast, where the formation of coral proceeds very rapidly at the seabed. People had not yet come to see that with submarine cables not cheapness but excellence is in the first place to be aimed at. It was apt to be forgotten that a single defect, if it cannot be repaired, spoils the whole cable, and that from any defect of insulation, however small, a greater one is sure to arise in course of time. Almost all the submarine cables laid in early days by the English – those in the Channel, in the Mediterranean and Red Sea, and also the first Atlantic cable, which was laid in the summer of 1858 by the engineer Whitehouse after an unsuccessful attempt in the preceding year – came to grief, because in the construction and fittings, as well as in the testings and laying, correct principles had not been followed. It was the perception of this fact that led the English government in the year 1859 to entrust the control of the preparation and the testing of cables which it contemplated laying to our London firm. In these testings for the first time a consistent rational system was adopted, which afforded assurance that the completed cable was faultless, if the conductivity of the copper conductor and the resistance of the insulating covering corresponded exactly to the specific resistances of the materials employed. The result was that the insulation of these new cables was more than ten times as great as had been the case in previous submarine cables.

In July 1860, my brother William and I communicated to the British Association, in a paper read by William entitled "Outline of the Principles and Practice Involved in Testing the Electrical Conditions of Submarine Cables," the substance of the report delivered to the English government on the performance of these testings and the methods and

The Siemens Brothers telegraph factory on the Thames at Woolwich, near London, around 1866.

formulae employed, and in this way we made our experiences public property.

Since then, no cables with defective insulation have been laid, and their durability has proved satisfactory wherever mischief has not been wrought by local causes or external violence. In cables laid in shallow water – both in the Mediterranean and also in the Black Sea – such a destructive agency presented itself in the shape of a small beetle belonging to a group particularly dangerous to wooden ships (Xylophaga). In the cables without iron sheathing laid by the firm of Newall & Co. in 1858 and 1859 in the eastern part of the Mediterranean, a large part of the hemp covering the conductor insulated by gutta-percha was eaten away before the end of the year. Moreover, the little animals had frequently attacked the gutta-percha itself, and there were numerous places where they had bored right through to the copper, and thereby entirely destroyed the insulation. Even an iron sheathing does not completely prevent destruction by woodworm of a cable laid in shallow water, as the places



A view of the interior of the Siemens Brothers cable factory in Woolwich, around 1867.

at which an outer wire has been fractured afford it access, and as the young brood can make their way through the interstices of the protecting wires and then grow to a dangerous size within the protective covering. To obviate this danger, brother William had constructed a special cable for shallow water, in which strands of the best hemp twisted around the conductors and insulated by gutta-percha or caoutchouc gave the cable the necessary support, while a layer of strips of copper sheathing placed over one another in the manner of scales was destined to protect the core of the cable from woodworm. Our London firm, which meanwhile had set up a good-sized mechanical workshop and a cable factory of its own at Charlton near Woolwich, received an order for such a cable from the French government for a line between Cartagena and Oran. The then director-general of the French telegraphs, M. de Vougie, had already expended much money in attempts to lay a cable from the French to the Algerian coast, without having obtained a satisfactory telegraphic communication. He now wished to effect this in the cheapest way by a very light cable via Spain, and entrusted us with the preparation and laying of a copper-sheathed cable between Cartagena and Oran. The French government had arranged for the chartering of the steamer as well as for its manning and officering by members of the Imperial Navy. The director-general, who was well known to me, as we had both served on the jury of the Paris Exhibition of 1855, intended to be present at the laying. William and I desired jointly to supervise the proceedings, and we accordingly met in Madrid in December 1863. I traveled from Moscow, where I had been staying, via St. Petersburg, Berlin, and Paris in five days, almost without break of journey.

My brother had meanwhile – in 1859 – married the sister of the aforementioned Mr. Gordon, a clever and charming lady. He brought his wife with him to Madrid, as she insisted on sharing the toils and the possible dangers of the enterprise. In Madrid it was unpleasantly cold and windy, so that I could not perceive that the climate had much improved since my leaving Moscow. We soon continued our journey to Aranjuez, Valencia, and Alicante, without even there finding a more congenial temperature. The winter was unusually cold for Spain, and it was a curious sight to see, all the way from Alicante to Cartagena, date palms and orange trees abundantly laden with golden fruit covered with snow. Even in Cartagena, where we had to wait some days for the cable ship, it was so bitterly cold in the houses bereft of

Five Siemens brothers, around 1860. Rear (L to R): Walter, Carl, Werner and Otto; front: William and his wife Anne, née Gordon (1821–1901).

fireplaces or stoves, that my sister-in-law often declared afterward that my stoves, brought from Russia had prevented her from freezing in Spain. It was not until Oran that we thawed out again. The necessary preparations were soon made, and we rejoiced in the hope that the whole laying would be over in a few days. But "there's many a slip between the cup and the lip" – after four weeks' toil and exposure to grave dangers, we had lost the cable, and had to congratulate ourselves that we had not also sustained loss of health or life.

Judged from the objective standpoint of advancing years, this cable laying was an egregious piece of folly, since cable, ship, and mode of laying were utterly inadequate. As an excuse for our undertaking it, nevertheless, only the following reasons can be offered. We desired under any circumstances to lay a cable of our own, because we saw that our inventions and experiences were being turned to account by English contractors without any regard for us, and even without our undoubted services in the development of submarine telegraphy being so much as mentioned; and further, and perhaps mainly, because the cable-construction and paying-out arrangements devised by brother William were so well conceived and interesting that we had not the heart to leave them unused.

The cable would have been excellent in every respect if it had remained in the condition in which it left the factory. Unfortunately, however, we were soon convinced that its proper breaking strain had been much impaired, although the hempen strands were supposed to be prevented from "dry rot" by being impregnated with a solution of tannin. In spite of its light weight it was hardly strong enough any longer to be laid with safety in

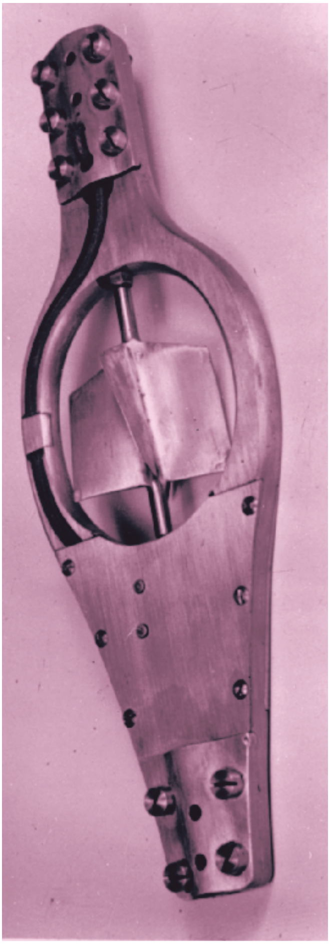
The London Industrial Exhibition

… The electric log can be understood even by a layman provided that he knows what a log is, as everyone should who has ever made a sea voyage and instead of gazing up at the stars has taken a look at what goes on on the quarterdeck … The Siemens log … always towed behind the ship marks by means of a connecting wire the number of rotations of the screw on a pointer indicator in the cabin …

National Zeitung, *August 23, 1862*

the considerable depths between the Algerian and Spanish coasts. Almost still worse was the fact that my brother had invented for the laying a new mechanism, which was now to be tried for the first time. It consisted in the cable being coiled around a large drum with stationary axis, which was to be turned for the winding and unwinding of the cable by a specially constructed small steam engine. This contrivance, though carried out in a very ingenious manner by my brother, yet appeared to me very dubious, for the uniform rotation of so heavy a drum, especially in a rough sea, was connected with difficulties whose extent could not be foreseen, and the portion of cable unrolled by the revolving drum could only be properly estimated when the ship's velocity, the ocean depth, and the currents were at all times exactly known. But as the weather was calm and fair, and I had moreover constructed an electrically worked velocity meter, which I desired to test, and which, as I hoped, would always accurately indicate the ship's speed, we resolved to make the attempt in spite of the decreased strength of the cable. Unfortunately, my fears proved to be justified. After the heavy shore cable had been laid, and the laying of the light copper cable, connected with it, had proceeded for perhaps an hour without disturbance, so that my hope of success noticeably rose, the cable suddenly broke and sank in the rather deep water, without any apparent reason. It was impossible to pick up again the cable already laid, as it was held fast at the seabed by huge boulders. In consequence we did not have sufficient cable left to undertake a laying to Cartagena, and determined therefore to take the shorter course to Almería and in the first place to run across, with the object of searching for a suitable landing place.

The trip to Almería, with glorious weather and a mirror-like sea, was enchanting. The town is masked by a hilly neck of land, which stretches far into the sea. For our purpose this fine situation was certainly rather unfavorable, for it compelled us to make so wide a circuit around the promon-



Electric log.

tory that the smaller linear distance from Oran was thereby almost neutralized. We landed, however, in order to take in stores, and enjoyed the hospitality of the inhabitants, who would not be denied giving us a festive reception and improvising an entertainment in the theater in our honor. What most surprised us at this entertainment was the classical beauty of the women, whose features were undoubtedly of Moorish type. One young girl struck us in particular. By the unanimous vote of our ship's company, composed of all nationalities from western Europe, she was pronounced the ideal of female beauty.

We did not dream on that enjoyable evening that the next day would bring us dangers the surmounting of which still appears to me little short of miraculous.

Rightly to understand what followed it must be borne in mind that our ship had not been built for cable laying, but had only been procured in the English market ad hoc by the French government. It was an English coasting vessel whose former function had been to tow colliers to London. These ships are not built for the open sea; they have a flat bottom, no keel, and no high prow for breaking the waves. The hold of this unfavorably constructed ship was for the most part occupied by a huge wooden drum, with fixed iron axis, on which the whole cable was wound; the load was therefore very unfavorably distributed for the open sea. But the weather was uninterruptedly fine, and the sea calm. This changed somewhat when, after leaving Almería we rounded the promontory and saw the open sea before us. A moderate breeze was blowing from the southwest, and masses of black clouds hung behind the neck of land along the coast. Then it struck us that the nearest of these dark lowering clouds was continued to sea level by a long armlike prolongation, and that the sea beneath was in wild commotion, so that it appeared in the unbroken sunshine as a dazzling and jagged ice field. Our vessel passed, according to our reckoning, about two leagues off this high foaming field, which was perhaps half a league broad while the length could not be estimated. It was surprising that this prolongation, coalescing bluntly with the cloud above and then tapering quickly, did not quite come in contact with the heaving surface of the water, but remained separated from it by a clearly discernible interval. There was also no special elevation of the foaming surface beneath to be perceived, but the whole surface appeared to be raised uniformly as high as a house above the level of the sea. The end of the prolongation at the same time executed an undoubted circular movement above the white part of the sea, so that it returned about every ten or twenty minutes to the same point. Unfortunately, we could not long continue the observation of this interesting spectacle, a so-called waterspout, as it rather quickly drew off along the coast in an easterly direction, and we were also diverted from it by another remarkable phenomenon. For the ship began of a sudden to rock with such violence that we could only with difficulty maintain an upright position. They were short high waves, so-called *dead sea,* over which we were being borne. Clearly we were following in the wake of the waterspout. The violent rockings of the ship made the captain, who was well acquainted with its construction, very anxious indeed; however, he kept his course in the direction of the troughs of the waves, in the hope of soon coming again into calmer water. Then dull short blows, which made the ship tremble at every oscillation, struck my ears. The thought flashed through me like lightning that the drum had got loose and would soon knock the ship to pieces. I rushed into the cabin to my brother, who was already contending with seasickness.

No one else knew precisely the construction of the drum and the mode of its attachment; he alone therefore could perhaps still save us. I found him already on his feet – deadly pale, but composed. He too had immediately understood the cause of the threatening blows, and that had sufficed to dispel every trace of seasickness. In the hold he in fact saw that the axis of the drum had worked loose from its upper frame, and that the blocks of especially hard wood, which had been carefully prepared and fitted for the protection of the drum and the frame, were wanting. The ship's French carpenters at first pretended not to know what had become of them, but when the blows increased in strength, and my brother called out that we should all be lost if the wood was not immediately found, their memory returned and the blocks were produced. The fellows had admired the solid unfamiliar wood and had regarded the pieces as superfluous.

With the violent rocking, we could not, however, succeed in placing the blocks in their proper places. Meanwhile, the blows had increased to such a degree that everybody was seized with fear lest the vessel should no longer resist them. Then my brother called to us through the open hatchway, "The oscillation is too great, steer against the wind!" The captain at once gave the necessary order, and the ship turned to meet the waves. A moment after, to my astonishment, I beheld the prow plunged under water, and the waves already washing over the forepart of the deck. I perceived at once the cause of the phenomenon. The ship with its full velocity had turned too suddenly against the wind, and when a wave had once washed over and depressed the prow, it retained the inclined position and was driven down the incline by its own velocity. At this critical moment I involuntarily assumed command, and called loudly into the engine room hard by, "Stop!" as the captain was wont to do. Luckily the engine men instantly obeyed. But the ship's velocity could only be slowly reduced. We all stood on the raised poop, and saw the foredeck becoming continually shorter and the sea approaching nearer and nearer to the place where we stood. Then the sea broke over the afterdeck, and a mighty whirlpool was formed, the water pouring through the open hatch into the ship's hold. Our end seemed at hand. Then the swirl became weaker, and after some further anxious moments the prow once more appeared above the water, and we breathed fresh hope, for the violent rocking and the ominous blows had now ceased.

My brother, who in the hold had not been able to observe the approach of danger, was completely surprised by the seawater suddenly deluging himself and the drum. All the greater was his delight when the rush of seawater ceased, and it soon after became possible for him to adjust the wooden supports, and thereby prevent the dangerous blows of the axis of the drum. The captain now cautiously resumed the course to Oran. The vessel indeed still continued to rock disagreeably, but we got accustomed to it, and rejoiced that the drum did not stir again. The great excitement had dispelled all seasickness, and when it became dark everyone sought his berth, and soon all was tranquil.

I had not been long asleep when loud orders and cries of alarm on deck suddenly awoke me. Immediately afterward the ship laid itself on its side in a manner I have never since experienced, and can even now scarcely consider possible. People were thrown from their beds and rolled on the steeply inclined floor of the large cabin into the cabins opposite. They were followed by everything movable on the ship, and at the same time all the lights were extinguished, as the hanging lamps were hurled against the cabin deck and shattered. After a brief, anxious pause there then followed a recoil, and a few repetitions of nearly the same intensity. Immediately after the first shocks I succeeded in gaining the deck. In the half-light I descried the captain, who in answer to my call only pointed to the stern, exclaiming, "Voilà la terre!" Indeed, a high rocky wall, feebly shining in the darkness, seemed to be standing behind the ship. On seeing it, the captain had suddenly brought the ship around, and thereby caused the violent oscillations. He thought we must have drifted, and were close on the rocks of Cap des Lions. Suddenly a voice called in the darkness, "La terre avance!" and the high uncanny gleaming wall now actually rose close behind the ship, and advanced with a strange roaring voice. Then came a moment so awful and overpowering that it baffles description. Tremendous floods, which seemed to burst in on all sides, poured over the ship with a force which I could only withstand by convulsively grasping the iron rail of the upper deck. I felt how the whole ship was tossed hither and thither with tremendous force by violent short blows of the waves. Whether we were above or under water was hardly to be distinguished. It seemed to be foam, which we breathed with difficulty. How long this state of things lasted no one afterward was able to say. Those who had remained in the cabin also had to contend with the violent shocks, which threw them hither and thither, and were terrified to death by the roaring noise of the mass of water cascading down on the deck. The estimates of time varied between two and five minutes. Then all was over as suddenly as it had begun, and the gleaming wall now stood before the ship, and moved slowly away from it.

When, after a short time, the whole ship's company collected with revived spirits on deck and talked over all the terrors and wonders, the French officers were of the opinion that the most incredible wonder of all had been that our lady had not once screamed. The thoroughly English composure of my sister-in-law, growing with the rising danger, appeared altogether incomprehensible to the lively Frenchmen. As we heard afterward, the waterspout which we had observed at Almería had moved eastward down the Spanish coast, had then passed over to the African side, and we had obviously crossed its path. That with our craft, so little seaworthy, and so injudiciously loaded, we had fortunately withstood the dangerous experiment is perfectly incomprehensible to me. When the waterspout had passed over us the sea still remained for some time in wild commotion, and, so far as we could observe, was covered with foaming crests. Then we beheld a natural phenomenon of a splendor and grandeur such as the most daring fancy could hardly paint. As far as the eye could reach the whole sea glowed with a dark red light. It looked as if it were composed of molten red-hot metal, and the foam crests of the procession of waves in particular radiated so bright a light that all objects could be distinctly seen, and even the smallest writing could be read. It was a beautiful eerie sight, which stands even today, although more than a quarter of a century has passed, with perfect distinctness before my eyes! We were at a point of the sea which was densely peopled by phosphorescent animalcula. A tumbler which I filled with seawater shone brightly in the dark when the water was violently shaken. The wild swirling motion produced by the waterspout had excited the whole mass of phosphorescent animalcula, visible even to the naked eye, and to their universal simultaneous phosphorescence we owed the marvelous sight of the glowing sea.

In Oran, where a few hours later we landed without our journey being further disturbed, we had to consider what was next to be done. According to an accurate estimate, we still had cable enough to reach Cartagena, if it were paid out with the least slack that was necessary for laying it without strain on the not quite level seabed. My brother had become bolder through the luckily surmounted dangers and wanted once more to attempt the laying, and with the present contrivances, without more ado. I opposed this, however, since I had lost all confidence in the drum, and the ship freighted with it. Finally we determined to coil the cable over, and carry out the laying in the usual way with cone and dynamometer.

When the troublesome and tedious coiling of the cable was finished and the fatal drum laid aside, we proceeded to our second attempt. The weather was again splendid, and the laying went forward without any difficulty. The depth of the sea, however, proved to be greater than was given in the French charts, and we were obliged to load the dynamometer to a hazardous degree in order not to pay out too much cable. I controlled the expenditure of cable by my ELECTRIC LOG, which hitherto had always done good service. Thus things went without disturbance until the high coast near Cartagena was already clearly in sight. Suddenly my log refused to act – as it subsequently transpired, because its screw had become entangled in seaweed. As my last reckoning had shown that we had cable to spare, and should arrive in Cartagena with a surplus, I went to my brother and requested him to unload the dynamometer somewhat, in order to be secured against the fracture of the cable. He was greatly delighted, and was about to show me first how beautifully and equably the cable was running out with the present loading, when all at once we saw the cable quite gently come asunder. The brake wheel stood instantly still, the torn-off end disappeared into the deep, and therewith, for our then circumstances, a considerable sum of money, as we had undertaken the laying at our own risk. But what for the moment aggravated us still more than the money loss was the technical fiasco. The labor of months, all the toils and dangers which not we alone, but our companions also, had undergone on account of this cable, were in a moment irrecoverably lost on account of a few rotten strands of hemp. In addition there was the unpleasant feeling at being the object of commiseration of the whole ship's company. It was a severe punishment for our temerity.

When, a few hours after the breaking of the cable, we landed in Cartagena, we had been over a month without news from Europe. In Almería we had also not heard much on our flying visit, except that war had broken out with

Denmark on account of the Duchies of Schleswig and Holstein. In the hotel at Cartagena we found French and English newspapers, and all the great political news of the last month from the fatherland poured in upon us. An altogether remarkable revolution had taken place in the newspaper articles on Germany since the declaration of war and the defeat of Denmark, which enjoyed the favor of England. We had hitherto been accustomed to read in English and French newspapers much well-meant praise of German science, German music, and German song, as well as compassionate utterances on the good-natured, dreamy and unpractical Germans. Now there were furious articles on the conquest-seeking, the war-loving, nay, the bloodthirsty Germans! I must confess that all this gave me no annoyance, but considerable pleasure. My self-respect as a German rose higher with each of these expressions. The Germans had for so long been only passive material for the world's history. Now one might read for the first time in black and white, in the *Times,* that they had of their own accord entered into its course, and thereby excited the wrath of those who hitherto had alone considered themselves entitled to the honor. In my dealings with Englishmen and Frenchmen during the cable

. . . In the land where the Goddess of Invention was born, where practical application follows closely on the heels of scientific discoveries, one of the most magnificent telegraph cable works in the world has been set up by a German. The Siemens works at Woolwich not only supplies submarine and land cables and telegraphic apparatus of all kinds; the establishment is at the same time a scientific laboratory, a place of continuous experiments and clever inventions. Cables from this factory loaded onto Thames steamers and shipped to all parts of the world connect St. Petersburg with Kronstadt and France with Corsica and Algeria; they run for the Pasha of Egypt over the bed of the Nile; they are working in India as well as in Brazil and La Plata, at the Cape, in Turkey and in Spain. Their total length is 6,000 nautical miles, a good part of the girdle which Puck promised to put around the Earth. And this piece of the girdle has been woven in the short space of time since the establishment of the factory, namely in 1859;** a proof of the high reputation which the name of Siemens enjoys all over the world . . .*
That the name of the founder of the works commands the highest respect in scientific circles in England is common knowledge. If educated Englishmen are beginning to renounce the old belief that the German is an essentially unpractical philosopher, the credit is largely due to men like Siemens.

Illustrierte Zeitung,
December 8, 1866

** The cable was made for Siemens by Newall & Co.*
*** A workshop was set up in 1858, but the factory was not established until 1863.*

laying, I had often had painful occasion to be convinced in what slight esteem the Germans were held as a nation by other peoples. I had long political debates, which always came to this: that the Germans had neither the right nor the ability to form an independent and united state of their own. "Well, what then do the Germans want exactly?" asked the highly respected director-general of the French telegraphs and former companion in exile of the Emperor Napoleon, M. de Vougie, after a long conversation on the reviving national aspirations in Germany at the close of the Franco-Austrian war. "A united German Empire," was my answer. "And do you think," he replied, "that France would suffer a state united and superior in number to itself as next-door neighbor?" "No," was my answer, "we are convinced that we shall have to defend our unity against France." "What an idea," he said, "that a united Germany would fight us. Bavaria, Wurtemberg, all South Germany will fight with us against Prussia." "Not this time," I answered. "The first French cannon shot will make Germany one; we have no fear therefore of a French attack, but await it cheerfully." M. de Vougie shook his head; yet the idea seemed to dawn upon him that the Pandora's box of the nationality question, which his ruler had opened in the war with Austria on behalf of Italy, might finally be turned against France. Three years later, when the question of the annexation of Lauenburg by Prussia was occupying people's minds, I paid a visit to the director-general in Paris. Remembering our political conversations, he called out to me on entering the room: "Eh bien, Monsieur, vous voulez manger le Lauenbourg?" "Oui, Monsieur," I returned in answer, "et j'espère que l'appétit viendra en mangeant!" It has truly grown, this appetite, and been also appeased, and M. de Vougie will have thought of my prophecy when with his Emperor he had to retire before German troops entering France in triumph. The first French cannon shot had in fact made all Germany one.

Johann Georg Halske. Painting from 1865.

The Cartagena – Oran cable was an unlucky one for us. When the lost cable had been replaced by a new and somewhat stronger one, my brother repaired again in the same year to Oran. All the arrangements were excellently made, the experience gained in former expeditions being fully utilized. The cable was new and strong, the employees experienced, the weather favorable – in short, a failure was this time not to be thought of. At the expected time I received indeed the hoped for dispatch from Cartagena, announcing that the cable had been successfully laid and messages already exchanged between Oran and Paris. Unhappily this dispatch was followed only a few hours later by another, stating that the cable for unknown reasons had snapped near the Spanish coast. Closer inquiry showed that the fracture had occurred at a point where the Spanish coast slopes down abruptly to an unusual depth of water. The crossing of such submerged ravines, as of extremely uneven seabeds in general, is always very dangerous. If the cable is laid in such a way that it rests on two rocks which are so far elevated above the seabed that it remains suspended on them without touching ground, it assumes the form of a catenary curve, whose tension may become so great that it snaps. Such a catenary curve the cable must at all events have formed at the foot of the abrupt declivity just mentioned, for the fracture occurred only a few hours after the cable firmly settled itself there.

The picking up of the cable was attempted, without success, however, as the ground was rocky, the sea deep, and the cable not strong enough for such a depth. In short, we had also lost the second cable for good and all, and had no satisfaction other than the feeling of relief at being relieved of the obligation of making another attempt by virtue of the fact that official dispatches were actually exchanged between Oran and Paris.

The great losses which these cable layings brought us caused a small crisis in our business relations. My partner, Halske, did not relish such undertakings attended with risks and serious losses, and feared also that the venturesome spirit of my brother William might entangle us in enterprises suited to the large scale of English commercial life, but to which our resources were unequal. He therefore proposed that we give up our English house. William Meyer, as business manager of the firm, ranged himself on Halske's side. Although I could not but admit the weightiness of the reasons adduced, I still could not bring myself to leave my brother William in the lurch at so critical a juncture. We accordingly agreed that the London business should be entirely dissociated from the Berlin house, it being taken over by me (at my private risk) and William. This was carried out, and the London business now became the firm of Siemens Brothers. Brother Carl in St. Petersburg likewise entered as partner. Agreements were drawn up between the three now independent firms in Berlin, St. Petersburg, and London to govern their mutual relations.

I may as well remark here that the copper-armed cable laid by the London firm in the Black Sea in 1869, of similar construction to the Cartagena – Oran cable, likewise did not prove durable. It was laid by my brother William with complete success as part of the Indo-European line, which I shall speak of later on, parallel to the shore between Kerch and Poti, but the very next year was destroyed simultaneously at many points by an earthquake. On attempting to take it up again it appeared that this was not possible, as it was covered for the most part with rubble and earth. This, and the

A map of the western Mediterranean, showing the telegraph lines laid with Werner von Siemens' assistance.

fact that the interruption of the telegraph service took place just at the moment when a severe shock was felt at the coast station, Sukhum-Kalé, proved that the breaking of the cable had actually been caused by the earthquake. This is moreover quite intelligible, since soil and rubble are carried down to the sea by numerous watercourses, and thus deposited on to the shelving shore. From time to time these masses must slip further, whereby a cable embedded in them will of necessity be torn. The movement alluded to could not but be initiated by an earthquake simultaneously at all places where the equilibrium had been rendered unstable by recent deposits.

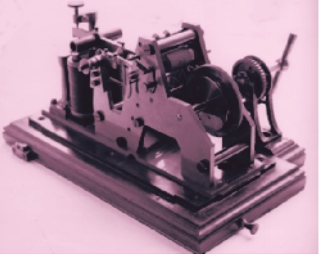
Through these and similar occurrences we have learned the lesson that submarine cables should never be laid on the slope of steep declivities, and especially not where soil and rubble are carried to a deep or inland sea by rivers discharging into them.

We may regard the period of the cable layings described in the foregoing as our proper apprenticeship for such undertakings. Instead of the anticipated profit, they brought us many anxieties, personal dangers, and serious losses, but they paved the way for the successes which subsequently fell to the lot of our London firm in its important and well-executed cable undertakings. I shall hereafter return to this second period of our cable layings, but only briefly review it, as I personally had less share in the labors connected with them.

SCIENTIFIC AND TECHNICAL WORK IN THE 1850s AND 1860s

I now turn to continue the short summary of my scientific and technical labors already brought down to the year 1850.

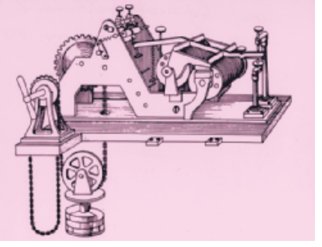
In the years 1850 to 1856, I was busily engaged with Halske in improving telegraphic apparatus, electrical appliances, and measuring instruments for scientific and technical purposes. It was still a tolerably unplowed field which we worked over, and our activity was accordingly extremely fertile. Our constructions, which were rapidly made known, especially through the Universal Exhibitions in London and Paris, have almost everywhere formed the basis of later contrivances. As already remarked, only a few of these innovations were patented, and the majority of them were either never, or only in later years, described in journals. This facilitated their general introduction and brought us many orders, but at the same time we lost in many ways the universal acknowledgment of their origination. I shall here instance only a few of the directions which our constructive activity took.



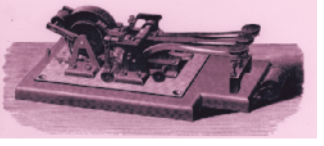
A Morse express writing transmitter, 1854.

Besides the practical development of the Morse telegraph for hand use, we were occupied in this period with the elaboration of that apparatus into an express writer for our automatic telegraph system, which was originally destined for the great Russian lines, and first came into operation on the Warsaw – St. Petersburg line in 1854. In this system the messages were pre-

Telegraph sets for the Russian lines.



The FIRST MORSE RELIEF WRITER *in "Camel" form, with a weighted drive, automatic triggering and translation device, 1854.*



Three-key puncher, 1854.

pared by the so-called THREE-KEY PUNCHER, whose object was to impress the Morse signs on a paper ribbon. By depressing the first key, a single round hole was cut out in the ribbon; by depressing the second key, a double hole. The necessary pushing forward of the ribbon took place automatically, while the greater interval required for the separation of the words was produced by the depression of the third key. When in this manner a message had been punched onto the paper slip, the latter was drawn along in the so-called EXPRESS-WRITING TRANSMITTER by help of wheelwork between a roller coated with platinum and a contact spring or brush. By this means, at the receiving station the single holes produced a dot, the double holes a dash. As it turned out that ordinary magnets with iron armature did not work quickly enough, we employed for the relays as well as for the inkers light cores, capable of turning in the stationary coils of the magnets, which were formed of bundles of wires or of thin split iron tubes, whereby the desired velocity could be attained with certainty.

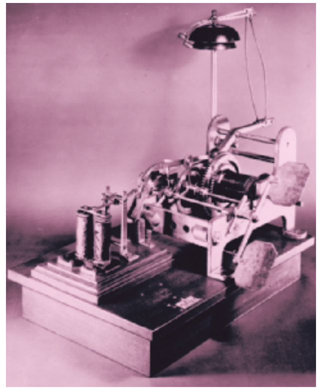
Bain had as early as 1850 employed a perforated slip of paper for his electrochemical telegraph, but he had no suitable mechanism for rapid punching of the slips. Wheatstone made good use of my three-key puncher in 1858 for his electromagnetic express writer, without, however, naming the source whence he derived it.

Werner to Carl, October 27, 1853

Our new Morse express writer is becoming progressively better and I hope that it will come into general use … I hope that we will get up to 300 letters a minute …

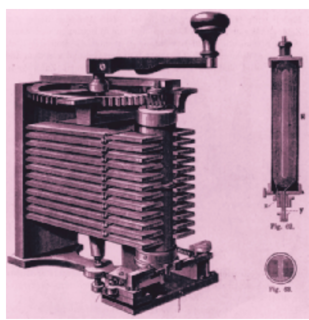
The signaling service of the railways, with which our firm had from the first been particularly occupied, brought further problems. On all the German railway lines, ringing apparatus had to be set up which on the departure of a train from a station should give audible bell signals for the whole distance. The mechanician Leonhardt had already provided such gong apparatus for the Thuringian line, but this acted imperfectly, as it was difficult to maintain the large galvanic batteries, which were required at the stations for setting the apparatus to work, in good condition. It was an obvious idea to employ magnetic inductors instead of batteries, but the magneto-induction machines, known up to that time, of Saxton and Stöhrer were not suited for the purpose. We now constructed a new kind of inductor, which worked admirably, and afterward entirely superseded all other constructions. The essential feature of our inductor was the employment of an iron cylinder acting as a rotating armature and which was provided with deep opposite grooves, forming a channel for the reception of the coil of copper wire. From the form of its iron cross section this armature became known as the double-T armature; in England it is known as the Siemens armature. The steel magnets, hollowed out at the end, which surrounded the rotating cylinder could be set up along its length and apart from one another, and accordingly exert a more powerful magnetizing effect and less impair each other's action. Inductors of this kind are today exclusively employed wherever it is desired to procure powerful currents by permanent magnetism.

My cylindrical armatures with transverse coil possessed the great advantage over the older constructions that they had powerful action but less mass, and in particular quick rotation and little inertia. I also employed them, therefore, for the construction of a very simple and surely acting



Railroad alarm system, 1847. An electromagnet released the catch on the weight-driven striker mechanism, and two bells were struck in succession. Two fly vanes regulated the clockwork so that the bells would ring in the right rhythm.

Magneto with a double-T armature for the dial telegraph, 1856.

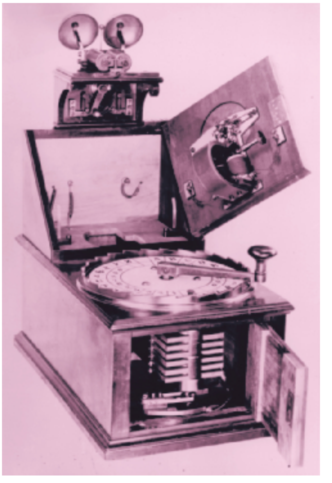


MAGNETO-ELECTRIC DIAL TELEGRAPH, in which the cylindrical inductor was quickly turned by a handle with wheel translation, while each semirevolution sent an alternating positive and negative current through the line, each causing the pointer of the receiving apparatus to advance by one letter on the dial plate. It was enough to place the handle successively on the letters to be telegraphed to make them visible in like order at the receiving station. The electromagnet of the receiving apparatus consisted of an iron cylinder with polar extensions revolving on its axis, which oscillated between the poles of two powerful horseshoe steel magnets. Therefore, according as a positive or negative current traversed the fixed coils of the electromagnet, one or the other magnet attracted the rotating armature, and thereby kept in motion the hands of the receiving apparatus. This quickly and surely acting magneto-electric dial apparatus was in great demand especially for the railway service, and is even now frequently used.

The arrangement of polarized magnets just described – i. e., those in which the oscillating armature or magnet has two resting places, according to whether a positive or negative current has last traversed the electromagnetic coils – has obtained more considerable and general importance through being used for relays. On the employment of polarized relays depends the possibility of telegraphing the Morse alphabet with short induced currents, the one direction of the current initiating a dash on the paper strip, while the other finishes it. Accordingly, the length of the dash produced does not depend on the duration of the current, but on the duration of the interval between two short successive currents of alternate direction.

On the Berlin – Anhalt railway not only has the telegraph equipment been completed along the whole extent of the permanent way, but now on the main Berlin – Köthen line all stations and signal boxes have been provided with ringing apparatus to signal the arrival and departure of trains. The introduction of simple mechanical devices has enabled not only considerable savings to be made in the maintenance of batteries, but also the telegraph and signaling apparatus to be effectively protected against the injurious effects of atmospheric electricity.

National Zeitung, *May 9, 1854*

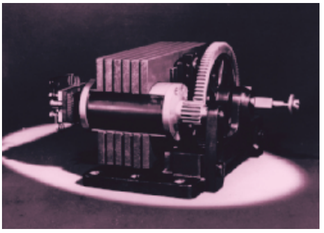


Dial telegraph for the railroad safety agency, with magneto and double-T armature, 1856.

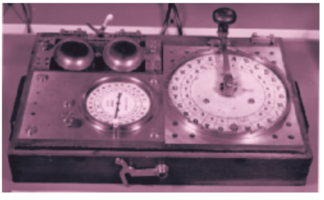
On this principle depend several of our telegraphic constructions, of which only the induction writing telegraph need be mentioned here. In this, the short currents of alternate direction required for its working were produced by a well-closed electromagnet, around which was wound a primary coil of short thick wire and a secondary of long thin wire. In the primary coil the currents required for telegraphing the Morse alphabet were produced in the usual way. In the secondary coils connected with line and earth there then occurred, at the beginning and close of the currents circulating in the primary conductor, powerful induced currents of alternate direction, which produced the required Morse signs in the telegraphic apparatus at the receiving station. For the magnetic inductors, magnetically closed electromagnets with massive iron cores were employed, to make the tension of the CLOSING AND OPENING CURRENTS equal as far as possible.

With such INDUCTIVE WRITING TELEGRAPHS it was possible by means of a single Daniell battery to telegraph with certainty over great distances on overhead lines. For underground and submarine lines, the induced electric currents also proved highly advantageous, for they made it possible to signal to greater distances and with greater speed. As already mentioned, the Sardinia – Malta – Corfu line was fitted in 1857 with our induction writing telegraphs. For the working of the first Atlantic cable, laid in the following year by the managing electrician, Mr. Whitehouse, induced currents were also made use of, until the destruction of the insulation, which unfortunately occurred soon after the laying, prevented their further employment. Subsequently, on long submarine lines recourse was again had generally to Thomson's mirror galvanometer with battery currents.

For land lines also there was this drawback to the use of



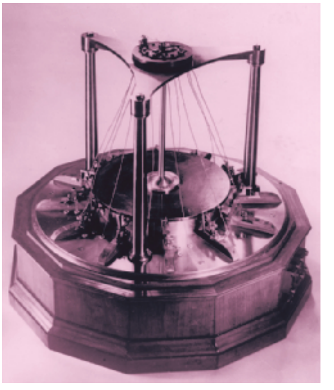
Magneto with a double-T armature, 1856.



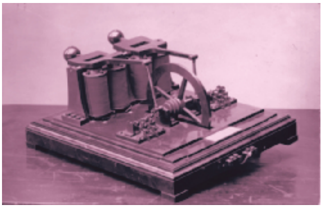
Magneto-electric recording telegraph, 1856.

short induced currents: that they had to be very powerful to be able to produce the necessary mechanical movements at the end of the line. But since the maintenance of very large batteries, such as the working of long lines with uniform current or intermittent battery current requires, was troublesome and costly, Halske and I tried mechanically to transform battery currents of low tension into uniform currents of higher tension. We exhibited, at the Universal Exhibitions of London and Paris, several mechanical arrangements constructed by us for this purpose, but they had the drawback at first that the currents of high tension obtained were not of uniform intensity. It was only through the construction of my so-called plate machine that the problem of the production of uniform currents of nearly constant tension by voltaic induction was actually solved.

This "teller" (plate) machine consists essentially of a large number of electromagnets, which are grouped in a circle, and the so-called teller, a conical-shaped iron plate whose apex lies in the center of the circle of magnets, which is set rotating above their poles. The magnets are furnished with double coils, of which one-half of the inner ones are always inserted in the circuit of a battery composed of a few large elements, and which by a suitable contact arrangement – the contact being always a fourth of a revolution in advance of the rolling "plate" – cause the rotation of the plate, while all the outer ones are united together into a closed conducting circuit. By rolling over the magnetic poles, the iron cone produces in the secondary coils of the magnets inserted in the battery circuit an induced current in one direction, but on the other hand in those of the magnets outside the battery circuit an induced current in the opposite direction. The two induction currents would neutralize one another, and no current could arise at all in the secondary circuit, unless at two oppositely situated points of this circuit there was a continuous contact by which the opposed currents of both halves were taken up and united into a continuous current. This contact is effected by means of brushes, which are moved around by the prolonged axis of the iron cone.



"Plate" machine to generate DC high voltages by voltaic induction, 1853.



DOUBLE AUTOMATIC GENERATOR *(a further refinement of the "plate" machine).*

The "plate" machine was constructed by me in 1854 and shown at several Universal Exhibitions, first at the one held in Paris in the year 1855. One of them, together with other apparatus of our construction, is preserved in the museum of the Berlin Post Office, which probably possesses the most complete collection of old telegraphic apparatus anywhere to be found. The "plate" machine is interesting, because it represents the first solution of the problem of how to generate by induction continuous currents in one direction, and follows precisely the same course as that taken by Professor Pacinotti ten years later in constructing his famous magneto-inductor; the principle of current ramification, which is carried out in the ring of Pacinotti, being already contained in it. My machine is thus the precursor of the modern dynamo machine with continuous current and at the same time of the transformer. Had the self-motion of the plate not been made a point of, and had it been effected by mechanical revolution of the axis together with the brushes, an effective dynamo-electric machine would even then have been obtained, and the period of the employment of the Siemens armature, by which the aim was finally reached, would have been skipped. This may serve as an instance of the difficulty which is often experienced in first apprehending the most obvious truths. Indeed I can only think with a certain sense of shame of the

Werner to William, May 29, 1856, on the idea of the double-T armature

... An iron bar, with continuous slots in it in which the wire is wound as on a galvanometer head, is rotated between the poles of a horseshoe magnet or a stack of such small magnets. In the position shown in the sketch all magnets are closed by the iron as armature. When the latter makes a half revolution the direction of the magnetism in the armature is reversed so that a current is induced. On the second half revolution a current follows in the opposite direction. We have made the rotating core 1⅓ thick and 10″ long, but will probably get too much current. Rotation is produced simply by means of a pinion which engages with a wheel 14 times larger. This wheel is rotated directly by the handle of the Wheatstone dial. Each half rotation gives one letter of the pointer. The advantages of this magneto-electric apparatus are:
1. a larger number of smaller magnets can be used instead of 2 or 4 larger ones. As the force of the magnets is proportional to the square root of their weights, the advantage is obvious. 2. For other than telegraphic purposes (light, detonation, galvanochemistry, etc.) we can make the apparatus as large as we like without a disproportionate increase in the weight of steel. 3. The inertia of the moving masses is insignificant by comparison with older designs. It is therefore easily turned either by hand or by a weight using keys ...

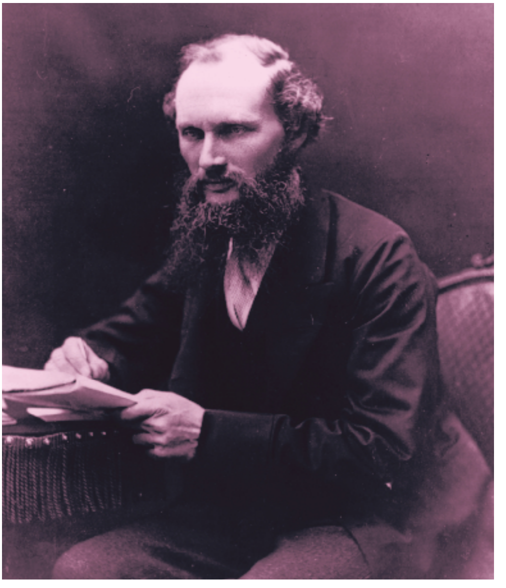
circumstance that, after establishing the principle of the dynamo machine, I did not at once hit upon the parallel connection of the two halves of the coils with opposed induction, employed in the "plate" machine, but was only led to it several years later by Pacinotti's example.

In the year 1854, telegraph engineers were greatly excited by a statement which appeared in the Leipzig Polytechnic *Centralblatt*. The statement was to the effect that the Austrian telegraph official Dr. Gintl had succeeded in telegraphing between Prague and Vienna by means of the Morse apparatus simultaneously in opposite directions through the same conducting wire. This was said to have been accomplished by providing the relays with two coils, through one of which the main current passed, while at the same time an equally strong local current passed through in the opposite direction. This second circuit had to be closed by a separate contact at the same moment as the main current. Dr. Gintl soon found, however, that this path did not lead to the desired end, because it was impossible to let two contacts actually occur at the same moment, and because the interruption of the main current taking place at the end of each signal could not but disturb the current coming from the other side. Gintl therefore abandoned this method and tried to solve the problem by making use of Bain's electrochemical telegraph. His experiments then yielded a better result, and betrayed him into the belief that two currents could traverse the same conductor in opposite directions without mutual interference. In an article, "Über die Beförderung gleichzeitiger Depeschen durch einen telegraphischen Leiter" (On Forwarding Simultaneous Messages through a Telegraph Conductor), which I contributed to Poggendorff's *Annalen,* I demonstrated the inadmissibility of this view, and expounded the theory of electrochemical duplex telegraphy, but also showed that this method was not capable of practical application. At the same time, I described a method of duplex telegraphy with electromagnetic apparatus, which completely accomplished the desired result. The same method was also independently discovered by the subsequent chief engineer of our firm, Herr C. Frischen in Hanover. It is known at the present day by the name "Duplex signaling method of Frischen and Siemens" and is still frequently employed. At the close of the above-mentioned article, I dealt with the theory of signaling in the same direction along the same wire with two sets of apparatus and with that of simultaneous transmission in the same and in opposite directions, describing also the current ramifications whereby these problems can be solved.

In the year 1857, I published in Poggendorff's *Annalen* a longer article, "On Electrostatic Induction and Retardation of the Current in Cores," which gives the final result of several years' experiments on the physical properties of underground conductors. In this article I took up again and further developed the theory of the electrostatic charge of underground conductors, broached by me as early as 1850. This theory obtained at first but little credit in scientific circles; even Wilhelm Weber trying to explain the disturbances occurring in the Prussian underground conductors by self-induction. Likewise, Faraday's ingenious theory according to which the electrostatic distribution is not effected

Carl Frischen (1830–1890). Undated.

by direct electric action at a distance, but by a distribution proceeding from molecule to molecule of the dielectric, was unable to obtain acceptance with most physicists of the old school. The actual influence of the matter existing between two conductors on the extent of the electric charge was explained by a more or less profound penetration of the electricity into the insulator and the diminution thereby brought about in the distance between the effective quantities of electricity in the two conductors. I determined, therefore, to carry out an experimental investigation in order to establish the actual state of things without connecting it with any of the existing theories. My investigation, which was made considerably more difficult by the then very imperfect development of the means and methods of investigation, led to a complete confirmation of Faraday's molecular distribution theory. The result arrived at was that the laws of the motion of heat and electricity in conductors also applied to electrostatic induction, and that consequently the form of Ohm's law for electric current is likewise applicable to it. In this way, with the help of Faraday's theory, I obtained Poisson's formulae for the density of electricity at the surface of bodies, and was able to furnish an experimental proof that in all cases the theory of Faraday suffices for the explanation of the phenomena. I then carried this theory further in several directions and solved problems with the help of it, as, e.g., the calculation of the capacity of a battery formed of any number of Leyden



Sir William Thomson (Lord Kelvin; 1824 – 1907). Undated.

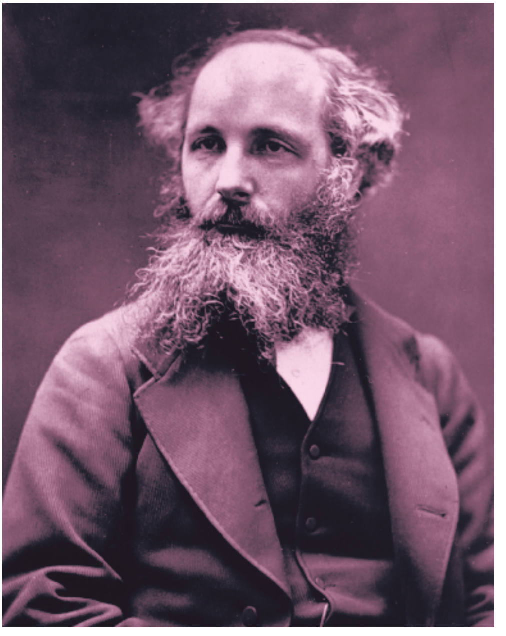
jars of different capacity placed one behind another, a problem which up to that time had not been solved. Unfortunately, I did not find the necessary leisure before the spring of 1857 to prepare my work for the press. Meanwhile, eminent English physicists, like Sir William Thomson and Maxwell, had anticipated sundry of my scientific results; in particular the formulae, given by Thomson, for the capacity of jar wires and the retardation of the current were the same as those which I had arrived at in a quite different and more elementary way. Maxwell has in his masterly works elaborated Faraday's theory in strict mathematical fashion, and proved that it is everywhere in complete harmony with the theory of potentials. We are therefore completely warranted in regarding electric distribution with Faraday as an action propagated from molecule to molecule, but not combined with direct action at a distance, for only one of these processes can actually take place.

At the close of the above-mentioned paper, I described the apparatus known by the name of the Siemens ozone tube, and explained the theory of its action. I succeeded with its help in converting oxygen into ozone by electrolysis. There is still a great future in store for this apparatus, as it enables us to subject gases to electrolysis. By it they are put into the so-called active state, rendering them capable of forming directly with other gases chemical compounds which could otherwise only be obtained in a very roundabout way.

I have already mentioned that even in the middle of this century one of the greatest obstacles in the way of the development of the physical sciences, and especially of physical technology, was the want of fixed standards. In scientific writings pretty generally, *meter* and *gram* were used as measures of length and weight, but, notwithstanding, technology suffered from an insupportable looseness and inaccuracy. Meter and gram at any rate always formed fixed points of comparison, to which all estimates of measure could be referred. Such a fixed point was entirely wanting, however, for electric standards. Wilhelm Weber indeed had already, in conjunction with Gauss, theoretically developed the admirable system of absolute magnetic and electric units, and had also perfected to an extraordinary degree the methods of exact measurement and the requisite instruments, but standard tallies, representing the absolute units and accessible to everybody, were wanting. It was in consequence usual for every physicist to set up his own standard of resistance, which was attended by the serious inconvenience that the results of his labors were not then comparable with those of others.

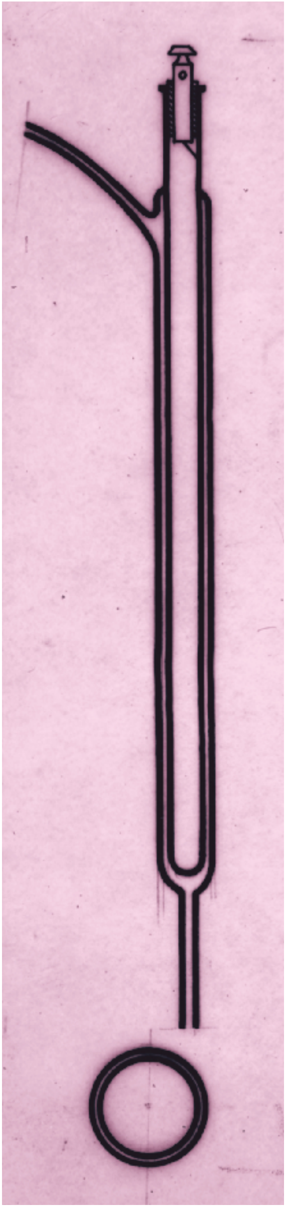
Jacobi in St. Petersburg then made the proposal to take as the general unit of resistance an arbitrarily chosen copper wire, which he deposited with a Leipzig mechanician. This attempt, however, fell through, because the resistance of the wire changed in course of time and the copies supplied showed values varying as much as ten percent from one another. The resistance of a German mile of copper wire of 1 millimeter diameter at first employed as a unit by Halske and myself, and pretty generally adopted in Germany and other countries for practical telegraphy, also proved to be only a makeshift. I soon became convinced that it is quite impracticable to set up an empirical standard in the manner of Jacobi, as the electrical resistance is not such a fixed and controllable property of bodies as (say) the dimension and mass of solid bodies. There was also no prospect of inducing the whole world to accept a standard of resistance deposited in any particular place.

On these grounds the choice remained between the absolute unit of resistance of Weber and an empirical unit everywhere reproducible with the greatest exactitude. Alas, the adoption of the absolute unit was not then to be thought of, its reproduction being too difficult, so that Wilhelm Weber himself declared to me that errors amounting to a considerable percentage were unavoidable. I therefore decided to take, as the basis of a reproducible standard of resistance, the only metal fluid at ordinary temperatures, mercury, whose resistance cannot be affected by molecular variations and is influenced less by changes of temperature than that of the solid metals available for the gauging of resistances. In the year 1860, my labors had progressed so far that I was able to come before the public with the proposal to adopt as a unit the resistance of a column of mercury of 1 meter in length and 1 square millimeter in cross section at 0 °C, and to publish my method of producing this mercury unit. The paper, which appeared in Poggendorff's *Annalen,* was entitled: "Vorschlag zu einem reproduzierbaren Widerstandsmaße" (Proposal for a Reproducible Unit of Electrical Resistance).



James Clerk Maxwell (1831 – 1879). Undated.

Although Mr. Mathiessen in London violently opposed the adoption of my unit and recommended instead as empirical unit a wire of gold and silver alloy with about the same resistance as Weber's unit, my proposal was soon generally adopted, and the Vienna International Telegraph



Ozone tube, 1857.

Conference of the year 1868 made the mercury unit the legal unit of telegraphy. Nevertheless, the English physicists continued their efforts to introduce as international standard the centimeter-gram-second system of resistance proposed by Sir William Thomson and adopted by the British Association – the so-called cgs unit – a resistance ten times as great as that of Weber's absolute unit. The British Association appointed a special committee, to which Sir William Thomson and also my brother William belonged, which carried on a lively agitation for the general adoption of the British Association unit, although there had as yet been no really exact representation of the same. Reliance was placed, however, on the expected progress in electrical methods of measurement, and it was justly urged that the adoption of a theoretically fixed standard of resistance, based on a fundamental dynamic standard, would considerably facilitate calculations with electrical forces. Although on the other hand it could be contended that the great majority of calculations with electrical resistances belonged to the geometrical and not to the dynamical domain, and that the reproducible unit with a geometrical foundation proposed by me might just as well be called an absolute one as the unit of Weber resting on a dynamical basis, or the modification of the same which was proposed as unit on the English side, yet the cgs unit of resistance has been subsequently adopted in principle as the international standard. I shall return to this once again in the sequel. The duty, entrusted to my brother William and myself by the English government, of controlling the manufacture of cables subsidized by it, caused us to make very exhaustive experiments with regard to the properties of submarine lines, and especially to elaborate a rational method for the testing of their electrical condition. The Malta–Alexandria cable was the very first which was subjected to systematic testing and control during its entire preparation, and which in consequence proved perfectly faultless after being laid, and has remained so. Such a rational testing was rendered possible by the exact standard of resistance described above, by our arrangement of resistance coils, which allowed the combination of any desired resistances in mercury units in the same manner as weights are used in scales, and furthermore by essential improvements which the methods of investigation and the measuring instruments underwent at our hands. For investigating the influence which the high pressure prevailing at great depths exerts on the cable, steel tanks that could be closed were constructed, and the insulation of the cables measured while they were subjected therein to a strong pressure. The fact already observed by us during the laying of the Red Sea cable was hereby confirmed, that the insulating capacity of the gutta-percha is increased by the pressure of the water, whereby the possibility was established of laying submarine lines even at the greatest depths. We further drew up tables for calculating the extent of the diminution which the insulating capacity of gutta-percha, india rubber and other insulating materials undergoes through increasing temperature, as well as for the diffusive capacity – specific induction – of these insulators. Our experiments showed that in these respects india rubber and its compounds are far superior to gutta-percha, a circumstance which caused us to institute extensive experiments to obtain a good insulation of conductors by coating with india rubber, but which did not quite lead to the sought for practical results.

A paper communicated by us to the British Association in the year 1860, entitled "Outline of the Principles and Practice Involved in Dealing with the Electrical Conditions of Submarine Electric Telegraphs," summarized the main results of our inquiries, and forms the foundation of the system of testing cables and detecting their faults which was afterward generally adopted. But although this paper was published in English, and my communication to the Paris Academy of 1850, in which my methods of detecting faults were likewise in principle contained, was in French, yet later writers and inventors have only in a few cases taken note of them, and have with slight variations published as new discoveries the methods given therein. I merely call attention to the point here in order that the history of the development of electrical technology may not be permanently falsified. A recent book compiled with much industry, bearing the title "Traité de télégraphie sousmarine," by E. Wünschendorff, gives occasion for this remark. At the very beginning of this work the original inventor of the electric telegraph, the German Dr. Soemmerring, is designated as "Professeur russe," who is said to have laid conducting wires underwater near St. Petersburg and in 1845 near Paris, and to have thereby become the inventor of submarine telegraphy. While, for a historical work, this is certainly a surprising confusion of the German Dr. Soemmerring with the German Professor Jacobi living much later at St. Petersburg, it is to be remarked that this and other projects of submarine communication before the year 1847 are only to be regarded as freaks of fancy, which could not possibly lead to practicable underground communication. It was my conductors with a seamless gutta-percha coating that first solved the problem of the construction of underground and submarine lines; and the wires laid by me for the mines in Kiel harbor, and the iron-armored cable wire across the Rhine at Cologne in the spring of 1850, that formed the first actual basis of submarine telegraphy. The German name of the Frenchman Wünschendorff may perhaps have contributed to the ignoring of German achievements running through the whole work!

PUBLIC ACTIVITIES

To the section of my activity just described belong two more events which were of great importance to me.

In the year 1859,* I was elected a member of the Council of the Berlin Merchants' Company, which forms at the same time the Chamber of Commerce of the March of Brandenburg. The election takes place by a poll of all the trading and commercial firms, and is accordingly regarded as a special distinction. Through this I gained the advantage of coming into closer personal contact with the heads of the Berlin industrial world. When, in the year 1860, the University of Berlin celebrated its jubilee, I received the degree of *Doctor honoris causa* in the philosophical faculty. The granting of this honorary title in my chosen home, Berlin, gave me especial pleasure, because I saw in it an acknowledgement of my scientific labors and was brought by it into a sort of academic relation with my scientific friends.

** Werner von Siemens was elected to the Board of Elders of the Berlin Merchants' Association as early as 1855.*

I come now to speak somewhat in detail of my political activity, to which I devoted myself with much ardor in the following years.

From my earliest youth, I had keenly felt the want of union and the impotence of the German nation. This feeling had been awakened in me and the brothers nearest to me in age through our being brought up in the petty and middle states of Germany, where a patriotism arising from a sense of political unity found no fruitful soil, as was the case in Prussia, thanks to its glorious history. Moreover, in our family national and liberal views had always prevailed, and my father in particular was devoted to them. In spite

Werner von Siemens' diploma conferring the degree of Doctor honoris causa from the Philosophical Faculty of the University of Berlin, October 16, 1860.


AVSPICIIS LAETISSIMIS ET SALVBERRIMIS
SERENISSIMI AC POTENTISSIMI PRINCIPIS
FRIDERICI GVILELMI IV.
BORVSSORVM REGIS CET.
REGIS AC DOMINI NOSTRI SAPIENTISSIMI IVSTISSIMI CLEMENTISSIMI
VNIVERSITATIS LITTERARIAE FRIDERICAE GVILELMAE
RECTORE MAGNIFICO
AVGVSTO BOECKH
EX DECRETO AMPLISSIMI PHILOSOPHORVM ORDINIS
FRIDERICVS ADOLPHVS TRENDELENBVRG
FACVLTATIS PHILOSOPHICAE H. T. DECANVS
WERNERO SIEMENS
PHILOSOPHIAE DOCTORIS ET ARTIVM LIBERALIVM MAGISTRI
ORNAMENTA ET HONORES
COLLATAQVE
PVBLICO HOC DIPLOMATE
PHILOSOPHORVM ORDINIS OBSIGNATIONE COMPROBATO

of the melancholy political condition into which Prussia and all Germany had again sunk after the glorious War of Liberation, yet the hope remained that the state of Frederick the Great, who by his deeds had awakened self-confidence in the Germans, must prove our future savior. It was this hope which had caused my father to advise me to enter the Prussian service, and this trust in a future strengthening of Germany through Prussia had always been strong in myself also. Thus it was that I was carried away with such irresistible force by the national movement of 1848 and in spite of opposing private interests drawn to Kiel, to fight with Prussia for Germany's unity and greatness.

When this movement of youthful enthusiasm, altogether overshooting the mark, had collapsed through the unfavorable circumstances of the time, when Germany had again relapsed into impotent disunion and Prussia had been deeply humiliated, a profound dejection crept over all German patriots. Our hope indeed was still fixed on Prussia, yet no one any longer believed that Prussia as a state would secure the union of Germany, and our hope rested entirely on the ultimate victory of liberal sentiments in the German and particularly the Prussian people. This revulsion of feeling explains the events of the period of conflict, which would be scarcely intelligible without it.

Up to the year 1860, I was so fully occupied with scientific and technical labors that I kept

Diploma for the Degree of Doctor Honoris Causa

By resolution of the distinguished faculty of philosophers and being constitutionally so authorized, FRIDRICH ADOLPH TRENDELENBURG, Doctor and Professor of Theology and Philosophy, Secretary of the Royal Prussian Academy of Sciences, Knight of the Order of the Red Eagle, Second Class with Oakleaves, nonresident Member of the Royal Bavarian Academy of Literature and Sciences, Professor in Ordinary, at present Dean of the Philosophical Faculty, has awarded to WERNER SIEMENS of Hanover, a man of great experience and famous throughout Europe, who, when our century learned to send messages with the power and also with the speed of lightning, improved, advanced and perfected telegraph apparatus and has also extended the knowledge of electricity, statics and dynamics, a man who has deserved well especially of our City because of his telegraph manufacturing establishment, the insignia and honor of a Doctor of Philosophy and Master of the Free Arts honoris causa on October 16, 1860, on the occasion of the Jubilee to celebrate the 50 anniversary of the University, this being confirmed in this official document by witness and seal of the Philosophical Faculty.

entirely aloof from politics. Only when, under the Regency of the Prince of Prussia, the political stagnation and the pessimism which till then had prevailed almost exclusively had diminished, and freer political views had again ventured to come forth, did I join the National Association formed under the lead of Bennigsen, and patronized by Duke Ernest of Saxe-Coburg and Gotha. I was present at the meeting which constituted it at Coburg, and continued to take part in its aims as faithful ally. Through this and my lively activity at the elections for the Prussian Diet I became more intimately acquainted with the leading politicians of the liberal party. I attended the meetings of the new liberal party then in process of formation, and assisted at the deliberations concerning its program and name. The majority was inclined to vote for the name "Democratic Party," while Schulze-Delitzsch wished to call it the "German Party." I proposed the name "Progressive Party," as it seemed to me more proper to designate the direction of activity rather than the principles by the party name. It was resolved to combine my proposal with that of Schulze-Delitzsch and to call the new party the "German Progressive Party."

I had repeatedly declined the invitation to allow myself to be elected deputy, but in the year 1864* I considered it my duty to accept my election, which had taken place without my intervention, as deputy for the district of Solingen-Remscheid.** At that time, the reorganization of the army proposed by the government formed the great issue determining party lines. The essence of this matter lay in the virtual doubling of the Prussian Army in accordance with the government plan, and the corresponding increase of the military budget. The mood of the country declared that this increase of the military burdens could not be borne without leading to a thorough impoverishment of the people. In fact the prosperity of Prussia lagged considerably behind that of the other German states, as the burden of the

** Werner von Siemens actually accepted the election in 1862.*

*** Not Solingen-Remscheid, but Lennep-Solingen.*

German defenses even after the War of Liberation had rested chiefly on her shoulders. If this burden was to be still further increased in so great a degree, without the enforcing of a corresponding participation of the rest of the German states, it was thought that the prosperity of the country could not but be retarded more and more, and the burden would finally become insupportable. It was known indeed that even as Prince of Prussia and as Prince Regent, King William had been convinced of the necessity of again raising the state of Frederick the Great to the stature consistent with its historical position at the head of Germany. No one questioned the sincerity of the personally popular and highly esteemed monarch, whose efforts were directed to that end, but there was much doubt with regard to the practicability of his plan. Faith in the historical mission of the Prussian state to effect the unification of Germany, and in Prussia's star, had sunk too low. Even the most eager enthusiasts for Germany's unity and future greatness, nay, even preeminently Prussian patriots, deemed it therefore incompatible with their duty to load Prussia with this new, and as it seemed, exorbitant military burden. The representatives of the people, in large part certainly with heavy heart, rejected the reorganization plan of the government, and after repeated dissolutions the people confirmed this vote at the new elections.

Werner von Siemens, around 1864.

It was especially hard for me personally to vote against the proposition of the government, as in my innermost heart I still maintained my old faith in the vocation of Prussia, and it might also look like ingratitude if I opposed the desire of a monarch who had once personally shown his goodwill to me. Moreover, from the attitude of the ministers von Bismarck and von Roon in the chambers and from their demeanor and utterances in the bitter war of words that often took place, I had gained the conviction that serious action was before us, for which an increased army would be required. But my political friends quieted me by saying that an active movement on the part of Prussia for creating a united Germany under the guidance of Prussia would necessarily lead to a war with Austria, and against this there stood as insuperable obstacle the testamentary admonition of Frederick William III to his son: "Hold fast by Austria!"

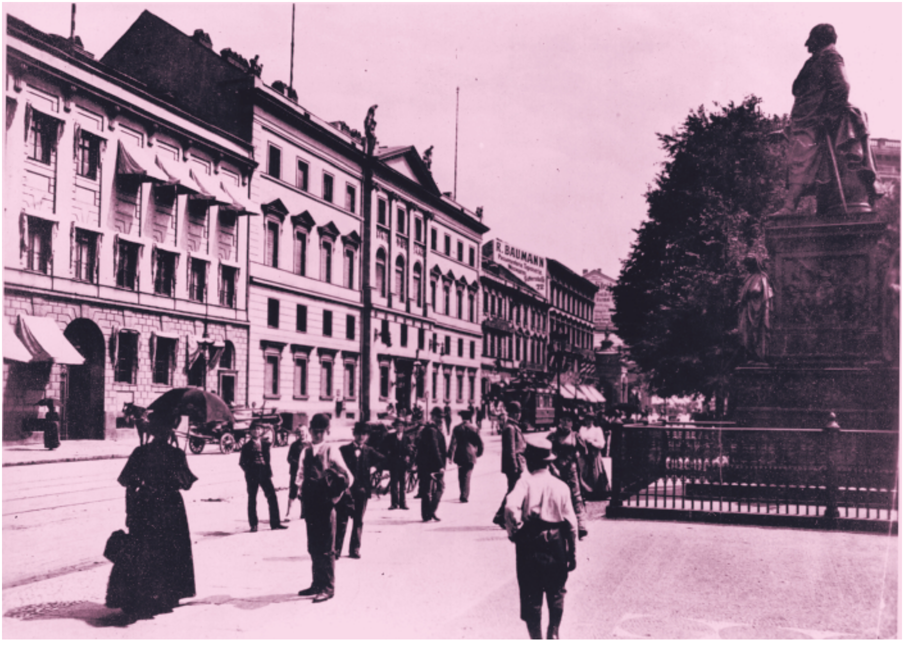
This inward conflict led me, in an anonymous pamphlet published by Julius Springer with the title "Zur Militärfrage" (On the Military Question), to discuss the question whether the doubling of the army in the event of war might not be obtained in another way than that proposed by the government, without the country being burdened with the serious expenditure which the government plan rendered necessary.

Meanwhile the reorganization itself was carried through by the Minister of War, von Roon, without any regard to parliamentary contests, and was fortunately already completed when, in the spring of 1866, the differences in regard to Schleswig-Holstein led to a breach with Austria. That this breach would actually occur and entail war few believed, despite the warlike preparations and threats. All the greater was the universal astonishment when, early in the morning of June 14, the news spread that war had been declared against Austria and the German Confederation, and that the declaration of war was already posted up on the advertising pillars. In fact, after a hasty walk from Charlottenburg to Berlin, I found the nearest of these pillars surrounded by a dense crowd. I was struck by the calm, earnest demeanor

The Prussian Landtag. Left foreground, Otto von Bismarck; fifth row center, Werner von Siemens.

with which the often changing crowd received the mighty event. No critical remark of any sort was heard when the serious and dignified announcement was repeatedly read at the request of the bystanders. Everyone, workman and privileged citizen alike, felt the immense gravity of the fact "It is war!," but nobody appeared to be depressed by it; everywhere it was received with self-conscious calm.

It was brought strongly home to me what a power lies in the glorious past of a people. In perilous times it enhances self-confidence, allows no pusillanimity to spring up, and awakens in everybody the resolve to contribute his part to overcoming the danger, as his fathers had done before him. As in front of this advertising pillar at the Potsdam Gate, so did it look in all Berlin, nay, in the whole country, at any rate in the old territories of Prussia. All political disputes were forgotten, or at least postponed. Every man had but



The Prussian House of Delegates on Dönhoffplatz. Here Werner von Siemens represented the district of Lennep-Solingen from 1862 to 1866. At that time he belonged to the (left-liberal) German Progressive Party.

one thought: to do his duty. That this feeling dominated all classes of the people was clearly manifested in a meeting which was called on the very day of the declaration of war by some private persons, with the object of forming a society for the care of the wounded. When a politician began the proceedings with complaints against the government which had brought on the war, a brief remark of mine sufficed for reply that war was now a fact, and the only question before us was how to pave the way for victory, and assuage as far as possible the sufferings of the wounded. This was received with such unanimous applause that all further discussion was cut short, and the formation of the aid society for the army in the field, which afterward worked with great success, was unanimously resolved.

When, after a few weeks, the war was ended with the final defeat of Austria and its allied German states, the world looked quite different. The insignificant, deeply humbled Prussia now stood in fact as proud conqueror without a rival at the head of Germany. With a wise understanding of the national mind, which regarded the unavoidable civil war only as a means to the attainment of the yearned for German unity, King William and his chief minister had imposed only extremely mild conditions of peace on the conquered states, where they were not entirely incorporated in the Prussian state for its necessary security. The King and Captain, now entering as victor into his residence, gave the world probably a unique example of magnanimous justice, by requesting from the Diet an indemnity for the transgression of its constitutional rights necessitated by state difficulties, and thus restored the country's internal peace. It certainly required many more struggles in the Chamber of Deputies before the wisdom and magnanimity of this kingly act received full recognition and approbation. As a result of the struggles continued with the government for several years, and the repeated dissolutions, a sort of fighting organization had been formed in the Diet, which gave its leaders a decisive influence on the divisions. WALDECK, in particular, the leader of the extreme democrats, had obtained great power. His friends rejected all compromise, and held it to be requisite for attaining their ends, as well as befitting the dignity of the House, to grant the desired indemnity only on very far-reaching conditions. This in the then political situation was an extremely dangerous proceeding, which seriously threatened the internal peace, and might again imperil all the achievements of the glorious victories of the Prussian Army. I had, soon after the conclusion of peace and before the convocation of the Diet, stayed for some time in Paris, and had an opportunity to become acquainted with the feeling of the masses, as well as of the leading circles. It was there considered as altogether beyond question that France could not suffer the powerful position acquired by Prussia at the head of North Germany and as leader of all Germany without very considerable compensation, and must break it down, if necessary, by force. From a thoroughly reliable source I learned that the reason why France had hitherto put a good face on a bad business was merely because the Mexican war had disorganized the army and in particular exhausted the stores, but that warlike preparations were proceeding at a great pace, and in the meantime a prolongation of the internal conflict in Prussia was being reckoned upon.

On my return to Berlin, I found the Chamber of Deputies already assembled and the indemnity question being hotly debated within the parties. Unfortunately, a large number of the parliamentary leaders not belonging to the Waldeck party, in the fixed expectation that this group would carry the day, at any rate in the Progressive Party, had announced their secession from the latter and declared for the formation of a new party, the "National Liberal." I myself had on principle never delivered long speeches in the House, as I regarded my political activity as only transient, and had resolved not to serve again in Parliament. On the other hand, I had always taken an active share in the party meetings and knew the leanings of most of the deputies perhaps better than the parliamentary leaders. It was my conviction that the great majority of the Progressive Party were disposed for peace with the throne, and that it only required a powerful impulse to give expression to this peaceful sentiment. In fact, my vivid description of the many-sided dangers which were connected with the refusal of the indemnity fell on fruitful ground in the party meeting, and after Lasker, who at my request had put off his declaration of retirement till after the sitting of the party, had confirmed my arguments in an eloquent speech, the Progressive Party by a considerable majority declared for the unconditional granting of the indemnity, although Waldeck himself pronounced most decidedly for unflinching insistence on the question of right and the refusal of the

Signing of the Franco-German commercial treaty in 1865. Standing, at the center of the picture, Werner von Siemens.

indemnity. When, thereupon, the granting of the indemnity was also resolved by the House itself and thereby internal peace was restored in the country, I retired from the political scene and henceforth devoted the leisure time which the management of my firm left me to my scientific pursuits.

In the three years of my parliamentary activity, I took an active part in the sittings of the committee and party meetings on the only three bills which obtained legal force by arrangement with the government and the Upper House. I was special reporter of the “Metals and Metal Goods” division of the Franco-German commercial treaty, and believe that I materially contributed to its final adoption by a minute report which I drew up on this most hotly disputed part of the treaty. Unfortunately, this report brought me into conflict with my constituents. The latter sent a special deputation to the Chamber to protest against the article which forbade the marking of manufactures with the names of firms and trademarks of the manufacturers of another country. The Solingen and Remscheid manufacturers declared that it was a customary practice to label the better class of goods, prin-

Five Siemens brothers, 1866.
Standing (L to R): Friedrich, Ferdinand, Otto and Wilhelm's wife, Anne;
seated (L to R): Friedrich's wife, Elise (1843–1919), née Witthauer, Werner and William.

cipally ordered by English manufacturers and dealers, with an English trademark, and that their business would be seriously injured if this were disallowed; the consequence of such a prohibition would be that they would not only lose the English but also the German market for their superior goods, as even in Germany English goods were preferred.

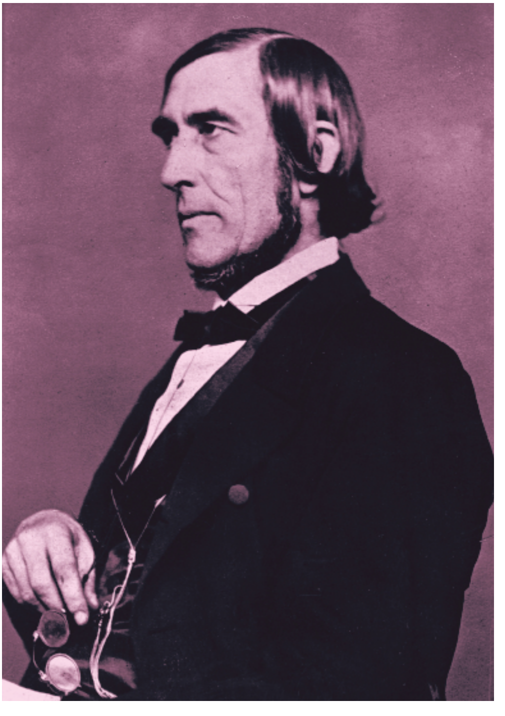
In spite of long discussions, we could not arrive at an understanding. The deputation admitted that German industry was acting suicidally in representing its good wares as foreign and only its inferior wares as its own manufacture; it threw the blame, however, on the purchasing public which demanded it. We accordingly parted in disagreement, and I believe I should not have been reelected if I had stood again. For the rest, the prohibition has worked well, although unfortunately it has not been carried out in all its strictness. Since then, in that old and famous seat of industry, as in general throughout Germany, a manufacturing pride has grown up which only permits the supply of articles of good quality, and it has also come to be seen in many ways that a more effective protection is afforded by the good name of the manufacturers of a country than by high protective duties.

An effective system of protection, securing the consumption of the produce of native industry, can in fact only be consistently carried out if the country, as, e.g., the United States of North America, includes all climates, and itself produces all the raw materials which its industry needs. Such a country can exclude all imports, but thereby at the same time diminishes its own exports. It must be regarded as a fortunate circumstance for Europe that America by its prohibitively protective system has checked the rapid, and for us dangerous, development of its industrial resources, and restricted its own exporting power. Europe, divided by high tariff barriers, thereby gains time to perceive the danger of its situation, which will make competition with a free-trading America in the world's market impossible if it does not in good time present a united front by a thorough mercantile organization. The contest of the old with the new world in all departments of life will in all likelihood be the great overwhelming question of the coming century, and if Europe wishes to maintain its dominant position in the world or at least its footing of equality with America, it will have to prepare itself betimes for this struggle. This can only be attained by the utmost possible removal of all inter-European fiscal barriers, which limit the market, enhance the expenses of production, and diminish the power of competing in the world emporium. Further, the feeling of the solidarity of Europe as against all other parts of the world must be developed, whereby the internal European questions of political power and economic interest should be turned toward higher ends.

INDO-EUROPEAN TELEGRAPH LINE AND THE CAUCASUS

During the period of my political activity, I earnestly continued my efforts to develop the large business I had called into existence. A change had meanwhile occurred in the management of the Prussian government telegraphs, which had again brought me and my firm into closer connection with it. In place of Privy Councilor Nottebohm – who could never forgive me for having in my previously mentioned pamphlet traced the entire failure of the Prussian system of underground communications to its real cause, the defective organization of the technical administration – an extremely intelligent officer of engineers, Colonel von Chauvin, had been named director of the Prussian state telegraphs. The latter renewed the relations with my firm, which had been broken off altogether for many years, and made use of its great experience in the telegraphic department to improve the working arrangements of the government telegraph system, which had remained almost stationary. As at the same time in Russia my old friend and patron, Colonel

Privy Councilor Friedrich Wilhelm Nottebohm (1808–1875), around 1852.



The route of the Indo-European telegraph line.

von Lüders, was again after a long illness managing director of the government telegraphs, I conceived the bold plan of calling into existence a special telegraph line between England and India by way of Prussia, Russia, and Persia – THE INDO-EUROPEAN LINE.

The way had already been paved for this plan by the attempts of England to construct a line through the Mediterranean, Asia Minor, and Persia, in the execution of which my brother William had taken an active part. The English government had in 1862 laid a cable from Bushehr in Persia to Kurrachee in India, in the laying of which our electrician Dr. Esselbach had unfortunately met his death. The land line through Asia Minor and Persia joining the cable had also been constructed under English direction by the Turkish and Persian governments, and thus an overland telegraph line to India had actually been called into existence. But the impossibility of really solving the problem in this way soon appeared. The line was usually interrupted, and even if it was actually in perfect order, the messages often took weeks in transmission, and at last reached their destination in an altogether unintelligible, mutilated state. Theoretically there also existed a second overland connection by means of the Prussian and Russian government lines, yet for the transmission of government and commercial messages in the English language this proved almost as unserviceable as the special line through Turkey.

From these experiences it was certain that the great need for a quick and reliable telegraphic communication between England and India could only be satisfied by a line through Prussia, Russia, and Persia planned as a connected whole, and under an undivided management. After I had thoroughly weighed the practicability of such a line with my brothers William and Carl, after, moreover, William had through his friend, Colonel Bateman-Champain, the constructor of the land line through Asia Minor, secured the benevolent support of the English government and Colonel von Chauvin had given the like assurance on behalf of the Prussian government, our three firms in Berlin, London, and St. Petersburg took the execution of the plan in hand.

The greatest difficulty lay in inducing the Russian government to give permission to a foreign company to construct and work its own telegraph line through Russia. This succeeded only after lengthy negotiations, in which our previous achievements both as engineers and as reliable contractors stood us in good stead. The concession finally granted gave us the right of laying and working a double line from the Prussian frontier by way of Kiev, Odessa, Kerch, thence partly underwater to Sukhum-Kalé on the Caucasian coast, and further via Tiflis (today Tbilisi) to the Persian frontier. Prussia herself undertook to construct a double line from the Polish frontier via Berlin to Emden, and to allow this line to be worked by the company we pro-

St Petersburg, November 6,
Indo-European telegraph.

An ukase dated of October 22 awards to Siemens of London and Siemens and Halske of St. Petersburg and Berlin the concession within the territory of the Russian Empire for the construction and utilization of an Indo-European telegraph line. The contractors undertake to hand over the telegraph line ready for service two years after receipt of the concessions from the Russian, Prussian, and Persian governments unless prevented by circumstances beyond their control. The concession is for 25 years from the day on which it comes into effect. Imported materials necessary for construction will not be subject to customs duties. The telegraph line can be run along railways and roads without payment being required for the land utilized. In a word, this line will be considered as a government installation and will enjoy all the rights and privileges granted to the public service.

National Zeitung,
November 6, 1865

Walter Siemens (1833 – 1868) was an engineer in Warsaw, Vienna, Paris and finally Tiflis, where he served as North German consul from 1866 onward. Undated.

posed to form. Persia, whither we sent to conclude an agreement our brother Walter and a young relative, Georg Siemens, then assessor, now first director of the Deutsche Bank in Berlin, gave us, like Russia, a concession for constructing a line of our own from the Russian frontier to Teheran. The completion of the line, already partially constructed from Teheran to India, was undertaken by the English government.

We obtained permission to transfer the concessions granted us to a company domiciled in England, on condition that the construction and maintenance of the whole line should be entrusted to our firms, and the further proviso that a fifth of the company's shares should always remain in our hands. We thereupon formed an Anglo-German company, with its offices in London, and cannot but regard it as a significant indication of the standing our firm had already attained that the considerable capital required was subscribed in London and Berlin at our direct invitation, without the intervention of a banker. I may here mention that the Indo-European line still exists as originally constructed and, in spite of dangerous competition caused by a new submarine line laid down by English companies through the Mediterranean and the Red Sea, regularly pays a considerable dividend to its shareholders.

The construction of the line was assigned to our firms in the following manner. The Berlin, in conjunction with the St. Petersburg, business undertook the management of the construction of the land lines, while the London concern

… The rate for a telegram of twenty words on the Indo-European telegraph line has for the present been fixed at £ 3.10 s … At the present frequency it may safely be assumed that 800 to 1,000 telegrams will be dispatched to India daily.

Über Land und Meer,
Allgemeine Illustrierte Zeitung, 1869

was entrusted with the laying of the submarine line in the Black Sea and the delivery of the materials for the construction of the lines. To the Berlin firm, moreover, was left the design and construction of the necessary telegraphic apparatus. In spite of great and unexpected obstacles, the line was completed by the end of 1869, although unfortunately the already mentioned destruction of the cable along the Caucasian coast resulting from an earthquake, and the inevitably slow replacement of the same by a land line, rendered a regular telegraph service impossible before the following year.

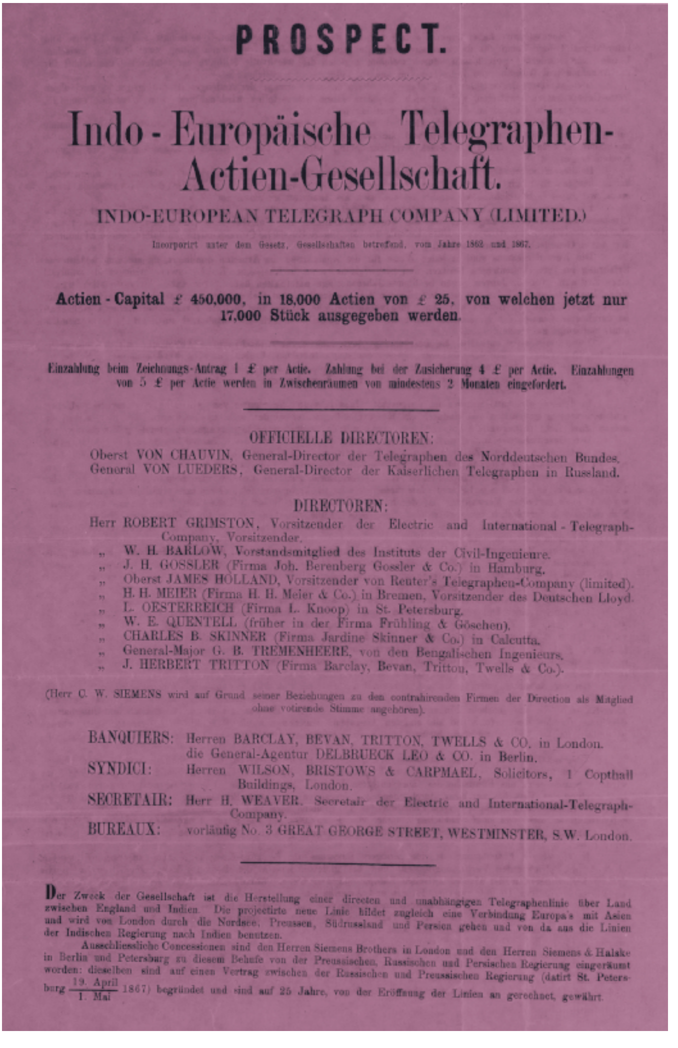
According to the working program drawn up by us, the messages from London to Calcutta were to be forwarded without any manipulation at the intermediate stations, i. e., by purely mechanical means, in order to preclude loss of time and mutilation by telegraphists in forwarding. For this purpose I constructed for the Indo-European line a special system of apparatus which completely solved this problem. It naturally excited great astonishment in England when, at the first official experiments, London and Calcutta conversed with one another along a line of nearly 10,000 kilometers as quickly and surely as between two neighboring English telegraph stations.

An unexpected difficulty was caused by the circumstance that the two wires, especially in dry weather, interfered with one another. This showed itself first in Persia, where the chief engineer of the Berlin firm, Herr Frischen, was occupied in arranging the telegraph service. With the very dry weather prevailing there, the two wires were entirely insulated from one another and from the earth, and nevertheless correct Morse writing was received on both receiving instruments of the distant station when a message was sent on one of the two lines. As the receiving apparatus of the sec-

Johann Georg von Siemens (1839 – 1901), 1866. He was the son of Justizrat Johann Georg Siemens, the co-founder of Siemens & Halske. Werner von Siemens engaged this young civil servant as a legal advisor for his company. When the Indo-European Telegraph Company was founded in 1866 he assisted William Siemens in London, and in 1868 headed the difficult negotiations in Teheran over the Persian concession for the telegraph line. Werner von Siemens would have liked to win Johann Georg over as a shareholder, but Johann Georg preferred to join the management of Deutsche Bank, founded in 1870.

ond line at the sending station showed reversed writing, the cause of the disturbances could only be in the electrostatic charge of the side line, for the currents dynamically induced in it should have given reversed writing at both ends of the second line. This was proved by a series of experiments which Herr Frischen made in Teheran on my wired instruction. After the cause of the disturbance was ascertained, it could be rendered innocuous by suitable precautions.

I take this opportunity to point out that this double cause of the induced currents arising in neighboring wires occasions in the working of telephones many disturbances hitherto not altogether intelligible, and still needs thorough investigation. I have subsequently had an opportunity, when my firm laid a seven-cored land cable, to institute an instructive experiment with reference to this phenomenon. With the permission of the imperial telegraph administration, one of the seven conductors of the cable from Darmstadt to Strassburg, insulated by gutta-percha, was coated with tinfoil, while the other six conductors were uncoated. It appeared from the experiments carried out after the laying that the tinfoil entirely obviated the electrostatic charge between the coated and the other wires, while


PROSPECT.

Indo-Europäische Telegraphen-Actien-Gesellschaft.

INDO-EUROPEAN TELEGRAPH COMPANY (LIMITED.)

Incorporirt unter dem Gesetz, Gesellschaften betreffend, vom Jahre 1862 und 1867.

Actien-Capital £ 450,000, in 18,000 Actien von £ 25, von welchen jetzt nur 17,000 Stück ausgegeben werden.

Einzahlung beim Zeichnungs-Antrag 1 £ per Actie. Zahlung bei der Zusicherung 4 £ per Actie. Einzahlungen von 5 £ per Actie werden in Zwischenräumen von mindestens 2 Monaten eingefordert.

OFFICIELLE DIRECTOREN:

Oberst VON CHAUVIN, General-Director der Telegraphen des Norddeutschen Bundes.
General VON LUEDERS, General-Director der Kaiserlichen Telegraphen in Russland.

DIRECTOREN:

Herr ROBERT GRIMSTON, Vorsitzender der Electric and International-Telegraph-Company, Vorsitzender.
„ W. H. BARLOW, Vorstandsmitglied des Instituts der Civil-Ingenieure.
„ J. H. GOSSLER (Firma Joh. Berenberg Gossler & Co.) in Hamburg.
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„ W. E. QUENTELL (früher in der Firma Frühling & Göschen).
„ CHARLES B. SKINNER (Firma Jardine Skinner & Co.) in Calcutta.
„ General-Major G. B. TREMENHEERE, von den Bengalischen Ingenieurs.
„ J. HERBERT TRITTON (Firma Barclay, Bevan, Tritton, Twells & Co.).

(Herr C. W. SIEMENS wird auf Grund seiner Beziehungen zu den contrahirenden Firmen der Direction als Mitglied ohne votirende Stimme angehören).

BANQUIERS: Herren BARCLAY, BEVAN, TRITTON, TWELLS & CO. in London. die General-Agentur DELBRUECK LEO & CO. in Berlin.
SYNDICI: Herren WILSON, BRISTOWS & CARPMAEL, Solicitors, 1 Copthall Buildings, London.
SECRETAIR: Herr H. WEAVER, Secretair der Electric and International-Telegraph-Company.
BUREAUX: vorläufig No. 3 GREAT GEORGE STREET, WESTMINSTER, S.W. London.

Der Zweck der Gesellschaft ist die Herstellung einer directen und unabhängigen Telegraphenlinie über Land zwischen England und Indien. Die projectirte neue Linie bildet zugleich eine Verbindung Europa's mit Asien und wird von London durch die Nordsee, Preussen, Südrussland und Persien gehen und von da aus die Linien der Indischen Regierung nach Indien benutzen.

Ausschliessliche Concessionen sind den Herren Siemens Brothers in London und den Herren Siemens & Halske in Berlin und Petersburg zu diesem Behufe von der Preussischen, Russischen und Persischen Regierung eingeräumt worden: dieselben sind auf einen Vertrag zwischen der Russischen und Preussischen Regierung (datirt St. Petersburg $\frac{\text{19. April}}{\text{1. Mai}}$ 1867) begründet und sind auf 25 Jahre, von der Eröffnung der Linien an gerechnet, gewährt.

Prospectus of the Indo-European Telegraph Company.

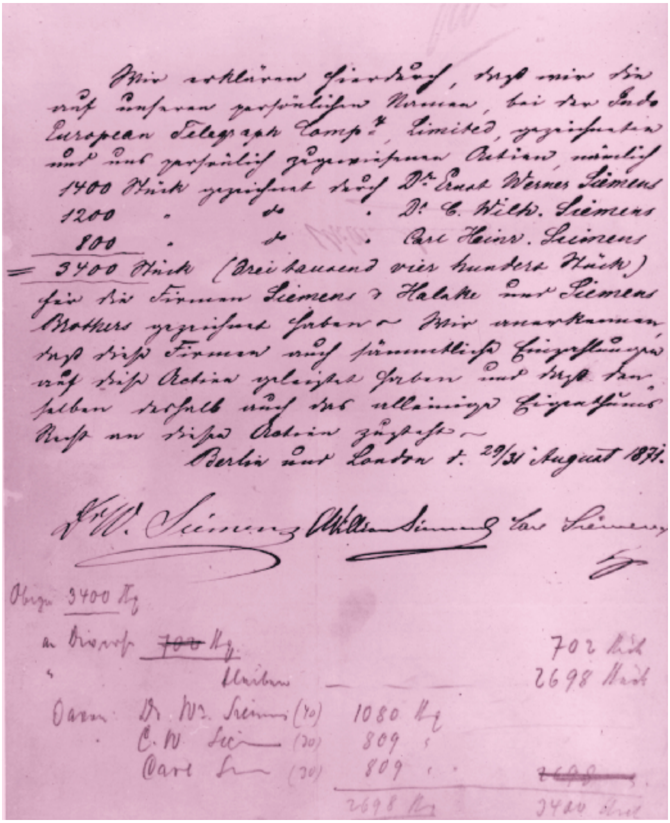
the electrodynamic induction between them remained quite unchanged. Unfortunately, the experiment could not be made with perfectly insulated tinfoil, as such an insulation was not to be attained.

Werner to Carl, April 12, 1870

We achieved a fine success today but only after a great deal of anxiety and excitement. When London called Teheran, there was interference on Berlin–London and it was horrible at Kerch.
In spite of all exhortations the intermediate stations then switched in out of curiosity and upset everything. While I was engaged in chasing off the unwanted stations all of a sudden there was good contact on the lines to Kerch.
I called Kerch on the second line with translation in all stations.
As it worked all right I called Tiflis, then Teheran and then made contact with London with this second line! In this way London has been in continuous communication with Teheran, i.e., with translation at all 9 stations! ... Now you can shout aloud and beat the 10 – 12 hours of the Red Sea with our 1 minute to Teheran and 28 minutes to Calcutta . . .

Even before the completion of the Indo-European line, our St. Petersburg firm had been entrusted by the Russian government with the construction and the remount of several telegraph lines in the Russian Caucasus, and had for this purpose established a branch in Tiflis, the management of which was entrusted to my brother Walter. When, after the completion of the government works, no sufficient occupation could be found for the latter, he proposed to us the purchase of a rich copper mine in the Caucasus at Kedabeg, near Elisabethpol. As mining did not fit into the framework of business activity of our firms, brother Carl and I privately gave him the not very considerable capital required for the purchase and the working of the mine.

The copper mine of Kedabeg is very old; it is even asserted that it is one of the oldest mines from which copper was actually extracted in prehistoric times. This is rendered probable by its position in the neighborhood of the large Goktcha Lake and of Mount Ararat rising on its western shore, a region which has indeed often been regarded as the cradle of the human race. A legend even runs that the beautiful valley of the Shamkhor river, which belongs to the forest district of the mine, was the site of the biblical Paradise. At any rate, the numberless old workings which crown the summit of the metalliferous mountain testify to the antiquity of the working of the mine, as does also the occurrence of native copper, and finally the circumstance that extensive prehistoric burial grounds exist in the vicin-



Wir erklären hierdurch, daß wir die auf unseren persönlichen Namen, bei der Indo European Telegraph Compy. Limited, gezeichneten und uns persönlich zugewiesenen Actien, nämlich
1400 Stück gezeichnet durch Dr. Ernst Werner Siemens
1200 " do " Dr. C. Wilh. Siemens
800 " do " Carl Heinr. Siemens
= 3400 Stück (drei tausend vier hundert Stück)
für die Firmen Siemens & Halske und Siemens Brothers gezeichnet haben. Wir anerkennen daß diese Firmen auch sämmtliche Einzahlungen auf diese Actien geleistet haben und daß denselben deshalb auch das alleinige Eigenthums Recht an diesen Actien zusteht.
Berlin und London d. 29/31 August 1871.

Dr W. Siemens CWilliam Siemens Carl Siemens

Obige 3400 Stk
an Bischoff ~~700~~ Stk 702 Stk
Bleiben 2698 Stück
Davon Dr. W. Siemens (40) 1080 Stk
C. W. Sie.. (30) 809
Carl Sie.. (30) 809
2698 Stk 3400 Stück

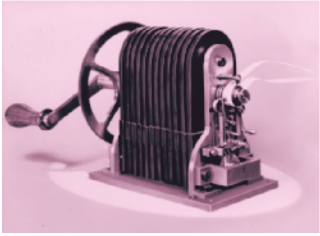
The declaration by brothers Werner von Siemens, William Siemens and Carl von Siemens on how many Indo-European Telegraph Company shares they had subscribed for, August 29–31, 1871.

ity of Kedabeg, in the investigation of which Rudolph Virchow has shown such great interest.

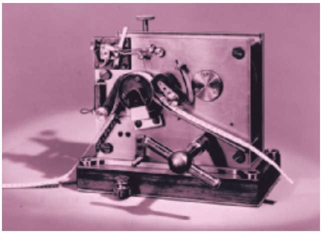
The mine has a beautiful, really paradisical environment, with a temperate climate. It lies about 800 meters above the great Caucasian steppes, which extend from the foot of the spur of the Lesser Caucasus – termed the Goktcha chain – to the Caspian Sea. The working of it, when the primitive pit sinking, subservient to operations on the

Werner to William, March 9, 1864

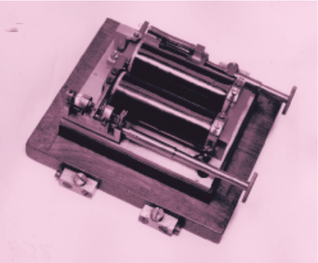
The most careful investigation convinces me that the undertaking really rests on very solid ground. Ore is certainly there in abundance in seemingly inexhaustible quantities. The transport of ore is practicable and should be given top priority …



Punched-tape transmitter with magnetic inductor for the Indian line, 1867.



Punched-tape transmitter *(battery-operated) for the Indian line, 1867.*



Polarized relay belonging to the Indo-European system, 1867.

exposed ore, could no longer be continued, came into the hands of the Greeks, whose slantingly sunk staircaselike shafts, by which they carried ore and water up on their backs, were still in use at the time of my brother Walter's taking possession. Operations in accordance with modern principles were commenced by us with very sanguine expectations – as is usually the case with such undertakings – under the direction of a young Prussian miner and metallurgist, Dr. Bernoulli. It soon became apparent, however, that considerable difficulties would have to be overcome and large sums of money spent before the working could be remunerative. This is intelligible when one considers that the mine is situated about 600 kilometers distant from the Black Sea and at that time was connected with it neither by railways nor regular roads, that all the material required for the mine and the projected copper smeltery, even to the fireproof bricks, of which there were then none in the Caucasus, had to be brought from Europe, and that for the life of a European colony in this waste, in which earth caves served for human habitations, all the conditions of civilization had first to be created.

No wonder that the amount of money which the mine swallowed up was great beyond all expectation, so that the question soon became urgent for us brothers whether we should continue or give up the undertaking. To decide the matter, I resolved in the autumn of 1865 to journey myself to the Caucasus, and learn the state of affairs by actual observation. I count this Caucasian journey among the most agreeable memories of my life. I had always felt an inner yearning toward the primeval seats of human culture,

Laying the Indian line in the Caucasus. After a drawing by Burgfeldt. Undated.

and Bodenstedt's glowing descriptions of the luxuriant Caucasian countryside had directed this yearning toward the Caucasus and long ago had excited in me the wish to know it. There was the further reason for the journey that I was mentally and bodily fatigued by the death of my beloved wife after much suffering, and seriously needed a change.

Accordingly, at the beginning of October 1865 I journeyed by way of Pesth to Basiash, where I embarked on one of the fine Danube steamers for Tchernawoda, in order to go from there via Kustendji to Constantinople. On the ship it was very interesting for me to meet the famous Omer Pasha, then commander in chief of the Turkish Army. As he exhibited a desire for conversation, we soon got acquainted; my Havana cigars were to his liking and his chibouk, which he ordered his slave repeatedly to fill for me, to mine. Omer Pasha had at one time been a sergeant in the Austrian Army, had then gone over to the Turks, had adopted their faith and rapidly risen during the war with Russia. The conquest of Montenegro, which had up to

The foot of a nearly century-old iron pole from the Indian line, Iran, 1966.

A telegraph station on the Indo-European telegraph line in Kashan, Persia, around 1880.

that time been considered impossible, finally carried him to the head of the Turkish Army. He was just returning from a prolonged visit to Vienna and Paris. My attempts to get him to relate his warlike exploits he unfortunately always evaded. The recollections of the victories which he had achieved over the ladies of the ballet and the opera in Vienna and Paris seemed to him to be more agreeable than those of his warlike deeds. Only with regard to the expected future war of the East against the West of Europe did he express himself, and that in a very sanguine manner. A powerful troop of Turkish horse would, so he thought, overwhelm the West as in former times, and ride down all resistance. For a Turkish generalissimo this opinion appeared to me as somewhat childish. He seemed to feel very dependent on public opinion in Turkey, as was made clear when a minor traveling mishap befell us. The engine of our vessel had suffered damage in passing the Iron Gate, and we were forced to spend the night in Orsova, that it might be repaired. In consequence we arrived somewhat late at Kustendji, and learned

to our dismay that the steamer, which went from there to Constantinople only twice a week, had not awaited the arrival of our boat. The prospect of remaining several days in that dreary place was extremely disagreeable to all of us, especially to the seraskier. A deputation of the passengers headed by me therefore went to him, and begged him to induce the steamship company to send us by small steamer there at hand, in the wake of the one that had already departed. He declined this, however, for not very intelligible reasons. But afterward he told me privately he could not do it on account of his position, for if the steamship company had not complied with his request, all the pashas in the whole empire of Turkey would have said "Haha! Omer Pasha has given an order, but has not been obeyed, haha!" – to which banter he dared not expose himself.

The overland route from Thorn to Teheran, nearly 5,000 kilometers long, was built by Siemens & Halske and Siemens Brothers between 1867 and 1869. It was over this line that direct telegraph traffic between London and Calcutta was opened on April 13, 1870.

The Bosphorus, the Sea of Marmora, the Fresh Waters, the incomparably beautiful site of Constantinople – all these have been so well described and are so familiar to the reader that I had better be silent about them. In spite of the splen-

An overall view of Tiflis, around 1850.

dor and grandeur of its situation, which betrays at first glance that nature intended it as the seat of a world empire, looked at from the sea, Constantinople with Pera opposite makes no cheerful or elevating impression. Nobody would say "I have seen Constantinople and now can die!" Probably the dark cypresses with which the Turk adorns his burying places, rising everywhere in large groups between the houses, give an air of gloom to the aspect of the city in spite of its glorious environment. It may also be the mental effect of the melancholy history of the place, or the presentiment that the struggle for Constantinople will one day set Europe in flames – in short, the sight of Constantinople excites our admiration indeed, but it does not delight us like that of Naples

Werner to William, October 29, 1865

The situation of Constantinople is heavenly, St. Sophia is divine, the city itself and its contents are shocking – voilà tout!

A map of the Caucasus showing the route of the Indian line and the location of Kedabeg. The undersea cable along the Black Sea coast to Sukhum-Kalé was destroyed in an earthquake and replaced by a land line along the coast in 1871.

or many another finely situated city. The prominent architectural structures also, such as the building of the ancient seraglio at the Golden Horn and even St. Sophia, have nothing stimulating or cheering about them, although they are imposing by reason of their size. The dome of the ancient church of St. Sophia indeed rises mightily above the sea of houses, but at a distance one perceives only the dome with its unornamental pillars, looking ungainly.

The external appearance of St. Sophia has been sacrificed to the beauty of the interior, which is indeed grand and sublime beyond all conception. Never has an architectural structure or any work of art, nay, hardly one of the grandest of nature's beauties, made so overpowering an impression upon me as the dome of St. Sophia seen from within. One altogether forgets in looking at it the heavy weight of the roof, which spans the wide square below, and receives an impression as if the dome, floating weightless over the large open space, were a gently curved lace veil, which only touches the rounding with the fine points of the edging. This illusion is produced by the dome resting on a number of short and narrow pillars, between which the dazzling light enters, causing the base of the pillars to appear like lace. I could only with difficulty free myself from the magic which this floating roof exerted on me, and must confess that thereafter the high vaulted dome of St. Peter's, with its heavy superstructure and massive symmetry, made no particular impression on me. In St. Peter's, one wonders that it is so much greater than it seems, while St. Sophia on the contrary appears greater than it is in reality, and thus the beholder is carried away in admiration of this sublime and by no means oppressive grandeur.

I was pleased during my stay in Constantinople to meet several of the officers who had already been sent there by Frederick William III to reorganize the Turkish Army, and to find among them some with whom I was acquainted in my military period. These officers had without exception remained Christians and true Germans, while the noncommissioned officers who had gone with them to Constantinople had in part become Mohammedans, and in consequence had already risen to higher grades in the army. One such renegade I met in Trebizond, whither I proceeded in the steamer going to Poti, after tarrying a few days in Constantinople. I there visited the Prussian consul, Herr von Herford, who was well known to me in Berlin. He considered it proper that I should pay a visit to the pasha of the place, who was entrusted with the special commission of constructing a high road to Persia. To my question whether the pasha was inclined to receive us, the answer came that he was at the moment occupied in his harem inspecting female slaves who were offered for sale; he would, however, after the lapse of an hour, receive us in his riding ground. When the consul presented me to him there, the slender fair-haired man, who was still in the prime of life, seemed somewhat familiar to me. The pasha must have had the same feeling; he scrutinized my face for some time and then asked if formerly I had been a Prussian officer garrisoned in Magdeburg. When I answered in the affirmative, he asked if I remembered about twenty years ago having had an order to inspect the lightning conductor of a powder magazine placed in the fortifications; he had been the pioneer sergeant who conducted me there. I had only a dim recollection of this, but could not help wondering at the pasha's excellent memory for faces. When the consul thereupon made mention of the great engineering task which the pasha had in hand, the latter proposed our taking a ride with him along the new road on some Arab horses he had just purchased, a proposal to which I assented with pleasure. It was a splendid ride at a rapid pace that we had on the noble animals, first on the seashore, then on the really beautifully made road in a charming valley with luxuriant vegetation. When about an hour had passed, the valley narrowed, and the road appeared to make a sharp bend. Then the pasha moderated the pace of his steed, and remarked that the evening was already far advanced and he must return, as he still had some business to attend to. Perhaps the purchase of the slaves was not yet completed, as the consul whispered to me. I was seized, however, with a great curiosity to see how the country would open out beyond the bend of the valley, and called to the pasha that I should like to take just one glance around the corner, as the beautiful landscape exceedingly took my fancy. But when at full gallop I reached this corner, I found to my great astonishment that the road came to a sudden end. Of course I immediately turned back and in a few minutes caught up my companions. The pasha evidently regarded me with some suspicion, but I was so full of the beautiful view which I had enjoyed around the turning that he was soon at his ease again, and took leave of me in very friendly fashion, as an old acquaintance. Afterward, however, the consul asked me if I had also seen where the road ended – the pasha had pocketed the continuation!

Trebizond is magnificently situated at the foot of the Armenian tableland, with a rather abrupt and broken descent along the entire coast. The beauty of its situation is very considerably enhanced by the exceeding luxuriance of the trees and shrubs, which characterizes the whole region. Perhaps I should have been still more enraptured with the town, had not Bodenstedt's enthusiastic descriptions raised my expectations to somewhat too high a pitch. My journey from Trebizond on the following day, favored by the finest weather, lay along the steep, beautifully shaped shore. We steamed past Kerasoun, the celebrated cherry city, from whose heights Xenophon's Ten Thousand had beheld the heaving sea and cried "Thalatta!" At Batoum our vessel reached its destination; then we were ferried across in a small coasting steamer to harborless Poti.

Batoum has indeed only a small harbor, but it is thoroughly safe, easily accessible even in bad weather, and has a very fine situation, with wooded mountainous country in the rear; whereas Poti lies at the mouth of the Rion, the Phasis of the ancients, in a wide marshy plain, and possesses no harbor at all, but only a roadstead, which must be avoided by vessels in windy weather on account of the shallow water. Thrice has the Russian government made the costly attempt to construct a breakwater, to afford some protection to vessels, but all these attempts have been fruitless. The wicked world asserts that the first mole made of wood was eaten by the bore worm, the second of cement by the seawater, and the third built of granite by the generals! Although the last assertion must be regarded as a bad joke, for in reality the immense cost of the stone dike arrested further progress, yet these repeated failures illustrate the necessity felt by Russia to obtain possession of the only available harbor on the coast, Batoum, because thereon depended the further development of the whole Caucasian territory. The acquisition of Batoum alone would have been a sufficient equivalent for the cost of the last Turkish war. I was met at Poti by my brother Walter, in whose company I now continued the journey to Tiflis, which both then and also three years later, when I made a second journey to Kedabeg, was attended with serious inconveniences. One had to go first in a river steamer up the Rion as far as Orpiri, a place which was exclusively inhabited by a Russian sect consisting of beardless men, who had been brought thither from all parts of the Russian empire. Apart from the interesting omnium-gatherum of the most varied nationalities and tongues on board the vessel, the only noticeable thing which presented itself on the voyage up the Rion was the sight of a really impenetrable, swampy, primeval forest on both banks of the river.

From Orpiri we drove to Kutais, the ancient Kolchis, which is situated on the slope of a mountain range connecting the Greater with the Lesser Caucasus, on the border of the Rion Valley, in surroundings pleasing and beautiful.

High above Kutais towers a famous monastery named Gelati, which is considered to be one of the oldest in Christendom, and is said to be built on a site regarded as sacred since the gray dawn of time. I visited it on my second journey, and found myself richly rewarded for the toil of a fatiguing ride, which brought me to the monastery situated some thousand feet above the level of the sea. The monastery, now for the most part fallen into ruin, commands a splendid prospect, and is especially celebrated through a small temple resting on four granite columns, each of which belongs to a peculiar architectural style. This temple is said to date from an extremely remote period, as generally the age of many architectural remains in the Caucasus is not to be reckoned as in Europe by centuries, but by thousands of years. Although a certain allowance must be made for exaggeration, yet all one sees and hears indicates that the Caucasus is one of the primeval seats of human civilization.

Kutais now has a railway station, and Tiflis is easily reached in a single day from Poti or Batoum. At that time, one thought oneself lucky to have at least a new road over the Suram mountains, by which the former very troublesome journey was considerably facilitated. As compensation, the Suram Pass was extremely picturesque, and afforded the most enchanting views. Here the undergrowth of the forest and the more open parts thereof consist entirely of rhododendrons and of the arborescent yellow-flowering azaleas of the Caucasus, both plants which present a most charming spectacle, in the flowering season, and fill the air with overpowering perfume. If in addition one imagines bluff walls of rock, often rising almost perpendicularly to a height of many hundreds of feet, and frequently covered from top to bottom with rank old ivy, an idea may be formed of the charms of this region. On the other hand, the Georgian tableland, upon which one enters after crossing the Suram mountains – the high road to Tiflis following closely the course of the Kur – has no particular beauty; it is stony, often rent by chasms, and poor in vegetation. Nevertheless, one is reconciled to the barren environment by the ever-recurring view of the snowy peaks of the Great Caucasus, which even from the sea afford a glorious spectacle.

Tiflis, traversed by the river Kur in its deeply cut course, leans to the north against a precipitous mountain wall, which is doubtless the main cause of the insupportable heat felt in the town during summer. Hence every inhabitant of Tiflis who can at all afford it possesses for the hot season a second dwelling, placed some thousand feet higher, which he only leaves to attend to business affairs in the town. Properly speaking, Tiflis is composed of two entirely distinct towns, the upper European, and the lower Asiatic, divided from each other by well-defined boundaries. The European Tiflis delights to style itself proudly "The Paris of Asia," or at least claims this title of honor immediately after Calcutta. It has indeed a thoroughly European appearance,

View of Tiflis. Undated.

being mainly inhabited by Russians and Western Europeans. In this part are situated the imperial residence, the theater, and all the government buildings. The adjoining town, on the other hand, is in appearance and population purely Asiatic. The reason why Tiflis in very early times became a seat of civilization is doubtless to be found in the famous hot springs, which possess an even higher importance for Orientals than for Occidentals.

From Tiflis, our course lay along a tolerably good highway to Axtapha, where the road to Baku via Elisabethpol branches off from that to the Goktcha Lake and to Persia, and the vast steppes extending to the Caspian Sea begin. On account of the high temperature, we chose to continue our journey in the early morning, and ordered the horses for 3:00 a.m. The postmaster energetically opposed this, however, as a band of robbers was rendering the country unsafe. Even to the present day, the Russian government has not entirely succeeded in suppressing brigandage in the Cauca-

Werner von Siemens and his second wife, Antonie (1840 – 1900), née Siemens, and daughter Hertha (1870 – 1939), around 1887.

sus. The Tartars of the steppes and of the neighboring mountain regions, in spite of severe punishments, cannot be weaned from it. Just now, in the summer of 1890, when on the point of making a third journey to Kedabeg with my wife and youngest daughter, I get the news that a band of robbers is carrying on its nefarious practices in the neighborhood of our mining works and has given occasion for extreme measures against them.

The predatory inclination of the Caucasian tribes, ever manifesting itself afresh, has its root in the habits and sentiments of the population of a country in which the bearing of arms still forms a man's pride. Plundering is there considered more as a prohibited sport than a crime. As knights in the Middle Ages deemed it compatible with their dignity to snatch his wares from the peddler on the high road, and to fleece the people of the towns, so the Caucasian Tartar yearns to roam on his steed as a free man through forests and over steppes, and to take by violence whatever comes in his way. It often occurred at Kedabeg, where the Tartars belong to the best and most reliable workmen, that pitmen, who had labored industriously for years and almost without interruption – the Moslem sect of the Shiites to which they belong having only one feast day in the year and no Sunday – suddenly disappeared when they had saved enough money to buy a horse and weapons. Sometimes they returned after a length of time. It was known that in the interval they had been practicing brigandage, yet this did not prevent them from becoming excellent workmen again, if they had been unlucky in their predatory occupation, or had lost the taste for it.

The warnings of the postmaster at Axtapha were not strong enough to detain us, but we continued our journey in the cool starry night with fleet horses, and trusted to our good revolvers, which for precaution's sake we held cocked in our hands. My brother Walter, however, whom the novelty of the situation did not keep awake like myself, was not able to resist fatigue very long, and soon slept the sleep of the just. Suddenly there rang from the box of our low springless open wagon, on which my brother's servant was seated beside the driver, a loud cry of "Robbers!" At the same time, I saw in the gloom a white figure galloping straight toward us. My brother awoke in consequence of the shout, and without any reflection discharged his revolver at the figure, now close in front of our horses and himself shouting loudly, fortunately without hitting him. As it soon appeared, it was no robber but an Armenian who imagined himself pursued by robbers, and had dashed toward us in search of protection. The Armenians generally pass in the Caucasus for very shrewd and smart men of business who possess little courage, and perhaps for this reason like to equip themselves in as martial a fashion as possible on their journeyings. As it seemed, the gang of robbers which had terrified our Armenian existed only in his imagination. His lack of caution, however, might easily have cost him dear, and the fault would have been entirely his own, as according to the custom of the country it is an understood rule that one must never approach chance travelers on a journey at a rapid pace.

Shortly after this exciting incident, we were delighted by a remarkable natural phenomenon. A brilliant luminous apparition suddenly arose right before us on the horizon of the boundless steppe. It gleamed with a magnificent many-colored light, but was distinguishable from a meteor by its remaining immovable at the same point of the heavens. We racked our brains as to the cause of the phenomenon, which we could only compare to a parachute rocket with colored fire. It soon, however, became weaker, and after a short time shrank to the dimensions of a bright star. It was the rising Venus, which appeared so remarkably magnified and colored through the mist of the steppes and the darkness in which the earth is still veiled in those southern regions even shortly before sunrise.

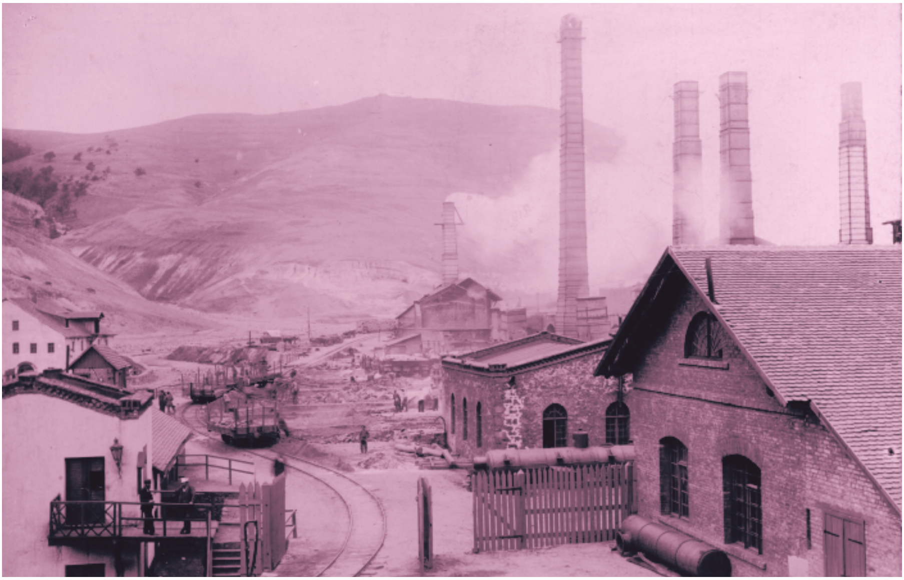
We passed the night in the Swabian colony of Annenfeld, which lies or rather lay at the foot of a steep declivity leading to the Kedabeg mine, near the Kur. It was a very fertile but not very salubrious region, and the colonists afterward abandoned the place and built for themselves a new village about five hundred feet higher up the slope of the mountain. There exists in the Caucasus a certain number of such Swabian colonies, I believe six or seven, Tiflis also being one of them. They owe their origin to some rigid Lutherans from Swabia, who left their fatherland in divers groups in the first decade of our century, and were desirous of migrating through Austria and Russia to the promised land, where, according to the belief of their leaders, earthly and heavenly joys awaited them. The Russian government of the time, however, set great store by the immigration of good German husbandmen into the Caucasus; it therefore stopped the columns, and induced them to send a delegation under escort to Jerusalem, to make previous inquiry whether land really suitable for them was to be had there. When, after a rather long interval, the delegation returned, it could only advise that the march to the promised land be discontinued, and as the Russian government granted the people large and fine tracts of land gratuitously, the Swabians settled there, and always remained the true Swabians they were at the time of the emigration. It comes upon a traveler as a great surprise to find in these Swabian settlements pure and unadulterated old Swabian customs and language. One fancies oneself suddenly transplanted into a village in the Black Forest, such is the appearance of the houses, the streets, and inhabitants of these colonies. It is true I found it difficult to understand their dialect, as I had not then studied it, as is now in some measure the case after twenty years' marriage to a Swabian lady. But I learned from a genuine Swabian that he too only understood it with difficulty, as it was the dialect spoken at the beginning of the century, and not the present one, much changed through the influence of time. With the language the people have also retained all their customs and usages, just as they were at the time of the emigration. They are, as it were, fossilized, and bitterly fight against all changes.

It looks, however, as if this immutability of national custom and language were a general characteristic of the Caucasus, which presents a real mosaic of nations. Besides the larger, sharply separated tribes, there are a number of quite small ones, inhabiting secluded and almost inaccessible mountain valleys, who have faithfully preserved both language and customs, which from time immemorial have been altogether different from those of all the neighboring peoples. Further, there exist in the Caucasus numerous Russian colonies, composed of sects which have been transported there from all parts of Russia in an endeavor to preserve the uniformity of the state religion, and these are united in separate settlements. After more than half a century, these too have still retained quite unchanged their language, creed, and customs. The most widespread of these sects are those of the Dukhobortsi and Molokani, which like those of the Swabians take their stand on definite and peculiar interpretation of biblical passages. They are excellent workmen, and orderly people, when not carried away by fanaticism.

The Molokani are almost without exception artisans, especially cabinetmakers, the Dukhobortsi on the other hand good husbandmen and drivers. The proximity of a colony of Dukhobortsi has always been of inestimable value to Kedabeg. Once only in the year do the people refuse to work, viz.

when their queen proceeds from one colony to another and celebrates religious festivals with them. These seem to lay great stress on earthly bliss, perhaps only to give the faithful a faint idea of the anticipated and infinitely greater joys hereafter.

From Annenfeld, a steep and not very well made road leads up to Kedabeg. At a height of about 1,000 meters a fertile undulating plain is reached, broken by small mountain ranges, formerly covered by fine forests of oaks, limes, beeches, and other leaf-bearing trees. Since the cessation of the Persian rule, the traces of which are especially recognizable in the numerous ruins of works of irrigation, the woods here, as in most of the elevated plains of the country, have been entirely extirpated; the reason being that, in the hot season when the grass dries up, and likewise in the winter when the steppes are covered with snow, the shepherds drive their herds up the mountains to let them browse on the young shoots. For this purpose they simply fell the trees,



The Kedabeg copper mine in the Caucasus, around 1865.

and let the cattle eat the buds and twigs. In this manner a single herd often annihilates square versts of luxuriant forest. The managers of our foundry have accordingly always experienced the greatest difficulty in preventing these devastating herds from destroying our woods, on which, in the absence of coal or other combustible material, the preservation of smelting is wholly dependent.

The smelting works stands by a small mountain brook, which below Kedabeg forces its way abruptly through the ridge separating Kedabeg from the exceedingly beautiful Shamkhor Valley. In the valley through which it rushes lie the ruins of a small Armenian fortress, while at about the level of Kedabeg the Shamkhor Valley conceals an old Armenian monastery, which was then still inhabited by a few monks. At present the appearance of Kedabeg, as seen by anyone ascending from the valley, after crossing the last mountain slope and passing an old cemetery on the way, is most surprising. What presents itself to view is the thor-

Smelting furnaces in Kedabeg. Undated.

oughly European spectacle of a small picturesquely situated manufacturing town with huge furnaces and large buildings, among them a Christian chapel, a school, and an inn fitted up in European fashion. There is also a railway carried over a lofty viaduct, connecting the branch smelting establishment of Kalakent, some thirty kilometers off, with Kedabeg and the neighboring metalliferous mountain. This remarkable spectacle of a modern civilized center in the midst of the wilderness has made Kedabeg a regular place of pilgrimage for the inhabitants of the country as far as the interior of Persia. When I visited it for the first time, the appearance of Kedabeg was certainly a very different one. Except for the wooden dwelling house of the managers, which struck the eye through its position on a commanding height, only a few smelting furnaces and administrative buildings were visible. The workmen's dwellings were only distinguishable by wreaths of smoke on the mountain slopes, for they all consisted of earth-covered pits.

In eastern Caucasia such pits serve almost exclusively for dwellings. They are, properly speaking, wooden houses, which are built in a pit and covered over with a layer of earth a yard in thickness, so that the whole looks like a molehill. In the middle of the roof a chimney peeps out, which affords an exit for the smoke from the one room, and apart from the entrance is at the same time the only admitter of light. For the rest, such caves are sometimes quite elegantly made. In a visit which, in company with my brother and the smelting director, I paid to a neighboring "prince" – so the larger landed proprietors of the district are called – we were introduced into a reasonably spacious saloonlike room, the floor of which was covered with handsome carpets, while the interior partitions were formed of Persian carpets suspended after the manner of tapestries. Opposite the divan was the fireplace, above it the aperture in the roof. Behind the carpets there was a stir of life, and every now and then we heard the voices of women and children. The prince received us

Ore smelting furnace No. 3 in Kedabeg, around 1880.

with great ceremony and made us sit on the divan, while he himself settled in front of it. After a short conversation through the medium of an interpreter, carried on with all the forms of oriental politeness, we were desirous of departing, but our intention met with very serious resistance. Soon after our entry, we had heard the bleating of a sheep, and at once surmised that it was being slaughtered in our honor. In fact the prince signified to us, with a very grave countenance, that he hoped we should not so offend him as to depart from his abode without having partaken of his hospitality. We were therefore obliged to wait patiently till the *shishlik* was ready, which was prepared before our very eyes. This preparation took place in the usual very primitive fashion. The flesh of the freshly slaughtered sheep was cut into cubes about the size of a walnut, which were then arranged on an iron ramrod and interlarded with discs of fat from the fatty tail of the animal. Meanwhile, a wood fire was made

Log cabins and sod huts in Kedabeg, typical of the housing in 1864, when Werner and Carl Siemens bought the copper mine. Ten years later, most workers were living in houses of stone. Kedabeg had become a European model town, and the copper mine was one of the most modern of its era.

between two stones, and when only the glowing embers remained from it, the prepared ramrods were laid across the stones and frequently turned. A few minutes after, the meal was ready, and each guest according to his fancy took cubes from the garnished ramrod presented to him. Such a *shishlik,* if the sheep is not too old and especially is quite recently killed, is very tender and savory; it always forms the basis of Tartar and Georgian meals, or what we should call the *pièce de résistance.*

The large underground stables in the Caucasus are constructed in precisely the same way as the underground abodes of princes. I had already made their acquaintance at one of the post stations during the journey, where I was reminded by the neighing and trampling of horses that I was walking over a stable. The coolness of the underground habitations in summer and their warmth in winter is extolled, and it has cost the directors of the smelting works in Kedabeg much trouble to accustom the Asiatic workmen to

A view of the town of Kedabeg, end of the 19th century.

stone houses. When at last, with the help of the women, this succeeded, the difficult workman question was therewith solved. For as the people there have only very few wants, there is no reason for their doing much work. When they have earned sufficient money to secure their maintenance for a few weeks, they cease to work and take their ease. To cope with this, there was only one recourse, viz. to accustom the people to needs the satisfaction of which could only be attained by continuous labor. The lever was afforded by the natural inclination of the female sex for a pleasant family life and their easily awakened vanity and love of dress. When a few simple workmen's houses had been built, and we had succeeded in quartering therein a few couples, the women soon found pleasure in the greater convenience and comfort of the dwellings. The men also found it an advantage not to have incessantly to take measures for securing their roofs from the rain. Further care was taken that the women should be able to procure all sorts of small appliances, which made their life in the house more comfortable, and themselves more attractive to their husbands. They had soon acquired a taste for carpets and mirrors, and improved their toilet; in short, they experienced wants for the satisfaction of which the men were now compelled to provide, and in so doing they were very well pleased with the change. This excited the envy of the women still dwelling in their caves, and before long there was a general rush for the workmen's dwellings, which of course necessitated the building of houses for all the permanent workmen.

I can only urgently advise proceeding on the same lines in our present colonial efforts. The man without wants is hostile to all improvements of civilized life. Only when wants are awakened in him, and he is accustomed to work for their satisfaction, does he form a promising object for social and religious civilizing efforts. To begin with the latter will always yield only illusory results.

When, three years later, I again visited Kedabeg, I found a quite considerable place of European aspect already arisen out of the troglodyte settlement. The bulk of the workmen were still nomadic, certainly, but this has remained the case even to the present day. These are people who principally come from Persia after the end of the harvest, work industriously in the mine or in the smelting house, but pass on when they have earned the necessary money, or when they are wanted at home. Now, however, there is a regular laboring class, which ensures the continuation of the necessary work at all times. The officials of the mine were Germans almost without exception, among them a sprinkling from the Baltic provinces of Russia. The business language has therefore always been German. It is comical to hear Tartars, Persians, and Russians murder the somewhat corrupted German names of implements and operations and even the terms of abuse common among the miners of the Harz.

The mountain, rich in sulfurated copper ore, is situated in the neighborhood of Kedabeg, and is connected with it by a so-called haulage line. Moreover, as has already been mentioned, a narrow-gauge line has been constructed by us, running far into the forests in the river valley of the wild Kalakent stream and yielding wood and charcoal to the beautifully situated branch smeltery at Kalakent, and from there to the wood wharves on the Shamkhor. For many years this mountain railway ensured a supply of combustible material, but carefully, as the cleared spaces were replanted in accordance with the principles of forest management, yet at last want of wood threatened to bring the smelting works to a standstill. However, necessity itself is usually the best helper in emergencies; which also held good in this case. We have recently succeeded, I believe for the first time in the world, in replacing coal for smelting by the raw material of petroleum, naphtha, and by masut, the residuum in the distillation of petroleum. These combustibles are brought from Baku by the Tiflis line, which has been in existence for some years, to the Shamkhor station at the foot of the mountain. With their help the roasted ore is smelted in large round furnaces, 20 feet in diameter, and worked up into copper. An electric refining establishment at Kalakent transforms the raw copper thus obtained into chemically pure copper, whereby the silver contained in it is obtained as a secondary product. As, however, it is difficult in winter and during the rainy season to bring masut and naphtha up the mountain from the railway station to Kedabeg along the impassable roads, a conduit has been constructed of Mannesmann's* weldless steel tubes, through which the masut is pumped about 1,000 meters up the slope from the plain. I hope personally to see this contrivance in action this very autumn. Furthermore, the necessary arrangements have now been completed for transforming the poorer ores, hitherto not paying for their working up into refined copper, according to a new process of my own, by a purely electrical method without the employment of combustible materials. For this purpose, large turbines of

** Werner von Siemens took part in the foundation of the "Mannesmann-Röhrenwerke" (Mannesmann pipe mill).*

over thousand horsepower have to be set up in the neighboring Shamkhor Valley for working the dynamos, which generate the necessary electric current. This current has to be conveyed over the ridge, about 800 meters high, dividing Kedabeg from Shamkhor, in order to extract and precipitate the copper from the powdered ore by electric current, at the very foot of the metalliferous mountain. When this arrangement, already elaborated in detail theoretically and practically, is ready, there will exist in the distant Caucasus a smeltery preeminent in the scientific industrial arts, and able to cope successfully with the disadvantages of its site.

It may easily be imagined that the results obtained by us in Kedabeg would bring us offers of metalliferous property from all sides. Although my brother Carl was as little inclined for further undertakings as I myself, Kedabeg having already given us cares enough, yet we could not always reject the invitation of people of influence to take a look at the proffered seams. When, after the death of my brother Walter, who died very suddenly after a severe fall from his horse, I traveled for the second time to Kedabeg in the autumn of 1868, I was in this way induced to make two tours in the Great Caucasus. One of these in particular, from Sukhum-Kalé to Cibelda, was of uncommon interest to me.

The Elbrus, 18,000 feet* high, the loftiest mountain in Europe if the crest of the high Caucasus range be taken as the natural limit of this part of the globe, is visible in its full height from a few points only, being surrounded by a circle of lofty mountains. The interval which separates it from this circle is accessible at only a few places, and is again cut up into different parts by several radial ridges, which render all human intercourse impossible. Among these, Cibelda is a natural impregnable fortress, which can be defended by a handful of men against whole armies. Long after the rest of the Caucasus had fallen into Russian hands, and the Circassians who would not bend beneath the Rus-

** Today's elevation: western peak 5,642 meters (18,510 ft.), eastern peak 5,621 meters (18,442 ft.).*

sian yoke had emigrated to Turkey, Cibelda remained still unconquered in the possession of its scanty population, forming a tribe by themselves. The Russians had conquered all apparently impregnable fortresses of the western Caucasus by the construction of roads, which afforded them convenient access into the parts to be subjugated. Cibelda, however, withstood also the attack by the military road, but hunger and the tempting proposals of the Russian government finally induced them to voluntarily evacuate their fortress, whereupon they likewise resolved to emigrate to Asia Minor.

Otto Siemens (1836 – 1871) earned his doctorate in chemistry in 1861. After his brother Walter died, he became the North German consul in Tiflis. Undated.

About a year had elapsed since this emigration, when General Heymann, governor of Sukhum-Kalé, invited my brother Otto, who had stepped into Walter's place in the business and also been appointed German consul in his stead, to make an examination of some deposits of copper and silver ore in Cibelda. When, in September 1868, I came to Sukhum-Kalé with brother Otto and my expert, the recently engaged director DANNENBERG, whose introduction to his new office was the main purpose of my journey, the general renewed his request, and promised to make our journey to Cibelda as easy and safe as possible. I could not resist the temptation in this way to visit the very center of the high Caucasus, which, as was said, had never before been trodden by the foot of a native of Western Europe. For the purpose of taking us to the metallic deposits a small military expedition was therefore equipped, under the command of a young Russian captain who had superintended the exodus of the population from Cibelda.

Sukhum-Kalé, i.e., the "Sukhum fortress," lies very picturesquely on a small rocky bay at the foot of the lofty ring of mountains girding Elbrus. Its surroundings are entrancingly beautiful, above all its vegetation, whose luxuriance defies all description. In the place itself my admiration was excited by a long avenue of weeping willows, the height of which vied with that of our loftiest forest trees, their massy branches hanging down from the domelike tops to the ground. Unfortunately, in the year 1877 this splendid avenue fell a sacrifice to the Russo-Turkish war. The way taken by our well-mounted expedition led immediately behind the town, up the valley of a small mountain stream studded throughout with magnificent trees. It struck me that the mighty oaks and chestnuts, especially in sunny places, frequently had a perfectly brown envelope which shut out all sight of green leaves. This was because of the wild hops, which covered them to the very summits, and gave them this hue through their large ripe umbels. As I knew the great value of the hop, I proposed to General Heymann on our return that these hops should be gathered by his soldiers, and sent as samples for examination to Germany. The general did so, but the trial, as I may as well state at once, unfortunately proved unfavorable. It was not then known to me that wild hops possess no bitter principle; this is only obtained from the fruit of the female plants when all the male plants are carefully kept apart, which of course is never the case with wild hops.

Our bridle path took us upward the whole day through equally beautiful scenery, untouched by human culture. At the same time we were often refreshed by enchanting distant views of the lofty snow-covered mountain chain, rising gradually before us, and the glittering mirror of the sea, lying at our feet. Toward evening we reached one of the small fortified Russian encampments whose continual advance on the newly made military roads was the means whereby the Russian forces finally broke the resistance of the brave Circassians.

Next morning, we continued our ride at sunrise, and now approached the lofty chain. We had frequently occasion to admire the bold construction of the roads by the Russians; obstacles were overcome which at first glance appeared altogether insurmountable. We reached without much difficulty the border of the district already designated by the name of Cibelda, which forms the foreland of the high stronghold of that name. To this there was only a single entrance along a deep cleft in the mountains, at the bottom of which a wild mountain river took its raging course. The cleft was bordered on the side whence we came by a rocky wall, certainly more than a thousand feet high, almost perpendicular and probably over a verst in length. About halfway up a horizontal shelf had been formed which was just broad enough to serve at need as a bridle path. This path was the only approach to Cibelda; we were therefore obliged to pass along it. The officer rode forward after advising us not to look into the chasm, but always at the head of the horse, and to let it go quite by itself. In profound silence we successfully reached about the middle of the defile; at the edge of the path some vegetation had settled, whereby the view of the yawning gulf was diverted. Then I suddenly observed that the forepart of the horse of my front man, the officer, was quite low down, and at the same time saw the latter swing himself gently from the saddle to the side of the rocky wall. The horse too did not lose its steadiness, but raised itself again, and continued its way by the side of the officer. Of my own accord I considered it advisable to do just as my front man, and also glided from my horse to the side of the rocky wall. When I had successfully passed the dangerous spot where the officer's horse, misled by the vegetation, had made the false step, I looked with anxiety after my brother, who followed me, but perceived to my relief that not only he, but the whole column of riders, had already followed our example. In this manner we all reached the end of the narrow pass in safety, and soon recovered from our toils and alarms by the enjoyment of a good meal, partaken in an enchantingly beautiful moss-covered grotto, open toward the deep and tolerably broad river valley.

From this point, the path ceased altogether, and it was utterly incomprehensible to me how our guide could find his way in the splendid primeval forest through which we now had to wend. The formation of the ground on the next stage of the journey was very peculiar. There were imposing undulating elevations perhaps seven hundred feet high with a bend from east to west, which we had repeatedly to cross. Their southern slopes were adorned with splendid trees, mostly oak, chestnut, and walnut, whose summits formed so perfect a roof that the plague of lianas and other creeping plants was precluded. The trees were of enormous dimensions. It is probable that human hand had never influenced the natural course of their growth; and, accordingly, old withered giants stood beside the verdant and flourishing, while trees of a younger generation overshadowed the mighty trunks lying on the ground, doubtless felled by storms. It often cost a good deal of trouble to evade such a dead tree barring the way, for summit and root formed at their ends an effective abatis. Many of these prostrate trees were so thick that a mounted rider was only just able to see beyond them. Now and again they were luckily arched in such a position that we could pass under them.

An altogether different picture was presented to us when we had crossed the summit of such a ridge, and had to come down again on its northern slope. Here the sun had not had the power to dry the ground. The whole slope was marshy in spite of its steepness, so that the horses' hooves stuck fast in the tenacious soil, and we were frequently obliged to dismount and assist our horses. Numberless creeping plants also thrived here, forcing us to make wide circuits; and the places sought out by us which were free from creepers on account of too much moisture bore a vegetation of reedlike plants of such a height that they overtopped horse and rider.

Once, the ground became so steep that the horses could not proceed. I could then not help admiring the cleverness of our Russians. They sought out a particularly steep and slippery spot, and cautiously let down the horses one by one with ropes attached to their tails, while we ourselves slid down without any such check.

At the next ascent, I made the discovery that the tail of the Caucasian mountain horse plays a further important part in difficult mountain tours. We were obliged to climb up the particularly steep height on foot, to spare the already much fatigued animals, which had necessarily to bring us to our goal before sunset, and I soon found myself at the end of my strength. In my distress it occurred to me to grasp the tail of the horse clambering quite cheerfully beside me up the stony path. That seemed to be a procedure well known to it; it redoubled its efforts, and I attained without difficulty the crest of the hill, where the officer received me with the applauding exclamation “Caucasian fashion!” When I looked back at the rest of my party, I found them also, to my surprise, clinging to the tails of their steeds. At last, as the sun was going down, we reached a narrow rocky gate, which forms the entrance into the natural fortress proper of Cibelda. When we had passed it, there spread before us a spectacle of such grandeur and beauty that it almost overwhelmed me at first. Before us in the clear evening glow lay the mighty Elbrus, covered far down with snow. Right and left beside it a number of further snow mountains were visible, which especially on the right developed into a long chain. Far below us, still partly illuminated by the sun, lay a rocky river valley, which bordered the foot of Elbrus, whose steep treeless slope precipitated toward it in a broad expanse without any visible break. It reminded me somewhat of the view one obtains from Grindelwald over the sun-illumined Alpine chain; only the mighty Elbrus was enthroned in the center of the picture, as if two Jungfraus were piled one on another.

After we had refreshed ourselves with this astonishing and incomparably beautiful view, we traversed the rather extensive plain which spread out before us and contained the aul or village of the tribe of the Cibeldians, who had emigrated the year before. It was not easy to advance on the plain, densely overgrown with burdock of more than a man's height, and to find the way to the aul. A way through the shrubs broken by bears stood us in good stead. That it had been so made could be inferred from the kernels of the fruit of the cherry laurels lying about, which form a favorite food for the bears of the region. The wooden houses of the large aul still stood entire, just as their inhabitants had left them a year ago; only here and there some destruction had been caused by the bears in their search for food.

When we had quartered ourselves, we had first to try to recover a human aspect, for in breaking through the dense vegetation of burs, which had made the former gardens of the aul almost impenetrable, every inch of our clothing as of our beards had become fringed with a layer of burs, so that we ourselves looked more like brown bears than human beings. The removal of the burs was an extremely troublesome and in part painful operation.

After a refreshing night's rest in the abandoned dwellings, our miner investigated the old copper pit, which he declared not to be worth working; but even had it been so in the highest degree, its situation would have made any mining operation impossible. My brother Otto and I had meanwhile fully enjoyed the overpowering grandeur and sublime beauty of the environment. By the morning light one perceived still better than in the evening the wild ruggedness of the exposed surface of Elbrus, with its ice fields and glaciers, to which the lines of the watercourses, rushing down the slopes and glittering in the sunshine, lent a quite peculiar charm. The plateau on which we stood descends abruptly to the river valley, which separates it from Elbrus; on the other sides it is surrounded by high mountains which, in contrast with Elbrus, presented the most luxuriant green of Caucasian vegetation. A walk around the edge of the plain looking toward the river afforded always new views, entirely different from all that went before, and of a sublimity and beauty baffling all description.

The return journey to Sukhum-Kalé we made by the same way as the journey to Cibelda, but in consequence of the previous experience, with less difficulty. Unfortunately, I had now to pay my tribute to the dangerous climate of this incomparably beautiful country. On reaching the Russian fort, where we again passed the night, I felt ill. The young military doctor who accompanied us at once perceived that I had caught the dangerous fever of that region, and applied without delay the usual remedy. Before the fever had fully developed, I received a powerful dose of quinine, which caused severe singing in the ears and other unpleasant sensations, but brought down the fever to a mild form, so that I was able to complete the journey. The fever in the district of Sukhum-Kalé is a tertian ague; on the third day I therefore had to take a second, somewhat weaker dose, with the direction to take after a further three days a third, still weaker one. The fever was thus cut short; however, I often suffered subsequently from intolerable pains in the side, as the doctor had prognosticated.

In former years, I had repeatedly suffered from intermittent fever, which obliged me to take small doses of quinine for several months, thereby seriously impairing my health. In the Caucasus, where climatic fevers occur often and in the most varied forms, the treatment described is always applied with the best results. Certainly there are also fevers in this district so malignant that they end in death on a first attack. The fever-producing regions are indeed as a rule marshy and covered with luxuriant vegetation, but highly situated dry grassland also often passes for unhealthy. I have in my journeys made the observation that such regions mostly bear the traces of an old, highly developed civilization, as is indeed also the case in the vicinity of Rome and in the Dobrudja, which in old times was styled the granary of Rome. When the soil is stirred up, fever breaks out in those regions with special severity. The fever germs must have been gradually formed in the fertile well-manured soil, which was subsequently left unworked for centuries, and excluded from the air by a covering of grass. Malaria accordingly represents nature's penalty for interrupted cultivation of the soil. This, in conjunction with the Caucasian treatment of fever, led me even then to the opinion that climatic fever depends on microscopic organisms which live in the blood, and whose term of life would coincide with the interval between the attacks of the fever. By the strong dose of quinine shortly before the attack the young emerging brood of these organisms is poisoned. The remarkable fact also that people who have long lived in a fever region are for the most part secure from fever, but lose this immunity when they have passed several years in regions free from it, could,

A residential building in the Caucasus, around 1890.

I thought, be explained by the assumption that in regions where the fever germs are continually being introduced into the body, living beings are formed therein which feed on these germs, and therefore perish when the source of nutriment is dried up for a long time. This, of course, was only an unproved hypothesis, which justly was regarded as such by my medically trained friends such as Du Bois-Reymond to whom I communicated it at the time. I have nevertheless been gratified to see the bacteriological researches of eminent scientists taking of late the direction indicated by me a quarter of a century ago.

Our second tour in the Great Caucasus had likewise reference to the investigation of a metalliferous property, situated in a very inaccessible region, belonging to a princely family of Georgia. We traveled from Tiflis to Tsarskie-Kolodzy, where our Tiflis branch had petroleum works which were given up after the completion of the railway from Tiflis to Baku. From there our way lay to the wine country Kakhetia, celebrated for the fiery Kakhetian wine. This district lies in the valley of the Alasan, and is separated from the Kur Valley by a ridge stretching far into the steppes. From the summit of this ridge we had magnificent views of the Caucasus, which from there presents itself as an unbroken chain of white peaks reaching from the Black to the Caspian Sea.

Kakhetia passes for the primeval land of the vine cultivation, and in the chief place of the country ancient thanksgiving festivals take place which recall the Roman Saturnalia. High and low from all Georgia then flock together to the festive place and offer the god Bacchus copious libations of Kakhetian wine, when universal brotherliness is said to be the order of the day. It is also vaunted of Kakhetian wine that it exceedingly gladdens the heart of its persistent drinkers, and those who know the country profess to recognize the inhabitants of Tiflis everywhere by their hilarity.

We accomplished the pleasant and interesting ride through Kakhetia under the guidance of two sons of the princely family which had invited us to make an inspection of the deposits. At the foot of the lofty chain the old prince and other sons joined us. The ancestral seat of the family, in which we passed the night, was remarkable. It consisted of a large wooden house at the foot of the mountains, but yet situated in the plain, which was built on posts some thirteen feet high. A convenient ladder, which was lowered, offered the only possibility of getting into the house. It was a regular prehistoric pile dwelling, the style having survived to our own day in the preservative Caucasian air. In the interior of the house we found a large hall, occupying the whole breadth of the building, in which, along the only wall provided with many windows, a table, over two yards in width, stretched from end to end. This table formed the sole furniture visible in the room, and had to fulfill the most varied purposes. For dinner a carpet of about half the width of the table was laid along its edge, on which the viands and flat cakes were placed. The large thin flat cakes served not only for food, but also for table covers and napkins, as well as for cleaning the table utensils. For us strangers chairs were brought in. When we had seated ourselves upon them, the old prince and his sons after him sprang upon the table, and crouched opposite us beside their bread-cloths. Only we guests were provided with knives and forks; the princes ate in true Oriental fashion, with their fingers. The meal itself was extremely savory, especially the *shishlik* fillets, which would have created a sensation in the finest Berlin restaurant. During the meal, Kakhetian wine circulated freely in buffalo horns; it was only rather embarrassing that custom required the draining of the horn in honor of every person whose health was proposed. We Europeans, unaccustomed to such copious drinking, could not long stand that. A second function of the large table in the hall we got to know at nighttime; all the beds, both for us and for the princes, were prepared upon it.

Early in the morning of the following day, we set out and ascended the slope of the great Caucasian chain. Our horses carried us quickly and indefatigably up the rocky way. When it was beginning to get dark, we were almost at our destination and bivouacked on a splendid ridge at the junction of two mountain streams. Under the protective roof of gigantic trees we encamped at a spot which afforded a wide view over Kakhetia, extended at our feet, and the mountain district lying beyond. With surprising skill the prince's satellites erected a hut of twigs over our camping place, leaving the view over the plain free, and made it so comfortable that it would not have been possible to have rested more agreeably. Then the meal was rapidly prepared, which we consumed in a recumbent position. After that the princes and their attendants reclined in front of us, and began a national drinking bout with a kind of mulled wine of generous Kakheian growth. In the course of this, each of the princes drank to my own and my brother's health with some doubtless very flattering words, expecting that thereupon we should also empty our horns. The princes spoke only Georgian, an interpreter translating what they said into Russian for us. No one of those present understood our German answers, a circumstance of which my frolicsome brother Otto took a somewhat dangerous advantage by delivering the replies, which I left to him, in extremely polite fashion indeed as regards voice, tone, and gesture, but with a verbal parody of the whole scene, which assuredly would have been cut short by dagger stabs if his words had been understood, and if we had not taken pains to give a good color to them by grave and respectful countenances.

When, on the following morning, we had happily slept off our little debauch in the refreshing mountain air without any unpleasant aftereffects, we inspected the lode. This was certainly a rich one, but not yet opened up, and owing to the troublesome access it offered insuperable obstacles to profitable working. After we had arrived at this conclusion, the return journey was commenced immediately.

At sunset, we again arrived at the pile-built palace and spent another night under its hospitable roof. The next morning, we took leave of our princes, and rode back through the valley of Kakhetia, with the intention of traveling across the steppe direct to Kedabeg. As robbers were infesting the neighborhood, the chief of the district gave us a body guard composed of men who themselves were not free from suspicion of the robbers' trade. Placed under their friendly protection, we traveled with perfect safety according to the custom of the country.

The crossing of the broad and rapidly flowing Kur, whose left bank we reached at noon, was attended with some difficulty. We found a single small boat there, which could only carry a few persons, but discovered no oars, which moreover with the rapid current would not have been of much use. The mode of crossing employed by our guides was very interesting, and I commend it to the Postmaster General for his description of the postal service in primitive times. The two best horses were driven into the water until their feet no longer touched the bottom. Then two Tartars in the boat laid hold of their tails and had themselves together with the boat and a few passengers carried over the stream by the swimming horses. When, after depositing the passengers, the boat had been brought back in the same manner, they carried over a second batch with other horses, and thus it went on, till only the Tartars remained. Finally these took their horses into the water and let themselves be carried over clinging to their tails.

My brother and I had remained to the last with our somewhat dubious escort on the left bank of the river. Our protectors squatted suspiciously together, and kept throwing glances at us, which we did not altogether like. Cigars, which we offered them, they proudly refused – because, as we found out afterward, being bigoted Shiites they were not allowed to take anything from the hands of unbelieving dogs. It appeared therefore advisable to show to the fellows that we were sufficiently armed for defense. We set up a board that had floated downstream as mark, and shot at it with our revolvers, in the use of which we were well practiced. Every shot hit the board at long range without much aiming. That interested our companions very much, who themselves tried with their long beautifully polished flintlock guns to hit our mark, but did not always succeed. Then came their sheik and gave me to understand by signs that I should show him my revolver, and lay it on the ground, as he dared not take anything from my own hand. This was a critical moment, but on Otto's advice I determined to comply with his request and put down the revolver. The sheik took it up, looked at it on all sides, and showed it with a shake of his head to his companions. After that he gave it back to me with gestures of thanks, and henceforward our friendship was sealed. Distrust of the fulfillment of the sacred law of hospitality may become very dangerous with these people, and on the other hand it is extremely rare that the confidence of the guest is betrayed. It has certainly occurred that a guest has been hospitably entertained and safely escorted to the boundary of the district, and then shot down on alien ground, but that is not considered to be proper. After crossing the Kur, we reached Kedabeg without further adventures.

In all our tours in the mountains we had had occasion to admire the cleverness and endurance of the small Caucasian mountain horses. Indefatigably and without tripping, they clamber with their riders up and down the steepest mountain paths; without them the broken and often fissured mountainous country could hardly be traversed. It is regarded in the Caucasus as safer to make difficult mountain journeys on horseback than on foot. That there are also exceptions to this rule I experienced personally on my second visit to Kedabeg. The autumn weather, always bright and beautiful even up to December, changed with unexpected suddenness to rainy weather with a slight fall of snow. We were just then proceeding to visit the Shamkhor Valley, and made use of the somewhat troublesome bridle path which runs by the side of the wild Kalakent brook as far as Shamkhor. When, however, it began to snow more heavily, we found it advisable to turn back before the path had been quite snowed over. It was astonishing with what accuracy our horses were able to find the mountain path, already considerably covered with snow, which was close beside the deeply cut riverbed, and always selected the particular parts where there was a sure footing. I was riding immediately behind my brother Otto when I noticed that just at a dangerous spot hard by the edge of the bank, here descending perpendicularly several yards, a stone became loose under the weight of his horse. A moment afterward, my horse trod upon the same stone, which thereby was entirely loosened and caused me to go tumbling down. I only remember having heard the cry of the succeeding riders, and then I was standing upright in the riverbed, my horse beside me. According to the statement of my companions, the horse fell over with me onto its side and then came to its feet. It was at any rate a remarkably lucky escape.

Of the homeward journeys, for which on both occasions I chose the route via Constantinople, the first in particular was rich in singular experiences. The fine weather lasted till the middle of December; only after we had left Kedabeg did it change, and on the Rion we encountered a fearful storm. With great difficulty we reached Poti, but there we learned that the steamship which was to convey us further had not put in, as an embarkation in such weather was impossible. We, namely the whole company that had arrived in the river steamer, were thus forced to take refuge for a full week in the only so-called hotel of the place, a most dreary abode. This, I may say, was the most unpleasant week of my whole life. A violent storm raged the whole night, not only outside but also in my room. I repeatedly got up to examine the windows and doors, but found them all closed. The next morning, however, I saw my room full of snowflakes, and discovered that they had penetrated through rifts in the floor. On account of the marshy ground, the houses in Poti are built on piles, which explains the marvel of a snowfall in a closed room. The stormy weather lasted several days without letting up, and what rendered my stay particularly disagreeable was that I had a severe inflammation of the connective tissue of one of my eyes. In the absence of medical aid, this painful inflammation in the midst of the cramped inn parlor filled with people of all classes and nationalities, with bad provisions and a total absence of any kind of attendance, made my life there simply intolerable.

At last the eagerly longed-for steamer came in sight, and in spite of the heavy sea succeeded in taking aboard myself and three other traveling companions. The passage was very stormy as far as the entrance to the Bosporus, and put our seaworthiness to a severe test. All four of us stood it, however, to the great astonishment of the captain. Among the party was a Russian general, consul in Messina and, as I discovered later, father of a very charming daughter, now the wife of my friend Professor Dohrn in Naples; further, a young Russian diplomat, who subsequently filled important posts, and finally an extremely original Austrian foundry proprietor, who never allowed his pipe to go out, except when eating or sleeping. As the captain also was a well-instructed, clever man, the unusually long voyage nevertheless passed quickly and agreeably for us, in spite of wind and waves.

In Trebizond, where we anchored for a few hours, I again met with one of my many small mishaps. I had taken a walk on the plateau above the town, to enjoy once again the splendid prospect, and was returning by the fine new road, which on the side descending abruptly to the sea was entirely unsecured by railings, when I met a large drove of donkeys laden with sacks of corn. I inconsiderately stepped to the unrailed side toward the sea, to let the drove pass. That was all right at first, but gradually the drove became denser, and finally occupied the whole width of the road. No pushing and no beating availed; the beasts could not, if they had tried, make room for me. The attempt to jump onto one of the donkeys failed, I was compelled to make way for them, and fell down the steep stonework into mud and among bushes, whereby luckily the force of the considerable fall was somewhat lessened. After I had found that I had got off without serious injuries, I worked myself laboriously out of the thorns and nettles, and only after long and many vain endeavors was able to scramble up again to the road. Fortunately, I found a small pond at the top in which I could wash myself and my clothes. The still powerful sun effected the drying reasonably quickly, and thus I could manage to go through the town without exciting attention and reach the steamer, which fortunately had awaited my return.

On the continuation of the voyage the strong wind grew into a storm, so that the captain began to fear for his old ship, and sought refuge in the harbor of Sinope. Twice on the following days he attempted to continue the voyage, but was each time driven back into the safe port. Thus I had the opportunity of experiencing by personal observation the correctness of the designation "inhospitable" which the ancient Greeks had given the Black Sea.

In the harbor of Pera I found an Austrian Lloyd steamer just ready to start for Trieste, where we landed on New Year's Eve safely and without let and hindrance. On the way, in Syra and Corfu, we had been suspected of being plague-stricken and compelled to hoist the notorious yellow flag, because the cholera was raging in Egypt. With these two Caucasian journeys I regard my traveling period proper as closed, for the European journeys of today in comfortable railway carriages or post chaises are only to be called pleasure trips. The third journey to Kedabeg, for which I am now preparing to take my final leave of the Caucasus, will hardly be anything else.

Harzburg, June 1891

Still full of the fresh impressions and pleasant reminiscences of my third Caucasian journey, which I made, as proposed, last autumn with my wife and daughter, I shall resume my narrative by giving an account of it. This tour, undertaken as a pleasure trip with all imaginable comfort, will thus stand out in strong relief to my first two journeys to Kedabeg.

We traveled in the middle of September from Berlin to Odessa. There, of course, I did not omit to visit the station of the Indo-European line, and held a telegraphic conversation with the manager of the company in London, Mr. Andrews. Such a direct telegraphic intercommunication after a long journey has always something uncommonly interesting, I might almost say elevating, about it. The victory of the human mind over inert matter is thereby immediately brought home to us.

From Odessa we proceeded to the Crimea, my acquaintance with which had hitherto been confined to the ports of call of the steamers running between Odessa and Poti. We decided to leave the vessel at Sebastopol, and travel by road to Yalta. The drive was favored by splendid weather, and permitted us to admire at leisure the magnificent coastal scenery, which stretches from the steep slopes of the southern tableland of the Crimea to the sea. Much reminded us here of the Riviera, indeed there were many points of the Crimean coast whose superiority we were obliged to allow. The situation of the country palaces Livadia and Alupka, belonging to the imperial family, as well as that of many another residence of Russian notables, is beautiful in the extreme. There was wanting, however, the fresh pulsating life of the Riviera, which so considerably heightens the charms of its scenery and climate. The climate of the southern Crimean coast is pleasant and free from fever, and the means of communication, becoming continually more rapid and convenient, will doubtless therefore soon bring it a great accession of tourists. On the other hand, it is impossible to speak as favorably of the climate of the incomparably more beautiful and grander eastern side of the high Caucasus, for there almost everywhere malignant intermittent fevers prevail, and the prospect of medical science overcoming this great plague of humanity appears as yet to be very slight.

It was an interesting coincidence that the glad tidings of the conquest of one of the greatest scourges of mankind, consumption, by the discoveries of Koch reached me in this third journey to the Caucasus, in the very regions where, so many years before, the theory of the excitation of climatic fever by microscopic life in the blood had obtruded itself upon me. The cure was said to be effected by introducing into the patient's system a poison produced by the phthisis-producing bacteria themselves, in the shape of their vital products. The reported results left no doubt as to the correctness of the fact, and we Germans heard with pride our countryman lauded on all sides as a benefactor of humanity. But the assumption of Koch, that the vital products of the disease-causing bacilli constitute the powerful deadly poison, even then excited my doubts. One could well imagine that this self-induced poisoning might check the development of the bacilli in the parts of the body occupied by them – thus affording an explanation of the remarkable phenomenon that not every infectious disease leads to the death of the person assailed by it – but it appeared inconceivable to me that an infinitesimal quantity of such poisonous vital products of a limited number of bacilli should produce in another body the powerful effects observed. A vital process alone could accomplish this, in which not the substance of the germs introduced, but the vital conditions prevailing, and the time required for their increase, are the chief factors in the case. The question as to the origin of these germs, which develop a life hostile to the bacilli whence they arise, appears to me only to admit of a plausible answer if one supposes the living beings producing the disease to be themselves subject to infectious diseases, whereby they on their part are checked in their vitality and finally killed. It would of course follow that life, animal as well as vegetable, is not restricted to the objects revealed by our microscopes, but that there are living beings related as regards size to the microbes and bacteria as these are to us. No scientific objection can be raised to this hypothesis, for the dimensions of molecules are in any case immeasurably less than living structures of even so low an order. The mysterious process of self-healing, the succeeding immunity, the otherwise inexplicable effect of the introduction of vital products of the disease-causing bacilli into the circulation of a body affected by the same disease, would on this assumption be the obvious consequences of the infection of the disease generators themselves, and the task of the future would be to produce such an infection, and bring it to the speediest issue, since these secondary disease generators themselves might also be subject to rapidly developing infectious diseases through microbes of a still lower order. If, however, not the vital products but the secondary disease carriers of the bacilli are the curative means, the bacilli must first become really diseased before their substance can act remedially. Perhaps herein lies the reason for the unsatisfactory action of Koch's tuberculin, and the present suggestion may be of service in the further investigation of this subject, which is of such vast importance to all mankind.

In Tiflis, we met my brother Carl, who accompanied us on our further journey to Kedabeg and Baku and back to

Carl von Siemens in Moscow, around 1895.

St. Petersburg. Dr. Hammacher, member of the Imperial Diet, who had formed one of our party from the first, also remained our faithful traveling companion as far as St. Petersburg. Tiflis appeared to me not to be much altered externally in the 23 years which had expired since my last visit, but it had lost its former aristocratic air, and can no longer boast today of being the Paris of Asia. The town was formerly not only a grand-ducal residence, but also the seat of the native Georgian nobility, which especially in winter took the lead in the social gatherings of Tiflis. All that is now changed. No grand duke resides any longer in Tiflis, and even the Georgian aristocracy has almost entirely disappeared. A quarter of a century ago the town was still Georgian, and the best houses as well as the administration of the town were in Georgian hands. But even then the Armenian nationality had begun to spread, and gradually the land and landed property passed into Armenian hands. In earlier, warlike times, the brave and vigorous Georgians maintained their possessions and their social position against the crafty and pushing Armenians. That ceased, however, when under Russian rule permanent peace and an orderly state of affairs were established. From that time, the Armenian element came to the front, and the Georgian was compelled to make way for it. Now well-nigh the whole property of the town is in Armenian hands. The proud figures of the Georgians in their dazzling accoutrements have disappeared from the streets of Tiflis; the Armenian dwells in their palaces and is master of the situation.

The intermixture of nationalities in the Caucasus offers excellent material for studying the influence of the intercourse of specifically different races of men in warlike as in peaceful times. It is surprising that in the Caucasus the Jewish element has not proved capable of coping with the Armenian. It is true Jews are to be found there in considerable numbers, but they are all drivers, and have the reputation of being rough fellows, always on the lookout for an opportunity of displaying their superior physical strength. Trading they have altogether renounced. The Russians, mostly clever and shrewd men of business, cannot, however, as they themselves admit, hold their own against Armenians and Greeks. The reputation for greatest longheadedness in all business relations in the Caucasus, as in the whole East, is enjoyed by the Greek, yet the Armenians, when they are banded together, carry off the palm from the Greek, who always traffics on his own account.

When, after a few days, we continued our journey by railway, we found at the foot of the Kedabeg tableland a new railway station, Dalliar, from which the road to Kedabeg runs by way of the new Swabian colony Annenfeld. Here we found in course of construction the already mentioned conduit through which the naphtha brought by rail from Baku to Dalliar was to be pumped about 1,000 meters up to Kedabeg. The operations, both as regards the laying of the tubes and the arrangements of the pumping station, were proceeding well, but we had to abandon the hope of seeing the completed work in action before the beginning of winter.

To the great delight of the ladies, our drive from Dalliar to Kedabeg formed a genuine Oriental spectacle. The beys of the neighborhood had heard of the arrival of the owners of the wonderful mine, and did not omit to greet us festively with their dependants, and escort us to Kedabeg. This party was continually renewed and increased on the road, which was nearly 40 kilometers long. They swarmed around our carriage on their fleet Caucasian mountain horses, mostly at a wild gallop, up hill and down dale, and afforded, in their Caucasian costume and accoutrements, an extremely attractive spectacle. In chasing past, the men performed the most daring, breakneck feats of horsemanship, at the same time firing off their guns, so that our approach produced the impression rather of a warlike encounter than of a peaceful reception. Near Kedabeg the entire population of the place, together with the miners and smelters, joined the procession. In the house of our head manager, Mr. Bolton, we were received by the ladies of his household, and lodged most comfortably. During our stay we derived some benefit from the visit, which had taken place a few weeks before, of the young Crown Prince of Italy, who, attended by the Russian grandees of the Caucasus, had visited our mine and smeltery. For the reception and entertainment of these guests unusual arrangements had of course been made, which had especially included provision for a comfortable descent into the mine and the procuring of an improvised saloon carriage for our railway. We repeatedly made use of the latter in our visits to the Kalakent outwork and the Shamkhor on the picturesque line, often carried over perilous abysses. Despite the often rather annoying fumes from the works, we fully enjoyed the charms of the beautiful surroundings of Kedabeg in glorious autumn weather. Among the special delights must be reckoned a bear hunt which we attended in the so-called paradise. This name is borne by a small tableland, bordered by the rivers Shamkhor and Kalakent, which is splendidly situated and adorned with many wild fruit trees. The great abundance of fruit in the autumn attracts the bears of the neighborhood, and the officials of our mine had often instituted successful bear hunts in this season.

We passed the night in the Kalakent branch smelting house, and at sunrise repaired for the chase to the neighboring mountains, which during the night had been surrounded

Werner and Carl von Siemens hunting bear in the Caucasus, 1890. Werner is sitting on the ground in the middle; Carl is to the right of him.

by our forest keeper with a chain of beaters. It was a wonderfully fine morning, and the noiseless march on the lonely hunting paths in constant expectation of the bears was not without delight. After a rather long time, passed in great expectation, we heard in the far distance the call of the beaters resounding from the summit of the slope, the base of which we held. Nothing else was heard in the general stillness except the falling of the autumn leaves, a sound with which hitherto I had only made acquaintance in novels. I was posted on a narrow mountain path between my brother Carl and Dr. Hammacher. My weapon was a rifle with two barrels, one charged with ball, the other with small shot. Similarly defective was the equipment of my companions in the chase.

Gradually, the clamor of the beaters came nearer, but of bears nothing was to be seen or heard. Suddenly the forest keeper called our attention by signs to a slight rustle in front of us, and immediately delivered a shot in the direction indicated. The bear slunk away to the left without being hit. A shot delivered by Dr. Hammacher took just as little effect. Then, on the other side of me, came the crack of a shot from my brother, and immediately after, a second. I thought my chance of getting a shot was gone when all at once, close beside me, a large brown female bear, accompanied by a cub, crossed the clearing. I delivered my ball charge at the bear, whereupon the cub fell on its knees with terror, which made me believe I had hit the latter. The mother and her young, however, ran quietly down the mountain. Everyone of us of course thought he had shot his bear, and the district was eagerly searched for the wounded. Traces of blood were indeed discovered, but neither then nor afterward was anything to be seen of our wounded bears. In the further beating up, too, no bear was slain; only one more in fact came to view and that close to the beaters. These and the bear seemed to have been equally terrified and fled in opposite directions, the beaters calling out as if in their death agony.

One of the finest tours in the outlying district around Kedabeg embraces the valley of the Kalakent brook above Kalakent itself, to the summit of the mountain enclosing the large Goktcha Lake. From the summit of the pass, the immense lake is seen in the foreground, while the chains of the Armenian highlands form the background of the splendid panorama. My traveling companions, who had not shrunk from the severe ride necessary to reach this com-

The works has been in existence since 1863 . . . In 1876 1,800,000 puds [1 pud = 16.381 kg = about 36 lbs.] of ore were mined, of which the richest contained up to 7 percent of pure copper . . . More than 1 million puds of ore are smelted annually and after various processes finally yield 40,000 to 50,000 puds of beautiful refined copper. For this, however, more than 500,000 puds of charcoal and more than 2,000 cubic fathoms of wood are required. An area of 12,800 desjaetins [1 desjaetin = 1.0925 hectares = about 2½ acres] provides the fuel . . . Since these works were established each machine and each piece of apparatus has had to make the long journey from England via Gibraltar and Constantinople to Poti. Formerly every piece had to be transported on carts through the ancient Kolchis to Tiflis and from there over the trackless mountains to its destination. Even now the cargoes of steel rails to build the railway already mentioned are brought to the mouth of the Phasis, to continue the journey by rail to Tiflis, then to be hauled slowly on wagons to the Kedabeg works.

Tiflis, February 1880
Illustrierte Zeitung, March 27, 1880

manding eminence, had the good fortune to enjoy a perfectly clear prospect, the snowcaps of the great and little Ararat standing out with perfect distinctness.

After brother Carl and I had taken our full delight in the great progress which our remote possession had made in the last years, and our companions had exhausted the charms of the surrounding forest-clad hills in extensive rides, we continued our journey to Baku, to pay a visit to the ancient sacred perpetual fires, and to make acquaintance with the sources of the modern fire-bringer – donor, at any rate, of far greater blessings – petroleum. We had quite special reasons for so doing, since it was owing to naphtha, the mother of petroleum, that we found Kedabeg in brisk and hopeful activity.

The route lay by way of Elisabethpol, the government town of Kedabeg, in the neighborhood of which is situated Helenendorf, the largest of the Swabian settlements. When the worthy Swabians heard of our presence in Kedabeg, they sent their mayor with an invitation to visit Helenendorf as well. We of course accepted it, and on our arrival in Elisabethpol were received by a deputation of the peasants, and were quickly driven to the village a few miles off. There the whole community took pains to show attention to their German countrymen and especially to their Swabian countrywoman. We had to inspect the church, the school, and the waterworks, and took genuine delight in the old thoroughly German orderliness, which has defied all opposing influences of the country and climate. Helenendorf is the most flourishing and prosperous of all the Swabian settlements in the Caucasus, and owes this in part, no doubt, to the healthy climate and the favorable situation in a fine, mountainous, and well-watered region. To its inhabitants the merit is due of having introduced German conveyances into the Caucasus. Recently the colony has taken to the cultivation of the vine, and turns out excellent products of the native grapes by the application of modern methods.

The railway journey through the monotonous steppe of Elisabethpol to Baku does not offer much that is noticeable. The vegetation is very scanty, with the exception of places which lie by watercourses or have artificial irrigation, of which certainly for the most part only a few traces have remained. It is not the land which has value in such regions, but the water which can be conveyed to it. Progressive culture will in this respect still be able to do much, but even if the rivers were deprived of all their water to fertilize the fields, this would benefit only a small part of the great steppes of Russia. The necessary amount of rain is lacking. Whether this has absolutely diminished within historic times, which might be concluded from many phenomena, or whether only its distribution has become different, cannot as yet be decided.

The astonishingly large number of wooden prospect towers, thirty to fifty feet high, in the wholly flat region which afforded but the smallest prospect, is explained by the circumstance that the inhabitants in the worst fever season pass the nights in these towers to escape the fever.

A peculiar spectacle was afforded toward the end of the journey by a whole town of similar wooden towers, standing much higher still, apparently close to one another, which crowned the summit of a near mountain range. More exact observation through a telescope revealed that they were high boring towers, such as are wont to be erected for deep borings. This was the district of the famous naphtha wells. Thence the oil is conveyed for refining through numerous conduits to the neighboring "black town" of Baku, or rather to its newer part, which contains the numerous petroleum distilleries. It is remarkable that borings in the closest proximity, sometimes more than a thousand feet deep, often yield altogether different results. Frequently, on reaching the petroleum stratum, a fountain arises, from which the naphtha spurts up to a height exceeding a hundred feet. A hollow is then quickly made in the neighboring soil, to col-

Oil derricks in the Caucasus. Undated.

lect the gushing naphtha. The yield of the well, however, soon diminishes. After a few weeks it is no longer inclined to "strike," as they say in Baku, and the naphtha must now be pumped up from the bottom of the boring. The boring towers are accordingly left standing, in order to be used subsequently as pumping towers. It is hard to explain how it happens that at a very slight distance from a boring, where the elasticity of the gases which at first pressed up the petroleum is already quite absorbed, a new and strong fountain can arise, as it must be assumed that all the wells spring from a single stratum of naphtha. Altogether the origin of petroleum is still veiled in darkness, and therefore one cannot say whether it will maintain a permanent place in the field of human civilization. How large an influence the naphtha wells of Baku already exercise on the life and industry of Russia is obvious from the long rows of reservoir wagons for the transport of petroleum and masut, which are met with on all the Russian railway lines. As the forests of Russia have almost everywhere been largely cleared, and coal is only found in quantities on the Don, masut and raw petroleum have quickly attained great importance as cheap and easily transportable fuel. A large number of the Russian locomotives and river steamers are even now heated by petroleum, and for many branches of Russian industry this has proved a great help in need, as was the case in the working of our Kedabeg copper mine.

The old town of Baku is beautifully situated on the abruptly rising shore of the Caspian Sea. Apart from the district of the naphtha wells with the very modernized everlasting fires, the "black town," and a number of interesting architectural remains of the time when it was the residence of the Persian Khans, the town offers few attractions for the stranger. But in favorable weather he may procure himself the pleasure of setting the Caspian Sea on fire, if he makes an excursion in an iron steamer to a place not far from the coast, where flammable gases rise from the seabed. In calm weather these may be ignited and then form a sea of flame around the ship, often lasting a considerable time.

We made the return journey by land via Moscow and St. Petersburg. In crossing the great Caucasus we traversed grandly beautiful wild mountain valleys in the depression at the foot of the Kasbek. But if one wishes thoroughly to enjoy their beauty, it is better to travel in the reverse direction, for the wild Terek Valley, which forms the northern slope of the mountains, is so quickly traversed in descending, that one has hardly time to enjoy the pleasures of the surrounding country; a further drawback being the abrupt bends in the otherwise marvelous road, which are disagreeable when passed over at full speed. From Vladi-Kavkas, the commencement of the Russian railway network, we traveled to Moscow in three days without break of journey. Unfortunately, owing to the cloudy weather of the first day, the fine views of the Great Caucasus, especially the towering Elbrus, escaped us. The numerous cairns on both sides of the road were highly interesting. They prove that for long periods of time a relatively high civilization prevailed on the northern slopes of the Caucasus, and it is here perhaps that we must look for the center of origin and rallying point of the tribes which have at different times deluged Europe.

I resist the temptation to describe Moscow, and will only refer to the feeling experienced there of being thoroughly in Russia, i.e., on the borderland of European and Asiatic culture. One has this sensation more keenly if, like ourselves on this occasion, one comes from Asia and therefore brings a vivid feeling for Asiatic life and doings. This is hardly to be put into definite words. "In Asia," said one of my fair traveling companions, "dirt and rags are not repulsive, here they certainly are." This is in fact quite characteristic of the transition from Asiatic to European civilization. The Asiatic in spite of dirt and rags always exhibits a certain degree of manly dignity, which the European in rags invariably lacks.

The Russian proper, i.e., the native of Great Russia, forms a true transition between Asiatics and Europeans, and is therefore the proper and successful carrier of European civilization eastward. The converse way, of which the Pan-Slavist Russians now often dream, the renewal of the "rotten West" by the native energy of Asia, has certainly no great likelihood of being ever realized. Indeed it cannot be denied that there lies a danger for the development of European-American civilization in the fact that Europe has become the voluntary teacher of Asia in procuring and utilizing the instruments of power, which the former owes to its technical progress. With the great capacity of the Asiatics for imitation and for utilizing their acquirements, and with the ever advancing art of depriving distance of its dividing power by improving the means of communication, undoubtedly our little Europe might be exposed to a new invasion from Asia subversive of culture, but the first annihilating blow would then light on the intervening countries, especially Russia, as history has indeed already repeatedly shown. For the rest, this danger can only arise when the scientific and technical progress of Europe comes to a standstill, so that it loses the great start in its technical development, which most surely protects its civilization from every inroad of barbarian nations. Only internal suicidal conflicts could lead to that, for in mental power and inventive faculties the peoples of Europe are far superior to the Asiatics and will doubtless remain so in the future.

In Moscow it was already intensely cold, in St. Petersburg sledging had actually begun and the Neva was covered with drifting ice, so that after a short stay we continued our journey and could still enjoy for a while the milder climate of home.

DYNAMO-ELECTRIC MACHINE, THE 1870s, EVENING OF LIFE

As in the past two years, I have come here to Harzburg at the end of June, in order to devote a few weeks to recording these reminiscences, and do not intend to leave before I have come to the end of them. I have repeatedly tried in Charlottenburg to continue my task, but there, where everything is pressing forward, I have not succeeded in persistently looking backward. For it is habit which puts the strongest shackles on us. I have never been able entirely to put aside the thoughts and plans which were just then occupying my mind, and this has frequently spoiled my enjoyment of the present, to which I could never wholly

Werner von Siemens' villa in Charlottenburg. Undated.

devote myself except in passing moments. But on the other hand such a mental life, partly spent in dreamy speculations, partly in strenuous aspirations, also affords great enjoyment. It sometimes even perhaps brings us the purest and sublimest joys of which man is capable. When a law of nature, hitherto hovering darkly before the mind, all at once clearly emerges from the enveloping mist, when the key is found to a mechanical combination long sought in vain, when the missing link of a chain of thought is happily inserted, this affords the discoverer the elevating feeling of a mental victory achieved, which alone richly compensates him for all the pains of the struggle and exalts him for the moment to a higher stage of existence. Certainly the ecstasy does not generally last long. Self-criticism usually soon discovers a dark spot in the discovery which renders its truth dubious or at least narrowly restricts it. It exposes a fallacy in which one has been entangled, or, as is unfortunately almost the rule, it leads to the perception that only an old friend has been met with in a new dress. Only when strict examination has left a sound kernel does the regular hard labor begin of elaborating and completing the invention, and then the struggle for its introduction into scientific or technical life, in which most men are ultimately ruined. Discovering and inventing therefore brings hours of supreme delight, but also hours of the greatest disappointment, and of hard fruitless work. The public commonly notices only the few cases in which successful inventors have hit, almost accidentally, upon a useful idea, and by making the most of it, have attained without much labor to fame and affluence, or the class of acquisitive invention hunters who make it their life's work to seek for technical applications of well-known things and to secure the benefit of them by patents. But these are not the inventors who open new paths for the development of mankind which will presumably conduct it to more perfect and happier conditions of life, but those who – either in the quiet of scholarly seclusion, or in the bustle of technical activity – devote their whole being and thought to this development for its own sake. Whether, by correct judgment and use of the opportunities of practical life, inventions lead to the accumulation of wealth or not frequently depends on chance. Unfortunately, however, the instances of success possess great attraction and have called forth a host of inventors who plunge into discovery and invention without the necessary knowledge and without self-criticism, and thus are mostly ruined. I have ever regarded it as a duty to turn such deluded inventors from the dangerous path which they had entered upon, and this has always cost me much time and trouble. Unhappily, my efforts have rarely been attended with success, and only complete failure and the bitterest self-inflicted distress occasionally brings these inventors to a perception of their errors.

There are two inventive ideas in particular which have misled and frequently also ruined innumerable people, otherwise fairly gifted and even remarkably clever in their own sphere of activity. These are the inventions of so-called perpetual motion, i. e., of a self-acting work-performing machine, and that of the flying machine and the manageable balloon. One might have thought that the knowledge of the law of the conservation of energy had already so far penetrated the popular mind that creating working power out of nothing would have come to be considered as contrary to nature as the production of matter, but it seems that generations must always pass away before a new fundamental truth is universally regarded as such. If a man is once possessed by the unhappy delusion that he has found the way to construct working machines by mechanical combinations alone, he has become the victim of a generally incurable mental ailment which defies all teaching, and even the most painful experience. Almost the same holds good of the endeavors to construct flying machines and manageable air balloons. The problem itself for every mind possessing a slight mechanical training is indeed a very simple one. It is indubitable that we can construct flying machines according to the pattern of flying animals, if only the fundamental condition be fulfilled which consists in this, that we have machines as light and powerful as the motor muscles of flying animals and which do not require a much larger supply of combustible material. When such a machine is invented, every skilled mechanician can make a flying machine. The inventors, however, always begin at the wrong end, and invent flying mechanisms without having the power for moving them. It is still worse with manageable airships. The problem of their construction has been solved long ago in principle, for every air balloon may, in perfectly calm weather, be slowly propelled in any direction by a suitable mechanism applied in the car. Progress, however, can only be slow, because in the first place power machines of sufficient lightness are still wanting to drive the voluminous balloon at greater speed through the air or against the wind, and secondly because the material of the balloon would not stand a strong counterpressure of the atmosphere, even if we possessed such machines. The oblong form, which the inventors give the balloon in order that it may better cleave the air, increases its weight with equal volume and is therefore worthless. The like holds good of the application of inclined planes which are intended to facilitate the raising of the weight.

Besides these two problems there are a number of others on which inventors squander time and money by failing to perceive that the means for carrying them out are not yet at the disposal of applied science.

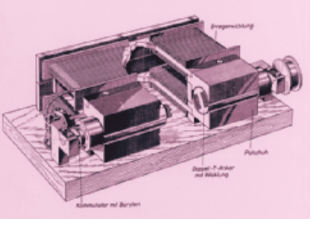
After these digressions, I resume the thread of my narrative with my retirement from political activity.

The war of 1866 had removed the obstacles which opposed the longed-for unity of Germany, and had at the same time restored internal peace in Prussia. A new support was thereby given to the idea of nationhood, and the hitherto vague, as it were, tentative, efforts of German patriots now obtained a firm foundation and definite direction. It is true, the Main boundary still divided Germany into a northern and a southern half, but no one doubted that its removal was only a question of time, if it was not rigidly fixed by external force. That France would make that attempt appeared certain, but there was a growing confidence that Germany would successfully stand this trial also. As a consequence of this great revolution of popular sentiment, there resulted the general endeavor to consolidate quickly what had been attained, to strengthen the feeling of solidarity of North and South despite the Main boundary and to prepare for the coming struggle.

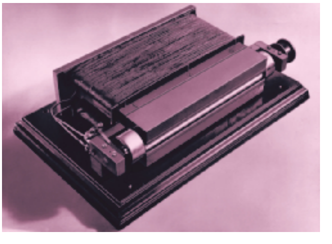
This buoyant feeling was evidenced by increased activity in all departments of life, nor did it fail to react on our business affairs. Magneto-electric mine exploders, electric range finders, electric apparatus for steering unmanned boats furnished with explosives against hostile ships, as well as numerous improvements of military telegraphy, were the offspring of this stirring time.

I will here only give a detailed account of a nonmilitary invention of this time, as it has become the foundation of a new and important branch of industry, and has exerted and still continues to exert a stimulating and transforming influence in all departments of the industrial arts; I refer to the invention of the dynamo-electric machine.

As early as the autumn of 1866, when I was intent on perfecting electric exploding apparatus with the help of my cylindrical inductor, the question occupied my mind whether it would



The structure (with cross section) of the dynamo machine.



The machine with which Werner von Siemens demonstrated the dynamo-electric principle in 1866 – a discovery that ushered in a new age of electrical engineering. The device was presented at the Universal Exposition in Paris in 1867, where Werner von Siemens received the Order of the French Legion of Honor.

not be possible by suitable employment of the so-called extra current to intensify considerably the induction current. It became clear to me that an electromagnetic machine, whose working power is very much enfeebled by the induced currents arising in its coils, because these induced currents considerably diminish the energy of the galvanic battery, might conversely strengthen the power of the latter if it were forcibly turned in the opposite direction by an external force. This could not fail to be the case, because the direction of the induced currents was at the same time reversed by the reversed movement. In fact, experiments confirmed this theory, and it appeared that there always remains sufficient magnetism in the fixed electromagnets of a suitably contrived electromagnetic machine to produce the most surprising effects by gradually strengthening the current generated by the reversed rotation.

This was the discovery and first application of the dynamo-electric principle underlying all dynamo-electric machines. The first problem, which was thereby practically solved, was the construction of an effective electric exploding apparatus without steel magnets, and such exploding apparatus is still in general use at the present day. The Berlin physicists, among them Magnus, Dove, Riess, Du Bois-Reymond, were extremely surprised when I laid before them in December 1866 such an exploding inductor, and showed that a small electromagnetic machine without battery and permanent magnets, which could be turned in one direction without effort and with any velocity, offered an almost insuperable resistance when turned in the opposite direction, and at the same time produced an electric current of such strength that its wire coils became quickly heated. Professor Magnus immediately offered to lay a description of my invention before the Berlin Academy of Sciences, but, on account of the Christmas holidays, this could only be done in the following year, on January 17, 1867.

The priority of my application of the dynamo-electric principle was afterward impugned in various quarters, when its enormous importance came to be seen during its further development. At first, Professor Wheatstone was almost universally recognized in England as simultaneous inventor, because at a sitting of the Royal Society on February 14, 1867, at which my brother William produced my apparatus, he immediately exhibited a similar apparatus, which was only distinguishable from mine by the wire coils of the fixed electromagnet being differently disposed in their relation to those of the rotating cylindrical magnet. Next, Mr. Varley came forward with the assertion that already in the early part of the autumn of 1866 he had given orders to a mechanician for just such an apparatus, and also subsequently handed in a "provisional specification" of the same. My first complete theoretical establishment of the principle in the printed transactions of the Berlin Academy, and its previous practical elucidation, have, however, finally been taken to be decisive in my favor. The name given by me to the apparatus, "dynamo-electric machine," has also become general, although frequently corrupted in practice into "the dynamo."

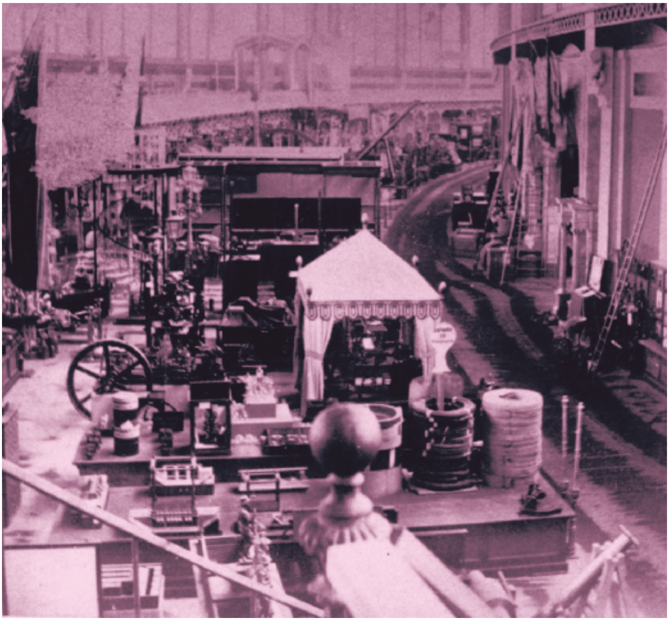
Already in my communication to the Berlin Academy, I had pointed out that the industrial arts were now in possession of appliances capable of producing electric currents of any desired tension and strength by the expenditure of energy, and that this would prove of great importance for

Werner to William, October 2, 1867

. . . An old acquaintance, now Engineer General and Chief of the Measurement Office, asked me whether it would not be possible to make an electric distance meter, as all other proposals had failed. At first it seemed to me paradoxical, but after further thought I have designed an extremely simple and practical distance meter which will leave all other known instruments far behind . . .

To test the suitability of electric light for military purposes, at the monument on the Kreuzberg on Wednesday evening a number of experiments were carried out with new appliances specially made for the purpose in the telegraph construction works of Siemens and Halske; the tests were conducted by Colonel and Director Chauvin . . . It was possible to illuminate the distant Tempelhof in such a way that the windows in the houses could be counted. This interesting spectacle, favored by the delightful summer night, attracted a large number of onlookers.

Die Post, *July 15, 1868*



The Prussian Pavilion at the Paris Universal Exposition, 1867.

many of its branches. In fact, large machines of the kind were immediately constructed by my firm, one of which was exhibited at the Paris Universal Exhibition of 1867, while a second was employed in the summer of the same year by the military authorities for electric lighting experiments in Berlin. These experiments indeed proved quite satisfactory, with the drawback, however, that the wire coils of the armatures rapidly became so hot that the electric LIGHT produced could only be allowed without interruption for a short time. The machine exhibited in Paris was never actually put to the test, as there were no appliances for the transmission of power in the space allotted to my firm, and the jury, to which I myself belonged, did not subject the exhibits of their members, which were *hors concours,* to any trial. All the greater was the sensation caused by an imitation of my machine exhibited by an English mechanician which produced from time to time a small electric light. It was considered a sufficient recognition that the Order of the Legion of Honor was awarded to me at the close of the exhibition.

When, at a later time, the DYNAMO MACHINE, after considerable improvement, especially by the introduction of Pacinotti's ring and Hefner's coiling system, had received the most extensive application in practice and both mathematicians and engineers had developed its theory, it seemed almost self-evident and hardly to be called an invention that one should arrive at the dynamo-electric machine by merely reversing the rotation of an electromagnetic machine. Against this it may be said that the most obvious inventions of primary importance are commonly made very late, and in the most roundabout way. For the rest, it would not have been easy to have arrived by accident at the discovery of the dynamo-electric principle, because electromagnetic machines only "excite," i.e., continuously and spontaneously strengthen, their electromagnetism on reversing the rotation, when their dimensions and the disposition of the coils are perfectly correct.

French medal with the head of Emperor Napoleon III and an allegory of telegraphy, 1867.

To this period also belongs my INVENTION OF THE ALCOHOL METER, which very successfully solved an extremely difficult problem and accordingly excited much attention at the time. The problem consisted in constructing an apparatus to register continuously and automatically the quantity of absolute alcohol contained in the spirit flowing through it. My apparatus solved this problem so completely that it indicated the quantity of alcohol, reduced to the customary normal temperature, as accurately as could be determined by the most exact scientific measurements. The Russian government has employed this apparatus for almost a quarter of a century in levying the high tax which is imposed on the production of spirit, and many other European states have also subsequently adopted it for the same purpose. Apart from a few important practical improvements due to my cousin Louis Siemens, the apparatus is still supplied in the original form as a regular article of manufacture by a factory specially erected for the purpose in Charlottenburg. No imitation has hitherto been successful anywhere, although the apparatus is unprotected by a patent.

The dimensions which the firm of Siemens & Halske gradually attained naturally required a corresponding organization of the management and the help of able technical and administrative assistants. The friend of my youth, William Meyer, who filled the post of chief engineer and confidential clerk from the year 1855 had, by his considerable organizing talent, not only rendered valuable service to the Berlin firm, but also to its branches in London, St. Petersburg, and Vienna. Unfortunately he fell ill of a serious disorder after eleven years in the business, and died after prolonged sickness, deeply lamented by me as a personal friend and faithful partner.

** On December 31, 1867*

Not long afterward, in the year 1868,* my old friend and partner Halske retired from the firm. The favorable development of the business – this will hardly appear credible to many at first sight – was the determining reason for his taking this step. The explanation lies in Halske's singularly constituted nature. He took great pleasure in the faultless productions of his clever hand, as well as in everything that he could entirely oversee and control. Our common activity was thoroughly satisfactory for both parties. Halske always gladly adopted my constructive plans and designs, which with remarkable mechanical tact he at once most distinctly apprehended, and to which he often first gave their full value by his practical skill. At the same time, Halske was a clear-headed, cautious man of business, and I have him alone to thank for the good business results of the first years. Circumstances altered, however, when the business increased and could no longer be managed by the two of us alone. Halske regarded it as a desecration of his cherished establishment that strangers should have rank and rule in it. Even the installation of a bookkeeper gave him pain. He could never get over the fact that the well-organized concern should exist and work without him. Finally, when the designs and undertakings of the firm became so large that he could no longer oversee them, he no longer felt satisfied, and resolved to retire in order to devote his whole activity to the administration of the city of Berlin, which afforded him personal satisfaction. Halske remained a dear and faithful friend to me till his death, which occurred last year, and always, even to the last, retained a lively interest in the establishment of which he was joint founder. Today, his only son takes an active part in the management of the present business as confidential clerk.

As Meyer's successor we appointed the former director of the Hanoverian telegraph system, Herr Carl Frischen, who after the annexation of Hanover passed into the service of the North German Confederation, and had for several years filled the office formerly held by Meyer as chief telegraph engineer of the government telegraphs. The business gained in Herr Frischen an eminent technical worker who had already distinguished himself by many original inventions. Further, it was now of great advantage to the firm that excellent departmental managers and constructors had been found among its junior assistants, who had received their training in the firm.

Friedrich von Hefner-Alteneck (1845 – 1904). Undated. The head designer at Siemens & Halske from 1870 onward. He developed the drum armature and the "Dosenschreiber," a type of keyboarding machine for telegraphs, created the Hefner candle and designed the differential arc lamp.

I shall only mention Herr VON HEFNER-ALTENECK, whose achievements as head of our construction office have earned for him a worldwide reputation.

Supported by such able coadjutors, I was able more and more to confine myself to the general management of the business, and with full confidence to leave the details to our assistants. In this way, I obtained greater leisure to occupy myself with scientific and such social problems as I had particularly at heart.

My domestic life underwent a complete transformation as a result of my second marriage, which took place on July 13, 1869, to Antonie Siemens. She was a distant relative, the only child of the meritorious Professor CARL SIEMENS of Hohenheim, near Stuttgart, who was well known in agricultural technology. I have often jokingly said in after-dinner speeches and the like that this marriage with a Swabian lady should be looked upon as a political act, as the Main line was bound to be bridged, and this could best be done by as many alliances of affection as possible being concluded between North and South, which must then of themselves soon be followed by political ones. Whether my patriotism was not considerably influenced by the amiable qualities of the fair Swabian herself, who has again brought warm sunshine into my somewhat gloomy and laborious life, I shall not here more closely inquire.

** The correct date is July 30, 1870.*

On June 30,* 1870, just as the news arrived by telegraph in CHARLOTTENBURG that the Emperor Napoleon had crossed the German frontier at Saarbrück and the fateful war between Germany and France had actually begun, my wife presented me with a little daughter, to be followed two years later by a son. I gave our daughter the name HERTHA, in pursuance of a vow to give her this name if the German war-

Werner to Carl, July 18, 1870

Our works has lost many men [68]; still, there is no lack of workers and still less of work. Chauvin, who returned yesterday, has commandeered practically everything that was nearly finished. You will therefore get no apparatus. It would in any case not be possible to ship it now …

ship so called, which the French fleet was pursuing in all waters, escaped capture. My four elder children were in Helgoland at the time of the declaration of war, and had to flee as speedily as possible with the whole troop of visitors in order not to be prevented from returning by the blockade. The telegram from my eldest son, then sixteen, from Cuxhaven may pass as a sample of the deep emotion and courage that had taken possession of all Germany – "I must join too," words that happily could not be translated into action, as no one is accepted in the Prussian Army before reaching seventeen years of age.

Werner von Siemens and his second wife, Antonie, 1869.

The war with France, like that of 1866, was speedily carried to a victorious issue for Germany, after a struggle of tremendous proportions. The joyful consciousness that, for the first time in the course of their history, Germans from all parts fought and conquered side by side under the same flag made the heavy sacrifices with which the glorious victories had to be purchased appear more endurable, and lightened the profound mourning and misery which the war entailed. It was a glorious and elevating time, which has left impressions never to be effaced on all who lived through it; and coming generations will assuredly never allow the feeling of devout gratitude which the nation owes to the great leaders

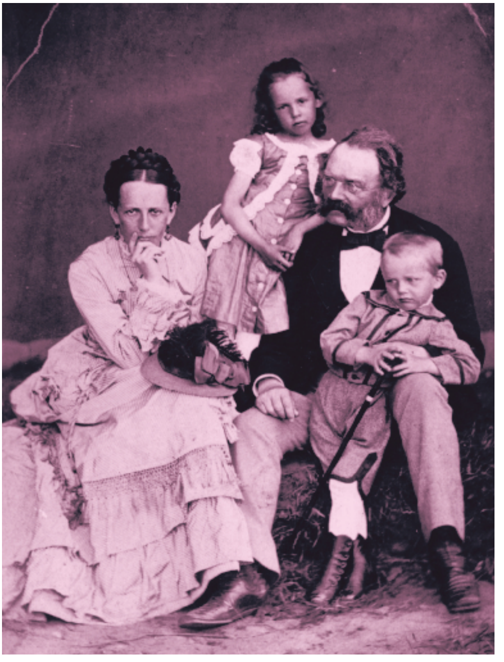
Werner to Carl, July 25, 1870

We are overloaded with orders: distance meters, lighting apparatus, telegraphs, etc. Unfortunately, some of our best men have been taken. You must therefore have patience with us. Military matters must necessarily have priority. Then only war material can be transported. Now all railways are reserved for nine days for transport of the army …

who put an end to its ignominious discords, and which made it united and powerful, to die out.

Although I had entirely renounced political activity after the year 1866, I still continued to take the greatest interest in public affairs. One question to which I had long before paid particular attention was that of patent right. It had long become clear to me that one of the greatest obstacles to the free and independent development of German industry lay in the lack of protection for inventions. It is true that in Prussia, as also in the other large states of Germany, patents were granted for inventions, but the grant entirely depended on the good pleasure of the authorities and lasted at the most only for three years. Even for this short time they afforded only a very unsatisfactory protection against imitation, for it rarely paid to take out patents in all the states belonging to the Zollverein, since every state applied its own test of originality, and indeed, strictly speaking, it was impossible, as many of the smaller states did not grant patents at all. The consequence was that inventors, as a matter of course, sought in the first instance to turn their inventions to account in foreign countries, especially England, France, and the United States. Altogether, therefore, the youthful German industry was thrown upon the imitation of foreign productions and, by only dealing in imitations, thereby indirectly strengthened still further the preference of the German public for foreign manufactures.

As to the worthlessness of the old Prussian patents, there could not be two opinions. Indeed, they were as a rule only applied for in order to obtain a certificate that an invention had actually been made. Furthermore, the then dominant, thoroughgoing Free Trade Party regarded the patenting of inventions as a relic of the old monopoly rights, and incompatible with the principles of free trade. In this sense, in the summer of 1863 a circular letter was sent by the Prussian Minister of Commerce to all the chambers of commerce of the state in which the uselessness, nay, even injuriousness, of the patent system was set forth and finally the question propounded whether the time had not come to abolish it entirely. This led me to draw up a memorandum to the Berlin Chamber of Commerce, the council of Berlin merchants, which adopted the diametrically opposite point of view, to set forth the necessity and utility of a patent law for the promotion of the industry of the country, and to sketch the outlines of a rational patent law.



Werner von Siemens and his wife Antonie, with their children Hertha and Carl Friedrich (1872–1941), around 1878.

My detailed statement was approved by the Council, although the latter consisted of very pronounced free-traders. It was unanimously adopted as the opinion of the Chamber of Commerce, and at the same time communicated to the other chambers of commerce of the state. Of the latter, those which had not yet sent in a reply assenting to the abolition of patents expressed their sympathy with the Berlin decision, and as a consequence the proposal for abolition was abandoned.

This favorable result afterward encouraged me to initiate a serious agitation for the introduction of an imperial patent law, on the basis proposed by me. I sent a circular to a considerable number of men who I supposed would have a special interest in the matter, and asked them to form a "Patent Protection Union," with the object of procuring a rational German patent law. The call was generally responded to, and, a short time after, the Union was called into existence under my presidency. I remember with pleasure the stimu-

Arnold von Siemens (1853 – 1918), Werner Siemens' first son, 1871.

lating debates of this Union, to which eminent legal authorities such as Professor Klostermann, Mayor André, and Dr. Rosenthal belonged. The final result of the discussions was the draft of a patent law which essentially rested on the foundation laid by me in my statement of 1863. This consisted of a preliminary inquiry in regard to the novelty of the invention and subsequent public exhibition of the specification, thereby affording an opportunity for objections to the grant; further, the grant of the patent for the term of fifteen years, with yearly increasing impost and complete publication of the patent granted; finally, establishment of a patent tribunal, which on application could always declare the nullity of the patent if the originality of the invention was afterward successfully disputed.

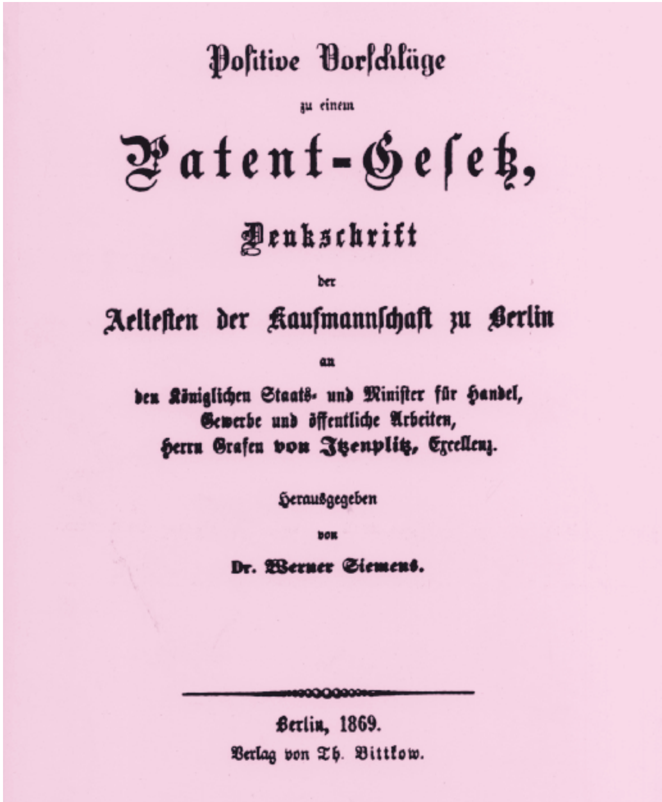
These principles gradually gained approval with the public also, and even the Free Trade Party, of the most rigid principles, was quieted by the economic basis of the proposal, which consisted in the protection appearing as a reward for the immediate and complete publication of the invention, whereby the new ideas underlying the patented invention became themselves industrial common property, and might even bear fruit in other fields. It took a long time, however, before the imperial government resolved to take legislative action in the matter. I fancy that a memorandum which as president of the Patent Protection Union I addressed to the Imperial Chancellor had a considerable influence on the decision for the promulgation of an imperial patent law. In this memorandum I laid stress on the inferior condition and the slight estimation of German industry, its productions being everywhere styled "cheap and shoddy"; and at the same time, I pointed out that a new firm bond for the young German empire would be created if thousands of manufacturers and engineers from all parts of the country could find in the institutions of the empire the long-desired protection for their intellectual property.

… As there was already such a shortage of surgical instruments in Berlin that there were no prospects of being able to procure them in adequate numbers, Messrs. Siemens and Halske immediately offered to see whether their works could make the most important and most urgently required of these instruments, whereupon Professor Virchow drew up the necessary specification and instructions to simplify and accelerate the work as far as possible …

National Zeitung,
September 6, 1870

In the year 1876, a meeting of manufacturers as well as of administrative officials and judges was called together from all Germany, which made the draft of the Patent Protection Union the definite basis of their deliberations. The bill resulting from these deliberations was adopted by the Reichstag with a few modifications, and has very materially contributed to strengthen German industry and procure respect for its productions both at home and abroad. In almost all its branches our industry has since been well on the way to losing the stigma of "cheap and shoddy" which Professor Reuleaux rightly gave to its productions at the Philadelphia Exhibition in 1876.

I will now take up my account of the development of the businesses established by us from the point where I described the changes which our London house had to go through after the unhappy cable undertakings between Spain and Algeria in the year 1864. The firm of "Siemens Brothers," from that time separated from the Berlin business, had quickly and regularly developed under my brother William's direction, both as a manufacturing and as a contracting concern. As William had also, at the same time, great success in the engineering business carried on by him



Positive Vorschläge

zu einem

Patent-Gesetz,

Denkschrift

der

Aeltesten der Kaufmannschaft zu Berlin

an

den Königlichen Staats- und Minister für Handel,
Gewerbe und öffentliche Arbeiten,
Herrn Grafen von Itzenplitz, Excellenz.

Herausgegeben

von

Dr. Werner Siemens.

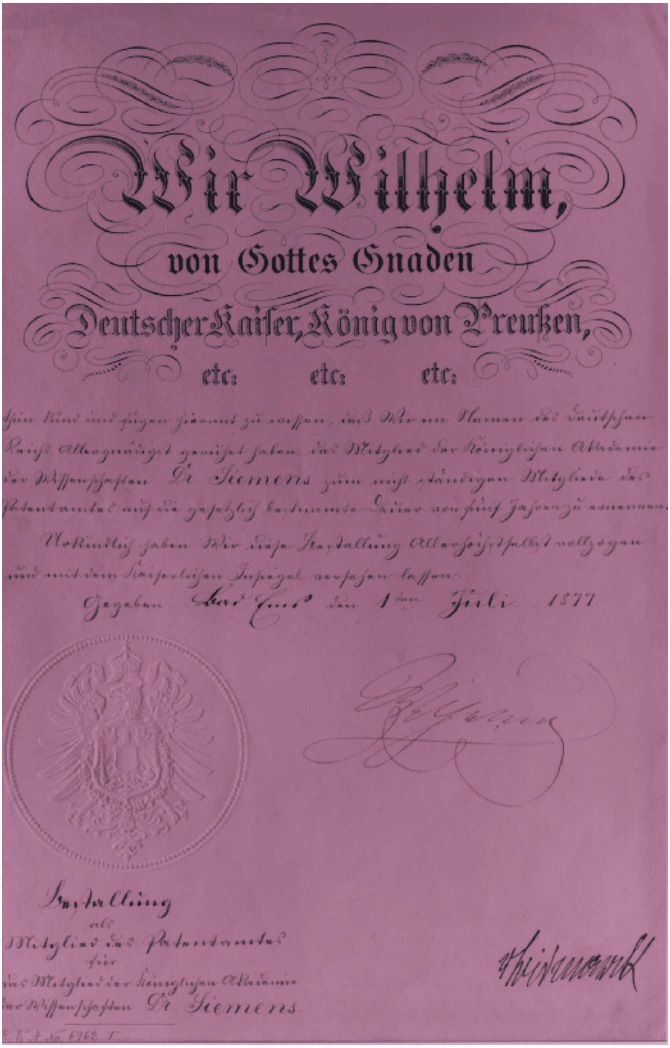
Berlin, 1869.
Verlag von Th. Bittkow.

The title page of Werner von Siemens' memorandum to the Board of Elders of the Berlin Merchants' Association, including a proposal for a Patent Act, 1869.

Philadelphia, June 2, 1876

… As the quintessence of everything the verdict is: German industry is based on the principle "cheap and shoddy." Unfortunately, we cannot deny that the ruthless pursuit of this principle is a sad feature of our industry, at least as far as the cheapness is concerned – and the shoddiness or bad workmanship is the unavoidable consequence. However much able, courageous industrialists who reject this principle have set themselves to combat it, however strictly many a person with a warm heart for our industry has condemned it, it still has the upper hand, as is only too evident in our Exhibition …

Franz Reuleaux
Briefe aus Philadelphia, *1877*


Wir Wilhelm,
von Gottes Gnaden
Deutscher Kaiser, König von Preußen,
etc: etc: etc:

Thun kund und fügen hiermit zu wissen, daß Wir im Namen des Deutschen Reichs Allergnädigst geruht haben, das Mitglied der Königlichen Akademie der Wissenschaften Dr. Siemens zum nicht ständigen Mitgliede des Patentamtes auf die gesetzlich bestimmte Dauer von fünf Jahren zu ernennen.

Urkundlich haben Wir diese Bestallung Allerhöchstselbst vollzogen und mit dem Kaiserlichen Insiegel versehen lassen.

Gegeben Bad Ems den 1ten Juli 1877.

Wilhelm

v. Bismarck

Bestallung
als
Mitglied des Patentamtes
für
das Mitglied der Königlichen Akademie
der Wissenschaften Dr. Siemens

Document appointing Werner von Siemens a member of the Prussian Patent Office, 1877.

privately, and his time and energies were thereby very much taken up, it was desirable at the end of the sixties that my brother Carl should undertake the special management of the London telegraph business. Carl consented, as, since the expiration of the Russian maintenance contracts, he no

In his comprehensive report to the Ministry of Commerce on the German Exhibition in Sydney, Professor Reuleaux says: Germany has never put up such a good show at an international exhibition as this time; by far the greater part of the German exhibits is above average, a smaller proportion stands very high and only a few inferior products of German industry are to be seen. The former prejudices are beginning to disappear. The expert eye will certainly still detect here and there relics of the old bad habits, but the public at large gets an excellent general impression.

Über Land und Meer,
Allgemeine Illustrierte Zeitung, *1880*

longer found any considerable sphere of activity in Russia.

Halske's resolution to retire from the Berlin firm was taken about the same time, and we three brothers decided, accordingly, upon an entire reform of the business connection of our different firms. A joint business was formed which embraced them all. Each firm retained its independence as regards administration and financial methods, but its profit-and-loss account was carried over to the joint business, of which we three brothers were the sole proprietors and partners. The St. Petersburg concern was placed under an able manager, while Carl went to England to undertake the special management of the London firm. How splendidly the London house, now named "Siemens Brothers & Co.," prospered in the period immediately following has been described at length in the book on my brother William by Dr. Pole, mentioned earlier. I therefore confine myself here to some remarks on the personal cooperation between my brother Carl and myself.

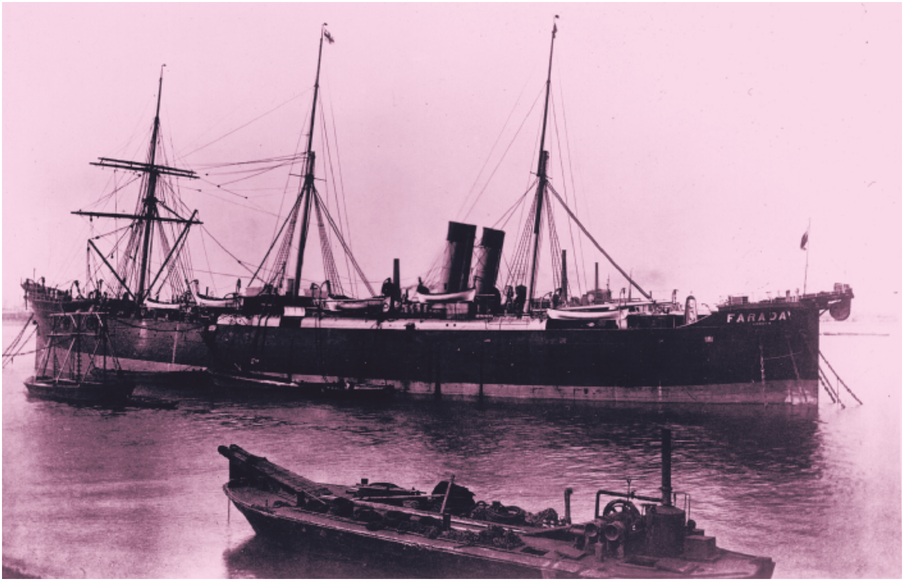
When, in the year 1869, Carl transferred his residence to London, the factory at Charlton was already in full production as a mechanical workshop for the construction of electric apparatus of every kind; a cable-sheathing shop was also combined with it, in which important cables had already been manufactured. The principle employed by me in the testings of the English government cables, that the permanence of a cable could only be assured if it were tested at all stages of its manufacture with scientific thoroughness and accuracy, had borne good fruit, and the system of cable testings, then elaborated, has as a consequence answered admirably well.

The remarkable success of the Malta – Alexandria line, which we tested according to this system for the English government, had considerably raised our technical reputation in England, and, perhaps for this reason, the only factory in England which then turned out wires coated with seamless gutta-percha according to my method threw difficulties in the way of supplying the purified gutta-percha which we ordered from it. We accordingly resolved to establish our own gutta-percha factory, and accomplished this with complete success. In this manner, we were enabled ourselves to undertake great cable layings, and thereby to break down the monopoly of the great cable ring which had meanwhile been formed and whose purpose was to monopolize the whole field of submarine telegraphy. In reality, my brothers succeeded in calling a company into existence which entrusted to us the production and the laying of an independent direct cable between Ireland and the United States. The requisite capital was subscribed on the Continent, as the English market was closed to us by the overwhelming competition.

Brother William showed his great constructive ingenuity by designing a large steamship expressly destined for the laying of cables, which was christened by us FARADAY. Brother Carl undertook the command of it for laying the cable. I considered Carl specially fitted for this task, as he was cool and deliberate, besides being a good observer and resolute in action. I myself was not to be deterred from sailing in the *Faraday,* laden with the deep-sea cable, to the starting point of the laying, Ballinskellig Bay, on the west coast of Ireland, and there undertaking the direction of the operations of the land station during the laying.

Our countryman Dr. William Siemens, whose improvements in iron production and whose work for the achievement of hitherto unattained temperatures are well known, has received from the Society of Arts on this account their highest distinction, the rarely awarded Albert Medal. It may also be remarked that the steamship Faraday *built for Siemens Brothers, with the new American cable made by them, will leave the Thames before the end of this week to commence the laying of the cable …*

National Zeitung, *May 15, 1874*



The cable-laying steamer Faraday, *designed by William Siemens, went into service in 1874.*

It was tolerably favorable weather, and everything went well. The difficult abrupt descent of the Irish coast into deep water was successfully overcome, and, according to the electrical testings, the state of the cable was faultless. Then, suddenly, there occurred a small defect in the insulation, so small that only extremely sensitive instruments such as we were employing could have detected it. According to previous cable-laying practice, this defect would have been allowed to pass, as it was without any influence on the signaling. But we wished to lay down a perfectly faultless cable, and determined therefore to take the cable up again to the point of the fault, which must be immediately behind the ship. This indeed went off well in spite of the great depth of 18,000 feet,* as was continuously telegraphed to us from the ship. Suddenly, however, the scale of our galvanometer flew out of the field of sight – the cable was broken! Broken at a depth from which to fish up the end again appeared quite impossible.

** About 5,630 meters.*

A view across the deck from the bridge of the Faraday. *Undated.*

It was a hard blow, which threatened our personal reputation as well as our business credit. The intelligence spread through all England in the same hour, and was received with very different feelings. Nobody believed in the possibility of recovering a detached piece of cable from so great a depth, and even brother William advised by telegraph to abandon the paid-out cable, and to recommence the laying. I was convinced, however, that Carl would not return without having made the attempt to pick up the cable, and calmly watched the continual fluctuations of the scale of the galvanometer to detect any signs pointing to the movement of the cable end by the search anchor. Such indications indeed frequently occurred, without having further consequences, and two anxious days passed without any news from the ship. All at once, a violent mirror vibration! The end of the copper wire must be in metallic contact. Then, for several hours, feeble regular twitching of the reflected image of the scale, from which I inferred a jerky lifting of the cable end by the grapnel. However, long hours of silence caused hope to sink again. Then, once more, strong mirror vibration produced by a current from the ship, which was greeted with repeated hurrahs by the workers at the station. The incredible had been realized. From a depth exceeding the height of Mont Blanc, the cable had been found by a single operation, and what is more, had been brought up to the surface unbroken. Many favorable circumstances must have combined to make this possible. Good sandy seabed, fine weather, suitable appliances for seeking and lifting the cable, and a good manageable ship with a skillful captain happily concurred, and made possible the apparently impossible with the help of much luck and self-confidence. Brother Carl, however, confessed to me afterward that during the uninterrupted lowering of the grapnel, which took seven hours to reach the seabed, giving him for the first time a clear idea of the known depth, he had lost all hope of success and was himself astounded when it came.

After successful removal of the fault and reestablishment of connection with the land, the laying was continued for some days without disturbance. Then the ship reported rough weather, and, soon after, a small fault again occurred in the cable, which was left, however, till reaching shallow water off Newfoundland, in order to seek and remove it when the weather was more favorable. The recovery proved to be very difficult, however, as the seabed was rocky and the weather persistently bad. Much cable was thereby lost, and the *Faraday* was obliged to return to England without finishing her task, to ship fresh cable and coals. Yet even the following expedition led only to the more accurate localization, but not to the removal, of the fault, and a third attempt was necessary in order to render the cable communication perfectly faultless.

This first transatlantic cable laying of ours was not only exceedingly instructive for us, but in point of fact led for the first time to the completely clear apprehension and mastery of cable laying in deep water. We had shown that even in unfavorable weather and at a bad time of year cables can be laid and repaired, and that, too, in very deep seas and with a single but well-constructed and sufficiently large ship. The loss of cable which we had had in the repairs was attributed by brother Carl to the unsuitability of the construction of the cable, which was identical with that adopted for the first successful transatlantic cable. To diminish the specific gravity of the cable, steel wires had been used for the covering and protection of the conductor, surrounded with hemp or jute. On a strong pull, these twisted the cable and produced kinks in the cable on the bottom of the ocean, which very much impeded or altogether prevented the recovery. In accordance with Carl's suggestion, we afterward used only a closed steel-wire sheathing and thereby removed all the difficulties which so considerably hampered our first deep-sea laying.*

** That is, the first laying of cables produced by Siemens.*

On the further technical improvements in the method of laying cables in deep water to which the preceding enterprise led us, I cannot here enlarge. I will only mention that my theory, propounded on laying the Cagliari – Bona cable in 1857, has held its ground very well. As already mentioned, I have further developed and mathematically treated this theory in an essay laid before the Berlin Academy of Sciences and the Society of Telegraph Engineers and Electricians in London, and believe that it may now be regarded as fairly settled. The laying of this, our first transatlantic cable, brought us brothers many exciting incidents, one of which occurred at a very unfavorable moment and profoundly agitated me.

In the year 1874,* the Royal Academy of Sciences in Berlin had elected me one of its ordinary members, an honor which hitherto had fallen only to the lot of professed savants.

** The election had taken place on October 20, 1873, and was confirmed in 1874.*

AUSPICIIS SERENISSIMI AC POTENTISSIMI
GUILELMI
BORUSSORUM REGIS
Academiae Scientiarum Borussicae Protectoris Clementissimi
Virum Illustrem suisque titulis condecorandum
WERNERUM SIEMENS
Regiae nostrae Academiae
SOCIUM
declaramus eumque honore, privilegiis, beneficiis Academicorum ordini concessis rite ornamus.
Cujus rei ut plena fides existat, ex decreto Academiae in acta relato hasce litteras sigillo nostro publico et subscriptione consueta munitas expediri jussimus.
Berolini die 22m.Dec. anno 1875.

Werner von Siemens' appointment as a member of the Royal Prussian Academy of Sciences in Berlin, 1873.

On the day fixed for the purpose I was about to give my prescribed inaugural address at a special meeting of the Academy when, on leaving the house, I received a telegraphic message from London to the effect that, according to a cablegram, the *Faraday* had been crushed by icebergs and had gone down with all hands. It required no slight self-control on my part, oppressed as I was by this terrible intelligence, still to deliver my address, which did not admit of postponement. Only a few intimate friends had perceived my violent emotion. Certainly I had hopes from the first moment that it was only a "love token" of our opponents to cause this dread intelligence to be concocted in America, whence it was telegraphed. And indeed so it soon turned out to be. How the story originated could never be discovered, and after the lapse

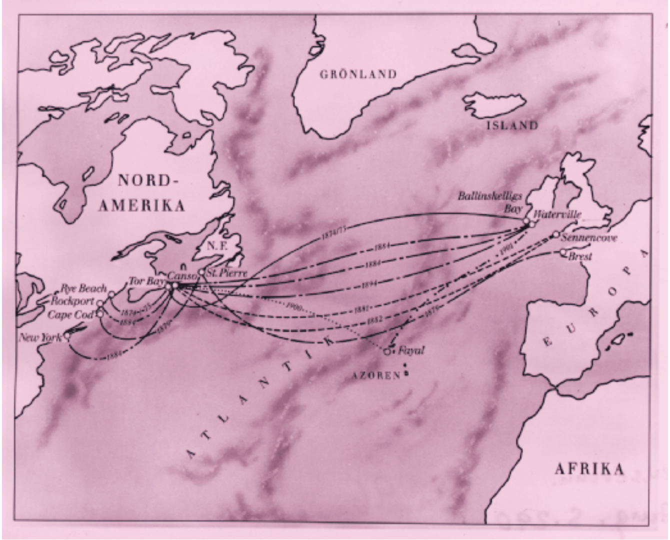
In conclusion, I am glad to be able to say that my tests proved the cable to be in perfect condition as to insulation, and showed its electrostatic capacity and copper resistance to be so small as to give it a power of transmitting messages, which, for a transatlantic cable of so great length, is a very remarkable as well as valuable achievement.

William Thomson
The University Glasgow
September 23, 1875

Werner von Siemens (second from left) at the Royal Prussian Academy of Sciences in Berlin, 1888.

of several anxious days the *Faraday* was reported safe and sound from Halifax. It had been detained at sea for a considerable time by a thick fog.

At a stroke, the successful completion of the American cable raised the London firm to a far higher level of English business life than it had occupied hitherto. The testing of the electric properties of the cable by the highest authority in this department, Sir William Thomson, had proved that it was entirely faultless and possessed a very high signaling capacity. It was of great importance that the cable ring, which had been formed under Sir John Pender's auspices, was now broken. It is true the attempt was made to restore it by subsequently admitting to the ring the cable laid by us. This, however, was to our advantage, for there was soon formed another, and this time a French, company, which gave orders to our firm to lay an independent cable. After a short time, this also was purchased by the Globe, as the cable ring was called, but this led to American capital being



Relief map of the North Atlantic with the cables laid by the Faraday*. The mountain chain down the Mid-Atlantic Ridge, visible in the center, always posed problems for laying transatlantic cables.*

attracted to cable telegraphy. In the year 1881, my brother William received a cablegram in which the well-known railway king Mr. Gould ordered a double cable to America, which was to be constructed entirely like the last laid by us – the French so-called Pouyer-Quertier cable. It is a sign of the credit which our firm also enjoyed on the other side of the ocean that Mr. Gould declined to receive a representative to conclude the contract, "as he had perfect confidence in us," and confirmed this by the remittance of a large installment. This was the more noteworthy, as Mr. Gould is well known in America as a very cautious and keen man of business, and it was a matter of some millions. At any rate, however, he had correctly speculated, for his unlimited confidence constrained my brothers to propose the most favorable conditions possible and to execute the work in the very best fashion. After some competitive contests, the Gould cables were also united with the Globe, but it was America that again broke through the monopoly. In the year 1884, the well-known Americans Mackay and Bennett gave orders to Siemens Brothers for two cables between the English coast and New York, which were faultlessly manufactured and laid within a year, and have up till now maintained their independence of the cable ring.

These six transatlantic cables have all been laid by the *Faraday*, which proved a most satisfactory ship for cable laying, and as such has served as a model for the competing firms. The double screw with axles inclined to one another, which was first employed in it, gave to the great ship of 5,000 tons a degree of mobility hitherto unattained, which made it possible to carry out cable-laying and repairing work in every season and even in unfavorable weather.

Brother Carl had already returned to St. Petersburg in the year 1880, after the London firm had at his instigation been transformed into a private limited liability company. In the year 1883, brother William was, alas, torn from us and his untiring activity by a quite unexpected and sudden death. Herr Löffler, an official of many years' standing, was installed as managing director of the London firm, and has been recently succeeded by a younger member of the family, Mr. Alexander Siemens.

My appointment as ordinary member of the Berlin Academy of Sciences was not only very honorable in itself for the favored individual, who did not belong to the class of professional savants, but it also had a profound influence on my later

Inaugural address to Werner von Siemens on being elected to the Academy of Sciences in Berlin, delivered by Emil Du Bois-Reymond; July 2, 1874

… Your telegraph wires girdle the globe. Your cable ships traverse the ocean. In the tents of nomads carrying bows and arrows, whose pastures your messages cross, your name is spoken with superstitious awe. But it is not so much the successes of this nature by which you attained such standing and honor that have opened for you the doors of the Academy. Rather is it the fact that from this eminent position, as a prince of engineering, holding the strings of innumerable combinations in your hand, with a hundred plans turning over in your mind, you have remained in your inmost being the German savant, in the most noble sense of the word, to which you were born, not even educated; that whenever the burden of business has allowed, you have returned with joy to the phenomenon, with devotion to the experiment, with an open mind to theory, in fact with genuine enthusiasm to pure science: this, not to speak of your sagacity, your ingenuity and your powers of observation, mark you in our eyes as an Academician.

William Siemens, around 1880. Werner's brother's scientific methods made a contribution to the development of English industry, for which he was knighted in 1883.

life. As my friend Du Bois-Reymond, who as presiding secretary of the Academy acknowledged my inaugural address, rightly pointed out, by natural endowment and inclination I belonged in a far higher degree to science than to practice. Scientific research was my first, my early love, and it has retained my affection to the advanced age which I now – I can hardly say – enjoy. At the same time, I have certainly always felt the impulse to make scientific attainments useful for practical life. I expressed that in my inaugural address, when I enlarged on the theme that science does not exist for its own sake, merely to satisfy the thirst for knowledge of the limited number of its votaries, but that its office is to increase the treasures of knowledge and power of the human race, and thereby to raise mankind to a higher level of civilization. It was noteworthy that friend Du Bois in his reply to my address at the end bade me welcome "into the circle of the Academy, which pursues science only for its own sake." In very truth, scientific investigation must not be a means to an end. The German savant has always been justly distinguished by this, that he pursues science on its own account, for the satisfaction of his thirst for knowledge, and in this sense I have always been able to consider myself more of a savant than an engineer, since the prospective profit has either not at all, or only in special cases, guided me in the choice of my scientific work. The entrance into the narrow circle of distinguished men of science could not therefore but elevate me in a high degree and spur me to scientific activity.

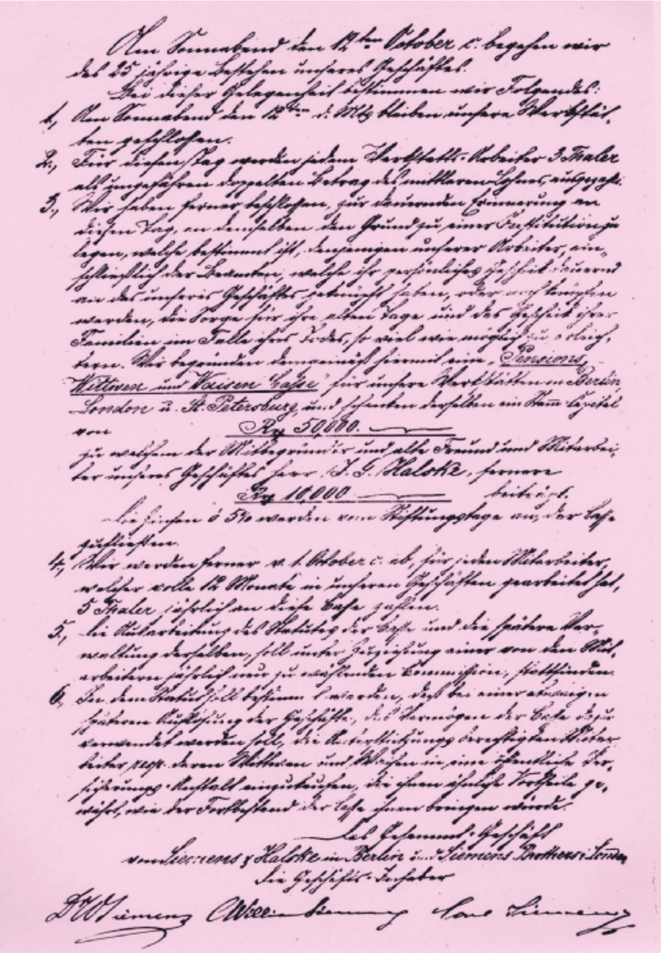
Moreover, the statutes of the Academy exerted a beneficial constraint upon me. Every member must in rotation give a lecture which is then printed in its transactions. As it was very disagreeable to evade this obligation, it compelled me to complete and publish researches which under other circumstances I should perhaps have postponed in favor of others seemingly more interesting, or have left altogether unfinished. While, therefore, before my reception into the Academy I seldom got as far as the publication of a piece of scientific work, and usually contented myself with the enlargement of my own knowledge – not without subsequent vexation, if my results were discovered and then made public by others – I was now obliged every year to finish and publish one or two contributions. To this state of things is also to be ascribed the circumstance that in my academic lectures I dealt less with matters of my special department, electrical industrial arts, than with subjects of general scientific interest. They were partly detached thoughts and reflections, jotted down in the course of my life, which were now brought together and scientifically worked up, partly novel phenomena which aroused my particular interest and called for special investigation. I shall once more return to these purely scientific publications at the close of these reminiscences. Although since my reception into the Academy I had been far more occupied than heretofore with purely scientific problems, unrelated to my business calling, I did not omit to continue to devote the necessary time to the latter also. The superior management of the Berlin firm, and the

Alexander Siemens (1847–1928) worked in Persia and on the Black Sea building the Indo-European telegraph line in 1868–1869. From 1871 onward he was an engineer in London. Undated.

technical work connected with it, usually claimed my whole working time during the day. The difficulty of my task was much augmented by the multifarious character and the far-reaching dimensions which the firm's operations had gradually assumed; and although able coadjutors relieved me of a considerable portion of the burden, yet there still remained for me much arduous and unceasing work.

It had become clear to me very early that a satisfactory development of the continually growing firm must depend on securing the hearty, spontaneous cooperation of all the workers for the furtherance of its interests. To attain this it seemed to me essential that all who belonged to the firm should share in the profits according to their performances. As my brothers acceded to my view, this principle came to be adopted in all our establishments. Arrangements to that end were settled at the celebration of the twenty-fifth anniversary of the original Berlin firm in the autumn of 1872. We then determined that a considerable portion of the yearly profits should regularly be set aside for allowing a percentage to officials proportionate to their salaries, and bonuses to workmen, and as a reserve fund for necessitous cases. Moreover, we presented the collective body of workers with a capital stock of 60,000 thalers (£ 9,000) for an old-age and invalid fund, the firm agreeing to pay every year to the account of the managers of the fund, chosen directly by those interested, five thalers (15 shillings) for each workman and ten thalers (30 shillings) for each official who had served in the business uninterruptedly for a twelvemonth.

These arrangements have worked remarkably well during the nearly twenty years of their existence. Officials and workmen regard themselves as a permanent part of the firm and identify its interests with their own. It is seldom that officials give up their position, since they see their future assured in the service of the firm. The workmen also remain permanently attached to the firm, as the amount of the pen-



The document founding the Pension, Widows' and Orphans' Fund, 1872.

sion rises with the uninterrupted period of service. After thirty years continuous service, the full old-age pension commences with two-thirds of the wages; and that this is of practical importance is proved by the respectable number of old-age pensioners who are still strong and hearty, and apart from their pension continue to receive their full wages. But almost more than the prospect of a pension it is the

Certificate of the reception of Werner von Siemens into the Prussian Academy of Sciences, December 22, 1873

At the behest of the Most Illustrious and Most Powerful WILHELM, King of the Prussians, Most Gracious Protector of the Prussian Academy of Sciences, we declare the distinguished WERNER SIEMENS, who be deservedly adorned with his titles of honor, to be a Member of our Royal Academy and invest him in the usual manner with the distinction, privileges and benefits proper to the status of the Academicians. In witness whereof we have had this document prepared in accordance with the duly recorded decision of the Academy and certified by our official seal and the usual signature.

endowment fund for widows and orphans connected with the pension fund that binds the workmen to the firm. It has been proved to be the case that this endowment is still more urgent than the invalid pension, as the uncertainty of the future of those dependent on him commonly weighs more heavily on the workman than his own. The aging workman nearly always loves his work, and does not willingly lay it down without actual and serious need of rest. Accordingly, the superannuation fund of the firm, in spite of a liberal use of the pensions by the workmen themselves, has only consumed the smaller part of the income from the interest of the funded capital and the contributions of the firm toward pensions; the larger part could be applied for the support of widows and orphans as well as for increasing the capital stock of the fund, which is destined to secure the workman's claim for pensions in the event of the possible liquidation of the business.

The criticism has been made of this arrangement that it binds the workman too much to a particular workshop, since by his leaving it he loses the advantages gained. This is quite true, although the hardship is considerably mitigated by the circumstance that, with dismissal for want of work, every dismissed workman receives a paper giving him a preferential claim to readmission over other workmen. Certainly, the workman's freedom to strike is considerably restricted by the conditions regarding pensions, for, by the rules, on his leaving voluntarily, his old-age claims lapse. It is, however, in the interest of both parties that a permanent working staff should be formed, for only thereby is the firm enabled to maintain the workmen even in unfavorable times and to pay them wages affording adequate subsistence. Every large factory ought to form such a pension fund, to which the workmen contribute nothing but which they themselves manage, of course, under the control of the firm. The strike mania, which seriously injures industry and especially the workmen themselves, is best coped with in this manner.

It is certainly somewhat hard that the provisions of the Workmen's Old-Age Insurance Law of Germany have no regard to the already existing or prospective private pension funds, and thus oblige the particular factories to pay double for pensioning their workmen. However, the peaceful relations between employers and employees, which are secured by the private pension fund, as well as a permanent staff of workmen, are so important that such an excess of expenditure is amply justified.

The *esprit de corps* produced by the arrangements described, which binds together all the fellow workers of the firm of Siemens & Halske and gives them an interest in its welfare, explains in great part the commercial success which we achieved.

This leads me to the question whether it is altogether in the general interest that large commercial houses should be established which permanently remain in the possession of the family of the founder. It might be said that such large firms are hindrances to the rise of many smaller undertakings and therefore act injuriously. That is cer-

Foundation document of the Pension Fund, 1872

On Saturday, October 12 of this year, we celebrate the 25th anniversary of the establishment of our firm. To mark this occasion we have decided on the following:

1. *On Saturday, the 12th inst., our works will be closed.*
2. *For this day each workman will receive 3 thalers, this being about double the average wage.*
3. *We have further decided, as a permanent memorial to this day, to found on this day an institution the purpose of which is as far as possible to relieve the concern of those of our workers, including the staff, who have linked their personal destiny permanently with that of our firm or will do so, for their old age and for the support of their families in the event of their death. We accordingly establish hereby a "pensions', widows' and orphans' fund" for our works in Berlin, London, and St. Petersburg and make an initial donation to it of 50,000 thalers of capital stock, to which our old friend and colleague J. G. Halske, the co-founder of our firm, contributes a further 10,000 thalers. The interest at 5% will accrue to the fund from the date of its foundation.* →

4. *Also, from October 1st we will pay into the fund 5 thalers annually for each worker who has served in the business uninterruptedly for a twelvemonth.*
5. *The drawing up of the Constitution of the fund and its subsequent administration will be carried out in cooperation with a committee elected annually by the employees.*
6. *It will be laid down in the Constitution that, in the event of a future dissolution of the firm, the capital of the fund will be used on behalf of the workers, widows or orphans entitled to support, to obtain for them through a public insurance institution benefits similar to those which continuance of the fund would provide.*

The combined firms of Siemens & Halske in Berlin and Siemens Brothers in London

The Principals:
Dr. W. Siemens
C. Wilhelm Siemens
Carl Siemens

tainly pertinent in many cases. Wherever it is possible to maintain an export trade by the productions of handicraftsmen, large competing factories have a prejudicial effect. Wherever, on the contrary, the development of new branches of industry or the opening of the markets of the world for those already in existence are concerned, large centralized business undertakings with abundant capital are indispensable. At the present day, such capital can certainly be brought together most easily in the form of joint stock companies, but these can nearly always be only purely gain-seeking companies which, by their own regulations, are only allowed to have in view the attainment of the largest possible amount of profit. They are therefore only adapted for reaping advantage from already existing well-tried methods of working and organization. The opening of new paths is on the contrary nearly always troublesome and attended with great risk, and requires also a larger store of special knowledge and experience than is to be found in joint stock companies, for the most part short-lived and often changing their management. Such an aggregation of capital, knowledge, and experience can only be formed and maintained in long-established commercial houses, remaining by inheritance in the same family. Just as the great commercial houses of the Middle Ages were not only money-making institutions, but considered themselves called upon and bound to serve their fellow citizens and the state by seeking out new commodities and new highways of commerce – the obligation being transmitted as a family tradition through many generations – so at the present day, in this awakened scientific age, the large technical business houses are called upon to put forth their whole strength, that the national industry may take the lead in the great contest of the civilized world, or at least the place assigned to it by the nature and situation of the country itself. Our political institutions still rest almost everywhere on the feudal system, according to which the landed proprietor was almost exclusively regarded and honored as the supporter and maintainer of the power of the state. Our time can no longer recognize the validity of this privilege. The social forces maintaining the state today and henceforth will not consist of possessions, whatever they may be, but of the spirit which animates and fertilizes them. Although it is conceded that inherited possession of the soil binds the owner by tradition and education more firmly to the state, and is therefore a better preserver thereof than the possession of land easily transferable and of capital altogether movable, yet it no longer suffices to protect the state from impoverishment and decay. This protection can only be secured today by the conscious cooperation of all the spiritual forces of the nation, the maintenance and further development of which is one of the most important problems of the modern state.

Although the fact that I owe my position in life to my own efforts has always afforded me a certain satisfaction, I have always gratefully acknowledged that my path was smoothed by my admission into the Prussian Army and therewith into the State of Frederick the Great. I regard the cabinet order of Frederick William III, which accorded me an entry into the Prussian Army, as the opening of the only path then possible in which my energies could be developed. I have often, in my later life, had opportunity to perceive how true had been the utterance of my father that, in spite of all discontent with the Prussian policy of the Holy Alliance, Prussia was yet the only firm point in Germany and the only anchorage for the hearts of German patriots. I have therefore always bestowed my, I may well say, inborn affection to the German fatherland first and foremost on Prussia, and have always been faithfully and gratefully devoted to it and its five kings under whose rule I lived. It was not only the knowledge to be acquired at the Prussian military schools and the mental culture there attained which facilitated my later progress in life, it was also the position of military officer, held in such esteem in Prussia, which was of the greatest assistance to me.

As I have already mentioned in another place, Prussia, down to the middle of the present century, was essentially a military and bureaucratic state. Only to the nobility and landed gentry appertained certain honorary privileges. An industrial class proper was entirely wanting, in spite of all the effort which enlightened officials, such as Beuth, made in order to form one from the insufficiently developed artisan class. Moreover, as the trade of the country was very limited, there was also wanting a prosperous cultured middle class as counterpoise to the army, the officials, and the landed nobility. Under these circumstances it was of great value in Prussia to belong as officer to the court retinue and to have the entrée to all social circles.

It is customary at the Prussian Court for this privilege, possessed by every, even the civil, officer, to be continually exercised. Thus, as early as the winter of 1838, when a young officer in the Artillery and Engineering School, I was commanded to attend great entertainments at the royal palace, and since that time, accordingly for more than half a century, I have frequently been permitted to be present at these great court gatherings, which faithfully reflect Berlin society and clearly illustrate the immense revolution which Prussia, and all Germany with it, has undergone during that time. At these assemblies I have frequently had the opportunity of becoming personally acquainted with the members of the Royal Family.

As previously mentioned, I had already had occasion at an earlier period of my life to be grateful to the Prince of Prussia for his kindness in liberating me at St. Petersburg from a painful position. I have ever retained this feeling of gratitude, but alas in consequence of my political views was constrained to incur the anger of the monarch by voting according to my convictions in the Prussian Diet against the reorganization of the army. When the declaration of war against Austria had actually taken place, and the brilliant victories of the reorganized Prussian Army had clearly proved the wisdom of the strengthening of the army by this reorganization, I took pains to help remove the injurious consequences of the parliamentary resistance to the reorganization, and successfully struggled for the grant of the indemnity so magnanimously asked for by the victorious ruler, but hardly thought I could ever hope to regain the former favor of the sovereign. I was therefore all the more agreeably surprised when, at the close of the Paris Universal Exhibition of 1867, at the same time as the French *croix d'honneur,* the Prussian Order of the Crown was conferred upon me.

A few years later, the Emperor gave a still more pronounced expression to this renewal of favor with a kindliness which could hardly be surpassed. For a number of years I had been a member of the Council of the Berlin Merchants' Company, and according to the prevailing practice had been proposed by the president of the Company for nomination as Councilor of Commerce, without my knowing anything about it. The Emperor had already approved of the nomination, and the president of police was kind enough to call upon me and personally to bring me the gratifying intelligence of this impressive mark of favor. The title of Councilor of Commerce, however, was not quite to my taste, for I considered and felt myself more a savant and engineer than a merchant. The president of police, who soon perceived my uneasiness, tried to combat my objection and asked what he should say to the Emperor, who had desired to do me a favor. Whereupon the remark slipped off my tongue that first lieutenant, honorary doctor of philosophy, and commercial councilor did not agree, that such a mixture would produce a stomachache! The police president finally promised to convey my petition to the Emperor that my appointment as Councilor of Commerce should not be published, and we agreed to meet at a particular spot at the court ball to be given the same evening. He came up to me there with a cheerful countenance and reported that he had communicated to the Emperor my scruples regarding the stomachache; that the Emperor had laughed heartily at it, and remarked he himself felt something of the same sort, and that I should therefore ask for some other favor when he addressed me. This unfortunately I could not do. A title more in accordance with my position did not exist in Prussia for nonofficials, and I could not possibly follow the advice of the president to request a higher order, since, as I said to him, one gratefully accepts such when offered, but does not solicit it. This refusal gave offense to the president, and as the Emperor passed soon after without addressing me, I imagined I had again incurred his displeasure. I was all the more delighted, nay, almost abashed, when the president of police communicated to me he had told the Emperor that I knew of nothing to ask from him, and that he had thereupon replied, "Well, then, present him to my wife."

In consequence of mistaken identity this presentation did not then take place, and I also afterward omitted to be presented to the Empress in the usual way, as it was repugnant to me to force myself into the presence of royalty, as is so often done. That this did not pass unnoticed I afterward learned from the Empress herself. During the Vienna Exhibition of 1873, the latter requested the German jurors to be presented to her, I being one of them. After the presentation was over, she sent for me specially and said: "I have a bone to pick with you, Herr Siemens, you try to give us the slip, but in future you will not find that so easy." Indeed the august lady often afterward gave me proofs of her esteem and graciousness in visiting our factories or inviting me to give lectures on electrical subjects.

One of these lectures, which I had to give in the Imperial Palace, had special significance. On the day before the delivery of the lecture, the Grand Duke of Baden had sent me a program, precise both in extent and subject, which the Emperor himself had dictated to him. The theme ran "Wesen und Ursache der Elektrizität und ihre Anwendung im praktischen Leben" (Nature and Cause of Electricity and its Application in Practical Life). It was not easy to satisfy the theoretical part of the program, as our knowledge of the nature of electricity is still very slight, but even the drawing up of such a program shows how profound was the interest taken by the Emperor in the physical sciences, the great importance of which for the further development of human civilization he fully perceived.

The Crown Prince and his family have also invariably displayed the liveliest interest in the gradual development and the scientific achievements of our establishment, and have frequently honored our factories with their presence. To this gracious and kindly recognition of my efforts I, in fact, owe my place in the list of recipients of honors which the Emperor Frederick announced on ascending the throne. Without the usual preliminary inquiry I was included in the list, and to my great astonishment first heard through the newspapers of my admission into the ranks of the nobility.

Although my time was very much taken up with my scientific work and my business, I never lost my interest in questions of public life. I was an active member of several scientific and technical societies, took part both commercially and privately in the great exhibitions, and was frequently appointed by the government to special com-

We Wilhelm, by the Grace of God Emperor of Germany, King of Prussia etc. etc. etc. make known and decree that we, in the name of the German Empire, have been graciously pleased to appoint the Member of the Royal Academy of Sciences, Dr. Siemens, as nonpermanent member of the Patent Office for the statutory period of five years.

We have confirmed this document of appointment by the affixation of the Imperial Seal.

Given at Bad Ems, July 1, 1877
Wilhelm v. Bismarck

Together with Dr. Siemens, the Postmaster General Stephan has initiated the foundation of an Electrotechnical Society with the object of developing and furthering the application of electricity.

Über Land und Meer, Allgemeine Illustrierte Zeitung, *1879*

missions for scientific and technical questions. Of this multifarious activity I shall here cite only a few instances which appear to me worthy of mention.

When the imperial patent law came into being, substantially in accordance with my proposals, an invitation was issued to me to assist the newly constituted Patent Office at least for a number of years. I willingly complied, in order to be enabled to ensure that the practical application should be in harmony with the adopted principles of the patent law. In this manner I obtained the rank of an official of the Empire, and as such was proposed by Prince Bismarck for the title of "Privy Councilor." I gratefully accepted the same, as the bearing of a title in Prussia is very general and my colleagues, the members of the Academy of Sciences, for the most part bore it.

I was an active member and for a number of years deputy chairman of the Association for the Promotion of Industry, which was called into existence by Beuth, the father of Prussian industry, and rendered great service to the industrial development of Germany under the long presidency of State Minister Delbrück.

I had a large share in the establishment of the Electrotechnical Society through the mediation of the Secretary of State, Dr. von Stephan. I was the first active president of the Society and made many of my technical labors public for the first time through lectures in this Society. Similar

Heinrich von Stephan (1831–1897) founded the Electrotechnical Association with Werner Siemens in 1879.

societies were founded in several places after the pattern of the Berlin Electrotechnical Society; at the same time the meritorious and older Society of Telegraph Engineers in London, called into existence by my brother William, expanded their name and program by adopting electrical engineering as the aim of the Society. The formation of the Berlin Society is to be regarded as the commencement of electrotechnical science as a special branch of civil engineering, the term *Elektrotechnik** itself occurring for the first time in the designation of the Society. By the adoption of the resolution subsequently brought forward by me, "to request governments to establish professorships of electrical engineering at all polytechnical academies, in order that young engineers may have the opportunity of getting to know the assistance which electrical engineering might afford them in their special work," the Society has rendered good service as regards the rapid development of electrical engineering in all its branches, as the resolution was almost everywhere complied with. Also by its endeavors to obtain an international system of electric standards, the Society has done great service. The initiative was taken by the Congress, which was connected with the Industrial Electric Exhibition in Paris of 1881 – a request being sent to the French government to bring about diplomatically the gathering of an

** Word coined by Werner von Siemens. See letter to Stephan of February 5, 1879, on the following page.*

... chairs of electrical engineering should be founded, in order to make at least our technical youth better acquainted with the science of electricity and its technical application ...

Scientific & Technical Papers of Werner von Siemens, *vol. II.* Technical Papers, *London, 1895, 483* international conference of delegates whose task should be the establishment of a scientific system of standards for electrical engineering.

Such a conference, to which Helmholtz, Wiedemann, Clausius, Kirchhoff and myself were nominated by the German Empire, met in Paris in the following year, and decided in principle for the absolute standard system of Wilhelm Weber, with the modification that the cgs standard, for which England had already pronounced, was adopted as the standard of resistance. Owing to the little accuracy, however, with which hitherto the absolute resistance unit of Weber could be reproduced in practice, it was resolved to take as a practical basis the mercury unit, which I had proposed, and to invite the scientists of every country to settle experimentally the relation of the modified cgs unit to the then widely adopted Siemens unit. As the mean of all the determinations in consequence arrived at, there resulted for this relation the value 1.06; and accordingly a column of mercury of 1 square millimeter in cross section and 106 centimeters long at 0 °C named "Ohm" was established at the final conference in the year 1884 as the international legal unit of resistance. In like man-

Werner von Siemens to the Postmaster General v. Stephan

Berlin, February 5, 1879

Your Excellency,
I beg to submit for your favorable consideration the enclosed "Draft Statute for a German Electrotechnical Society."
I have been forced to the conclusion that a telegraph association would not find sufficient material and active participants here to give it a status comparable with that of the existing English institutions. I therefore beg to suggest that your Excellency assume the patronage of a German association embracing the whole field of electrical engineering. Such an association has become essential and could be of the greatest benefit. In addition to telegraphy, the development of which has already been directed into more settled paths and which represents the aristocratic, conservative element of electrical engineering, we see everywhere a wild rush, a restless striving, to gain for electricity an important place in the old branches of industry and to base new ones on it. Especially since dynamo-electric machines have made possible the generation of cheap and powerful electric currents by mechanical power, the future field for electricity is practically unlimited. I need only mention electric light, power transmission by electricity and electrical copper refineries on a large scale, which have already paved the way. In all probability the whole of the metallurgical industry will be completely revolutionized. I would also mention the new railway safety system which will transform the whole railway service. The vanguards of advancing electricity are to be met almost everywhere. The military already →

ner, the names of meritorious physicists were selected for the remaining units of the system; it is, however, to be regretted that the name of Wilhelm Weber, the creator of this absolute standard system, was passed over, although this honor ought to have been specially paid him, when his own system was adopted. For myself it was a small triumph that a reproduction of my mercury unit, which Lord Rayleigh made according to a method somewhat different from my own, should yet agree to a ten-thousandth part with the standard tallies delivered by our firm.

uses it for making war in 6 or 7 different forms. All these activities have so far lacked a properly constituted focal point.
I am convinced that all other civilized countries will soon follow Germany's lead in the establishment of electrotechnical societies, but it will always be of great value to have been first in the field! In no country is there more fruitful soil for the development of electrical engineering than in Germany for in no other country is knowledge of the natural sciences so widespread. If Your Excellency were to assume the leadership and help the new society over its teething troubles with the energy and power for which you are well known, it would soon attain a position of respect and be of great value to the fatherland. I thought that a letter would cause Your Excellency less inconvenience than a visit, but should Your Excellency desire to discuss the matter I would of course be glad to do so at any time.

Your Excellency's most obedient servant
Dr. Werner Siemens

It was certainly somewhat hard for me that my resistance unit, arrived at with so much trouble and labor, which had generally speaking made possible the first comparable electric measurements, was then employed for more than a decade throughout the world and adopted as legal international standard of resistance for telegraphy by the International Telegraph Congress, should now have suddenly to be set aside with my own cooperation. But the great advantage of a theoretically established system of standards, consistently carried out and universally adopted, necessitated this sacrifice offered up to science and the public interest.

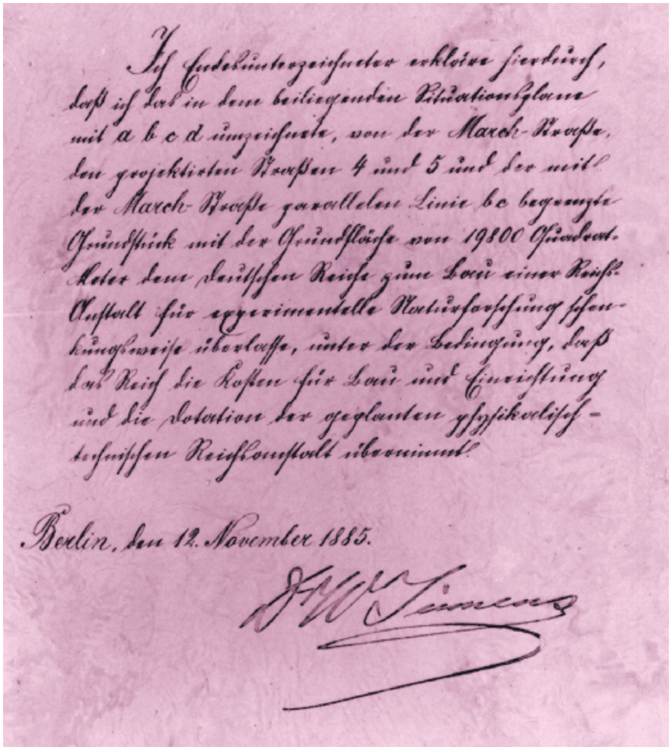
My literary activity was in general limited to the presentation of my scientific and technical labors and the description of the mechanical contrivances which I had constructed. I was, however, often obliged to repel attacks which were leveled directly or indirectly at my firm or at myself personally. This was the more necessary as my firm never advertised, and only let good workmanship proclaim its merits. Unfounded attacks on its achievements could therefore not pass unchallenged, and frequently had to take the form of an appeal to the law of libel, as the newspapers usually had more sympathy for their regular profitable advertisers.

Of such corrections I will only here instance one sent in April 1877 to the *Elberfelder Zeitung,* since it is of a more general interest. The anonymous writer who gave rise to this communication had praised the dynamo-electric machines of M. Gramme in Paris, whom he styled the meritorious inventor of the dynamo-electric machine and electric lighting, and for whose recognition he claimed the German love of justice in high-sounding phrases, without even making mention at all of the German share in these inventions. In my reply I emphasized the undoubted merit of Gramme in the development of the dynamo-electric machine, which consisted in the combination of the ring of Pacinotti with my dynamo-electric principle; however, I could not omit to reverse the appeal to German love of justice in favor of foreign services by pointing to the fact that the German is always inclined rather to recognize foreign and exotic than home growths. This was, I added, a great obstacle to the development of German industry, since the latter was often compelled by the preference for foreign manufactures to send its better products to the markets of the world under a foreign flag, whence it came to pass that German manufactures were everywhere wrongfully characterized as inferior cheap wares.

I have had occasion before to refer to this, and in particular have characterized as unpatriotic and despicable the suicidal practice of bringing the better German manufactures to market as English, French, or even American. It is difficult to decide whether the blame rests mainly with the German public or the German manufacturers; in any case, it is the outcome of a reciprocal action between the prejudice of the former and the shortsightedness of the latter, who have only their momentary advantage in view. Since the establishment of the new German Empire and the national advance connected with it there has undoubtedly been an improvement in this respect, but the eradication of the evil is still far from complete. Our manufacturers still lack too much the pride to supply only good articles, and our public the perception that such commodities even at a higher price are the cheapest. Only from the reciprocal action of both is the national pride in the products of one's own industry developed, and it is this which affords the best protection for the latter. How strongly the feeling of the superiority of native to all foreign products is developed in England was vividly brought home to me when I was once watching, with brother William, the unloading of a vessel which for the first time brought ice to London from a Norwegian port. The ice was deposited in handsome cubical blocks on the wharf, and was regarded with obvious interest by the purchasers. My brother began a conversation with one of them by praising the fine appearance of the blocks. "Oh yes," was the reply of the person addressed, a herculean butcher. "It looks very well, but it has not the quality of English ice." Even English ice must necessarily be colder than foreign ice. This prepossession of every Englishman in favor of native products, which always influences his choice, strengthens the pride of the English artisan and manufacturer in the excellence of their work and thereby often causes the preconceived opinion to become truth.

Of my other popular publications I will here cite only my lectures "Die Elektrizität im Dienste des Lebens" (Electricity in the Service of Life) of the year 1879 and "Das naturwissenschaftliche Zeitalter" (Age of Natural Science) of the year 1886.

In the former lecture I expounded on the state of electrical engineering and added some reflections on the further



Ich Endesunterzeichneter erkläre hierdurch, daß ich das in dem beiliegenden Situationsplane mit a b c d umzeichnete, von der March-Straße, den projektirten Straßen 4 und 5 und der mit der March-Straße parallelen Linie bc begrenzte Grundstück mit der Grundfläche von 19800 Quadrat-Meter dem Deutschen Reiche zum Bau einer Reichs-Anstalt für experimentelle Naturforschung schenkungsweise überlasse, unter der Bedingung, daß das Reich die Kosten für Bau und Einrichtung und die Dotation der geplanten physikalisch-technischen Reichsanstalt übernimmt.

Berlin, den 12. November 1885.

Dr W Siemens

The deed of gift by which Werner Siemens donated the land in Berlin for the Physico-technical Imperial Institute, 1885.

progress, confidently to be expected, which would result from the fact that electricity could now with the help of the dynamo-electric machine also perform heavy work, whereas hitherto it had only been useful through the rapidity of its action in mediating, directing, and controlling intelligence and signals, leaving the execution of the heavy work itself to other natural forces.

The lecture "The Age of Natural Science," which I gave in Berlin at the opening meeting* of the Society of Naturalists and Physicians in the autumn of 1886, dealt with the change in conditions through the rapidly growing command of man over the forces of nature. I set forth that engineering, resting on the basis of physical science, was

** A reference to the annual meeting in 1886 of the society, which was founded in 1822.*

relieving man more and more of previous severe bodily labor which nature had imposed on him for the maintenance of his life, that the wants of life and means of enjoyment would be satisfied by everdiminishing bodily exertion, and thus become cheaper and accordingly more accessible to all; further, that through the distribution of power and the inevitable fall in the rate of interest the superiority of large factories to individual labor would more and more be neutralized, and consequently the practical ends of Social Democracy would be attained without a violent overthrow of the existing order solely by the undisturbed progress of the Age of Science. I also tried in my lecture to show that the study of the physical sciences in its further progress and general diffusion would not brutalize men and divert them from ideal aspirations, but on the contrary would lead them to humble admiration of the incomprehensible wisdom pervading the whole creation, and must therefore ennoble and improve them. The occasion appeared to me opportune for publicly asserting my convictions, since the unshakable belief in the beneficial consequences of the undisturbed development of the Age of Natural Science is alone competent to repel with success all the fanatical attacks which threaten human civilization on all sides.

Deed of gift of the Physico-technical Imperial Institute

I, the undersigned, hereby declare that I present to the German Imperial Government the premises indicated by a b c d in the attached ground plan and bounded by the Marchstrasse, the planned streets 4 and 5 and the line b c parallel to the Marchstrasse with an area of 19,800 square meters for the erection of an Imperial Institute for experimental scientific research on the condition that the government bear the costs of the building and equipment and of the endowment of the proposed Physico-technical Imperial Institute.

Berlin, November 12, 1885
Dr. W. Siemens

It is not sufficient, however, to leave scientific engineering to its own undisturbed development; it is, rather, necessary to assist its progress as far as possible. For this, certainly, much has already been done in Germany through the

The building that housed the Physico-technical Imperial Institute, founded in 1887.

highly developed system of scientific technical instruction, for which the best conceivable arrangements have been made at the numerous universities and polytechnic schools. There was a total absence, however, of any organization for the furtherance of scientific investigation, i.e., for the extension of the area of our physical knowledge, on which technical progress is also dependent. In Prussia, years ago, the necessity had been perceived for an institute which should have for its object the scientific support of engineering and especially of applied mechanics; and a commission, to which I was summoned, had elaborated a plan for such an institute, which was to be added to the new polytechnic school in course of erection in Charlottenburg. This was, however, no solution of the problem of furthering scientific investigation itself.

The need for an institute not subserving instruction but scientific research exclusively had appeared very strikingly at the conferences on the establishment of international

Hermann von Helmholtz (1821–1894), in 1889.

electric standards in Paris. There was found no suitable place in all Germany for carrying out the difficult work of exactly producing the absolute resistance unit of Weber. The laboratories of the universities are, in conformity with their function, arranged for the purpose of instruction and indeed as a rule entirely claimed for that object. German scientists have, nevertheless, in the leisure hours which their teaching vocation left them, used these for carrying on their researches, and have accomplished much, but for extensive, thorough research neither the rooms and their fittings nor the leisure time of the scientists were sufficient. My proposal to add to the planned institute for the scientific support of engineering a second, which should be exclusively at the service of scientific research, met indeed with much sympathy, but the execution of the plan was regarded as impossible under the existing circumstances. Suitable premises, sufficiently large and not liable to vibration from vehicular traffic, were lacking, and it also appeared difficult to obtain the consent of the Prussian Diet to the considerable expenditure required for the erection and subsequent maintenance of such an institution.

I had already bequeathed in my will a considerable sum of money to be applied to the furtherance of scientific research, but precious time would perhaps have been lost before my possibly still remote death; and in particular the favorable opportunity would then have passed for calling into being a large undertaking, answering to the needs of the time, by the combination of the planned institute destined for scientific research with the scientific-technical one already agreed to in principle. I therefore resolved not to wait till my death, but to make the imperial government the offer to place at its disposal a large piece of ground perfectly suited to the purpose or the equivalent capital for an imperial institute devoted to scientific research, if the Empire would undertake the cost of building and the future maintenance of the institute. My proposal was accepted by the imperial government, confirmed by Parliament, and on this foundation the Physico-technical Imperial Institute at Charlottenburg has grown up, which now forms a German home for scientific research under the guidance of the first physicist of our time, Privy Councilor von Helmholtz.

Charlottenburg, June 1892

I hoped last year to bring these recollections to a close in Harzburg, but was prevented by my wife's illness and many other troubles. In the autumn, I myself had a severe attack of influenza, which compelled me to winter in the south. Accompanied by my wife and youngest daughter, I resorted to Corfu in December. It is true that there is not much provision in the place for sick persons, and the climate in January and February is about the same as that of a rainy North German summer, but the glorious situation and the beautiful surroundings of the town afford great pleasure even at that season of the year. Corfu still lives on the benefits which the English protectorate formerly brought the island. The fine roads made by the English, although already in part thoroughly out of repair, still continue to afford fair communication between the most important parts of the island. The English waterworks also, which have made the city of Corfu a healthy place, are luckily still kept up. Till a short time ago the Corfiote lived in ancient Phaeacian ease on the profits which the numerous old olive trees of the island brought him; he never took the trouble properly to gather the fruit, but waited till it fell to the ground of itself, and then collected what was in good condition. Recently, however, petroleum has sent down the price of oil, and anxiety for daily bread is beginning to be felt even in Phaeacia. Greater attention is therefore now paid to the cultivation of the vine, which indeed costs much more labor, but is also far more remunerative than the cultivation of the olive. One sees with regret in many parts of the island the old picturesque olive trees cut down to make room for the more profitable vine cultivation. Almost the only foreigners who permanently reside in Corfu are French traders, who buy up all the wine. The large amount of red coloring matter which the wine of Corfu contains doubtless makes it very suitable for the manufacture of "genuine" claret. In former times, no wine could be exported from the island, as the Corfiotes preferred to drink their wine themselves. Thus the most ancient habits change in an age that does not suffer the unchangeable!

At the end of February, when the fruit trees began to bloom, we left Corfu and went to Naples, where we hoped to find better weather and more amusement. But the Apennines were still thickly covered with snow, even dear Vesuvius wore a light snowy mantle, and in Naples it rained still more persistently and severely than in Corfu. As a compensation we there enjoyed the pleasant intercourse with friend Dohrn and his amiable family. A month later we went to Amalfi, but not before Sorrento did the ardently desired blue Italian sky at last smile upon us. There I first began to feel my strength returning when, taking a walk with my wife, we were attracted by the prospect of a fine view and reached the highest point of the neighborhood, the monastery of Deserto. My hope of being able to pay another visit to Vesuvius, and perhaps of taking another look into the sources of its changing activity, unfortunately remained unfulfilled, on account of the unfavorable weather. However, it gave me much pleasure to see it again. One clings to persons and things which have earned our gratitude, and during an ascent in the year 1878 Vesuvius had given me such unmistakable indications of the cause of its activity, by its regularly recurring explosion-like eruptions, that the sphere of my ideas concerning the formation of the earth's crust and the underlying forces was considerably enlarged.

At the beginning of May, we returned home, but unfortunately I had still to sustain two violent attacks of fever. Now, luckily having got the better of these too, I hope that the sick period of my old age has passed and that a calm and cheery evening of life will be granted me in the midst of my beloved ones.

I have already in the foregoing pages frequently spoken of my brothers and sisters, but considering the great influence which they had on my career, I feel constrained to append a condensed and connected summary of their lives.

I will first mention my brother WILLIAM, snatched, alas, so early from us. How, in a foreign land, upon which he set foot without any acquaintances and introductions and with very limited means, he worked himself up to a position of great distinction has been admirably recorded by the pen of so competent a writer as Dr. Pole. Many foreigners, Germans among the rest, have made their fortunes in England, but that has usually depended on certain lucky hits, among which a single invention of great material importance is commonly to be reckoned. William achieved more; he forced the public opinion of England to honor him in his lifetime, and in a still more striking manner after his death, as one of the leading spirits to whom the country owes the great development of its industrial arts by the diffusion and application of scientific knowledge. By participating indefatigably in the work of the numerous associations which made good in England the previous want of sound preliminary technical education, William contributed much to bringing English engineering up to the level of advanced physical science, and it redounds to England's honor to have impartially acknowledged this service on the part of a foreigner. William's exertions were considerably as-

In Memoriam William Siemens

. . . The death of Sir William Siemens at the comparatively early age of 61 deprives the world of the services of a singularly powerful and fertile mind . . . His name recurs upon every page of the history of iron manufacture since he came among us . . . Sir William Siemens was essentially an inventor. In whatever direction he turned, his thoughts seemed to perceive new methods of working out old problems, or to discover new problems which it immediately became his province to solve . . . But the inventor proper is one who, like Sir William Siemens, is continually throwing out original ideas in spheres where others find it sufficiently difficult to master what has already been done. His patents were numerous and various . . . Whenever machinery was required for the carrying out of his aims he seemed to invent new arrangements with the same facility. . . . His experiments remain extremely curious, and form another illustration of the extraordinary originality and resource of the intelligence now prematurely quenched in death . . .

Times, *London, November 21, 1883*

sisted by the uninterrupted and close connection with his brothers, and by his marriage with the amiable Miss Gordon of an honorable Scottish family, which made it easier for him to obtain a firm footing in English society. William died on November 19, 1883, in his sixtieth year, of a slowly developing and scarcely noticed disease of the heart. His sudden death overtook him at the height of his activity. 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, among others first president of the Society of Telegraph Engineers and Electricians, founded by himself. 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. The funeral service took place with befitting solemnity in Westminster Abbey. A year after his death, a window was dedicated to his memory in the Abbey, presented by the scientific and technical associations of England, the leading English men of science and the industrial arts taking part in the proceedings. His wife retired to her beautiful country house, which the forethought of her husband had bequeathed her, at Sherwood, near Tunbridge Wells, there to mourn her lost happiness. We brothers, and I in particular – for William was to me more than a brother – felt his unexpected death as a severe blow, which the lapse of now nearly ten years can soften but not expel from memory.

Of my brothers Hans and Ferdinand, who became agriculturists, Hans afterward devoted himself to agricultural engineering, and set up a spirit distillery in Mecklenburg. That certainly did not bring much grist to his mill, but gave him the opportunity of falling in love and getting engaged. After his marriage, he acquired with my assistance a bottle manufactory near Dresden, which he managed till his death in the year 1867. Ferdinand still lives on his estate of Piontken in East Prussia. He was again betrothed in 1856 and then married; one of his two daughters is the wife of my son Wilhelm, and some years ago presented me with my first grandson.

Wilhelm von Siemens (1855–1919) and his wife, Elly (1860–1919), the daughter of Ferdinand Siemens, 1882.

My brother Friedrich had in the fifties actively participated in William's efforts to improve his regenerative steam engine and evaporating apparatus. In the year 1856, he hit on the happy idea of employing the regenerative system, hitherto but little successful, for metallurgical purposes, and in particular for reverberatory furnaces. A number of patents, which he took out in different countries, partly alone, partly in conjunction with William, for a perfected form of regenerative gas furnaces, formed the basis of a furnace-building business established by William and himself. To work this in Germany and Austria, he transferred his residence to Berlin, shortly after his marriage in 1864. In 1867, after the death of our brother Hans, he took over the glassworks near Dresden, and by his technical gifts and energy soon raised the same into a model factory for glass manufacture. Through the introduction of the regenerative system, and afterward of the heating by radiation, he gave the impulse to an epoch-making improvement in metallurgy and especially in the glass industry. Recently he has made over the Dresden glassworks and the works appertaining thereto in Bohemia to a joint-stock company, since they

A. D. 1816, N° 2861 Furnaces

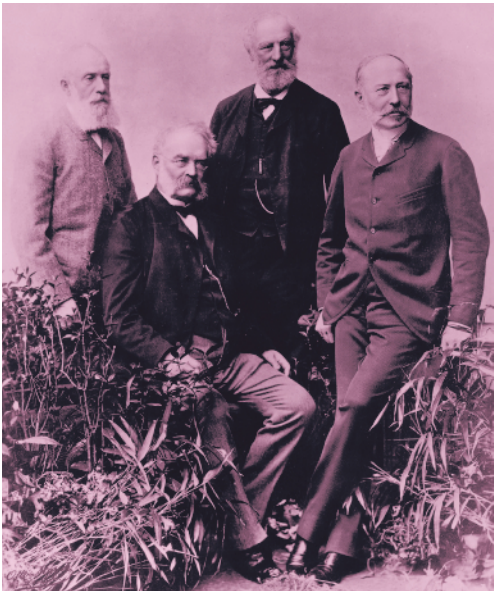
… "Improved Arrangement of Furnaces, which Improvements are applicable in all Cases where Great Heat is required."

From English Patent No. 2861, granted to Friedrich Siemens for the invention of the smelting furnace using Robert Stirling's regenerative principle. Sealed January 27, 1857, and dated December 2, 1856.

no longer afforded him material enough for his inventive activity. He is now busily engaged in perfecting his regenerative heating process and steel manufacture. In a widely different department also, that of gas lighting, he has introduced great improvements, bringing into use in gas burners the regenerative principle of heating, and in this manner has considerably increased the illuminating power of the gas. He has thereby not a little retarded the victory of the electric light over gas, which, however, has not produced any friction in our fraternal harmony. After William's death, he undertook the latter's furnace business in England, and has continued it with the best success. An amiable wife and a delightful troop of children will, we may hope, give him still many years of happiness and stimulate him to further untiring endeavors.

Carl had found in Russia a sphere of action extremely congenial to his faculties, and very considerably contributed, by the successful execution of our large undertakings, to the firm establishment and financially sound development of our business. But when, in the year 1867, our Russian maintenance contracts expired, and the Russian government took all further telegraphic affairs into its own hands, the St. Petersburg firm seemed condemned to lose its position of importance. As about the same time Carl's wife began to ail, and a change of climate appeared urgently necessary for her, Carl transferred his abode to Tiflis, and undertook the management of the branch founded there, as well as of our Kedabeg mine, which had already grown to considerable proportions. Unhappily, however, the condition of his wife grew continually worse, a prolonged residence in Vienna and Berlin equally failing to restore her health. She died in Berlin in the year 1869, leaving Carl with one son and two daughters. I now proposed to Carl to stay in Berlin for good, and to take part in the management of the Berlin firm. We were even planning, as we were both widowers, building a house for joint occupation, when William came forward with the wish that Carl should settle in London. Carl accepted this proposal and till the year 1880 managed the business of Siemens Brothers & Co. in conjunction with William. He showed himself in London, just as in St. Petersburg, a farseeing man of business, an able organizer and manager of large undertakings. The factory at Charlton near Woolwich was considerably extended at his suggestion, the cable works especially much enlarged, and a gutta-percha factory set up. But after several years' residence in England, Carl's health, formerly always very good, began to show signs of decline; he could not bear for long the damp English climate. Moreover, an irresistible longing manifested itself in his children for their native country, Russia. For these reasons, in 1880 Carl returned with them to St. Petersburg and once more undertook the management of the business there, which he soon raised again into a flourishing condition. His two daughters have married in Russia; his son assists him in the management of the business, so far as a disease of the eyes, with which he is unfortunately afflicted, allows. Carl's own health has been quite restored since leaving England. He himself, as well as the firm under his management, which is now chiefly occupied with arrangements for electric lighting and transmission of power, hold a highly esteemed position in Russia.

The youngest brothers, Walter and Otto, both died in Tiflis, and rest in the same grave. Walter died, as I have already stated, in consequence of a fall from his horse. He was a fine, stately man with pleasing ways, which quickly made him popular in the Caucasus; to us brothers he always showed the greatest attachment. Otto succumbed some years later to his feeble health, of which he had not always been sufficiently mindful. He was a highly gifted man of sterling



The four Siemens brothers still surviving in 1889: L to R, Friedrich, Werner, Ferdinand, Carl.

worth, but did not always possess the requisite self-control and strength of character, and has therefore often been a cause of anxiety to us older brothers. When he had contracted a serious lung disease in London, where he was to be prepared under William's guidance for a technical career, we sent him for a voyage around the world in a sailing ship, in the hope that this would effect a cure. He arrived in apparently good health in Australia; could not, however, resist the temptation to join an expedition which was about to cross the continent to seek for traces of the lost traveler Leichhardt. But the fatigue was too much for him, and he nearly perished in the desert interior from the effects of a hemorrhage. When, after a series of further adventures, he returned to England, we sent him to the Caucasus, which had often proved beneficial to consumptives. In truth, a rather long stay in Kedabeg seemed to have perfectly restored him. At Walter's sudden death he entered upon the latter's functions. In the house of Prince Mirsky, governor of the Caucasus, he made the acquaintance and became enamored of the widow of General Prince Mirsky – a brother of the governor – who had fallen in the Crimean War. Unhappily, his death after a few years severed the union of the happy pair.

Our sister Mathilde, the wife of Professor Himly, died at Kiel in the summer of 1878, mourned by us as an affectionate and faithful sister. Sister Sophie unhappily lost her husband many years ago, who at the time filled the office of advocate to the Supreme Court at Leipzig.

Werner von Siemens with his wife Antonie and children, around 1876; L to R: Arnold, Käthe (1861–1949), Wilhelm, Werner with Hertha, Anna (1858–1939) and Antonie with Carl Friedrich.

With regard to my own life in the last few years, it only remains for me to mention that since the beginning of 1890 I have left the business management of the firm of Siemens & Halske at Berlin, Charlottenburg, St. Petersburg, and Vienna to the former active partners, my brother Carl and my sons Arnold and Wilhelm, and am now only a silent partner in the firm. It is a great joy to me to be able to testify that my sons have shown themselves fully equal to their grave and responsible position, nay, that my retirement has manifestly given to the firm a fresh impulse. This is the more deserving of recognition as my old assistants in the technical management, Messrs. Frischen, von Hefner, and Lent, are also no longer in the firm, the first named being unhappily taken from his labors by death. It is with commercial houses as with states: they need from time to time regeneration in their administration in order to remain young. The

London business and my private undertakings were not affected by my retirement from the firm of Siemens & Halske, and thus continue to give me sufficient technical occupation.

My children by the first union are all happily married. My firstborn, Arnold, married the daughter of my friend von Helmholtz, and has already, as well as his brother, provided for a continuation of the lineage by two grandsons.

When at its close I survey my life, and search for the determining causes and impelling forces which carried me over all hindrances and dangers to a position which brought me outward recognition and inward satisfaction, and superabundantly provided me with the material blessings of life, there I indeed am bound to admit that many fortunate circumstances have cooperated and that altogether I owe a large debt to fortune. It was a lucky coincidence that my early years were passed in a time of rapid progress of natural sciences, and that I devoted myself especially to electrical engineering, when it was still quite undeveloped and therefore formed a very fertile ground for inventions and improvements. On the other hand, however, I have also frequently had to contend with very unusual misfortune. This continual struggle with altogether unexpected difficulties and unlucky accidents, which as a rule in the beginning hampered my undertakings, but which I mostly by good hap succeeded in overcoming, William Meyer, the dear friend of my youth and faithful companion, very forcibly described in students' slang as: "*Sau beim Pech*" (bad luck coupled with astonishing flukes). I must admit the correctness of this view, but still do not believe that it was only blind fate, when the wavelike line of happiness and unhappiness on which our life moves carried me so frequently to the desired goals. Success and failure, victory and defeat, often depend in human life entirely on the timely and right use of the opportunities offered. The quality of quickly making up one's mind in critical moments, and of doing

Werner von Siemens, 1892.

the right thing without long reflection, has remained tolerably faithful to me during my whole existence, in spite of the somewhat dreamy meditative life in which I frequently, I might almost say usually, was plunged. In innumerable cases this quality has preserved me from harm and rightly guided me in difficult situations. Undoubtedly a certain stimulus was always necessary to give me full control of my mental qualities. I needed it, not only to be snatched from my own meditative life, but also as a protection against my own weaknesses. Among these I especially reckon an excessive benignity, which made it uncommonly hard for me to refuse a request, not to fulfill a known wish, nay, in general to say or do anything to anybody that would be unpleasant or painful to him. To my good fortune, this quality, very inconvenient especially for a businessman and master over many people, was neutralized by another, that of being easily provoked and excited to anger. This anger, which was always easily aroused when my good intentions were misunderstood or abused, was ever a relief and outlet for my feelings, and I have often declared that anybody with whom I had unpleasant dealings could never do me a greater service than by giving me cause to be angry. For the rest, this irascibility was usually only a form of mental excitement, which never got beyond my control. Although in younger years I was often nicknamed by my friends "curly head," wherewith they would hint at a certain connection between my curly hair and "curly" mind, yet my easily roused anger has never led me to actions which I had afterward to regret. For a manager of great undertakings I was also in other respects but inadequately suited. I lacked the good memory, the orderly sense, and consistent, unbending strictness. If, notwithstanding, I have founded large business concerns and managed them with unusual success, this is a proof that industry coupled with energy often overcomes our weaknesses or renders them less harmful. At the same time, I can say on my own behalf that it was not desire of gain which impelled me to devote my working power and my mind in so great a degree to technical undertakings. In the first place, it was generally the interest for technical science which led me to my task. A business friend quizzed me once with the assertion that I always let myself be guided in my undertakings by the public benefit they would bring, but that ultimately I always found my account thereby. I admit this remark to be correct within certain limits, for such undertakings as further the public welfare command a general interest, and thereby present greater prospects of being successfully carried through. However, I will not undervalue the powerful influence which success, and the consciousness arising from it of doing something useful, and at the same time of giving their bread to thousands of industrious workers, exerts on mankind. This gratifying consciousness has a stimulating effect on our mental qualities and is doubtless the foundation of the otherwise somewhat paradoxical German proverb: "To whom God giveth an office, He also giveth understanding therefor."

A main reason of the rapid growth of our factories is, in my opinion, that the products of our manufacture were in large part results of our own inventions. Though these were in most cases not protected by patents, yet they always gave us a start on our competitors, which usually lasted until we gained a fresh start by new improvements. This could certainly only have lasting effect in consequence of the reputation for great solidity and excellence which our products enjoyed throughout the world.

Besides this public recognition of my technical achievements, marks of honor have been so abundantly conferred upon me personally both by the rulers of the larger states of Europe and by universities, academies, scientific and technical institutes and societies, that hardly anything remains for me to desire.

I began the writing of my recollections with the biblical aphorism "The days of our life are threescore years and ten, or even by reason of strength fourscore years," and I think I have shown that also the close of the sentence, "yet is their pride but labor and sorrow," has held good in my case. For my life was beautiful, because it essentially consisted of successful labor and useful work, and if I finally give expression to the regret that it is approaching its end, I am only urged thereto by the pain that I must be parted from my dear ones, and that it is not permitted me to continue to labor for the full development of the Age of Natural Science.

APPENDIX – SCIENTIFIC PUBLICATIONS

In these memoirs I have repeatedly had occasion to make a few explanatory remarks about the technical publications that were described in the second volume of the collection of my *Wissenschaftliche und Technische Arbeiten* (*Scientific & Technical Papers*, English edition, London, 1892 and 1895), published by Julius Springer in 1889 and 1891. I have also discussed most of my earliest research work, because it affected the further course of my life in so many ways, and because it is probably rather unknown to the younger generation of physicists. But my later research work has diverged in many regards from the accustomed paths of prevailing physical theory, and therefore has not won general recognition; hence I feel that at this point I should also add a few critical remarks about that work and explain the implications of its results.

In several research projects that I conducted between 1860 and 1866 and published in Poggendorff's *Annalen,* I investigated the ability of metals to conduct electricity, and developed the first and so far only method of establishing an empirical, reproducible measurement of resistance. I demonstrated that my method made it possible to determine the resistance of an approximately prismatic space filled with pure mercury, with an accuracy to within one ten-thousandth of its value. Thus I solved the problem of establishing an absolute unit of resistance – i.e., one based on a definition – with a precision consistent with the capability of our measuring instruments. This discovery made it possible to take exact and mutually comparable electrical measurements for the first time.

During the course of these investigations, I found confirmation of the principle, already stated by others, that the resistance of solid metal alloys is always greater than the total of the individual resistances of their constituent metals; but I demonstrated that this is *not* the case for *liquid metal mixtures*; instead, these *retain unchanged the resistance of the individual metals in the liquid state*. I showed that this behavior of metals can be used to determine the specific resistance of refractory metals in the liquid state. I also discovered that melting increases considerably the resistance of metals, while the *latent heat of the liquid contributes more to the development of resistance than the free heat of the solid or liquid conductor*. I found that the increase in resistance caused by melting does not occur discontinuously, but rather that resistance rises continuously within a given temperature interval, and that the resistance curve of the molten metal likewise follows at a constant rate. From this I concluded that the physical processes of melting and solidification consist largely in the absorption and release of latent heat, both of which take place within a specific temperature interval during the melting process.

In a later work on how carbon's ability to conduct electricity changes as a function of temperature, I confirmed Matthiessen's contention that the ability of coal to conduct electricity increases with temperature, and demonstrated that Beetz and Auerbach's objections to this position were in error. To explain this curious behavior of carbon, I proposed the hypothesis that the various states of carbon – charcoal, graphite, diamond – are *allotropic states of "latent-heat-free" carbon, which does not occur in nature, and differ from one another mainly in the quantity of latent heat absorbed.*

This hypothesis was confirmed and developed further by a study of selenium's ability – discovered by Willoughby [ed: corrected spelling] Smith – to conduct electricity better when exposed to light than in the dark. I found that in addition to the fact that small increases in temperature cause selenium to transform from an amorphous, nonconductive state to a so-called crystalline, electrically conductive state, there is also a third modification of selenium, which is induced when one heats amorphous selenium for an extended time to a temperature close to its melting point, or in other words, to approximately 200 °C. These two modified forms of electrically conductive selenium differ significantly in that the former conducts *electrolytically* – that is, it conducts *better at higher temperatures,* as electrolytic liquid conductors do; while the latter modification, with extended heating, conducts *metallically,* or in other words, it conducts *less well at higher temperatures,* as metals do. This behavior of amorphous selenium rapidly cooled from the molten state – i. e., that when heated above 80 °C it loses much of the latent heat of melting that it had retained during quick cooling, and becomes electrically conductive, yet when heated for an extended time close to its melting point it surrenders additional latent heat and then becomes much more conductive, namely metallically conductive – seemed to me a confirmation of a hypothesis that I had already developed in earlier investigations: first, that the electric resistivity of a substance is an equivalent of the quantity of heat stored within it in both the free and the bound state; and further, that latent heat has a greater resistance-enhancing effect than free heat, and that substances having no allotropically bound heat conduct metallically, namely in such a way that resistance increases uniformly with temperature from an absolute zero point, while the resistance-enhancing effect of allotropically latent heat decreases as temperature increases.

According to this theory, all simple substances that are not an allotropic modification of their original metallic state through the absorption of latent heat must conduct *metallically,* and it is probable that the so-called *active* state of substances is none other than this *latent-heat-free* state, the state I call *metallic,* which can exist in metalloids and nonmetals only in chemical compounds, without immediately transforming into an allotropic modification while binding heat. Thus, according to this hypothesis, one must conceive that *the molecules of all nonmetallic solids may assume different states of quiescence, whose nature corresponds with certain values of work consumed in their constitution*. Only metallically constituted substances can combine chemically. Thus latent heat represents an obstacle to chemical combination, and if combination occurs nevertheless, heat must be released in the process. Conversely, a chemically released substance must be metallically constituted, or in other words, will be in the active state at the moment when it becomes free. Left to itself, it will absorb latent heat, consuming heat, if it is a metalloid or nonmetal, thus partially or entirely eliminating its ability to conduct electricity. Elevated temperature causes the molecular arrangement corresponding to the absorption of heat to become less stable, and *therefore increases ability to conduct electricity and, at the same time, chemical affinity*. Since heat is bound when metals are alloyed, in such alloys resistivity does not increase proportionately to absolute temperature, as in the case of simple, pure metals, but instead the alloy's latent heat of combination constitutes an interfering aspect that increases resistance and thus eliminates the proportionality of resistance to absolute temperature.

I was also able to put to technical use the metallically conductive Modification II of crystalline selenium that I had discovered, in building a selenium photometer.

In an earlier work I demonstrated that *a dielectric heats up through repeated charging and discharging,* and thus found experimental confirmation for Faraday's molecular induction.

In 1875, I had an opportunity to apply a modified form of the method of measuring the speed of propagation of electricity in suspended wires, which I had already proposed back in 1845. The experiments, using an iron double conductor 12.68 kilometers long, yielded a speed of propagation of 32,600 geographical miles – a result that shows a satisfactory correspondence with the results of Kirchhoff's calculations, when one allows for the delay caused by the jar discharge of the lines and by self-induction. Before these experiments, conducted with great attentiveness by Dr. Frölich, I was inclined to believe that the actual speed of electricity along conductors was immeasurably great, since an experiment I had performed with a water-filled rubber tube more than one-hundred feet long showed no perceptible difference in the position of the spark marks. Thus the speed of propagation of electricity could not depend significantly on the specific resistance of the conductor along which the electricity traveled, and I therefore thought it probable that the widely varying values found by Wheatstone, Fizeau and Gounelle, and others were only the expression of the delay caused by the surface charge of the employed conductors. The experiments described above eliminated these reservations, but I have unfortunately had no time or opportunity to pursue the investigations since.

I was led into a field of research that had been quite foreign to me by an observation of the activity of Vesuvius in May 1878. I noticed that in the brightly glowing opening at the tip of the ash cone that had formed in the interior of the great, dark crater, explosive ejections occurred with great regularity at intervals of several seconds. Closer observation showed that each explosion was followed by an intake of air that was so powerful that often the opening actually sucked back slag or rocks that it had ejected and that had fallen nearby. Combustible gases had to be forming continuously from the Earth's interior; they then mixed in the upper passage of the crater with atmospheric air drawn in by the rarefaction of air caused by the previous explosion, and thereupon exploded, thus producing a new region of rarefied air. This observation led me to a consideration of the process by which the Earth was formed, and of its current state, from the viewpoint of physical mechanics. The results deviated considerably from prevailing opinion.

In geology, hitherto two viewpoints have stood bluntly and directly opposed to one another, that of the professional geologists and that of the mathematicians. The former adhere to the old opinion, which can already be called historical, that the Earth had once been a fiery liquid, while air and water formed the atmosphere, which was likewise incandescent; as the process of cooling advanced and a solid crust formed on the Earth, this atmosphere precipitated the oceans, which then with the assistance of frequent partial uplifting and subsidence of the Earth's crust laid down the massive layers of sediment that now cover almost all of the Earth's surface. This uplifting and subsidence was supposed to be caused by internal volcanic forces, which are still visible in volcanoes today. English physicists, including Sir William Thomson (now Lord Kelvin), advanced weighty arguments in opposition to this basis for the theory of the Earth's formation. Lord Kelvin declared it necessary that the entire body of the Earth must be more solid than glass-hard steel, since calculations showed that otherwise its surface would participate in the tidal movements caused by the attraction of the Moon and the Sun, and therefore the sea then could not have its own distinct tides. J[oseph] Thomson supported this calculation with a physical observation, to the effect that the melting temperature of substances that expand upon solidification is reduced by pressure, while that of substances that contract upon solidification is increased by pressure. But since silicates, as he believes, contract 20% upon solidification, the pressure that increases with depth would not permit the mass of rock to melt, despite the elevated temperature, and would instead make it even more solid.

It is remarkable that these starkly opposing viewpoints regarding the nature of the interior of the Earth have persisted for many years, alongside one another, without any conflict, even though they concern the foundation of all practical geology. As already noted, most geologists have held firmly to the idea of a crust floating on a liquid or gaseous core of the Earth, and the mathematicians adhere to Lord Kelvin's theory of a rigid core, without concerning themselves much with the difficulties of explaining the facts of the formation of the surface!

I have now attempted to resolve this contradiction by demonstrating that there are factual reservations against the physical foundations of Thomson's calculation. These difficulties lie in that Bischoff's information that silicates become about 20% heavier upon making the transition from the liquid to the solid state is incorrect – as is already evident from the well-known fact that solid silicates always float on molten ones, once they have almost reached the temperature of the latter. I furthermore pointed out that Lord Kelvin's calculation does not take account of the time needed by the thickly viscous mass of the Earth to assume the shape prescribed to it at any given moment by the deforming tendencies of the attraction of the Sun and the Moon. Since these changes of form involve shifts in mass that are distributed continuously from molecule to molecule over the entire surface of the Earth, and that therefore need a considerable time in order to take place, a general tidal wave cannot arise and advance uniformly with the rotation of the earth, and such a wave can become evident at all only to a very small degree. Thus far these arguments against the mathematical necessity of a solid core of the Earth have still not been refuted, and therefore when considering the formation of the Earth's surface, one is entitled to assume that the interior of the Earth is viscous or gaseous.

With regard to the formation of the Earth's surface, another matter of interest even to the non-geologist is local uplifts; the formation of the stratified diluvium that deeply covers almost the entirety of the Earth's surface; and earthquakes and volcanoes. I have attempted to give these facts an explanation based on a foundation of physical mechanics; it satisfies my own need for causality, but in many regards contradicts conventional geological views, and therefore has remained rather unrecognized. In these conventional views, I must first consider untenable even the assumption that underlies all the others – that there was a period in the formation of the Earth when the Earth was a fiery liquid surrounded by an atmosphere containing the permanent gases and all water, in the form of incandescent vapors. It will become clear what arguments led me to that position when we take a step farther back into a period when the mass of the Earth coalesced. At that time, the elements in that mass must have been mixed uniformly, and thus, by mutual attraction in the gaseous state, consolidated into a magma. But the more volatile substances could have separated out only at the solidification boundary, where the gaseous state was making the transition to the liquid and solid states. Depending on how this zone of solidification advanced, only then could the more volatile substances separate out in the gaseous state. But this separation from the fiery, liquid interior could have taken place only very slowly, because a lower specific gravity was the only force that might drive aggregations of lower-specific-gravity masses toward the periphery. It cannot be determined how great a difference in density in the interior of the Earth there may be, since we still have too little knowledge of the behavior of substances at such high temperatures and pressures as prevail in the Earth's interior. However, it seems clear that the separation of our atmosphere and oceans from the mass of the Earth was the product of many geological periods, and has not yet been completed, as is shown by the geysers and hot springs still active today. It will be necessary to assume a "Geyser Period" as a specific geological period following the formation of the solid crust of the Earth, and during which volcanoes and geysers ejected the lower-specific-gravity masses, meaning water and air, at countless points on the solidified surface of the Earth, and through the changing flows of the resulting ocean, laid down the stratified sediments on that surface. Nor is the assumption that mountains were uplifted by the forces of internal pressure compatible with the assumption of a fiery-liquid or gaseous interior of the Earth, on which the solid crust floats. Only tangential forces can have lifted up the mountains, and still lift up portions of the Earth's surface today. These tangential forces are provided by the progressive cooling of the Earth's interior, since the vault formed by the solid crust of the Earth must be compressed inward by gravitation when the vanished liquid interior no longer supports it adequately. The phenomenon of volcanic eruptions does not force us to assume an internal pressure that is greater, equivalent to the weight of the solid crust. If one reflects that the more recently solidified strata of solid rock must develop cracks as they cool, cracking which we experience as earthquakes on the Earth's surface, then it is clear that such cracks will also include the adjacent cooled crust, which was already broken up extensively in earlier geological periods, and thus can establish direct connections between the Earth's liquid center and the Earth's surface. The still liquid mass of the Earth must then penetrate into these cracks, and because it is hot and therefore lighter than the overlying rock, it must spring forth and form a mountain that is as high as the difference in specific gravity dictates. Since the reduction of the pressure acting on the hot liquid rising in the cracks causes the gases and vapors contained in the magma to escape, the content of gas bubbles must reduce the specific gravity of the column of liquid rock even further, and substantially, and this explains the height to which the liquid interior of the Earth is lifted in volcanoes, with no need to invoke an enigmatic force of pressure in the Earth's interior to overcome hydraulic equilibrium.

It is noteworthy that for more than a decade now the professional geologists have left unacknowledged and un-refuted this view, which modifies the foundations of their conventional theory in such significant points.

In an essay, "Über das Leuchten der Flamme" (On the Luminosity of Flame), I described a series of experiments that I conducted – some of them jointly with my brother Friedrich in Dresden, at his large glass furnace equipped with a regenerative heater – on the question of the incandescence of gaseous substances. It developed in these experiments that when permanent gases are quite dust-free, they do not incandesce even under extreme heat. Yet since they also have a great capacity for heat radiation, one must probably assume that if the heat were raised further they ultimately would indeed begin to incandesce, because light radiation and heat radiation differ only in that the former has a higher frequency, and radiation capacity generally appears to decline with frequency. In any case, the light radiation capacity of dust-free, pure gases is so extraordinarily low that the incandescence of a flame must specifically be different from the incandescence of the gases heated by the combustion process. Apart from the incandescence of the solid particles of matter emitted by combustion or suspended as contaminants in the gas, the incandescence of a flame can only be an electric process which is linked with the chemical rearrangement of the molecules in the burnt gases. The light of a flame would accordingly be just as much electric light as the light in an ozone tube or Geissler tube.

The interesting controversy in which my late brother William became embroiled with astronomers through his work "On the Conservation of Solar Energy" led me as well to look at the Sun, and prompted me to write "Über die Zulässigkeit der Annahme eines elektrischen Sonnenpotentials und dessen Bedeutung zur Erklärung terrestrischer Phänomene" (On the Admissibility of the Assumption of an Electrical Solar Potential and its Importance for the Explanation of Terrestrial Phenomena). As the ways known to us for evoking electrical phenomena are always founded on a separation between positive and negative electricity, we must assume that this is also the case for the Sun, and therefore a solar electric potential can arise only if one type of electricity is conveyed away from the Sun. My brother's theory that the rotation of the Sun flings off solar matter and distributes it through space therefore makes it admissible to assume that the Sun has a potential. I attempted to answer the astronomers' objection that space cannot contain the slightest quantity of matter, because that would lengthen the time taken by the planets to orbit, by observing that that the mass driven off by the Sun must itself orbit the sun at a planetary speed, and that therefore it could not inhibit the planet's travel. I also adhered to my brother's view that sunlight derives from solar mass that combusts while rising, although I could not accept his opinion that the cause of solar radiation is the combustible atmosphere that lies on the liquid or solid surface of the Sun and is flung off in the burnt state, then dissociated by sunlight in space and attracted in this state again by the Sun – although I did agree that the entire gaseous solar mass could participate in combustion, and I hold that the mass flung off is only of secondary importance for the thermal economy of the Sun, but is of crucial importance for the question of the Sun's electrical charge.

Ritter's splendid and still insufficiently appreciated works eliminate all reservations about the gaseous state of the Sun, given which there can be no separate solar atmosphere at all. We must therefore assume that the entire solar mass is involved in a continuous process of combustion, but that this process can really come into being only in the outermost stratum of the solar body, where the solar gas has already cooled so much through expansion that chemical combinations can occur. These combinations then take place over the entire surface of the Sun, forming flames and causing greater heating, while a flinging off as my brother conceived can occur only to a very limited degree in the equatorial zone. The general rising of the uppermost solar matter as a consequence of its combustion and heating above the adiabatic temperature consistent with expansion must be followed by a general descent of the burnt mass cooled by radiation, either in countless descending streams that give the surface of the Sun its scaly appearance, or else, at middle solar latitudes, also in the form of colossal descending vortices, which are darker than the rest of the Sun's surface, since compression causes the descending, burnt gases to return almost to the temperature they had at the time when they began their ascent, but at the same time they consequently re-dissociate and cool accordingly. For this reason, and because of the absence of flames, these descending vortices appear as dark sunspots. Of course this combustion theory is still contradicted by the fact that the existence of oxygen in the Sun has so far been demonstrated spectroscopically only at the bottom of the sunspot funnels – yet a very strong probability argues that the Sun is essentially composed like the Earth, and that therefore it cannot be lacking oxygen.

I have attempted to buttress this solar theory, which permits the development and maintenance of a solar electric potential, by demonstrating that this potential would explain many previously unexplained terrestrial phenomena. Given the Sun's colossal dimensions in comparison with the Earth, through electrical distribution the solar potential would induce a terrestrial potential of almost half the size, if one assumes that the electricity released on the Earth's surface, having the same nature as solar electricity, is absorbed by radiation and compensation with the electricity of the oppositely charged matter that is emitted from the Sun in the direction of the solar equator, according to my brother Wilhelm's theory. The fact that this high electric voltage is not noticed on the Earth's surface is a consequence of the size of the radius of the Earth. The rotation of the Earth also carries along the electricity bound on the

Earth's surface by solar electricity, and thus exercises the effect of an electric current surrounding the Earth, making the Earth magnetic. Like the Earth's magnetism, Earth currents and the northern and southern lights can also be explained by the electric potential of the Sun, and likewise the effect of solar processes such as the development of sunspots and solar flares upon terrestrial processes can be explained if we conceive these processes as being associated with changes in solar potential. Atmospheric electricity and the electricity of thunderstorms can likewise be explained by the Sun's electric potential.

Under the title "Beiträge zur Theorie des Elektromagnetismus" (Contribution to the Theory of Electro-Magnetism), I sent the Berlin Academy two articles in 1881 and 1884 in which the theory of magnetism was expanded significantly, and hitherto obscure points in that theory were clarified. I arrived at those insights through experiments with self-contained, tubular electromagnets that yielded the expected result that iron exercises no shielding effect against remote magnetic effects, or at least no such effect worth noting, and that the magnetic maximum of iron is independent of the direction of magnetism. The consequence is that the magnetism induced in iron by a magnetizing force is reduced by simultaneous magnetization in another direction. The maximum magnetization that occurs in ring magnets even under weak magnetizing effects shows that the amplifying magnetizing effect exerted by magnetized iron molecules upon their neighbors significantly predominates over direct magnetization. This leads me to a modification – which as I later discovered, Stefan had already assumed – of Weber's electromagnetic theory, to the effect that the assumed elementary solenoids must be double solenoids which as such move freely in space and are first aligned by a magnetizing force acting upon them and then rotated apart by it, like a pair of scissors. If one assumes that all of space is filled with such double solenoids, which one might conceive as vortices of ether in accordance with the theory of Fr. Secchi and Edlund, and that iron and the remaining magnetic substances differ from nonmagnetic substances in that the preexisting ether vortices per unit volume are present in larger numbers in the former than in the latter or in empty space, then one can also view magnetic "action at a distance," according to Faraday's process, as an effect that progresses from molecule to molecule or from space element to space element, and one is then justified in applying the laws for the molecular transmission of heat, electricity and electrostatic distribution to magnetism as well.

This theory in turn entails the assumption that magnetism, like electric current and electric distribution, can exist only in closed circuits, in which the magnetic moment is inversely proportional to the resistance of the circuit. This observation therefore leads to the introduction of the concepts of the "magnetic distribution resistance" and "magnetic conductivity" of space and of magnetic substances. Accordingly, an electric current flowing around an iron bar can generate only as much magnetism in that bar as can be either transmitted or bound from one pole to the other through the space surrounding the bar. My experiments have confirmed this view, and have shown that the magnetic conductivity of soft iron is approximately 500 times as great as that of nonmagnetic matter and of empty space.

Accordingly, to determine the most useful dimensions in designing electromagnetic machines, Ohm's law can be applied – a development that will be of benefit to the electrical engineer in many cases. So far as I am aware, I am the first to use the concept of magnetic conductivity, and this concept has now been used and refined in numerous technical papers – albeit without reference to my own prior use.

The attempt, described in my paper on solar potential, to associate certain meteorological phenomena with disruptions in the indifferent equilibrium of the atmosphere had convinced me that meteorology had not yet given the requisite attention to the requirements of mechanical equilibrium and the principle of the conservation of force. In its effort to derive all phenomena of movement in the atmosphere out of its extensive observational material, more recent meteorology has too much lost sight of the causes of these movements. In general, the discipline has been content to be able to attribute air movements to the observed maximums and minimums in atmospheric pressure and the migration of these extreme values, and in explaining the causes of these maximums and minimums has been content to invoke local influences of temperature and the rotation of the Earth. In my essay "Über die Erhaltung der Kraft im Luftmeer der Erde" (On the Conservation of Energy in the Earth's Atmosphere), I initially stated and defended the principle that all air movement is attributable *exclusively* to the uneven heating of the air by solar radiation, and that the rotation of the Earth cannot generate new air movement, but only alter the direction of the movement generated by the work of the Sun. A direct consequence of this principle is that the total of the living force stored up in the rotation of the sea of air around the Earth's axis must be unchanged, and equal to the total that would exist if no meridional air movement were generated by the work of the Sun, and the air had the same velocity of rotation everywhere as the part of the Earth's surface upon which the air rests. Now, as a consequence of the accelerating equatorial driving force of the overheated air flowing toward the Equator in the trade winds, in the higher regions of the atmosphere there is a return flow toward the poles, only a small part of which can achieve polar latitudes, however, because the narrowing of the upper stream bed and the simultaneous widening of the lower stream bed – as a consequence of the reduction in the length of latitudes as one approaches the poles – must continuously cause a partial transition of the polarly directed upper stream into the equatorially directed lower stream. Here it is the inertia of the polarly directed upper air stream that conveys the air in the lower stream back to the Equator. This circular flow, continued over countless millennia, intimately mixes the air of the upper latitudes with that of the lower latitudes, and the entire sea of air must therefore rotate at the mean eastward velocity of the Earth's surface. This explains the westerly direction of the trade winds and the mean easterly direction of the air streams in the middle and polar latitudes. The maximums and minimums are essentially phenomena accompanying the change in the temperature and in the speed of movement of the upper, equatorial air stream, and are always founded on disruptions in the indifferent equilibrium of the overlying air strata. If an air stream erupting in the highest regions of the sea of air has a higher or lower temperature than would be compatible with its elevation in the adiabatic temperature curve, this disrupts the indifferent equilibrium of the entire air column, and a compensation must take place through an upward or downward movement of the air, depending on whether the erupting higher air flows are too warm or too cold, and therefore too light or too heavy, for the indifferent equilibrium. This upward or downward air movement must continue until the indifferent equilibrium of the air column is restored, and then has the consequence that the atmospheric pressure on the Earth's surface becomes as great as it would be if the temperature of the entire air column had changed by the same amount by which the equatorial air stream that caused the disruption deviated from the adiabatic temperature compatible with its location and elevation. Since the heat consumed in the working expansion of a quantity of air is independent from the initial temperature of the air, the air rising at various points in the hot zone must retain the temperature differential that it possessed before it rose. It follows that relatively warm and cold air streams will flow polewards at different velocities in the higher and highest air strata, and will thus disturb the indifferent equilibrium of the atmosphere along their entire path. Slow-flowing, overly cold streams will transmit their excess pressure to the underlying lower air strata by compressing those strata, without causing major disruptions, and thus will result in rising barometric pressure combined with a calm atmosphere. By contrast, relatively light, hot air streams that therefore accelerate sharply as they rise will cause wavelike movements in the surface of the air strata which they do not compress sufficiently and over which they travel, and will carry that surface along with them, and will thus cause upward air movement and declining barometric pressure, which will continue until a state of indifferent equilibrium has been reestablished in the entire air column. According to this view, temperature fluctuations of 10 to 20 degrees C in the uppermost air strata will suffice to induce the fluctuations in barometric pressure observed on the Earth's surface – in other words, the maximums and minimums of atmospheric pressure.

This theory has met with much applause, but the adherents of prevailing opinion have approved it only in some points, or ignored it entirely. I have had repeated occasion to defend it and develop it further; the essays in question are entitled "Zur Frage der Luftströmung" (On the Question of Currents of Air), 1887, "Über das allgemeine Windsystem der Erde" (On the General System of Winds on the Earth), 1890 and "Zur Frage der Ursachen der atmosphärischen Ströme" (On the Question of Causes of Atmospheric Currents), 1891. I am convinced that my theory will gradually find general acceptance, because it is founded on a factual basis. However, it is in the nature of our educational system that new fundamental views that contradict previous teaching come to prevail only slowly. They must first be included in the textbooks, and that can only happen when the new theory has been worked out in all directions, and the ruins of the previous dominant opinion have been removed.

APPENDIX

WERNER VON SIEMENS' PARENTS, SIBLINGS AND CHILDREN

CHRISTIAN FERDINAND
* 7/31/1787
† 1/16/1840

⚭ 6/11/1812
ELEONORE DEICHMANN
* 1/11/1792
† 7/8/1839

LUDWIG
* Oct. 1812
† Died Jan. 1871

MATHILDE
* 4/17/1814
† 8/25/1878
⚭ 10/3/1838
CARL HIMLY
* 11/26/1811
† 1/26/1885

WERNER
* 8/24/1815
† 10/7/1815

ERNST WERNER
* 12/13/1816
† 12/6/1892
⚭ ① 10/1/1852
MATHILDE DRUMANN
* 7/8/1824
† 7/1/1865
⚭ ② 7/13/1869
ANTONIE Née SIEMENS
* 9/16/1840
† 12/22/1900

HANS
* 12/3/1818
† 3/28/1867
⚭ 6/29/1855
ALMA MÜLLER
* 2/20/1831
† 11/11/1914

FERDINAND
* 7/24/1820
† 9/8/1893
⚭ 9/1/1856
EULALIA HERTZOG
* 3/21/1835
† 4/11/1916

SOPHIE HENRIETTE
* 9/22/1821
† 10/13/1821

ARNOLD
* 11/13/1853
† 4/29/1918
⚭ 11/10/1884
ELLEN VON HELMHOLTZ
* 4/24/1864
† 11/27/1941

WILHELM
* 7/30/1855
† 10/14/1919
⚭ 6/21/1882
ELLY Née SIEMENS
* 3/2/1860
† 7/26/1919

ANNA
* 12/19/1858
† 7/27/1939
⚭ 5/23/1887
RICHARD ZANDERS
* 8/25/1860
† 3/28/1906

KÄTHE
* 9/23/1861
† 6/16/1949
⚭ 10/27/1884
KARL AUGUST PIETSCHKER
* 6/5/1846
† 6/14/1906

HERTHA
* 7/30/1870
† 1/5/1939
⚭ 10/2/1899
CARL HARRIES
* 8/5/1866
† 11/3/1923

CARL FRIEDRICH
* 9/5/1872
† 7/9/1941
⚭ ① 6/14/1898
o|o Nov. 1922
TUTTY BÖTZOW
* 2/2/1878
† 3/22/1935
⚭ ② 11/19/1929
MARGARETE HECK
* 12/11/1890
† 11/17/1977

WILHELM	FRIEDRICH	CARL	FRANZ	WALTER	SOPHIE AUGUSTA	OTTO
* 4/4/1823 † 11/19/1883	* 12/8/1826 † 5/24/1904	* 3/3/1829 † 3/21/1906	* 2/5/1831 † 4/24/1840	* 1/12/1833 † 6/11/1868	* 12/29/1834 † 12/6/1922	* 11/7/1836 † 10/10/1871
⚭ 7/23/1859 ANNE GORDON	⚭ 1/24/1864 ELISE WITTHAUER	⚭ 11/24/1855 MARIE FREIIN VON KAP-HERR			⚭ 6/15/1852 FRIEDRICH CROME	⚭ 6/17/1870 ANNETTE VON KREHMER
* 9/4/1821 † 4/12/1901	* 3/9/1843 † 7/22/1919	* 8/3/1835 † 2/1/1869			* 11/28/1821 † 12/16/1883	

BIOGRAPHICAL INFORMATION ABOUT WERNER VON SIEMENS

1816	Werner Siemens born on December 13, on the Lenthe estate near Hanover.
1823	Family moves to Menzendorf. Instruction by private tutors.
1832–1834	Pupil at St. Catherine's School, Lübeck.
1834	Entry as cadet into the 3rd Prussian Artillery Regiment, Magdeburg.
1835–1838	Officers' training in Berlin at the United Engineering and Artillery School.
1838	Promotion to Second Lieutenant in the Artillery.
1838–1840	Officer in Magdeburg.
1839	Death of his mother, Eleonore Siemens née Deichmann.
1840	Death of his father, Christian Ferdinand Siemens.
1840–1842	Officer at Wittenberg on the river Elbe.
1842	Confined in the citadel of Magdeburg. Transfer to Spandau as Fireworks Officer, later to the Engineering School. Berlin becomes the permanent residence of Werner Siemens. Member of the Polytechnic Society in Berlin. Award of a Prussian patent for his method of galvano-plastic gilding and silvering.
1843	Werner's brother Wilhelm (William) goes to England to market this patent.
1844	Travels abroad (London, Brussels, Paris).
1845	First scientific publication. Member of the Physics Society.

1846	Important improvement of Wheatstone's dial telegraph.
1847	Invention of the gutta-percha press for seamless coating of wires and trial service of the insulated wires on the Potsdam–Berlin route. On October 1, founding of the "Telegraphen-Bauanstalt von Siemens & Halske" with Johann Georg Halske and Johann Georg Siemens in Berlin. Commences manufacture (dial telegraphs, ringing devices, electromedical inductors) in the back premises of Schöneberger Strasse 19 on October 1 with three workmen.
1848	The defense of Kiel harbor against the Danes is entrusted to Lieutenant Werner Siemens by the Prussian General Staff. Werner Siemens constructs a telegraph line for the Prussian State from Berlin to Frankfurt am Main to establish a connection with the German National Assembly being held in the Frankfurt Paulskirche.
1849	The number of workers at Siemens & Halske is now 25. Werner Siemens resigns from the army.
1850	Siemens & Halske opens an agency in London under the direction of William Siemens.
1851	Siemens & Halske begins a manufacture of water meter constructed by Werner and William Siemens. The first electric fire alarm by dial telegraphs, supplied for the Berlin police. At the first International Industrial Exhibition in London Siemens & Halske receives the Council Medal.
1852	Siemens & Halske moves its factory to Markgrafenstrasse 94. Werner's first journey to St. Petersburg. On October 1, marriage to Mathilde Drumann in Königsberg.

1853	Werner's brother Carl moves to St. Petersburg to head the office there. Arnold, Werner's first son, born.
1853–1855	Long telegraph lines constructed by Siemens & Halske in Russia; firm also secures contract for maintenance.
1855	Establishment of the St. Petersburg branch under the direction of Carl Siemens. Wilhelm, Werner's second son, born.
1856	Werner Siemens invents the double-T armature.
1856–1857	Technical collaboration in the laying of the British cable from Cagliari to Bona.
1858	The London agency of Siemens & Halske becomes an independent branch under the direction of Werner's brother William.
1859	Werner establishes a unit based on electrical resistance and creates a standard of mercury (Siemens unit). Scientist in charge of the British cable laying enterprise across the Red Sea. Stay in Egypt.
1860	Doctor of Philosophy *honoris causa* of Berlin University. First experiments with the express typewriter.
1862–1866	Member of the Prussian Chamber of Deputies for Lennep-Solingen.
1863	Memorandum on a German patent law. Building of a cable works at Woolwich, near London.
1864	Purchase of the Kedabeg copper mine in the Caucasus by Carl and Werner Siemens. Cable laying, Cartagena–Oran.
1865	After the withdrawal of Johann Georg Halske from the British business the British firm is reconstituted under the name "Siemens Brothers." First journey to the Caucasus. Death of Werner's wife Mathilde Siemens, née Drumann.

1866	Werner Siemens discovers and demonstrates the dynamo-electric principle.
1867	His treatise “Über die Umwandlung von Arbeitskraft in elektrischen Strom ohne Anwendung permanenter Magnete” (Of the Conversion of Mechanical Energy into Electric Current without Permanent Magnets) is read before the Royal Academy of Sciences in Berlin by Professor Magnus. Dynamo-electric machine shown at the Paris International Exhibition. First use of the dynamo-electric machine as a mine exploder. Johann Georg Halske retires from the firm of Siemens & Halske.
1867–1870	Founding of Indo-European Telegraph Company in London and construction of the line by Siemens & Halske and Siemens Bros.
1868	Use of the dynamo-electric machine for searchlight illumination. Second journey to the Caucasus.
1869	On July 13, marriage to Antonie Siemens of Hohenheim, near Stuttgart.
1870	Karl Frischen, engineer with Siemens & Halske, develops the railway block system. Werner’s daughter Hertha born. Carl Siemens goes to London and becomes director of Siemens Brothers.
1872	Founding of the firm “Gebrüder Siemens & Co.” for the manufacture of alcohol meters in Lichtenberg, near Berlin. Invention of the drum armature by Friedrich v. Hefner-Alteneck, chief designer of Siemens & Halske. Carl Friedrich Siemens, Werner’s youngest son, born. On the 25th anniversary of Siemens & Halske a pension fund is created for the employees.
1873	Werner Siemens becomes an ordinary member of the Prussian Academy of Sciences.

1874	The first direct transatlantic cable (built by Siemens Brothers) is laid from Ireland to the United States, under the direction of Carl Siemens and using the cable ship *Faraday* designed by his brother William.
1876	Siemens & Halske erects a cable factory in Berlin, at first with the primary purpose to supply underground cable for the Telegraph Cable Network of the German Reich.
1877	The first telephones of Alexander Graham Bell reach Berlin. Werner Siemens improves Bell's telephone and invents the electrodynamic system of sound transmission. Siemens & Halske installs the first electric power transmission system in the small arms factory at Spandau. In recognition of his services in connection with the German patent law Werner is made a member of the Imperial Patent Office.
1878	Development of the differential arc lamp by Friedrich von Hefner-Alteneck to Werner's instructions.
1879	A small railway with electric drive is exhibited and operated by Siemens & Halske at the Berlin Trade Exhibition. Founding of a branch in Vienna under the direction of Arnold Siemens. With Postmaster General Heinrich von Stephan, Werner Siemens founds the Electrotechnical Society in Berlin.
1880	Werner Siemens submits to the city of Berlin a complete design for the building of an elevated railway in the Friedrichstrasse. The first electric lift is exhibited by Siemens & Halske at the Mannheim exhibition. Carl Siemens returns to Russia. Building of a cable and an apparatus works in St. Petersburg.

1881	Werner Siemens advocates the establishment of chairs of electrical technology at the technical colleges. At the International Electrical Exhibition in Paris Werner Siemens meets Thomas A. Edison. Siemens & Halske builds and operates an electric tramway in Lichterfelde, near Berlin.
1882	Werner Siemens takes part in an international conference in Paris which establishes a practical system of units. Siemens builds the first electric mine railway in Zaukeroda, Saxony. Siemens & Halske commences manufacture of its own filament lamps. Werner's son Wilhelm Siemens marries his cousin Elly Siemens.
1883	Werner's brother William is knighted by Queen Victoria. He dies in the same year. Agreement between Siemens & Halske and the German Edison Co. which leads to the establishment of AEG four years later. The Charlottenburg factory on the Salzufer commences manufacture.
1884	Werner's son Arnold Siemens marries Ellen von Helmholtz, a daughter of Hermann von Helmholtz.
1886	Werner Siemens proposes the possibility of producing nitrogen compounds industrially with the aid of electricity. Doctor of Medicine *honoris causa* of the University of Heidelberg.
1887	The Physico-technical Imperial Institute proposed by Werner Siemens (1883) and founded with his help commences its activities.
1888	Werner Siemens, with his brothers Carl and Friedrich, takes part in the development and introduction of the Mannesmann process for the manufacture of

	seamless tubes. Werner receives the honor of Prussian nobility from the Emperor Friedrich III.
1889	Werner von Siemens begins to write his *Recollections* in the Ettershaus in Harzburg.
1890	He hands over the management of the firm to his brother Carl and his sons Arnold and Wilhelm. Last journey to the Caucasus.
1891	On the occasion of the International Electrotechnical Exhibition in Frankfurt am Main, the Congress of Electrical Engineers elects Werner von Siemens to be its president.
1892	Death of Werner von Siemens on December 6 in Charlottenburg.

NOTES

Page 29: Parents. Christian Ferdinand Siemens (1787–1840) studied the science of public finance at the University of Göttingen and, after returning home to become a farmer like his father, married Eleonore (1792–1839), the daughter of the neighboring landowner Deichmann. Werner's father leased land in Lenthe near Hanover in 1813, on an estate that had belonged to the local von Lenthe family for 600 years. Here Werner von Siemens was born on December 13, 1816. The adverse conditions of the post-Napoleonic era caused Christian Ferdinand Siemens to fall into arrears with the rent despite his best efforts, and in 1823 he gave up the leasehold. He paid off his debt the following year.

Page 38: The grand-ducal domain of Menzendorf, near Schönberg in Mecklenburg. In 1823, Christian Ferdinand Siemens took over the farming of the Menzendorf domain near Lübeck. Here, he slowly improved the economic status of the family, but debts again accumulated due to bad harvests and misfortune. In addition, his health failed and he died in 1840. His sons Ferdinand and Hans carried on with the help of their neighbor, the capable farmer Ekengren. In 1843, the tenancy was disposed of with a modest profit for the family.

Page 44: The St. Catherine's School in Lübeck was founded in 1531, during the Reformation, as a grammar school. At the end of the 18th century the curriculum began also to take account of practical callings. In the three top grades the classical languages continued to be taught; in the four lower grades, the so-called middle-class grades, the teaching was more on the level of the manual worker and tradesman. At Easter 1832, Werner von Siemens entered the Upper Third. Although classical languages were not his strong point, he was second in his grade when he moved up. He left school at 17 in 1834, with a diploma that would allow him to enter only a limited range of university studies.

Page 49: Louis Siemens (1819–1892). Cousin of Werner; their fathers were brothers. He was a landowner in Saxony and after the sale of his estate lived in Dresden, later in Charlottenburg, near Berlin. He invented some agricultural appliances and was also concerned with the development of the alcohol meter, for the manufacture of which he and Werner founded the firm of "Gebr. Siemens & Co." in 1872.

Page 52: Artillery and Engineering School. The United Engineering and Artillery School in Berlin was founded immediately after the War of Liberation on July 13, 1816. Its purpose was the higher scientific education of artillery and engineer officers based on experience gained in the fight against Napoleon. Lectures were given, in addition to actual military subjects, in mathematics, physics, chemistry, geography, drawing and French. The lectures were supplemented by practical exercises and visits to works, laboratories, magazines, etc. The complete course lasted three years. After 1831, junior officers as well as ensigns attended. The instructors consisted of officers and civilians. The school had a library of 4,500 volumes and from 1831 onward a valuable chemico-physical instrumentarium.

Page 53: Martin Ohm (1792–1872). Author of several fundamental textbooks on mathematics; brother of the physicist Georg Simon Ohm, after whom the unit of measurement for electrical resistance is named.

Page 53: William Meyer (1816–1868), regimental comrade of Werner von Siemens. From 1855 to his death, he was chief engineer and authorized officer with Siemens & Halske. His services were of great value to the firm in the practical and organizational execution of telegraph construction contracts.

Page 55: Carl Himly (1811–1885). Chemist, university lecturer in Göttingen and later Professor of Chemistry at Kiel University. In 1838, he married Werner's sister Mathilde, born 1814. He assisted his brother-in-law in 1848 in the installation of an electrically detonated minefield at the entrance to Kiel harbor.

Page 58: A. (Adolf) Siemens (1811–1887), distant cousin of Werner, brother of Werner's father-in-law by his second marriage. Adolf was an artillery officer, first in the Hanoverian Army and after 1867 in the Prussian Army, and acted as Chairman of the Artillery Testing Commission in Berlin. After his retirement as major general in 1872, he worked for a time in the laboratory of Siemens & Halske. He was responsible for a number of inventions relating to artillery.

Page 58: Friction tubes. Small metal tubes containing an explosive and detonated by pulling out a roughened wire. For firing cannon.

Page 63: A Daniell cell. The Daniell cell, used by Werner von Siemens in 1840, was invented in 1836 by the british chemist and physicist Johann Frederic Daniell (1790–1845). After the frog-leg experiment of Galvani in 1780, the voltaic pile was constructed as the first galvanic cell. When current was taken from it, however, its voltage gradually fell because of the production of hydrogen at the electrode (polarization). In the Daniell cell, this polarization was avoided and it thus maintained its voltage even when supplying current. It consists of two liquids separated by a porous pot. A zinc cylinder is immersed in diluted sulfuric acid and a copper cylinder in copper sulfate solution. The projecting metal strips constitute the positive and negative poles of the cell. The Daniell cell was later also built by Siemens & Halske, until it was superseded by the Leclanché cell of zinc and carbon with manganese dioxide, now also made as dry cells.

Page 69: Rudolf Christian Böttger (1806 – 1881). Chemist, professor, lecturer at the Physics Society, Frankfurt am Main.

Page 70: Anastatic printing. Chemographic method of reproducing printed pages and complete books without resetting, now generally superseded by photographic processes.

Page 72: Carl Gustav Jacob Jacobi (1804 – 1851). Professor of Mathematics in Königsberg and Berlin. Famous for his theory of elliptical functions and his research in the fields of differential equations and variation calculation.

Page 73: Heinrich Gustav Magnus (1802 – 1870). Teacher at the School of Artillery and Engineering, Professor of Physics in Berlin. On January 17, Magnus presented the dynamo-electric principle to the Prussian Academy of Sciences and thus secured the patent rights for Werner von Siemens, since as a non-academic, Werner had no access to the Academy. Professor Magnus was the first to describe the flow of air or liquid around spinning bodies, which is known after him as the “Magnus effect.” The Flettner rotor for ships’ engines is based on this effect, which also explains the deviation in the path of spinning bullets.

Page 73: Heinrich Wilhelm Dove (1803 – 1879). Professor of Physics at Berlin University. He established meteorology as a science and propounded the law of the rotation of the winds named after him. Dove was a member of the Prussian Academy of Sciences.

Page 73: Emil Du Bois-Reymond (1818 – 1896). Professor of Physiology in Berlin. Measurement technique is indebted to him for a great many suggestions. From 1867, he was permanent secretary of the Prussian Academy of Sciences. He was a personal friend of Werner von Siemens from the early days of the Physics Society – 1845. As secretary of the Academy in 1873, he proposed Werner von Siemens as an ordinary member and delivered the inaugural address on his introduction.

Page 73: Ernst Wilhelm Ritter von Brücke (1819 – 1892). Physician, physiologist, assistant at the Museum for Comparative Anatomy, later Professor of Physics in Königsberg and Vienna.

Page 73: Hermann von Helmholtz (1821 – 1894). Physicist, physician, and physiologist. He started his career as a military doctor in Potsdam. In 1871, he was appointed to the chair of physics at Berlin University. His fundamental physical and physiological studies in optics and acoustics stamp him as the most important German scientist of the second half of the 19th century. He put the law of conservation of energy into scientific form. He also introduced the ophthalmoscope into medicine. The recognition of the quantum structure of electricity is attributable to him. In 1888, he became the first president of the Physico-technical Imperial Institute, the founding of which was largely due to his friend, Werner von Siemens. Werner's eldest son, Arnold, married Helmholtz's daughter Ellen in 1884.

PAGE 73: Rudolf CLAUSIUS (1822 – 1888). University lecturer in Berlin, then professor in Zurich, Würzburg and Bonn. He added the concept of entropy to that of the conservation of energy set out by Robert Mayer and Hermann von Helmholtz in the first fundamental law. The second fundamental law of thermodynamics, discovered by him, states that in a closed system all processes must be such that entropy never decreases. He also established the kinetic theory of gases, which explains the appearance of heat from the motion of molecules.

PAGE 73: Gustav WIEDEMANN (1826 – 1899). Physicist and chemist, professor at Basle, Brunswick, Karlsruhe, and Leipzig.

PAGE 73: Karl LUDWIG (1816 – 1895). Physiologist and physicist, Professor of Comparative Anatomy at Marburg, professor in Zurich, Vienna and Leipzig.

PAGE 73: Wilhelm von BEETZ (1822 – 1886). Physicist, professor at the Artillery School, at the cadet corps in Berlin and at the Technical University in Munich.

PAGE 73: Karl Hermann KNOBLAUCH (1820 – 1895). Physicist, university lecturer in Berlin, later in Bonn; professor in Marburg and Halle.

PAGE 74: Peter Christian Wilhelm BEUTH (1781 – 1853). Founder of the Berlin Industrial Institute, forerunner of the Technical University in Charlottenburg. Prussian ministerial counselor, from 1827 an important figure in Berlin. Prepared the way for the training of engineers in Germany. Prussian legislation for the furtherance of industry in the 1830s was largely due to him.

PAGE 76: AIR ENGINES. A device based on the principle that air expands when heated and contracts when cooled. A power cylinder receives alternately cold and hot air from two pump cylinders, whereby the power piston is moved backward and forward. For heating and cooling of the air, the pistons of the pump cylinders force the air alternately into compartments heated by a flame and cooled by water at the ends of their cylinders.

PAGE 78: OPTIC TELEGRAPHY was the idea of the French clergyman Claude Chappe, 1791. Chappe's optical telegraph was of great use to Napoleon in his campaigns. After the conclusion of peace, it was nearly twenty years before the Prussian General Staff had an optical telegraph line constructed from Berlin to Koblenz in 1832/1833.

PAGE 78: In 1823, Hofrat Conrad Heinrich SOLTMANN and the apothecary Gustav Struve founded a curative water-drinking establishment at Belle-Alliance-Platz in Berlin. In 1835, Struve handed over its direction to Soltmann and devoted himself to his business in Dresden. Soltmann, who was very interested in technical matters, registered a Prussian patent for the dial telegraph of his friend Charles Wheatstone, and set it up in his drinking garden. It was probably here that Werner von Siemens got to know it through his colleague Hermann Soltmann, the son of Soltmann senior. The impulse to improve it and make it of practical use, however, did not come to Werner until some years later, in 1846.

PAGE 78: Sir Charles WHEATSTONE (1802–1875), owned a musical-instrument factory in London and concerned himself with questions of acoustics and associated fields arising from his business. In 1837, in conjunction with Sir William Cooke, he obtained the first English patent for a needle telegraph. In 1839, he became Professor of Experimental Physics at King's College in London. Later, he constructed a DIAL TELEGRAPH (see note p. 79) and a number of other electrical appliances such as bells, buzzers, clocks, etc. In 1867, shortly after Werner von Siemens' announcement of his dynamo machine with series winding, he published a very similar idea, a dynamo machine with shunt winding. His name is perpetuated in the circuit devised by him, the Wheatstone bridge, which is still widely used in measurement and control technique.

PAGE 79: The DIAL TELEGRAPH of Werner von Siemens. Electric telegraphy was first accomplished by Samuel Thomas von Soemmerring in 1809 using an electrolytic principle. Carl Friedrich Gauss and Wilhelm Weber, in 1833, first applied electromagnetism to telegraphy. Their apparatus was, however, very delicate and could only be operated by experts. The dial telegraph of Werner von Siemens made by Johann Georg Halske was the first practicable and reliable instrument which could be operated even by the then untrained telegraphists. Whereas the Wheatstone dial telegraph was actuated by a weight-operated and electromagnetically remote-controlled escapement, whereby a pointer was moved over a letter and number dial, the pointer of the Siemens transmitter and receiver instrument was rotated forward stepwise (step-by-step motor) via a ratchet wheel by the electromagnetic Wagner hammer with self-interruption (publication by Christian Ernst Neef), shown on the left of the drawing. Consequently, transmitter and receiver must necessarily keep in step because both could only make a new step forward when their two electromagnetic hammers, connected in series, had reclosed the circuit. Compared with the Wheatstone dial telegraph this was a decisive advantage, because with this, if the characters were transmitted too quickly, the armature and the catch of the escapement could not follow the electrical impulses exactly, owing to the slow rise of the current and their inertia; they would then fall out of step and the letters would be wrongly indicated. Technically, the Siemens apparatus was so constructed that the movement necessary to advance by one letter was achieved by the hitherto unknown method of the drag contact, and in the transmitters and receivers the spring tension was so set by means of a fine drive with scale that their electromagnetic hammers were mechanically matched. By pressing a key, the pointer of the transmitter was mechanically stopped, causing the pointer of the receiver to remain at the same character. The magnet shown on the right in the sketch was used as a bell call for the telegraphist, who then switched the apparatus over to the working position. From the "Patentgesuch auf eine neue Art elektrischer Telegraphen und eine damit verbundene Vorrichtung zum Druck der Depeschen" (Application for a Patent for a New Kind of Electric Telegraph and Combined Arrangement for Printing Messages), May 1, 1847: "What I consider as new and essential, and desire on that account to patent, is: 1. The automatic reversal of the current, effected by means of a movable piece of metal. 2. The method described of assuring the motion of the tread wheel by pushing a solid or spring stop between its vertical teeth. 3. Obviating the possibility of the sticking of the armature of an electromagnet by the insertion of a shunt at the moment of arrest. 4. The combination of steel and electro-magnets, as described, by which the weakening of the magnetism of the steel is obviated and the motion of the former assured with any strength of current. 5. The construction of electro-magnets with insulated iron wires."

Page 79: Johann Georg Halske (1814–1890). Son of a Hamburg merchant, he came to Berlin in his early years and became a mechanician. He got to know Werner von Siemens in the Physical Society. He made the first model of the dial telegraph improved by Werner von Siemens. In 1847, together with the barrister Johann Georg Siemens, they founded the "Telegraphen-Bauanstalt von Siemens & Halske." In 1864, Halske withdrew from the English Siemens firm, which was directed by William Siemens. The extension of the commitments of the Siemens brothers and the transition of his Berlin firm from hand work to machine manufacture were foreign to his nature. In 1867, he gave up the direction of the Berlin firm, but for the rest of his life remained a close friend of Werner von Siemens.

PAGE 80: JOHANNES RONGE (1813–1887). Parson, originator of the German Catholic movement, Founder of the Religious Reform Society.

PAGE 80: "UNDER THE TENTS." Beer gardens in the Berlin Tiergarten on the Spree.

PAGE 83: Christian Friedrich SCHÖNBEIN (1799–1868). Chemist, Professor at the University of Basle.

PAGE 87: Franz August von ETZEL (1784–1850). Major-general; from 1832 to 1848 director of the optical telegraph. From 1837, he endeavored to introduce the electric telegraph and supported Werner von Siemens.

PAGE 88: GUTTA-PERCHA. Coagulated latex of the Malayan tree *Isonandra gutta*.

PAGE 90: Johann GEORG SIEMENS (1805–1879). Barrister-at-law in the Upper Tribunal in Berlin. Joint founder and up to 1854 silent partner of the "Telegraphen-Bauanstalt von Siemens & Halske," for which he had put up the initial capital of 6,842 thalers. He assisted Bernhard Wolff in the founding of the first German telegraph bureau in 1849. He retired from the firm in 1855.

PAGE 90: 6,000 THALERS. The balance sheet of December 31, 1849, covers the first two and a quarter years of Siemens & Halske; it was drawn up by Johann Georg Halske, who personally kept the accounts. It is an account typical of a craftsman, a mixture of balance sheet, giving a statement of assets and liabilities, and a profit-and-loss account. The invested capital of 6,842 thalers and 20 silver groschen (1 thaler consisted of 30 silver groschen, each of 12 pfennigs) was two-thirds of the 10,000 thalers originally promised by the barrister Johann Georg Siemens. Werner von Siemens received the same sum initially from the profits of the firm in consideration of the inventions and patents contributed by him, namely the dial telegraph and gutta-percha press. The profits were divided among the three founders in the proportions two-fifths, two-fifths and one-fifth. Accordingly, Werner von Siemens and Halske each drew 1,640 thalers as their share of the profits for these years while Johann Georg Siemens drew only 400 thalers of his share of the profits up to January 1, 1850, leaving the remaining 420 thalers in the business. He withdrew from the firm on January 1, 1855. His share of the assets was assessed at that time at 60,000 thalers, which was paid to him in six annual installments of 10,000 thalers.

PAGE 91: Use of telegraph lines by the PUBLIC. The telegraph was at first a purely military installation. Not until October 1849 was its use by the public in Prussia and Germany permitted.

PAGE 95: Felix PRINCE LICHNOWSKY (1814–1848). Officer and politician. Was originally in Prussian and later in Spanish military service; in 1840, he returned to Germany. He was a notable political speaker of the conservative wing and fell in 1848 as a victim of the Frankfurt uprising.

Page 117: Friedrich Wilhelm Nottebohm (1808 – 1875). As an assistant of Peter Beuth in the Industrial Institute, he was concerned with the Rhenish Westphalian industrial district. After a study tour abroad, he became, in 1842, Assessor of the Royal Technical Deputation for Industry; in 1849, as Counselor, technical member of the Prussian Telegraph Construction Commission. From 1850 to 1856, he was head of the telegraph organization and introduced the Morse telegraph in Prussia. He played an important part in founding the German-Austrian Telegraph Society, which existed from 1850 to 1872.

Page 119: Electrostatic charge. Because of their capacitance, buried insulated electric wires act like Leyden jars, of which the inner coating is represented by the conductor wire and the outer coating by the damp soil.

Page 120: Voltaic inductor. According to the books of Siemens & Halske, medical slide induction apparatus was supplied at a price of 12 thalers each in the early years of the firm as follows:

1848	March 4 to June 7	Dr. Rosenberger, Kösen Prof. Ludwig, Marburg
1849	August 24	Prof. Volkmann, Halle
1850	February 7	Gasscot, London
	March 1	Prof. Bischoff, Giessen
	April 22	Messrs. Fonrobert & Pruckner, Berlin
	July 17	Prof. Schellbach, Berlin Friedrich-Wilhelm Grammar School, Berlin.

The demand continued in the following years. In the decade from 1855 to 1865, 450 appliances were sold.

Page 122: Plate-type lightning conductors. As protection against the destructive effects of overvoltages, which can appear on telegraph lines due to atmospheric electricity, two plates are placed facing one another a short distance apart in a small box. One plate is connected to the line and the other to earth. When too high a voltage occurs, flashover takes place between the plates so that the electricity is discharged to earth. After this flashover, the air gap between the plates again acts as insulation.

Page 130: Cologne firm. Felten & Guilleaume.

Page 136: Fire-brigade telegraph. The fire alarm of 1852 for the Berlin police was installed at 50 police stations. It was actuated when the handle seen on the right was pulled. This released a weight drive, which set a cam disc in rotation. Each station had a special disc with a cam arrangement different from those of all the other stations, which, through contacts, transmitted a corresponding current pulse train to the central station. This automatic signal eliminated possible errors as to the identity of the station calling.

Page 137: Samuel F. B. Morse (1791–1872), american painter and engineer. In 1837, he invented a telegraph apparatus which wrote telegrams by the electromagnetic movement of a stylus on paper strips that were drawn past it. The Morse telegraph is a landmark in the development of electrical communications.

Page 138: Go-between relay. This relay is connected between two line sections. As the current is attenuated with increasing length of line, the go-between relay switches a new battery onto the following line in synchronism with the Morse signs. By multiple application of this method, at that time called "translation," it was possible to telegraph over very long lines.

Page 138: Karl August Steinheil (1801–1870). Professor of Mathematics and Physics in Munich. In 1836, he constructed an electromagnetic writing telegraph; in 1838, electric clocks and a telegraph line between the Academy in Munich and the observatory in Bogenhausen, for the first time using the earth as return. He was head of the department of telegraphy in the Austrian Ministry of Commerce. In 1834, he founded an optical-astronomical establishment in Munich.

Page 139: Claude Servais Mathias Pouillet (1790–1868). Physicist, director of the Conservatoire des Arts et Métiers in Paris.

Page 139: Henri Victor Regnault (1810–1878). Physicist and chemist. Director of the Royal Porcelain Works in Sèvres.

Page 139: Urbain Jean Joseph Leverrier. (1811–1877). Chemist, astronomer, director of the observatory in Paris.

Page 139: Alexander Bain (1810–1877), a Scotsman. He was a mechanician, built telegraphs and gained great merit in the construction of electric clocks.

Page 142: Michael Faraday (1791–1867). English scientist, discoverer of electromagnetic induction. From humble beginnings, he rose to become one of the most distinguished savants of his time. Through Humphry Davy, whose assistant he was, he became associated with the Royal Institution. Discoveries in chemistry and physics and, above all, the law of magnetic induction were named after him, 1831, and the demonstration of the rotation of the plane of polarization in the magnetic field (the Faraday effect) made him world famous.

Page 142: Alexander von Humboldt (1769 – 1859), came of a noble family from the Brandenburg March, who were domiciled in Tegel near Berlin. After studying in Frankfurt an der Oder, Göttingen and at the Freiberg (Saxony) Mining Academy, Humboldt first became Chief Mining Officer in Franconia. From 1797, he devoted himself entirely to his studies, especially of geography, botany and physics. With Carl Friedrich Gauss he organized magnetic observing stations and corresponded with Friedrich von Schiller and Johann Wolfgang von Goethe. Travel took him to France, Italy (thermal measurement on Mt. Vesuvius), England, Spain, Denmark, and especially to South and Central America, which he opened up to European scientists in his works. He lived for a considerable time in Paris in connection with a political mission. In 1811, he was joint founder of the Berlin University, the creation of his brother Wilhelm. He was a friend of Friedrich Wilhelm IV. That Berlin became the focal point of the young German natural science is largely due to him. In an epoch when scientific research was splitting up into specialist fields, he, the grand old man, was the last universal savant who as thinker and teacher still comprehended the scientific knowledge of his time as a whole.

Page 145: Measurement of the velocity. The method of measurement with the aid of marks which an electric spark burns on polished steel is the basis of modern spark chronographs.

Page 152: Water-meter question. The water-supply networks, which were first constructed in England about the middle of the 19th century, necessitated the selling of water and, consequently, the metering of the quantity supplied. For this, water meters had to be inserted in the pipes. In the type invented by William Siemens, a small turbine in the inlet pipe moved a pointer over a calibrated dial through reduction gearing. Siemens & Halske took up the manufacture of these water meters in 1851 and for reasons of tradition retained this nonelectrical part of their manufacturing range up to 1962.

Page 155: J. K. Ekengren, farmer on an estate near Menzendorf. On the death of Werner von Siemens' parents, he became the guardian of the children not yet of age.

Page 158: Carl von Siemens (1829 – 1906). Werner's brother and closest collaborator. He built up the associated Russian firm and directed it with great success. The contract for and construction of the telegraph lines, which Siemens & Halske laid in Russia in 1853, the planning and execution of the Indo-European telegraph line from 1867 to 1870 and the transatlantic cables which were laid by the Siemens brothers with their cable ship *Faraday* in the 1870s and 1880s were largely due to him. In the 1870s, Carl put new life into the English business. After Werner's death, he became head of Siemens & Halske. When the firm was made a joint stock company in 1897, he was appointed chairman of the board of directors. He had become a Finnish-Russian citizen, and in 1895 he was raised to the hereditary Russian nobility. His grandson died young and childless, so this noble branch of the family came to an end.

Page 161: Alexander Count Lüders (1790 – 1874). General director of the Russian state telegraphs from 1866.

Page 161: Wilhelm Drumann (1786 – 1861), a German researcher in history and classical culture. From 1821 Professor of History in Königsberg, where he taught until 1856. His most important work was the six-volume *History of Rome* (First edition 1834 – 1844).

Page 162: Mathilde Siemens née Drumann (1824 – 1865), daughter of Wilhelm Drumann, Professor of Ancient History at Königsberg University, and his wife Sophie née Mehlis. Sophie was a cousin of Werner von Siemens. Mathilde became Werner's wife on October 1, 1852. They had four children: Arnold (1853), Wilhelm (1855), Anna (1858), Käthe (1861).

Page 163: Markgrafenstrasse 94 in Berlin. The premises were bought by Siemens & Halske in 1852 for 40,000 thalers. After some reconstruction, the works was moved there. From 1853, Werner von Siemens, the barrister Johann Georg Siemens and Johann Georg Halske occupied the front building. In 1870 and 1878, the premises in Markgrafenstrasse 92 and 93 were purchased to meet the growing needs of the firm. In 1905, the factory was moved to the new Wernerwerk on the Nonnendamm in Spandau (Siemensstadt) and the Markgrafenstrasse premises were sold.

Page 169: Kadettenlinie (Cadet line). The streets running parallel on William Island (Wassili–Ostrow) in St. Petersburg were called "lines."

Page 170: Adolf Theodor von Kupffer (1799 – 1865). Physicist, Professor of Physics and Chemistry in Kasan.

Page 170: Heinrich Friedrich Emil Lenz (1804 – 1865), a Balt, Professor of Physics in St. Petersburg. He is the author of the well-known rule that the current produced in a conductor by a moving magnet according to Faraday's law of induction must be in such a direction that the movement of the magnet requires energy.

Page 170: Moritz Hermann von Jacobi (1801 – 1874). Architect and Professor of Physics in St. Petersburg. Of German descent. His special interest in galvanic electricity led him, in 1838, to the construction of the first "electromotor," which, when driven by 64 cells, propelled a ship with fourteen persons on board upstream on the Neva. He discovered galvanoplastics and a process for its practical application.

PAGE 170: Karl Ernst VON BAER (1792–1876). Scientist, Professor of Zoology in Königsberg and St. Petersburg.

PAGE 171: Hermann Freiherr von KAP-HERR (1801–1877). German banker and merchant in St. Petersburg. He was originally, until succeeded by Carl von Siemens, representative of Siemens & Halske in Russia. Carl married his daughter Marie in 1855. Relations between Werner and Kap-herr were sometimes strained, but Carl acted as mediator.

PAGE 180: The WINTER PALACE in St. Petersburg. A massive building about 450 feet long, which was rebuilt in 1838 to 1839 on the initiative of Pjotr Count Kleinmichel after a fire the previous year. The terminal station of the optical telegraph to Warsaw was in this building. The central station of the Russian state telegraphs was installed by Carl von Siemens in the Emperor's tower room in 1854.

PAGE 198: CROSS-SECTION THROUGH THE FIRST DEEP-SEA CABLE from Cagliari to Bona. Instead of a single copper wire as conductor, four thin copper wires were stranded to avoid breakage with a stronger pull. The iron armoring consisted of eighteen wires. The cable withstood a pull up to 8,130 kg; the weight was 1,360 kg per km.

PAGE 199: The DYNAMOMETER. It consists of two fixed pulleys arranged at a certain distance at the same height. The cable runs over them into the water. The principle of the dynamometer is that between the two pulleys there is a third to which a weight is attached, hanging freely on the cable. From the sag and the weight, the pull on the cable and, accordingly, the suspended length can be determined.

PAGE 205: Ludwig LÖFFLER (1831–1906). From 1853, he was assistant to Carl von Siemens in St. Petersburg. In 1858, he transferred to Siemens & Halske in England, where he worked in close collaboration with William Siemens, whom he succeeded in 1883 as head of the English Siemens firm following the death of the latter. He tried to run the English firm according to his own ideas and often contrary to those of the Berlin firm and the Siemens family. In 1888, he was replaced as head of the English firm by Alexander Siemens.

PAGE 210: POLARIZED RELAY of 1859. Whereas earlier electromagnetic relays always attracted their armature when current was flowing, irrespective of its direction, the position of the armature of the polarized relay depends on the direction of the current. With this relay it was therefore possible to transmit alternating current (positive and negative DC pulses). It was thus possible to insert "amplifier stations" in the long-distance line, the contacts of the relay being connected to new sources of energy. The advantage of polarized over nonpolarized relays is that resetting springs are unnecessary; further, the additional magnetic polarization field of the relay makes the relay more sensitive to the telegraph pulses so that it can be used over longer distances. Transmission with alternating current is also much less subject to disturbance.

PAGE 212: The POLARIZED MORSE INKER FOR LONG UNDERSEA LINES (1859) represented a development of the relief writer; it made a trace of black dots and dashes on the paper tapes automatically set in motion by clockwork. The symbols were recorded when a disc, which received ink from an inking roller, was pressed onto the paper for shorter or longer times. The receiver could both write out a telegram and also, by means of a translation device, repeat it amplified when a message had to be transmitted through several stations. Its polarized relay transmitted the currents as alternating currents (direct currents in both directions, so-called double currents), which was essential with lines of high capacitance, e.g., submarine cables. The apparatus was therefore used with success for long submarine lines such as the Red Sea line.

PAGE 214: POLARIZING BATTERY consisted of a cell which, by means of a rotary switch, individually charged up a number of platinum elements one after the other (by polarization), like accumulator cells. These were connected in series, so that it was possible to draw from them a higher voltage than that of the charging cell.

PAGE 215: The unused length of cable with its capacitance was connected to the telegraph line as a CONDENSER in series with the writer. A condenser has an impedance which decreases as the frequency is increased. Thus, by inserting the unused cable, the disturbing direct current was blocked and the slowly running component of low frequencies was dampened. The component consisting of the higher frequencies of the sending pulse was able to reach the receiver as a more steep-fronted wave and to transmit more sharply defined pulses at a higher speed to the writer, which then recorded easily recognizable traces.

PAGE 215: A 1 OHM STANDARD RESISTOR USING MERCURY. Developed by Werner von Siemens, it was accepted as the international unit in Paris in 1882. The coiled glass tube has a cross section of 1 mm^2 and a length of 1.063 m and is filled with cleaned mercury. This container is immersed in melting ice so as to be at the specified temperature of 0 °C. The mercury column then has a resistance of 1 ohm.

PAGE 217: ABSOLUTE UNIT OF WEBER. From the definition that two charges or two magnetic poles which at a distance of 1 cm apart exert a force on one another of 1 dyne (unit of force of the cgs system, corresponding approximately to a weight of

1 milligram) should be the unit charges or unit poles, Carl Friedrich Gauss and Wilhelm Weber derived a so-called absolute electrostatic and an electromagnetic system of units. In these systems the resulting units for resistance were unsuitable for practical use. The units of the electromagnetic system were therefore increased by certain powers of ten at a conference held in Paris in 1884. The result was the now generally used "system of practical units" with the units volt, ampere, watt, ohm, etc. The resistance unit first established by Werner von Siemens by means of a mercury column was within 6 percent of the later internationally accepted value of 1 ohm.

Page 238: Woolwich. A town and later a borough of London, on the south bank of the Thames. It is home to large military workyards and a military academy.

Page 248: Electric log. The log consists of a propellerlike spinner, which rotates according to the velocity at which it is drawn through the water by the motion of the ship. At each revolution an electrical contact is made. The number of contacts is counted electrically and is a measure of the speed of the ship. Developed by Siemens & Halske about 1859 to 1860.

Page 256: Three-key puncher. The three keys punched a round hole for a dot, two holes for a dash and no hole for the spacing between words. Due to the use of preperforated ribbons, it was possible to telegraph more quickly than by hand over the long and costly Russian lines.

Page 256: Morse express writing transmitter (1853). When the paper ribbons had been prepared by the three-key puncher, they were drawn through the express writing transmitter between a metal roller and a metal brush pressing lightly on it; in this way contacts were made which caused current pulses on the telegraph line.

Page 256: First Morse relief writer with a weighted drive, self-release and translation device. One of the oldest Morse instruments made by Siemens & Halske. It had a rotating magnet core and a peculiar so-called camel shape. It was developed in the 1850s as a receiver in conjunction with the three-key puncher and the express writing transmitter for the automatic telegraph system of the Russian telegraph lines. This oldest Morse writer made by Siemens & Halske still had a weight drive instead of the later spring drive for advancing the paper strips. It impressed the Morse signs into the paper with a steel stylus (relief writer). Attempts to write with an inked stylus were at first unsuccessful.

Page 258: Magneto-electric dial telegraph. This telegraph needed no galvanic batteries. The current was generated by turning a crank inductor, of which the double-T armature used in it for the first time was sufficiently powerful to actuate a fairly large polarized relay in the receiver. The relay was coupled to a ratchet which, on each movement of the magnet caused by the relay moving to right or left, caused the pointer to be advanced by one step. By means of gearing, the armature of the inductor was rotated so quickly that, when the handle at the transmitting end was turned through the space of one letter, the double-T armature made half a revolution, whereby a positive or negative half-wave of current was fed into the line, causing the pointer at the receiver also to be advanced by one letter through the action of the polarized relay. The instrument was designed by Werner von Siemens in 1856 and supplied for the first time to the Bavarian railways.

Page 259: Closing and opening currents. When an inductor is used with intermittent direct current, two secondary currents appear, the closing current when the primary circuit is closed and the opening current when it is opened.

Page 259: Inductive writing telegraphs. Using modern terminology, the principle of the induction telegraph may be described somewhat as follows: When the primary circuit of the transformer is closed, a high-voltage, positive current pulse is induced in the secondary circuit; at the receiver end this pulse energizes the polarized relay, which switches on the local battery, thus actuating the stylus of the Morse apparatus; when the primary current is interrupted by the key, a negative current pulse flows from the secondary coil along the line and the polarized relay drops out, causing the stylus of the receiving apparatus to be lifted from the paper. Because of the turn ratio of the transformer, the voltage on the actual telegraph line is increased, and the range thus extended. The internal resistance of the battery is better matched to the line by means of the transformer.

Page 261: Double automatic generator. Like the plate machine, the double current generator is used to increase the voltage of galvanic cells by transformer action for telegraphing over long lines. By means of a commutator the two pairs of electromagnets are energized alternately by cells and attract their armatures alternately, thus driving a flywheel through a crankshaft. Like the spark induction coil, each of the electromagnets has a second winding with a larger number of turns in which, when the machine is working, a voltage 60 to 90 times higher than that of the cell is induced due to the magnetic flux change. This voltage is rectified by the commutator and even under unfavorable conditions it is possible to telegraph with it over a distance of up to a thousand kilometers.

Page 263: Duplex signaling method. By means of a differential connection of each pair of magnets of the receivers, the station responds only to incoming and not to out-going signals. The receiver does not therefore respond to signals transmitted from its own station and can simultaneously receive telegrams from another station.

Page 263: Wilhelm Weber (1804–1891). Professor of Physics at Göttingen University. He was one of the famous "Göttingen Seven," the professors who were dismissed because of their participation in a protest when, in 1837, the King of Hanover annulled the State constitution. In 1833, in collaboration with his friend Carl Friedrich Gauss, he built the first electromagnetic telegraph. He devised units for electrical and magnetic quantities, which he derived from the mechanical effects of electricity and magnetism. Based on the cgs system of units suggested by Gauss he developed the basic units of our modern electrical dimensions, for which later, after some modifications, the designations volt, ampere, ohm, etc. were established. He also invented an AC ammeter, which worked on the dynamometer principle and made measurements which were, for his time, very accurate.

Page 265: Sir William Thomson, Lord Kelvin (1824–1907). British physicist and engineer, Professor of Physics in Glasgow. Achieved success with telegraph and measuring instruments. His work was concerned mainly with the theories of heat and electricity. He was knighted in 1866 and became Lord Kelvin in 1892. In 1855, he correlated the influences of resistance, leakage, capacitance and inductance of a cable with the voltage and current in the telegraph equation. The electrical phenomena on a line are completely and definitively described by it.

Page 267: James Clerk Maxwell (1831–1879). First occupant of the newly established chair of physics in Cambridge in 1871. He expressed the interrelationships between magnetism and electricity discovered by Hans Christian Ørsted and Michael Faraday in mathematical formulae (Maxwell's equations) based on the concept of an electromagnetic field of force existing in space and avoiding the former theory of force acting at a distance. From these equations it was possible, among other things, to predict, in addition to the familiar conduction of electricity through a conductor, the propagation of electrical energy through nonconducting space as a wave similar to light. Heinrich Hertz, in fact, demonstrated the existence of these electric waves experimentally in 1886.

Page 265: Siemens ozone tube. One glass tube is inserted into another. The outer and inner surfaces of the glass tube combination are coated with metal and the coatings are connected to the wire ends of the secondary of a powerful induction coil; when voltage is applied, the space between the glass tubes begins to glow, and at the same time the air in it is ozonized. By blowing air into the pipe connection, the air can easily be changed so that large quantities of ozonized air can be obtained.

Page 266: Carl Friedrich Gauss (1777–1855). Professor of Mathematics and director of the Göttingen observatory. In his time he was called the "prince of mathematicians." At the age of 17, he proved the fundamental principle of algebra that an equation of the *n*th degree can only have *n* solutions; propounded the method of least squares for balancing deviations in a set of observations; and devised the error distribution curve, which is of fundamental importance in statistics. He carried out measurements of the earth, devised a method for calculating the orbits of planets and invented the Gauss double objective, which is still used in optics. The Gauss number plane for representing a complex number is named after him and forms the basis of the graphical calculation of AC phenomena with the aid of vector diagrams. In addition to important mathematical work, he studied terrestrial magnetism and, in 1833, in collaboration with Wilhelm Weber, built the first electromagnetic telegraph between the observatory and the physical institute in Göttingen. He sponsored the cgs (centimeter-gram-second) system of units for magnetic quantities, which was then extended by Wilhelm Weber for electrical units. The unit of magnetic induction is called a *gauss*.

Page 270: Samuel Thomas von Soemmerring (1755–1830). Professor of Anatomy at Munich. He made important studies of the brain and nervous system. In 1809, he constructed an electric telegraph in which the signal was given by galvanic dissociation of water. As the apparatus required one wire for each letter, i.e. 24 wires, it was impracticable.

Page 278: Benedikt Waldeck (1802–1870). In 1848, he received four mandates to the Prussian National Assembly; from 1861 to 1869 he was a member of the Prussian Chamber of Deputies. Waldeck was regarded as leader of the "German Progressive Party" founded in 1861, from which the "National Liberal Party" split off in 1866. The latter supported Bismarck's policy, whereas the Progressive Party opposed the so-called Conflict Ministry.

Page 283: Franz Alphonse Desiderius von Chauvin (1812–1898), knighted in 1864. Engineer officer and lieutenant-general; from 1856 to 1872 Director of the Prussian Telegraph Directorate; from 1867 Director-General of the Telegraph of the North-German Confederation and from 1871 of the German Reich. In this capacity he gained great merit in the construction of the Indo-European line. It was at his suggestion that the Siemens unit was accepted as an international unit of measurement at the Second International Telegraph Congress in Vienna, 1868.

Page 284: The Indo-European line, 1867 to 1870. The Indo-European telegraph line was designed and built by the three brothers Werner, William, and Carl von Siemens, with their Berlin, London, and St. Petersburg firms in close collaboration. The financing and subsequent operation of this large undertaking was in the hands of a company established for the purpose, the capital of 9 million marks being mainly subscribed in Germany. The line worked up to 1931 with good financial results.

Page 286: Johann Georg von Siemens (1839 – 1901), son of the barrister-at-law Siemens, joint founder of Siemens & Halske. As a young assessor he was sent by Werner to London in 1868 and later to Persia to help with the preliminary financial, legal and political work for the Indo-European line. In this he showed the skill and energy of the born entrepreneur. In 1870, he became First Director of the Deutsche Bank, which is indebted to him for its prestige and success. The Berlin elevated and underground railways and the planning of the Baghdad railway were largely due to him. In 1899, he was ennobled. At his death, the Deutsche Bank was the largest institution of its kind in Germany and one of the leading banks in the world.

Page 290: Kedabeg. In 1864, Werner and Carl von Siemens bought the Kedabeg copper mine in the Caucasus on the recommendation of their brother Walter, who was directing the Tiflis branch of the St. Petersburg firm of Siemens & Halske. As the management of the mining operations and the yield of copper did not come up to expectations, Werner von Siemens visited the Caucasus in 1865 and Carl moved there in 1867 to supervise the management. In 1868, their partner Walter Siemens died suddenly and Carl also had to leave the Caucasus on account of his wife's health, so that in the same year Werner, being personally concerned about the undertaking, paid a second visit. After many trials and tribulations between 1876 and 1879, Kedabeg showed a considerable profit. Bad times followed, and not until 1886 was the development again favorable. The mine was expropriated in the First World War.

Page 292: Punched-tape transmitter. Developed from the magneto-electric dial telegraph of 1856, the telegraph was designed to transmit telegrams mechanically from punched paper strips. It was used for the first time on the Indo-European line. A crank inductor generates alternating current. The gearing is such that the armature of the inductor rotates once when the cylinder for the punched strip advances by one pin. Accordingly, a current is transmitted depending on the holes in the strip, e.g., from the positive and the following negative half-wave, whereby the polarized relay in the receiver is deflected to one side or the other causing the signal to commence and then to cease immediately. In this case a dot is registered. If, on the other hand, the holes in the strip are farther apart, it is the negative half-wave of the next rotation of the armature which resets the relay and ends the signal; a dash is therefore registered in the receiver.

Page 317: J. Dannenberg, mining and metallurgical engineer. Joined Siemens & Halske in 1868 to work in Kedabeg and became technical director there in 1869.

Page 331: Anton Dohrn (1840 – 1909). German scientist who, in 1874, established a research station for submarine zoology in the Bay of Naples. Among his numerous friends and patrons there were Werner von Siemens and William Siemens, who helped him by word and deed to get a suitable research ship built by Thorneycroft in England.

Page 334: Robert Koch's tuberculin. These ideas of Werner von Siemens, written down in 1890, are now confirmed by the general biological concepts of microbiology and the modern theory of infectious diseases.

Page 336: Friedrich Hammacher (1824 – 1904). From 1864 onward, member of the Prussian Chamber of Deputies and later, as a National Liberal, member of the German Reichstag. His particular interest was in trade and industry.

Page 338: George William Bolton (1831 – 1900). In 1854, assistant to Carl von Siemens in St. Petersburg on the construction of the Russian telegraph lines. In 1876, he became director of the copper mine which Carl and Werner had acquired at Kedabeg in the Caucasus in 1864.

Page 347: Harzburg. In 1881, Werner von Siemens purchased this property at the foot of the Ettersberg in Harzburg from a Magdeburg merchant, in order to spend the summer months there with his family. Werner von Siemens' daughter, Hertha Harries, inherited the property and presented it to the firm as a convalescent home for Siemens officials. The house and garden were handed over for this purpose in 1910.

Page 351: Mine exploders. The first practical application of the dynamo-electric principle was achieved in 1867 in this machine for generating short powerful detonating currents. The machine was first short-circuited by a contact on a cam disc so that its field magnets could be powerfully excited. After further rotation, the short circuit was removed and the detonating circuit was connected instead.

Page 351: Range finders. Two instruments at a measured distance apart are connected by a double line. The one on the left consists of a movable graduated straightedge, with which a bearing is taken on the object through a telescope, and of a second remote-controlled straightedge which is always turned in the same direction as the telescope from the right-hand part of the apparatus on the other end of the line with which a bearing is taken on the object from the right-hand observation point. As the distance between the pivots is known, the distance of the remote object can be easily determined from the angular positions of the two straightedges or can be read from a table.

Page 351: Invention of the dynamo-electric machine. Previously, the only known generators had permanent magnets of steel or electromagnets excited by battery current, as well as combinations of the two principles. In 1866, Werner von Siemens showed that excitation by auxiliary magnets or battery current could be omitted completely if the field winding is connected to the armature. The remanent magnetism always present even in wrought iron is sufficient for self-excitation of the machine if the winding resistances and the magnetic circuit are correctly dimensioned. Thus Werner von Siemens made practical use of the principle of self-excitation in machines for the first time; this was later to be of the greatest importance for the excitation of electrical oscillations by means of amplifier tubes. The illustration shows a machine of 1866 with double-T armature, which Werner von Siemens had invented ten years earlier. The double-T armature with field magnets of wrought iron, which is magnetically better than steel, had such a good magnetic circuit that only 60 percent of the power generated was required to excite the machine. Compared with other designs, these conditions were very good, since Hopkinson's theories of the magnetic circuit of 1886 were not yet known and it was not yet possible to draw up a power balance of a machine. It was due to these conditions that the machine was able to work as a generator at all and that Werner von Siemens succeeded in demonstrating the electrodynamics principle experimentally, a matter which at that time appeared by no means self-evident. Up to 1876, the number of dynamo machines supplied annually by Siemens & Halske was less than ten, but in 1878 it increased fairly rapidly with the invention of the differential arc lamp. By 1882, a total of 1,700 dynamo machines had been supplied. With the invention of the carbon filament lamp in 1882, fewer dynamo machines were built for individual installations. From 1885 onward, large central stations were built from which consumers were supplied by a network of lines.

Page 354: Light. The first arc lamps had to be adjusted by hand when the carbons had burned down so far that the arc extinguished. The problem was to prevent the carbons from getting too far apart or approaching too close to one another. For this Werner von Siemens suggested a differential principle which Friedrich von Hefner-Alteneck put into practical form.

An electromagnet with a few turns of thick wire is connected in the main current circuit, and a second one with many turns of fine wire as a shunt across the arc. The two electromagnets act on a differential mechanism such that the main current tends to draw the carbons apart and the shunt current to bring them together. When the carbons are a certain distance apart, a state of equilibrium occurs. This automatic adjustment first made the extensive use of the arc lamp practicable.

PAGE 355: DYNAMO MACHINE. The double-T armature of the first dynamo machines was very effective because of its good magnetic circuit, but had the disadvantage that the current appeared only in two half-waves and severe sparking occurred at the commutator. The Pacinotti ring was developed by Zénobe Théophile Gramme so that a more continuous current could be taken from points in quadrature with the field magnets. But electricity was generated only in the outer wire parts of the Gramme ring. In 1872, Friedrich von Hefner-Alteneck, chief engineer of Siemens & Halske, constructed for the first time an armature in which coils of wire were so disposed over a drumlike iron core that currents were induced in both the outward and return wires. With a commutator divided into a number of segments, this armature was a kind of multiple double-T armature, although the windings were not embedded in slots in the iron core until later.

PAGE 355: INVENTION OF THE ALCOHOL METER. The quantity of spirit was measured by emptying a measuring drum divided into three compartments, the rotations of which are counted by a first register. The quantity of absolute alcohol contained in the spirit is measured by means of a float. This turns a second register forward every time a compartment of the measuring drum is emptied by an amount depending on the depth of immersion of the float, which depends on the alcohol content (Patent granted in 1865).

PAGE 357: KARL FRISCHEN (1830 – 1890), before he became chief engineer with Siemens & Halske, was an official of the Hanoverian state telegraphs. He was responsible for the electric railway block system, which was introduced on the Prussian state railways in 1870. The development of a number of instruments in connection with this new branch of railway engineering is also attributable to Frischen. To help prevent collisions between trains – a fairly common accident in the early days of the railroads – Frischen conceived the electric track blocking system. Each line was divided into segments by signals. When a train was on the track, the signal at the beginning of the track segment was locked electrically, and could be reset to “clear” by the trackmaster only after it had been unlocked electrically from the other end of the segment.

PAGE 358: Friedrich VON HEFNER-ALTENECK (1845–1904), inventor and designer. In 1867, he joined Siemens & Halske as a mechanician and rose rapidly to become chief designer. In 1872, he created the drum armature and in 1878, the differential arc lamp. The definition of the standard candle, which was for a long time the accepted unit of luminous intensity, also originated from him.

PAGE 358: KARL VON SIEMENS (1809–1885), a distant cousin of Werner. He was a farmer and distillery expert near Brunswick, and went as Professor of Technology to the agricultural college at Hohenheim, near Stuttgart. Agriculture is indebted to him for a number of useful technical appliances. He was ennobled for his services. His daughter Antonie became Werner's second wife in 1869.

PAGE 358: CHARLOTTENBURG. In 1861, Werner von Siemens bought the property at Berliner Strasse 36 from the widow of its previous owner, one Johannes. He remodeled the house, and in 1875 added a ballroom and a building for offices. Electric lighting was installed in the ballroom in 1879. This house was his constant residence from 1882 onward; until then, it was a kind of summer house. In 1887 electric lighting was installed throughout the house. After Werner's death, his widow Antonie retained ownership. Siemens & Halske took over the house in 1926. It was completely destroyed in the Second World War.

PAGE 358: Werner's daughter HERTHA Siemens (1870–1939) married the chemist Carl Dietrich Harries, Professor at the universities of Berlin and Kiel and at the Charlottenburg Technical University. As the sister of Carl Friedrich she took a great personal interest in the social activities of the House of Siemens.

PAGE 363: Franz REULEAUX (1829–1905), important mechanical engineer. He established the scientific basis for the theories of mechanical motion (kinematics) and paved the way for the close collaboration of science and technology. In 1868, he became director of the Berlin Industrial Academy. In addition to his teaching activities, he did much to sponsor German industry by his publications. As German Government Commissioner he visited and reported on the 1876 International Exhibition in Philadelphia. His courageous critical epithet for the German export products, "cheap and shoddy," shook up German industry. He was later professor at the Charlottenburg Technical University and a friend of Werner von Siemens, who shared Reuleaux's ideas and demands as regards the objectives and the future of German industry.

PAGE 363: SIEMENS BROTHERS. In 1863, the English firm of Siemens & Halske, which had been in existence since 1858, set up a factory for the manufacture of submarine cables at Woolwich, near London. In 1865, after the withdrawal of

Johann Georg Halske, the concern was named "Siemens Brothers." In the course of time, manufacture was greatly extended and improved. The transatlantic cables, which were laid from 1874 onward by the firm's own cable ship *Faraday,* were made in the Woolwich works. Equipment for the Indo-European telegraph line was also made there. At the end of the 1870s, the manufacture of telephones was taken up and Woolwich was soon one of the leading telephone factories in England. The heavy-current work, which was also carried on from there, was separated in 1903 in accordance with the German development as Siemens Brothers Dynamo Works Ltd. and a special works was set up for it in Stafford. In the First World War the works were confiscated by the British Government as German property.

Page 367: The Siemens brothers' cable ship Faraday was built in 1873 in Mitchell's shipyard in Newcastle for Siemens Brothers, London, as a twin-screw ship specially for cable laying, to the designs of William Froude and William Siemens based on the experience and the theory of Werner von Siemens. The *Faraday* was of 5,000 gross register tons. It was launched in 1874, and in the same year the first direct transatlantic cable was laid with it. Provision was made so that the cable drums in the hold would be firmly supported even in heavy seas. The ship had rudders fore and aft to increase maneuverability, also braking equipment for the cable drums, two dynamometers for measuring the cable tension, workshops for repairs and the attachment of cable ends, as well as a cabin for electrical tests on the cable. The ship was in service up to 1922, and up to 1914 laid 60,000 km of cable, including no fewer than eight transatlantic cables.

Page 375: The apparatus works in St. Petersburg. In 1880, a new works was built by Siemens & Halske under the direction of Carl von Siemens on a site on the Smolenka Quay, on a navigable arm of the Neva, to combine the manufacture of heavy- and light-current apparatus with the exception of cables. Being the first and only one of its kind in Russia, this electrotechnical factory soon achieved great importance. As the result of close contacts with the parent firm in Berlin, production kept pace with the development of electrical engineering in Germany.

Page 375: Alexander Siemens (1847–1928), distant relative of Werner von Siemens; became director of Siemens Brothers, London, in 1888.

Page 388: Heinrich von Stephan (1831–1897), son of a Pomeranian artisan. Thanks to his intelligence, diligence and a talent for leadership, he rose rapidly and step by step from an ordinary post-office clerk until, in 1875, he became Postmaster General of the German Post Office. The credit for the Universal Postal Union of 1874 was due to him. His colleagues in

North America called him the "Bismarck of the Post." The subterranean deposition of the German telegraph system in the 1870s was directed by him. In collaboration with Werner von Siemens he introduced the invention of Graham Bell, the telephone, to Germany. The two men were responsible for the founding of the Electrotechnical Society in 1879–1880. In 1885, he was elevated to the Prussian nobility.

Page 390: Gustav Kirchhoff (1824–1887). Physicist and professor at the universities of Breslau, Heidelberg and Berlin. In conjunction with Robert Wilhelm Bunsen, he laid the foundations of spectroscopic analysis and propounded the law relating to currents flowing in networks and at the junction points. The basic principles of the theory of heat radiation are also attributable to him.

Page 391: Lord Rayleigh (1842–1919). Professor of Physics at Cambridge. Made contributions to nearly all fields of physics and received the Nobel Prize in 1905. Wrote an important work, *Theory of sound*, on acoustics.

Page 401: Sir William (Wilhelm) Siemens (1823–1883), Werner's brother and collaborator. Founder of the associated firm in England and its director for many years. Took an active part creatively and by his writings in many technical and scientific fields, especially in heat engineering. With his brother Friedrich he applied the regenerative principle especially to smelting furnaces (Siemens-Martin steel process, 1864). He took an important part in the submarine cable projects. He was recognized in England as one of the most outstanding technicians and was knighted in 1883.

Page 403: Wilhelm Siemens (1855–1919), Werner's second son. After the death of his father, he became to an ever-increasing degree the dominant personality in the House of Siemens.

Page 403: The first grandson of Werner von Siemens was Werner Ferdinand von Siemens (1885–1937), son of Wilhelm. He studied electrical engineering and later music, to which he primarily devoted himself.

Page 403: Friedrich Siemens (1826–1904), brother of Werner and after him probably the greatest inventive genius in the family. Based on earlier English experiments, he constructed the regenerative furnace, and in conjunction with the French engineers Émile and Pierre Martin developed the so-called Siemens-Martin process for steel production. Friedrich applied the principle of regenerative heating to glass melting and other special furnaces with brilliant success.

Page 403: Regenerative system. The regenerative process of Friedrich Siemens for the production of steel was first introduced in France in 1864 by the Frenchmen Pierre and Émile Martin; it works on the heat storage principle. In a conventional furnace, air and the combustible gas are introduced cold into the combustion zone and the hot waste gases are discharged into the open. In the regenerative process, the heat of the waste gases is used for preheating the air and the combustible gases. This is effected by passing the combustible gases through two or four chambers with large thermal storage capacity, preheated by the waste gases. In this way, higher temperatures are attained with a simultaneous saving in heat.

Page 407: Siemens & Halske at Berlin. In 1876, Siemens & Halske also began to manufacture cables, which had previously been made in their English cableworks, in the Markgrafenstrasse in Berlin. In 1883–1884, cable manufacture was transferred to the Charlottenburg works on the Salzufer. In 1899, a separate works was built for cable manufacture on the banks of the Spree near the Nonnendamm; in 1912, cable manufacture was transferred to Berlin-Gartenfeld.

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