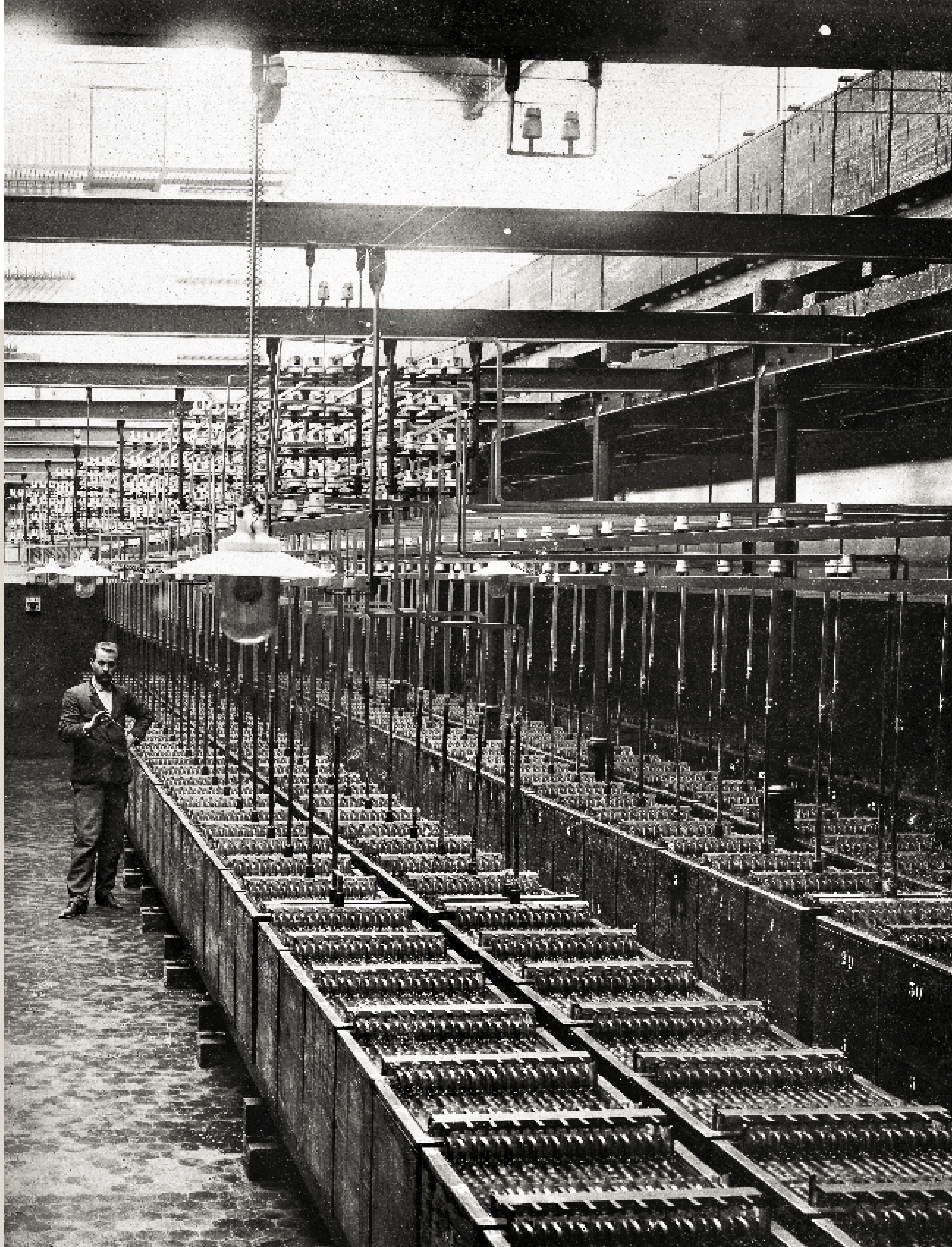
AGE OF ELECTRICITY

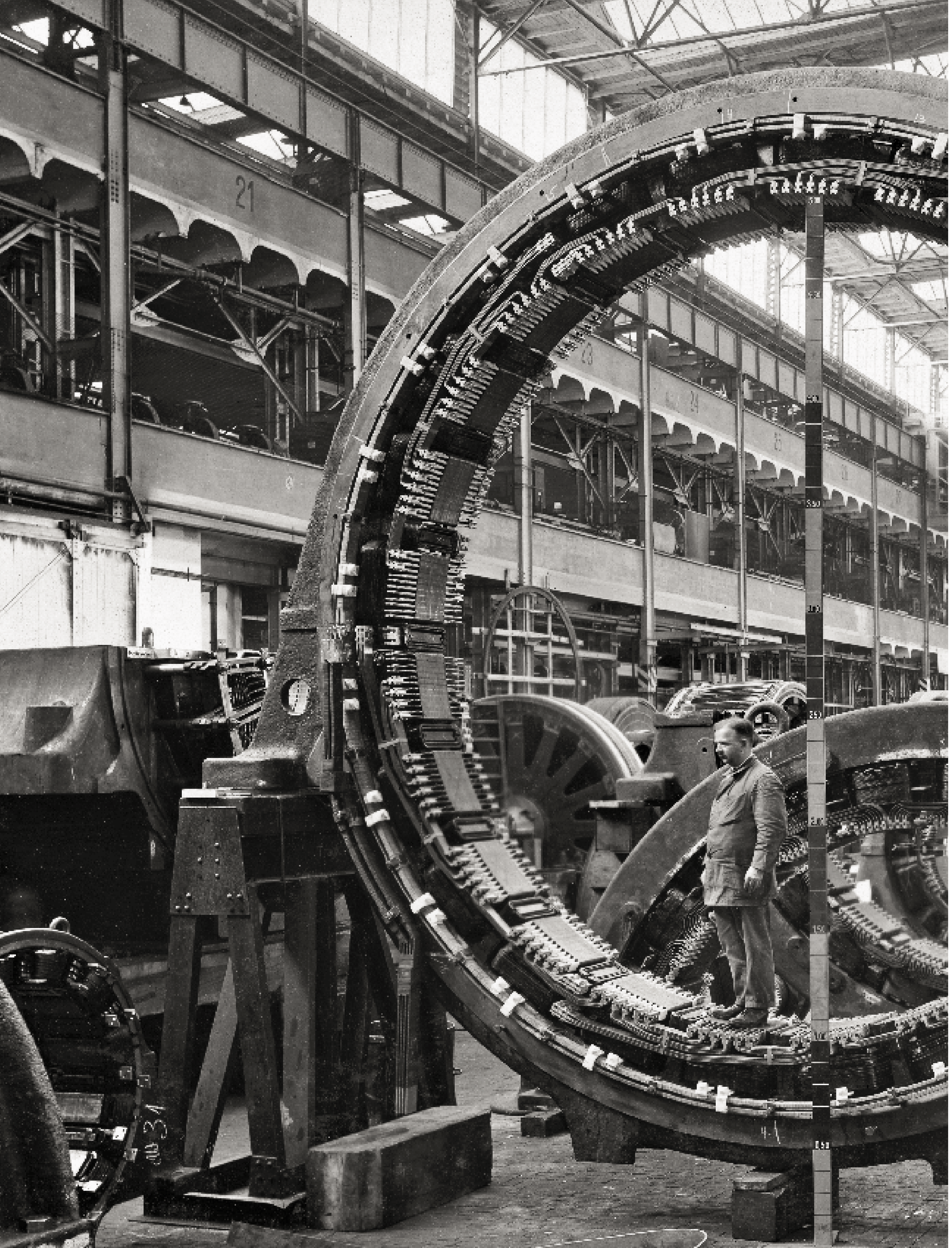
Pioneering Achievements in Electrical Engineering

Photographs from the Siemens Historical Institute

DEUTSCHER KUNSTVERLAG

Contents





Preface

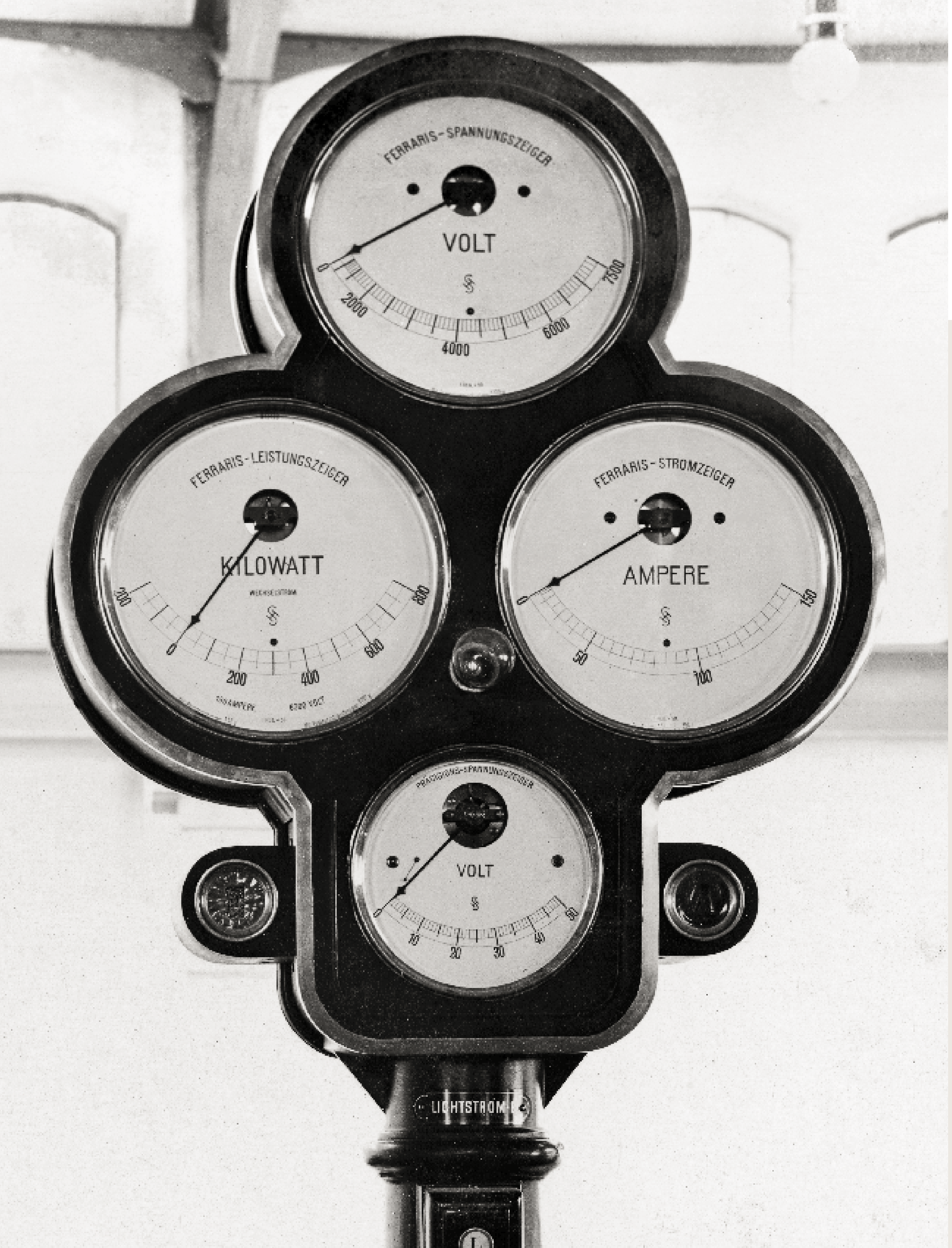
From a small backyard workshop in Berlin to a global enterprise: only a few industrial enterprises can look back on such a long and successful history as Siemens. For more than 160 years, the Siemens name and brand have stood for innovative strength, incredible technical achievement, quality, reliability, and internationality.

In the early years of Telegraphen-Bauanstalt von Siemens & Halske, the success of this electrical engineering enterprise was due above all to the innovative concepts and visionary ideas of Werner von Siemens. Together with his partner, the precision mechanic Johann Georg Halske, and in close collaboration with his two younger brothers Wilhelm and Carl, the electrical pioneer built an internationally active enterprise — a “Weltfirma” (global company) — in the second half of the 19th century. The company still bears his name today.

This volume, however, is not mainly devoted to the accomplishments and contributions of Werner von Siemens; instead, it focuses on the second generation of entrepreneurs and the rise of the power engineering industry. The presentation of selected success stories in the fields of energy, mobility, industry, and communications illuminates the key role played by Siemens in the worldwide electrification of infrastructure and day-to-day life, and thus the company’s important contribution to economic development and industrialization.

Selected electrification projects are presented using short texts and numerous photographs which have been preserved in the collections of the Siemens Historical Institute (SHI). These photographs convey a vivid and memorable impression of the pioneering achievements of this electrical engineering company in Germany, Europe, Latin America, and Asia in the period from the 1880s to the early 1930s. In this book, Siemens provides a representative look at the more than 750,000 images contained in its collection of historical photographs about the company and the electrical engineering industry.

Siemens Historical Institute



ENERGY

1896 **Moscow Steam Power Plant** Russia

1897 **Brakpan Coal-Fired Power Plant near Johannesburg** South Africa

1905 **Necaxa Hydroelectric Plant** Mexico

1907 **Komahashi Hydroelectric Plant** Japan

1913 **Großkraftwerk Franken** Germany

1916 **Tocopilla Steam Power Plant** Chile

1926 **Cacheuta Hydroelectric Plant** Argentina

1929 **The Shannon Scheme** Ireland

1931 **Soochow Electric Power Plant** Suzhou, China

1931 **Großkraftwerk West, Berlin** Germany

1897 Brakpan Coal-Fired Power Plant near Johannesburg South Africa

South Africa's First Public Power Plant

Extensive coal and gold deposits were discovered at the southern tip of Africa toward the end of the 19th century. When the world's largest known gold field was discovered on the Witwatersrand in Transvaal in 1886, it triggered an outright gold rush. But while coal could generally be mined by hand, gold had to be mined by machine because of the harder rock. That called for more energy, which meant a greater need for electric power. At the same time, energy demand was growing in Johannesburg and Pretoria. Ultimately local power producers were no longer able to meet the need. The solution: a three-phase power plant that could supply electric power to mines and city simultaneously.

Siemens & Halske designed and built a coal-fired power plant right next to the coal mines in Brakpan, where fuel was cheap. The generated power was carried over high-voltage lines to various consumers at the gold mines. Rand Central Electric Works (RCEW), near Johannesburg, was not just the first public power plant in South Africa, but the first to transmit power at 10,000 volts.

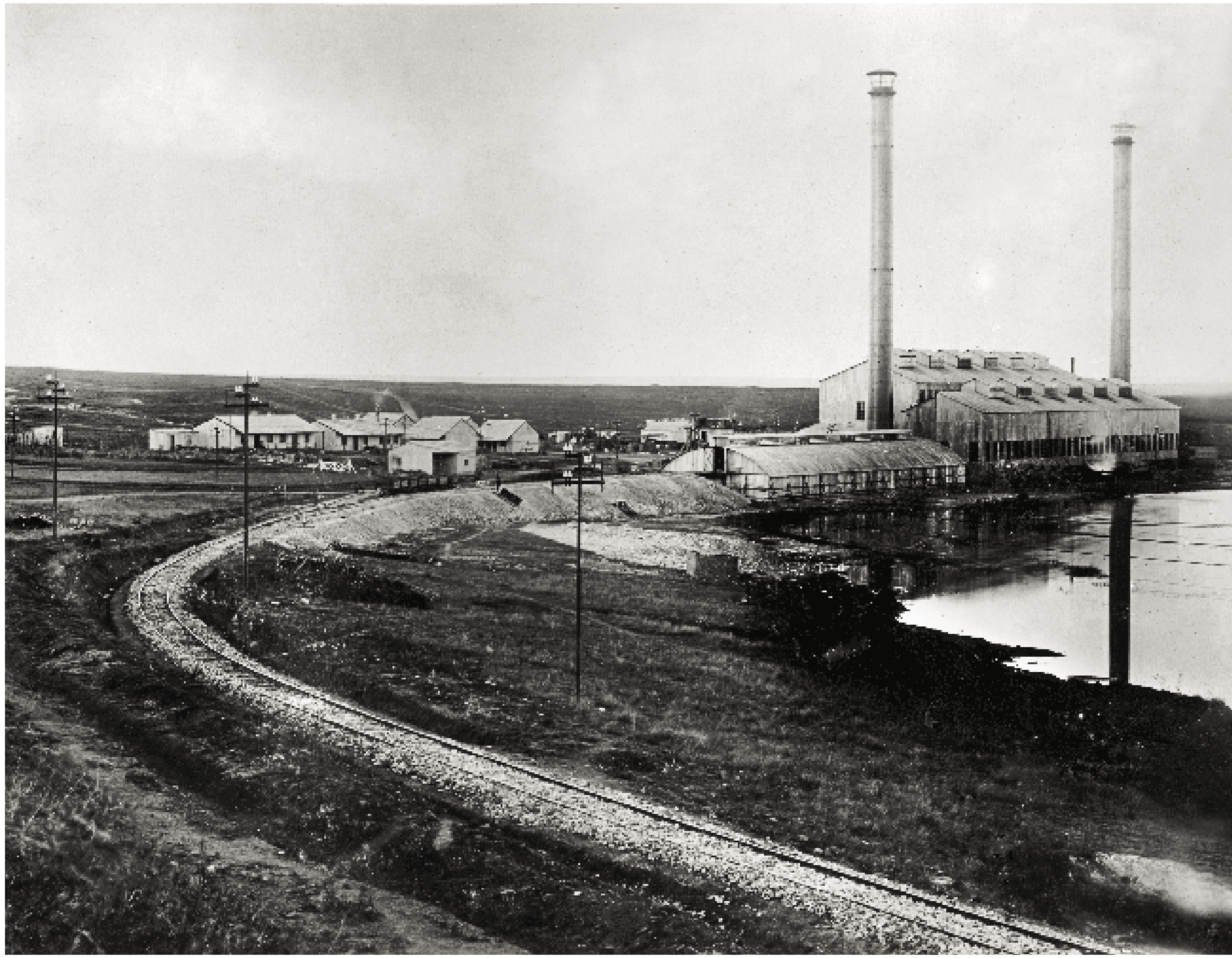
The Biggest Three-Phase Plant Built by Siemens & Halske to Date

As a first step, in 1894 Siemens obtained a concession to build and operate a power supply for the mines at the Witwatersrand. For some years it had also held the concession to supply electricity to the growing city of Johannesburg, which would now also be among the customers. All of which ensured good utilization of capacity at the projected plant — an important factor for successful business. Construction work began at the end of 1895 under a contract from Rand Central Electric Works Ltd., a London-based company that had been founded specifically for the project. The plant's technical equipment was based on the power plants that Siemens & Halske had built to date in Berlin. It was not just the power plant itself that had to be built, but apartment houses, boarding houses, and other accommodations for married men and bachelors, together with a mansion for the director, complete with stables. So much infrastructure was essential, because enough skilled workers had to be recruited from Europe and kept on the job to build and operate the plant.

After two years of construction, the biggest three-phase power plant Siemens & Halske had ever built went on line at the end of 1897 — at first with only three of its four three-phase generators. One was kept in reserve. To reduce transmission losses, transformers increased the generators' 700-volt power to 10,000 volts. The voltage was then lowered to 120 or 500 volts at the consumer end.

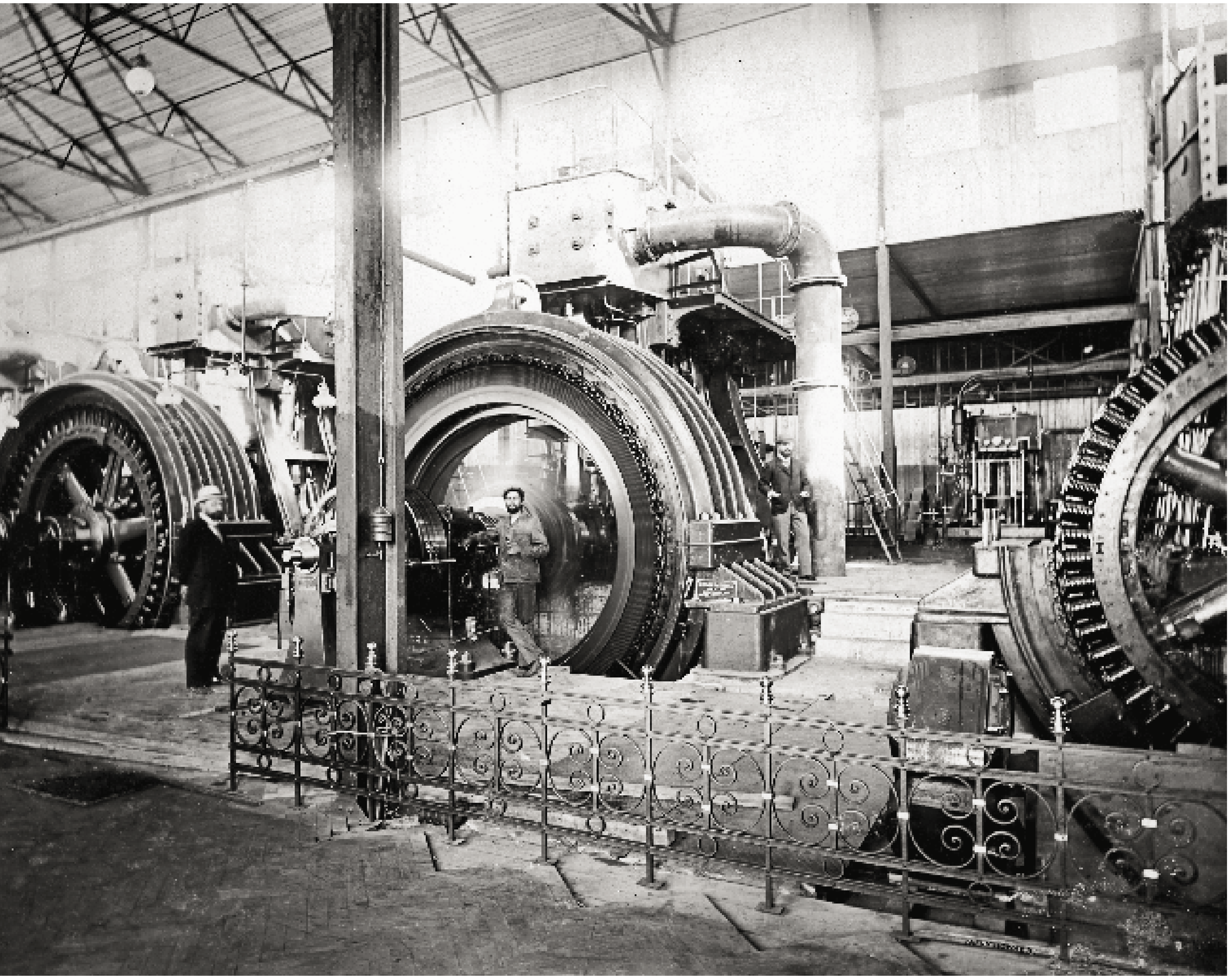
The region's demand for electricity rose steadily up to the end of the 19th century. For example, gas lighting in Johannesburg increasingly gave way to incandescent electric lamps. Other gold mines joined the clientele.

But there were also setbacks. In 1899 the Second Boer War broke out between the Boer republics and the British Empire, not only interfering with mining operations but making the power plant itself a target for destruction. The rebels blew up the generators early in 1901 — only one generator escaped largely undamaged. The equipment was rebuilt, and power production ramped up again by the end of the year. Then, in 1903, with all four generators running, the plant reached full capacity, supplying half of the electric power for Johannesburg, among other customers.



View of the power plant, 1898

The Rand Central Electric Works power plant was built on the Brakpan Dam, which supplied the water for steam. A specially built rail line to the Brakpan coal mine, two and a half kilometers away, ensured there would be enough coal to fuel the steam engines.

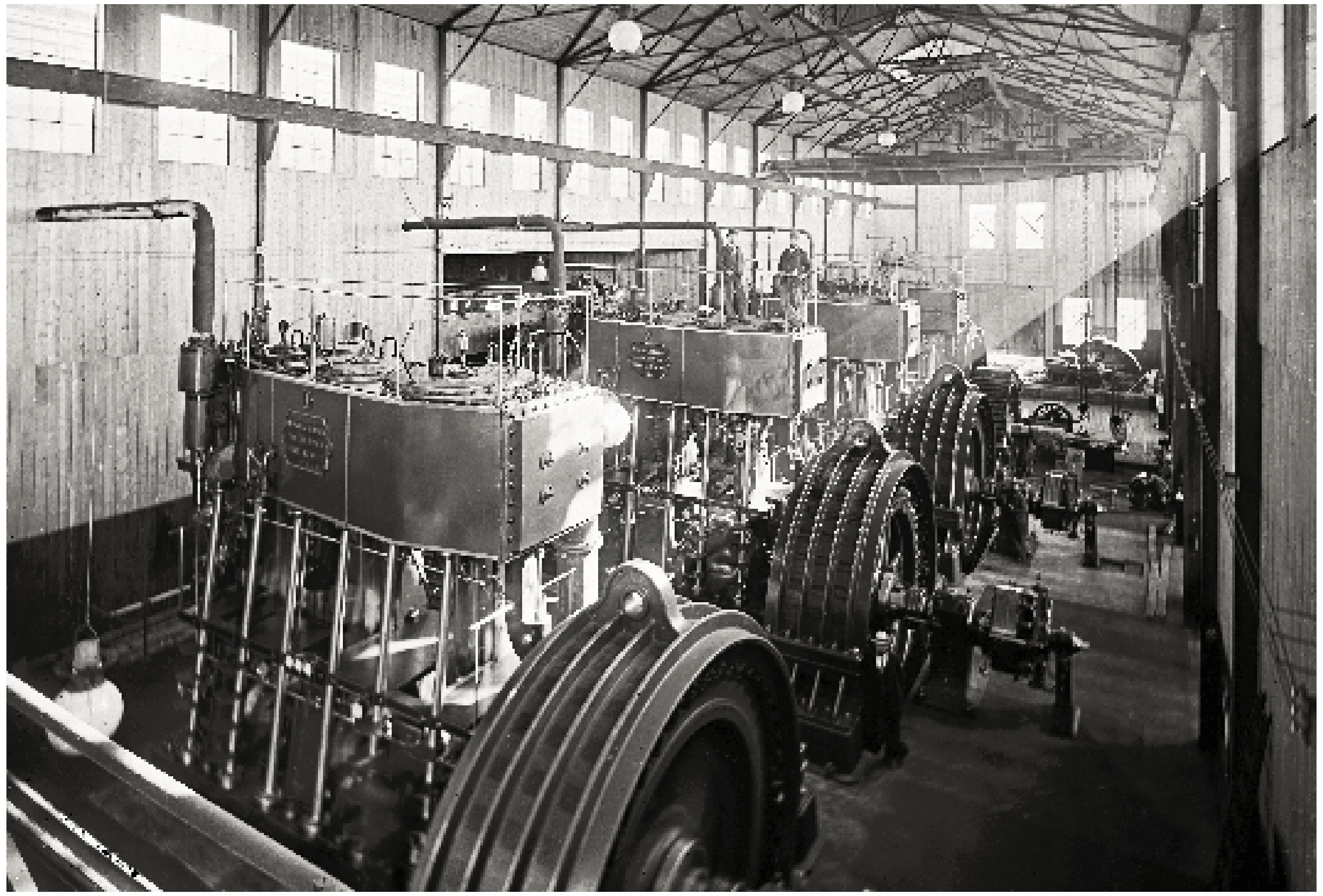


Machine room, 1897

Each of the Siemens & Halske three-phase generators—among the biggest of their day—generated 975 kW at 700 V. The steam engines, which were coupled directly to the generators, were supplied with steam from a boiler unit with an automatic firing system. The total available capacity came to about 4,000 kW.

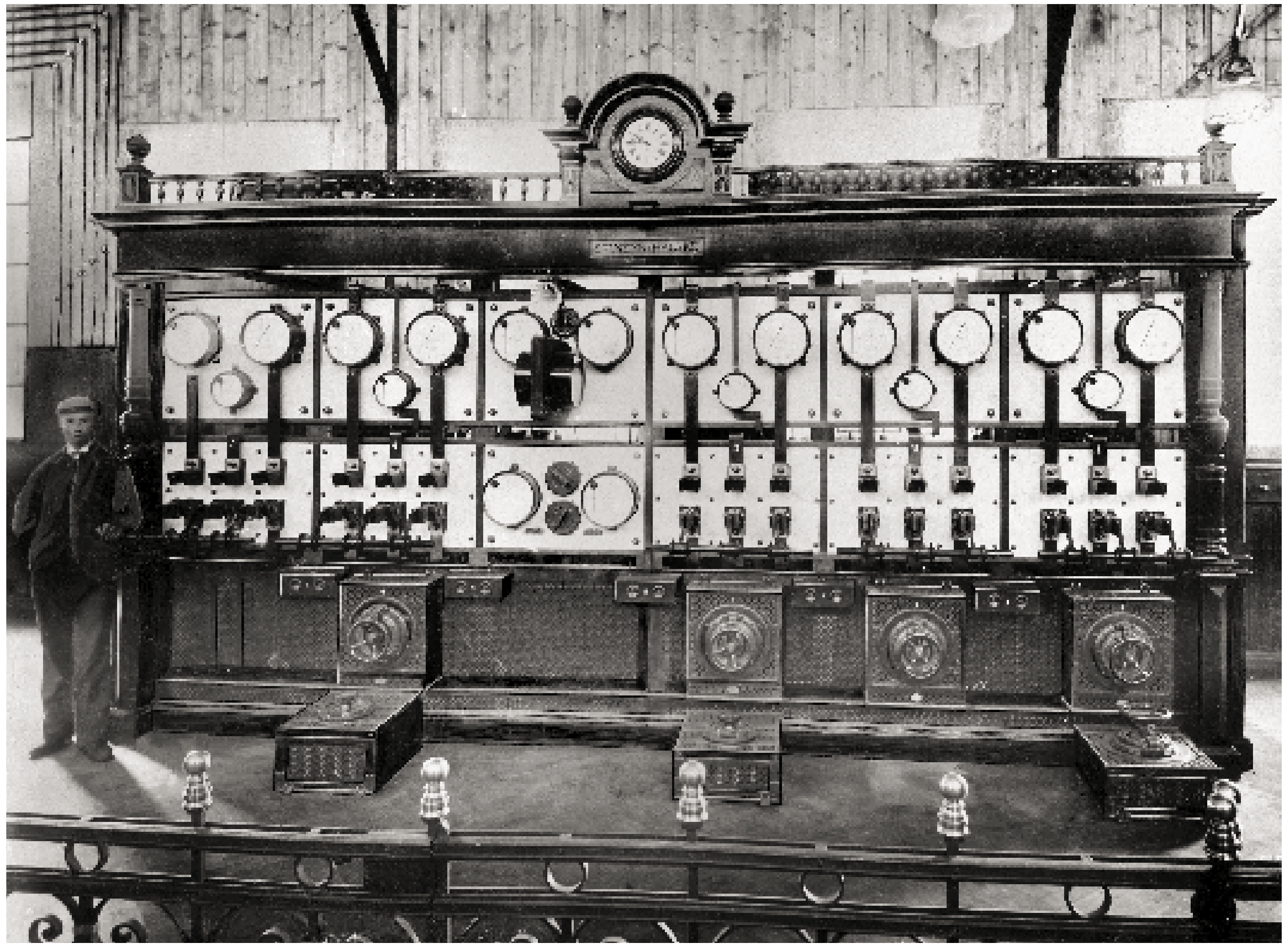
Machine room, 1897

Besides the difficult installation work on location, another major challenge was to design the massive machinery so that it could be shipped to South Africa in the first place. For example, the generators—weighing 80 metric tons—were dismantled into four parts to travel the more than 13,000 kilometers from Berlin to Brakpan.



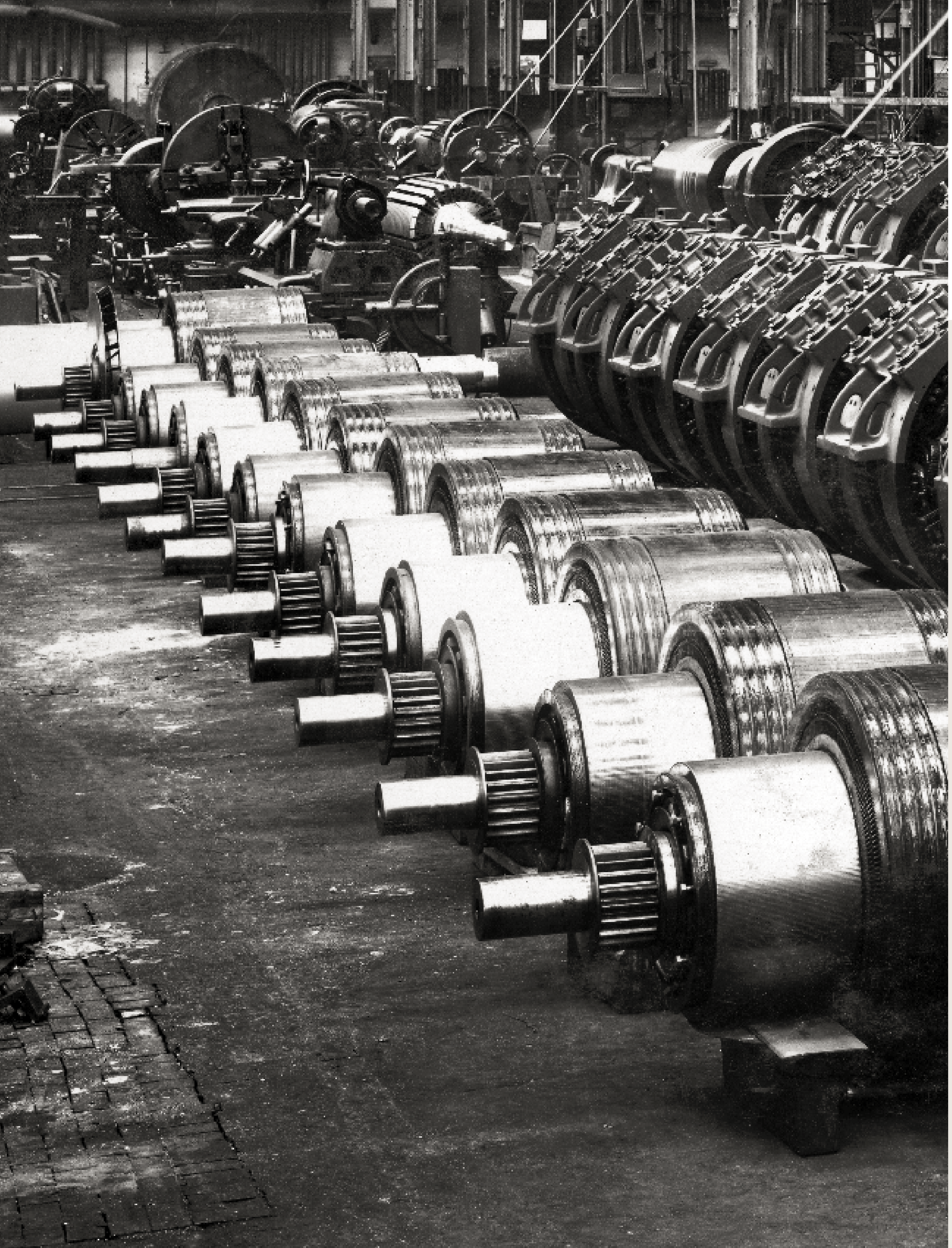
A visit by the Volksraad, 1897

September 18, 1897: the plant's exceptional importance was highlighted by a visit during its opening year from President Paul Kruger and members of the South African parliament, the Volksraad. After all, gold mining was the backbone of the self-assured Boer republic.



Control board, 1898

From here, power was supplied not only to the gold mines, but to Johannesburg, 40 kilometers away.

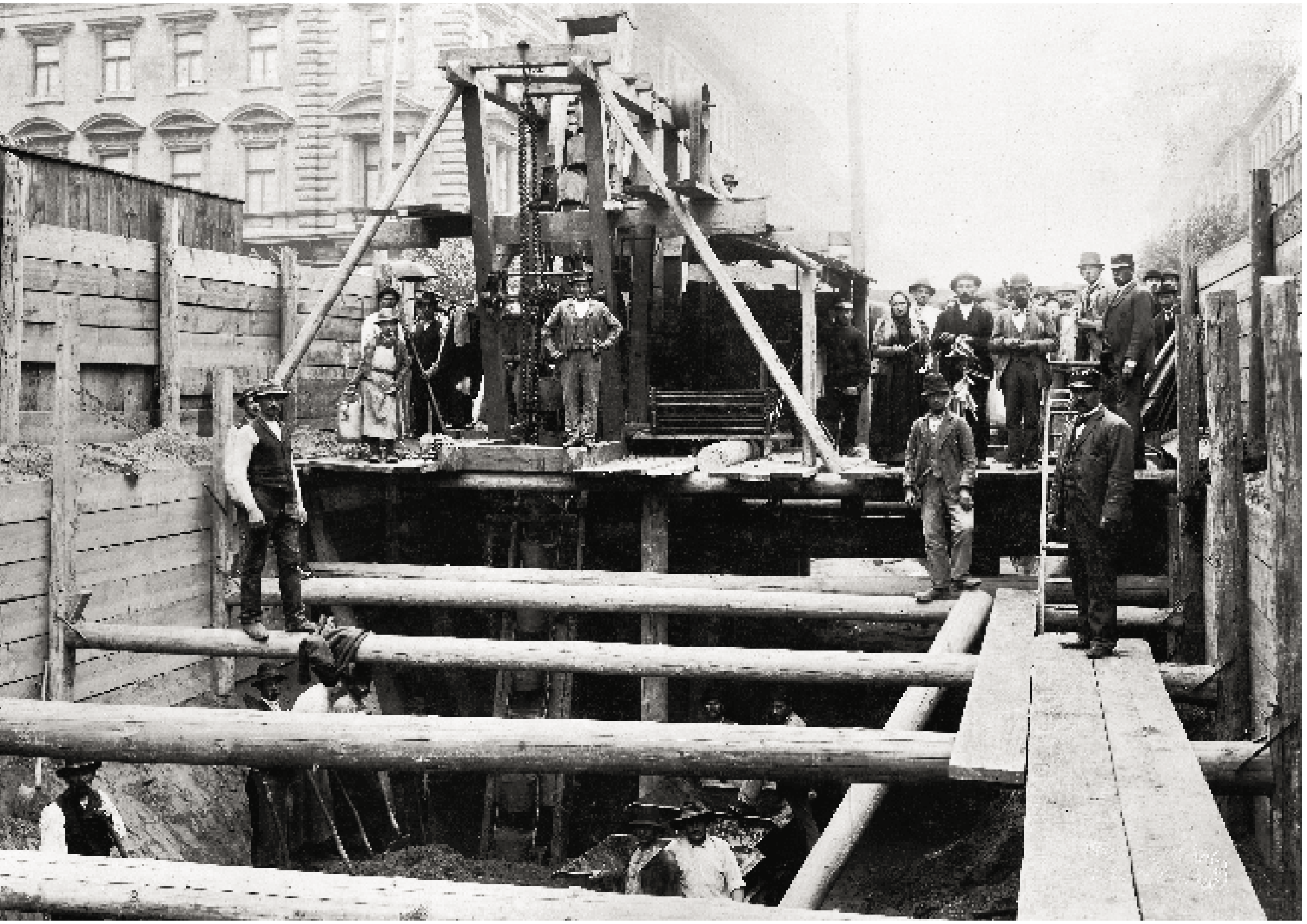


MOBILITY

1884 **Frankfurt–Offenbach Tram** Germany
1896 **Franz-Josef-Elektrische Untergrundbahn Budapest** Hungary
1897 **Salvador Tram** Brazil
1899 **Beijing–Ma-chia-pu Interurban Tram** China
1902 **Elektrische Hoch- und Untergrundbahn Berlin** Germany
1904 **Industrial Rail Lines at Rombacher Hüttenwerke, Lorraine** France
1905 **Lokalbahn Murnau–Oberammergau** Germany
1907 **Hamburg-Altonaer Stadt- und Vorortbahn Blankenese–Ohlsdorf** Germany
1908 **Mine Railway Schoppinitz** Szopienice, Poland
1911 **Mariazellerbahn St. Pölten–Mariazell** Austria
1911 **Dessau–Bitterfeld Railway** Germany
1913 **Constantinople Tram System** Istanbul, Turkey
1913 **Pachuca Passenger and Freight Railway** Mexico
1915 **Riksgränsbanan Kiruna–Riksgränsen** Sweden
1923 **Soerabaja Tramway** Surabaya, Indonesia
1933 **The "Fliegender Hamburger" Berlin–Hamburg** Germany

1896 Franz-Josef-Elektrische Untergrundbahn Budapest Hungary

The First Electric Subway on the European Continent



Andrássy Allee construction site, 1895
Excavation and all concrete and installation work was performed by the Robert Wünsch construction firm of Budapest.

Budapest, which had been the capital of the Hungarian half of the Austro-Hungarian Empire since 1867, enjoyed a lively upswing as the 19th century drew to a close. The Danube metropolis became the most significant city east of Vienna. The population grew from 371,000 to 732,000 between 1880 and 1900 alone. Because of the country's centralized governmental organization, Hungary's economic development concentrated in its capital; the industrial revolution also remained largely limited to Budapest. In the lead-up to the 1896 celebrations of the millennial anniversary of the Magyar conquest of Hungary, many large projects were undertaken in connection with the Budapest Millennium Exposition — including the first electric subway on the European continent.

The subway's main purpose was to carry the many expected Exposition visitors quickly to the exhibition site in the Stadtwäldchen municipal park without exacerbating the city's already severe traffic problems.

A Race against Time

At the beginning of the 1890s, Budapest had an extensive network of horse-drawn trams, as well as an early electric streetcar system built and financed by Siemens & Halske. Plans to build another streetcar line on Andrássy Allee, one of the city's key thoroughfares, repeatedly came to grief because of official resistance. In those days, Budapest's grand boulevard could be traveled only by landau carriages and horse-drawn omnibuses. But the impending millennium celebrations created pressure for public transportation to be extended out from the city center toward the park.

At the end of January 1894, two tram companies — Budapester elektrische Stadtbahn-Actien-Gesellschaft and Budapester Straßeneisenbahn-Gesellschaft — presented the municipal authorities with a design for a metro developed by Siemens & Halske. The route, 3.75 kilometers long, would run largely underground to the exhibition site from Giselaplatz, in the center of the Pest part of town, by way of Waitzner Boulevard and Andrássy Allee; only the last part of the route, in the Stadtwäldchen municipal park itself, was above ground. Since time was of the essence, the project had to pass swiftly through the necessary levels of the bureaucracy. After only a few months, on August 9, 1894, the construction and operation concession was granted — subject to the requirement that the line had to be ready in time for the "Millennium." That left just 20 months to do all the work on the system construction and the electrical equipment for the cars. Wasting no time, work began on August 13.

Despite some troubles that could not have been foreseen when the pioneering project was in the planning stage, the new metro was ready on time. It opened with great ceremony on May 2, 1896. For the duration of the Exposition, it ran from 6 a.m. till 1 a.m., with cars departing as often as every two minutes at the heaviest travel hours. By the end of September alone, it had carried nearly 2.3 million passengers, and covered 370,000 car-kilometers.

The first electric subway on the European continent has been modernized many times since then. Now known as the "Millennium Metro," it is still an integral part of the Budapest Metro network. In 2002, today's M1 Line and Andrássy Allee were declared World Heritage Sites.

Excavation on Andrássy Allee, 1894

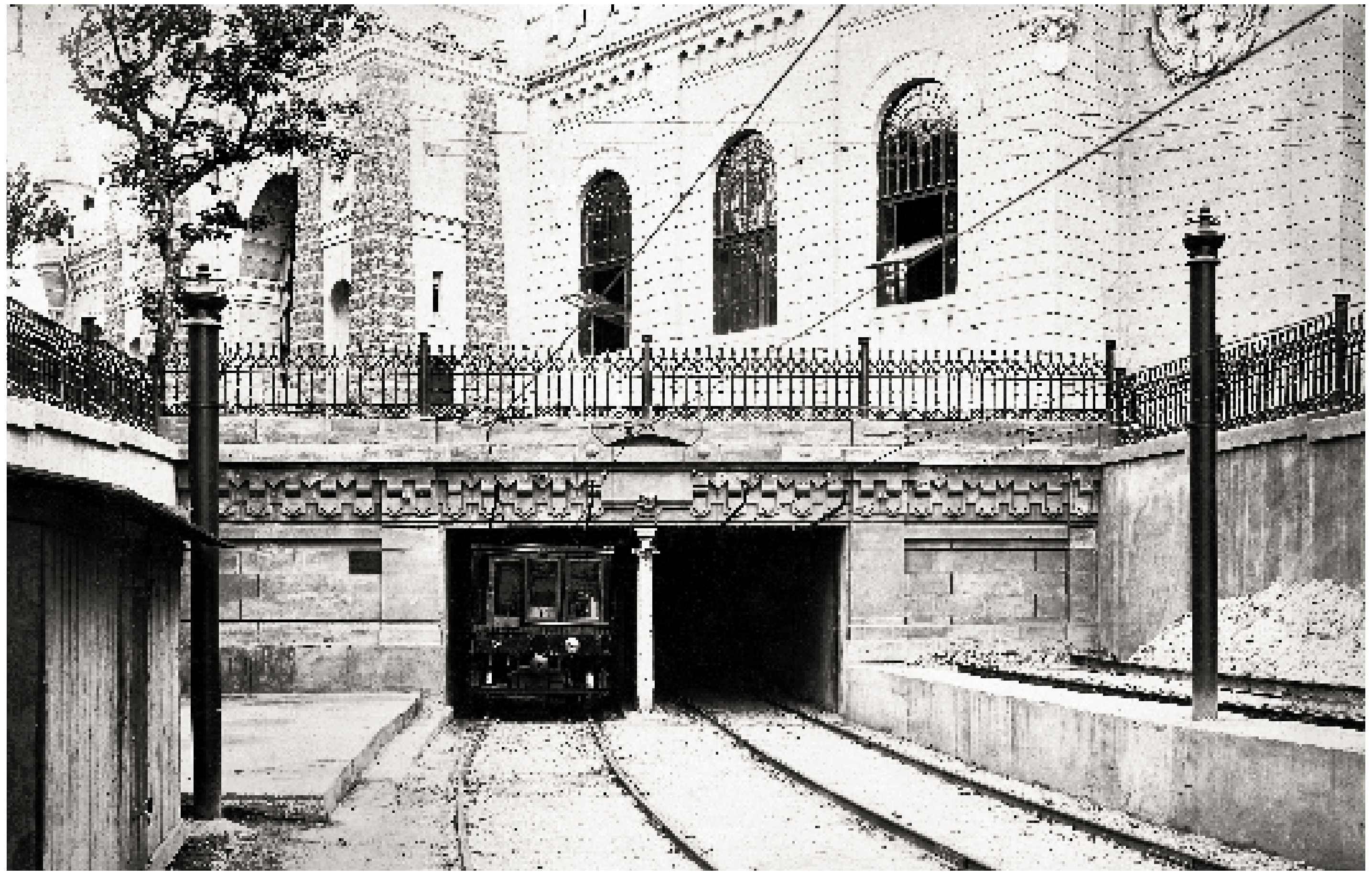
Since there was little time to lose, work went on in two shifts. After dark, the site was lit with arc lights. A total of some 140,000 cubic meters of earth were excavated. The support structures took 47,000 cubic meters of concrete and 3,000 metric tons of iron.

Construction site in Giselaplatz, 1895

The subway was built segment by segment. First the pavement was torn up, then the ground was excavated and carried off. The foundation and side walls were poured after that. The photo shows the site before the steel roof structure was installed.

Construction site near Eötvösgasse, 1894

Since time was so precious, the subway tunnel was built using the cut-and-cover method. It ran directly under the street pavement. The foundation, side walls, and roof of the tunnel, a consistent 2.85 meters high, were concrete. Steel support pillars were anchored on the foundation slab to support the steel roof beams. Once the steel frame was in place, the spaces between the individual beams were filled in with poured concrete.

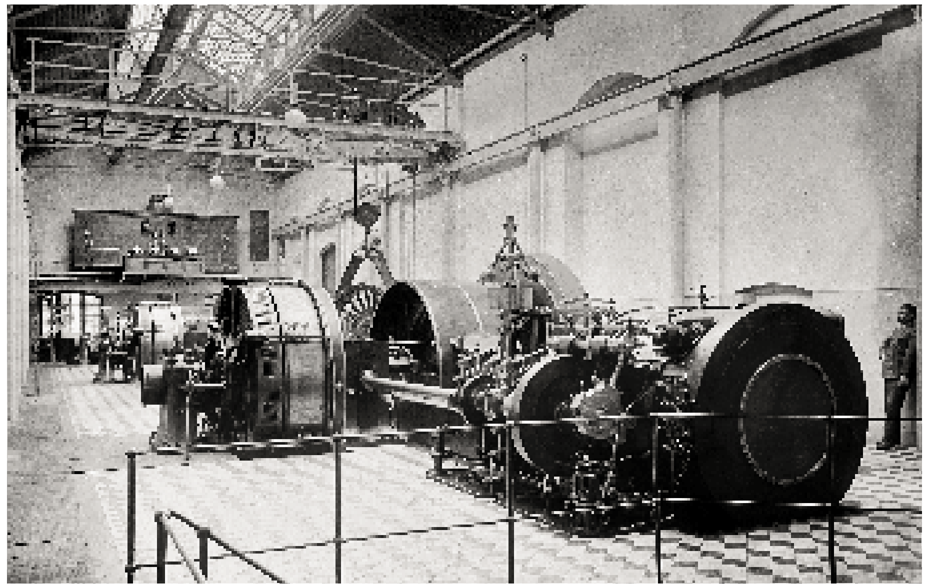


Tunnel portal in Stadtwäldchen municipal park, 1896

The metro ran on two tracks for the entire length of the tunnel, which was six meters wide. The tunnel section had a two-pole power supply that used mine rails attached to the tunnel roof, while the above-ground section was powered from double overhead contact lines.

Interior view of the power plant, 1896

The Budapest Metro was powered with electricity from its own small power plant, which was created by expanding the existing Gärtnerstraße power plant of Budapester elektrische Stadtbahn AG through the addition of two compound steam engines, each driving a Siemens DC machine.

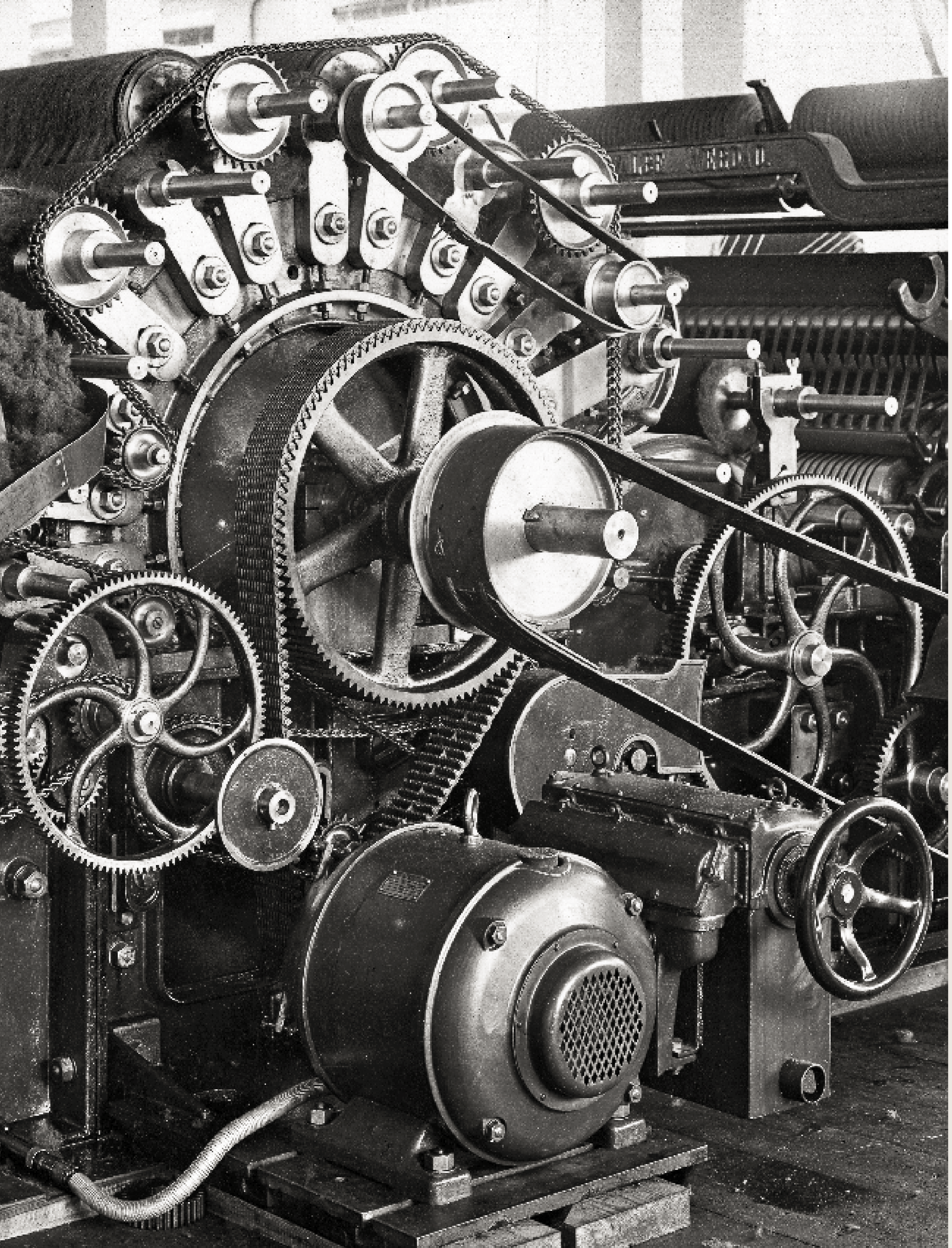


The Franz Deákplatz Metro Station, 1896

The city authorities set great store on good design for the waiting rooms. The walls and staircases of this pavilion, part of which was connected to a kiosk, were lined with pale-colored majolica tile.

Four-axle metro car, 1896

The metro ran 20 railcars built at the Budapest plant of the Schlick company. All electrical equipment was supplied by Siemens & Halske. To fit the narrow metro tunnel, the cars were relatively small, attracting the system the nickname "Kleine U-Bahn" (little metro). Each car had 28 seats and 14 places for standees.



INDUSTRY

1893 **C. G. Hoffmann Spinning Mill, Neugersdorf** Germany
1894 **Rijnhaven, Rotterdam** Netherlands
1895 **Königlich Sächsische Hofbuchbinderei Gustav Fritzsche, Leipzig** Germany
1904 **Zeche Zollern II, Dortmund** Germany
1905 **Glückhilf Mine, Hermsdorf** Sobięcin, Poland
1907 **Georgsmarienhütte, Osnabrück** Germany
1908 **Bevan Works, Northfleet** United Kingdom
1912 **Witkowitzer Eisenwerke, Witkowitz** Vítkovice, Czech Republic
1913 **Druckerei Rudolf Mosse, Berlin** Germany
1916 **Stickstoffwerke Piesteritz, Piesteritz** Germany
1925 **Ihsien Mine, Tsaochuang** Zaozhuang, China
1928 **Nippon Kokan, Tokyo** Japan
1928 **Cotonificio Triestino Brunner, Gorizia** Italy
1929 **Peiner Walzwerk, Peine** Germany
1929 **Cableway to Table Mountain, Cape Town** South Africa
1930 **Kedawoeng Sugar Factory, Kedawoeng** Kedawung, Indonesia
1933 **Compañía Manufacturera de Papeles y Cartones, Carena** Chile

1925 Ihsien Mine, Tsaochuang Zaozhuang, China

The Latest Mining Technology

Following initial contracts in the period before the turn of the century, China continued to be an interesting market for the German electrical engineering industry in the years between the world wars. Unlike many other countries, China had suffered little in the First World War, and also was under no debt burden. The country had a population of some 400 million at the time, and sufficient natural resources. Yet industrialization had gained a foothold only in the coastal cities, which had been opened to world trade. In the interior a certain distaste for all technical innovations prevailed. But though there was vast potential to be tapped here, any industrial upswing was hindered by persistent civil war.

Amid this setting, Siemens China Co. enjoyed a vigorous recovery of its business early in the 1920s. In addition to its Shanghai headquarters, it had major offices in Tientsin (Tianjin), Beijing, Mukden (Shenyang), Harbin, Hankow (Hankou), Hong Kong, and Yünnanfu (Kunming). In 1926 Siemens China had some 300 employees, about 80 percent of them from China.

The Siemens name had been very closely linked with the electrification of China from the very start. Even before the First World War, Siemens-Schuckertwerke had built China's first hydroelectric plant and its first high-voltage line. The hydroelectric plant near Yünnanfu in the southwestern part of the country was commissioned in 1913, and electricity was conveyed to Yünnanfu, 35 kilometers away, via a 23,000-volt high-voltage line. Pioneering projects like this one helped Siemens to beat out increasing international competition during the inter-war years in winning contracts to outfit more power plants for a public electricity supply, and to electrify mines and industrial operations.

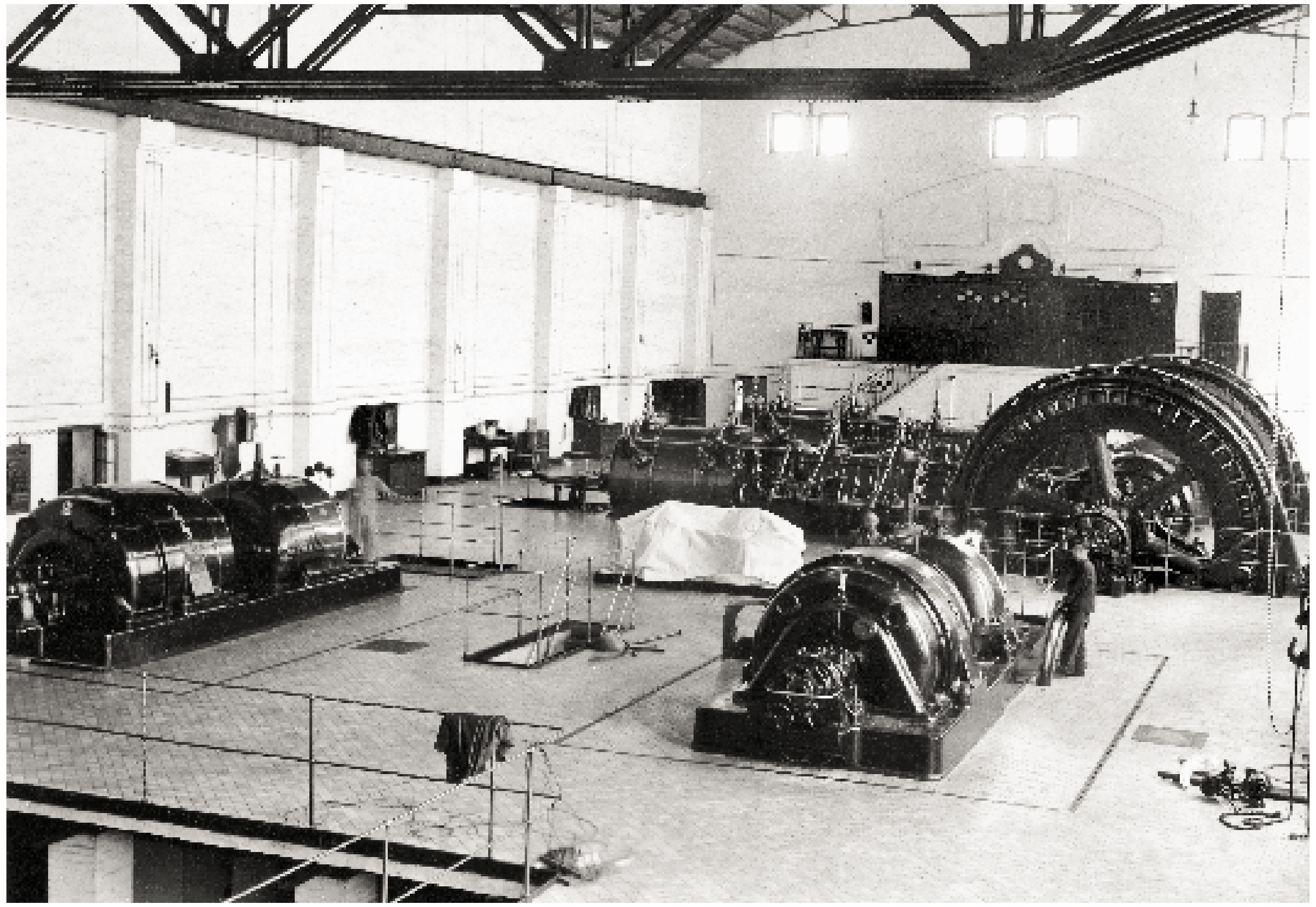
Electrifying the Chinese Mining Industry

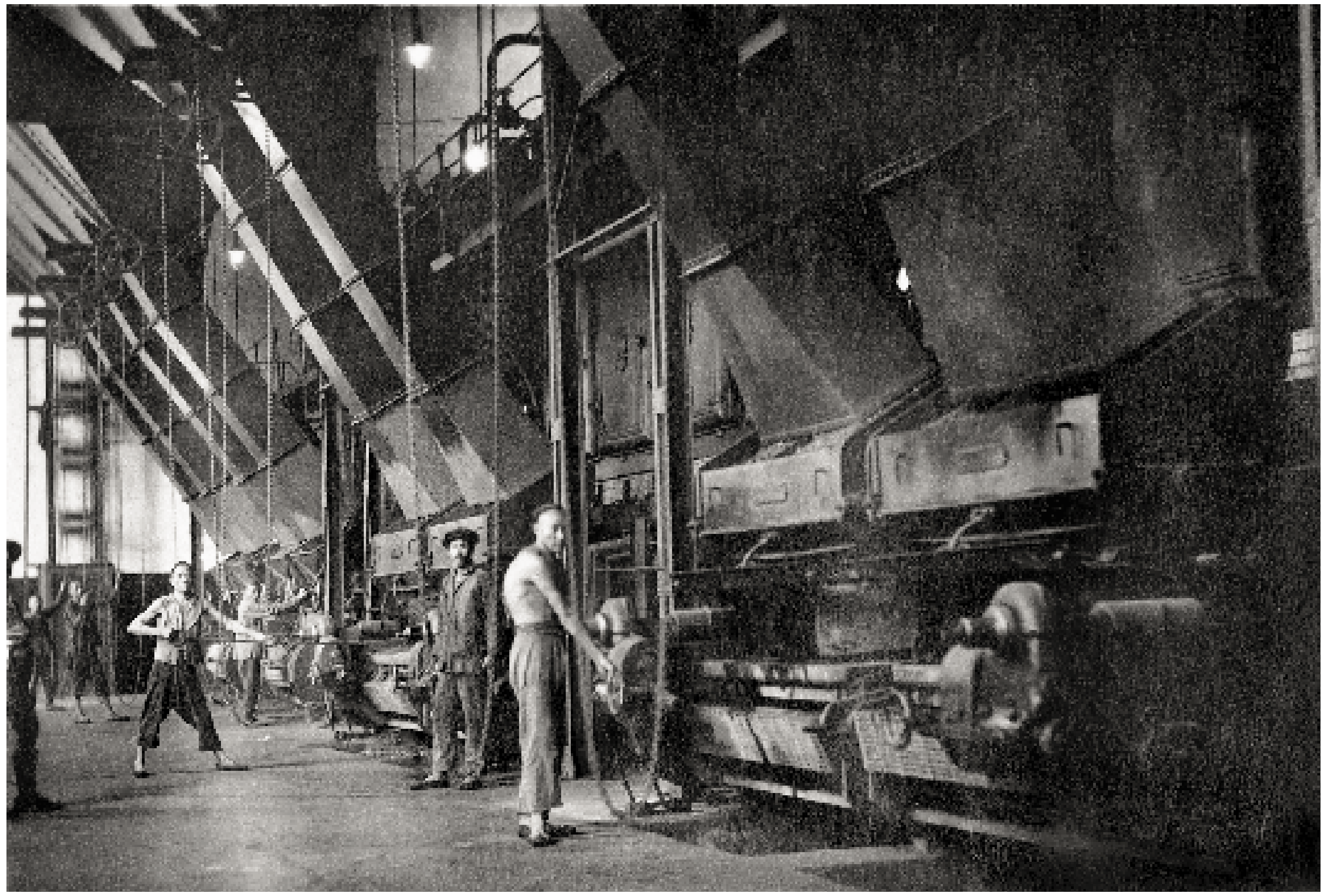
One example was the Ihsien mine near Tsaochuang in Shantung (Shandong) Province. Here the Siemens companies —again the first in China—installed ultramodern facilities around 1925 that could have served as role models even for European businesses. The coal mine, opened up back in the 1870s, was by this time China's third-largest coal producer, and was owned by Chung Hsing Coal Mining Co. In addition to the power plant, Siemens built an electric hoisting system for a shaft 320 meters deep. Drainage was also electrified. One unusual detail was the construction of a four-kilometer fortification wall around the mine installation to protect it from attack during the civil wars. Finally, 500 soldiers "with the best small arms and machine guns" were stationed at the mine to guard it.

But mine management was concerned with more than security—it opened up new paths in social aspects as well. It built a large, modern hospital, headed by Chinese doctors trained in Europe or North America. The medical equipment was of the highest quality. All electrical medical equipment, including the latest X-ray machines, was also supplied by Siemens.

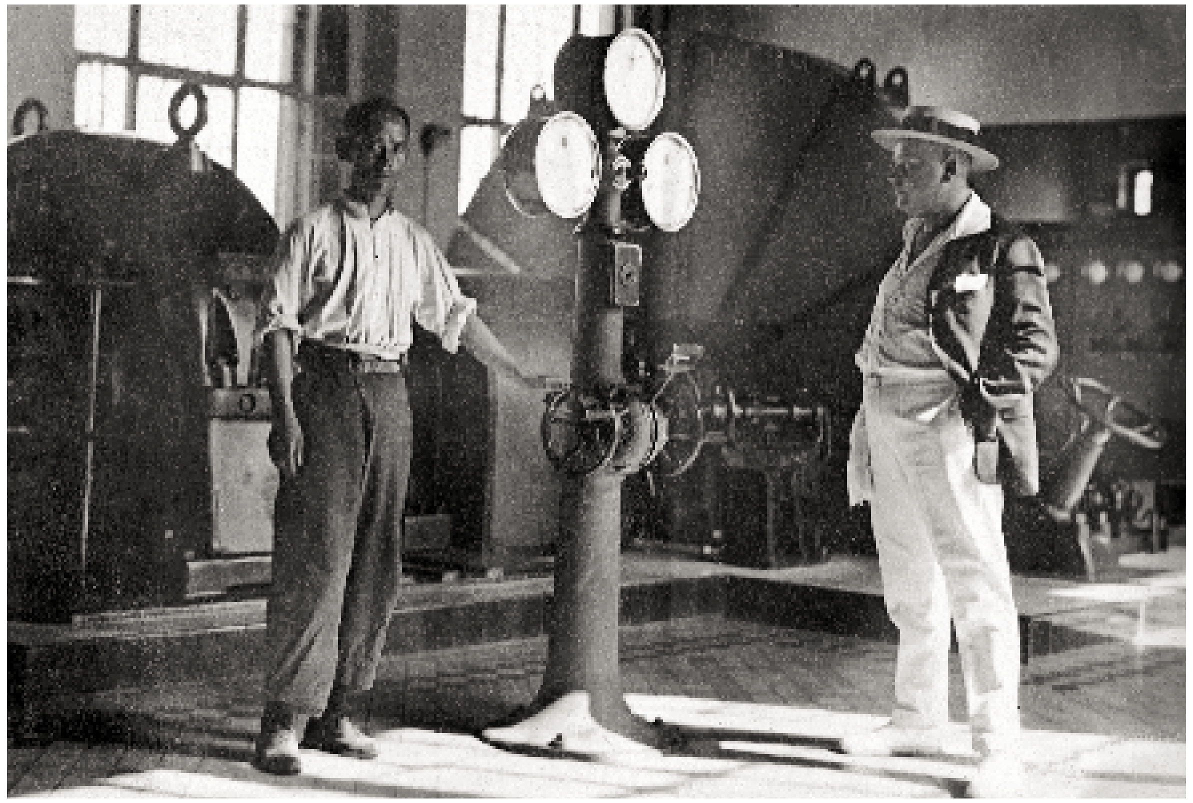
Part of the hoist system, 1920s
The headframe of the hoist is visible. A visitor from the parent plant poses proudly on a motorcycle in the foreground.

A view of the machine room, 1920s
The machine room had two 900 kVA steam generators, and two 2,000 kVA turbo sets, adding up to a total plant capacity of 5,800 kVA.

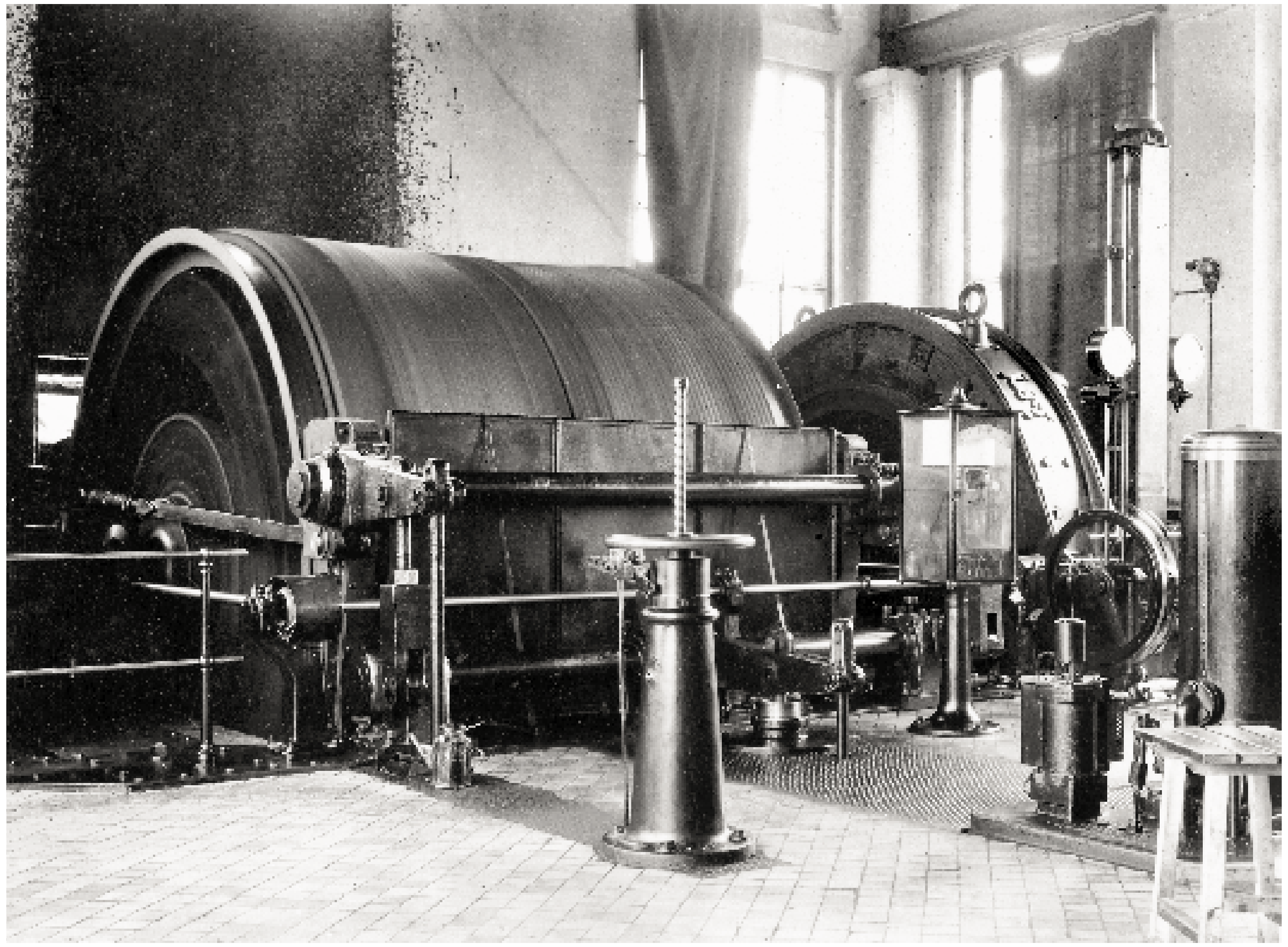




A view of the boiler house, 1920s
Workers fuel the steam boilers in the boiler house of the company's power plant.

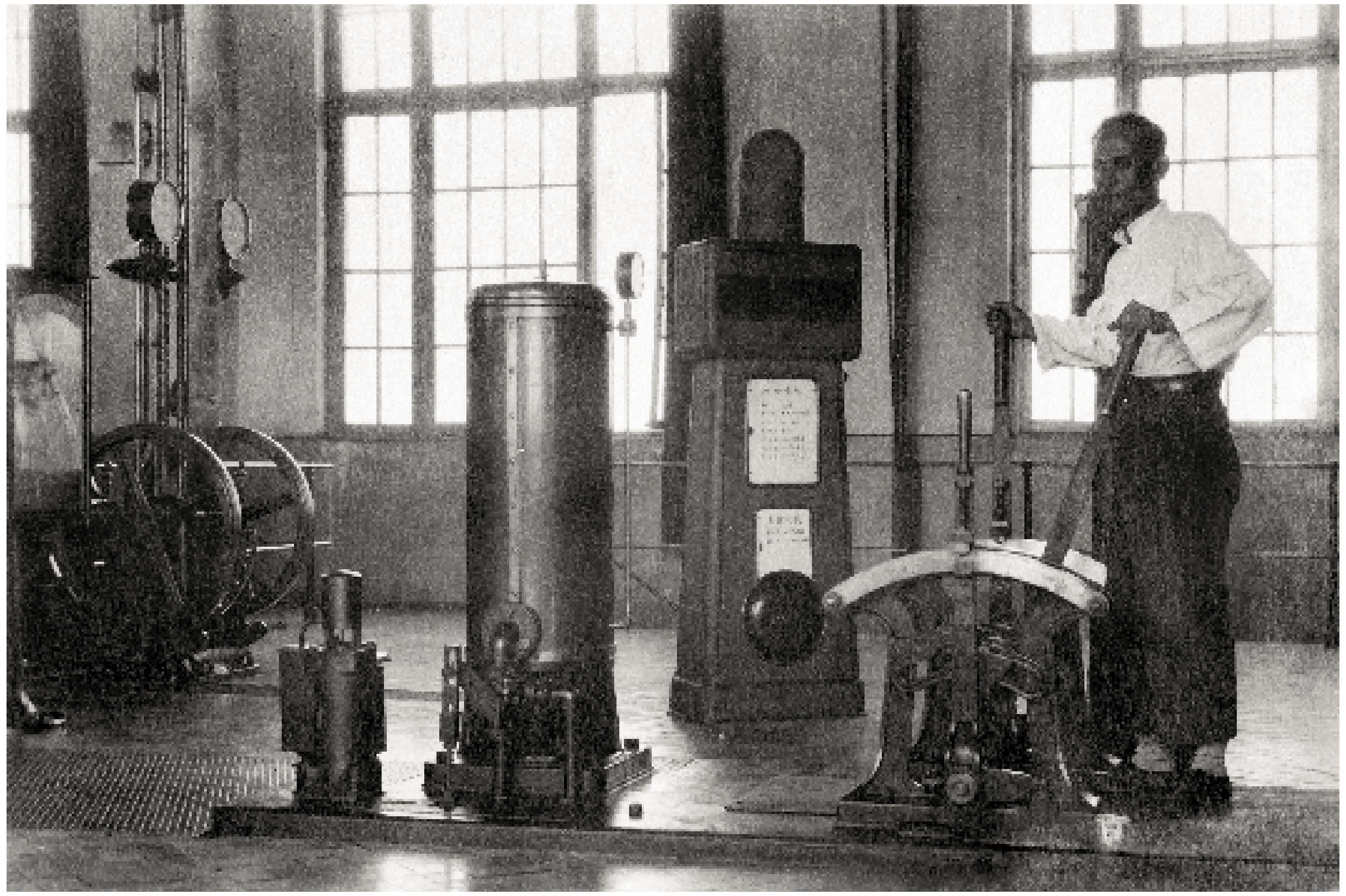


Workers at a control pillar, 1920s
The social distance between the local workers and the European management is clearly evident in the picture from the differences in their clothes and posture.

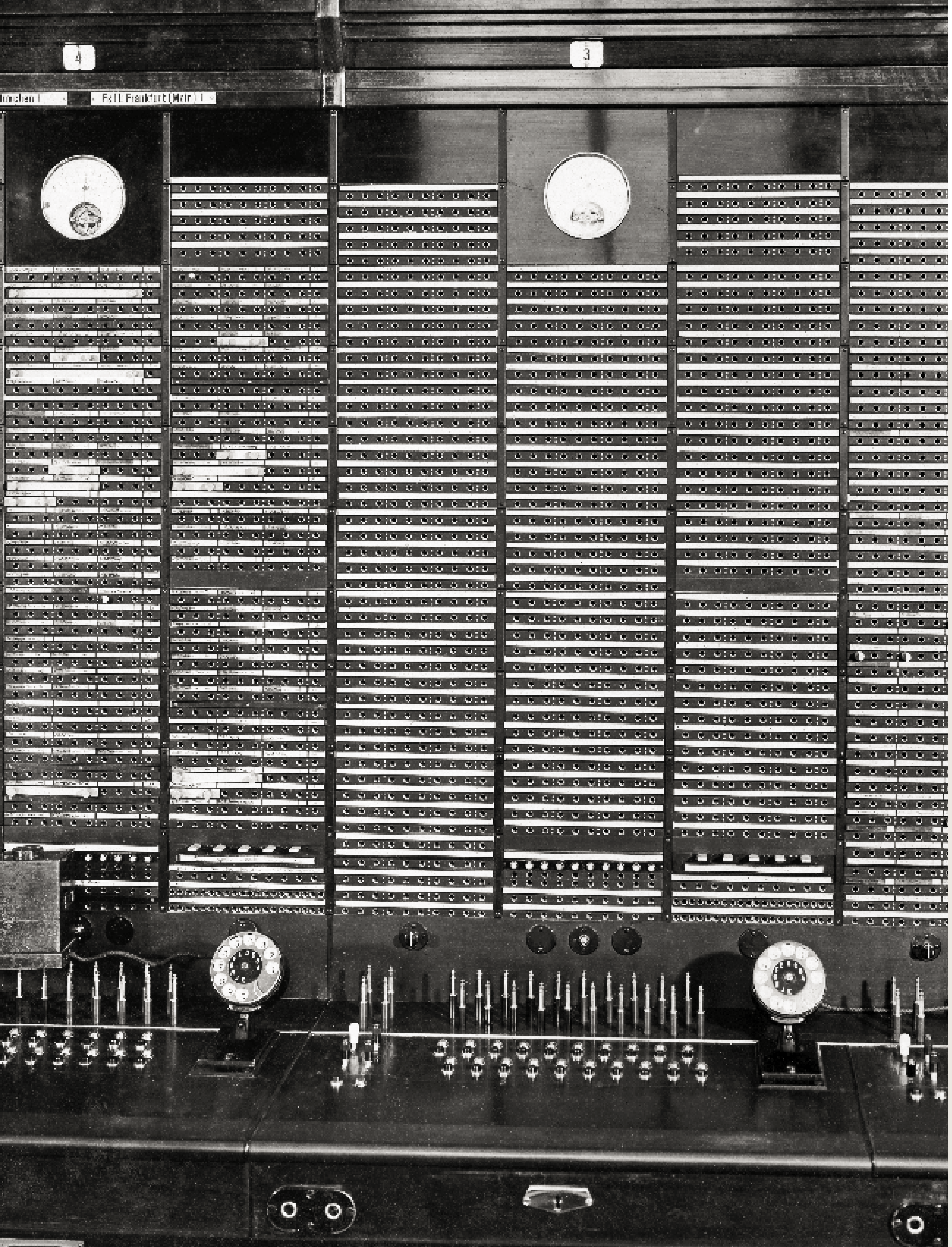


Medical device at the hospital, 1920s
The medical equipment set new Chinese standards for the day, and gave Siemens a chance to tap into additional lines of business.

Part of the hoist system, 1920s
The winch drum for the hoist can be seen in the foreground, and the drive motor is in the background. A Ward-Leonard-Ilgner system was used for control. Capacity was 500 kW.



Worker, 1920s
Mine management was largely in European hands. Chinese employees worked mainly as assistants in technical and commercial capacities.



COMMUNICATIONS

1906 **Berlin Telephone Offices** Germany
1906 **Bodenseekabel Friedrichshafen–Romanshorn** Germany/Switzerland
1910 **Dover–Calais Channel Cable** United Kingdom/France
1913 **Rheinlandkabel, Berlin–Magdeburg Section** Germany
1921 **Beijing's Western Telephone Office** China
1929 **Paris–Bordeaux Long-Distance Cable** France
1929 **Fernamt Berlin Winterfeldtstraße** Germany

1906 Bodenseekabel Friedrichshafen–Romanshorn Germany/Switzerland

The World's First Submarine Pupin Cable

By the time the 20th century dawned, the telephone was already decades old. In addition to local networks, there were now the first long-distance lines. But because of physical problems, telephones remained limited to a range of no more than about 35 kilometers.

Michael Pupin was responsible for a fundamental improvement in long-distance telephone service. At the end of the 19th century, the Serbian-born physicist living in the United States had the idea of introducing inductance coils with iron cores into the telephone lines at certain intervals so as to increase the range and quality of telephone transmissions. Siemens & Halske acquired the European licenses for Pupin's patents around the turn of the century. But before these "Pupin coils" — now more commonly called loading coils — could be applied in practical use, the Siemens researchers had to resolve a number of technical details. The first experiments with "pupinized" telephone cables equipped with loading coils began in Germany in 1901; three years later, Siemens & Halske made its first delivery of a Pupin cable to another country.

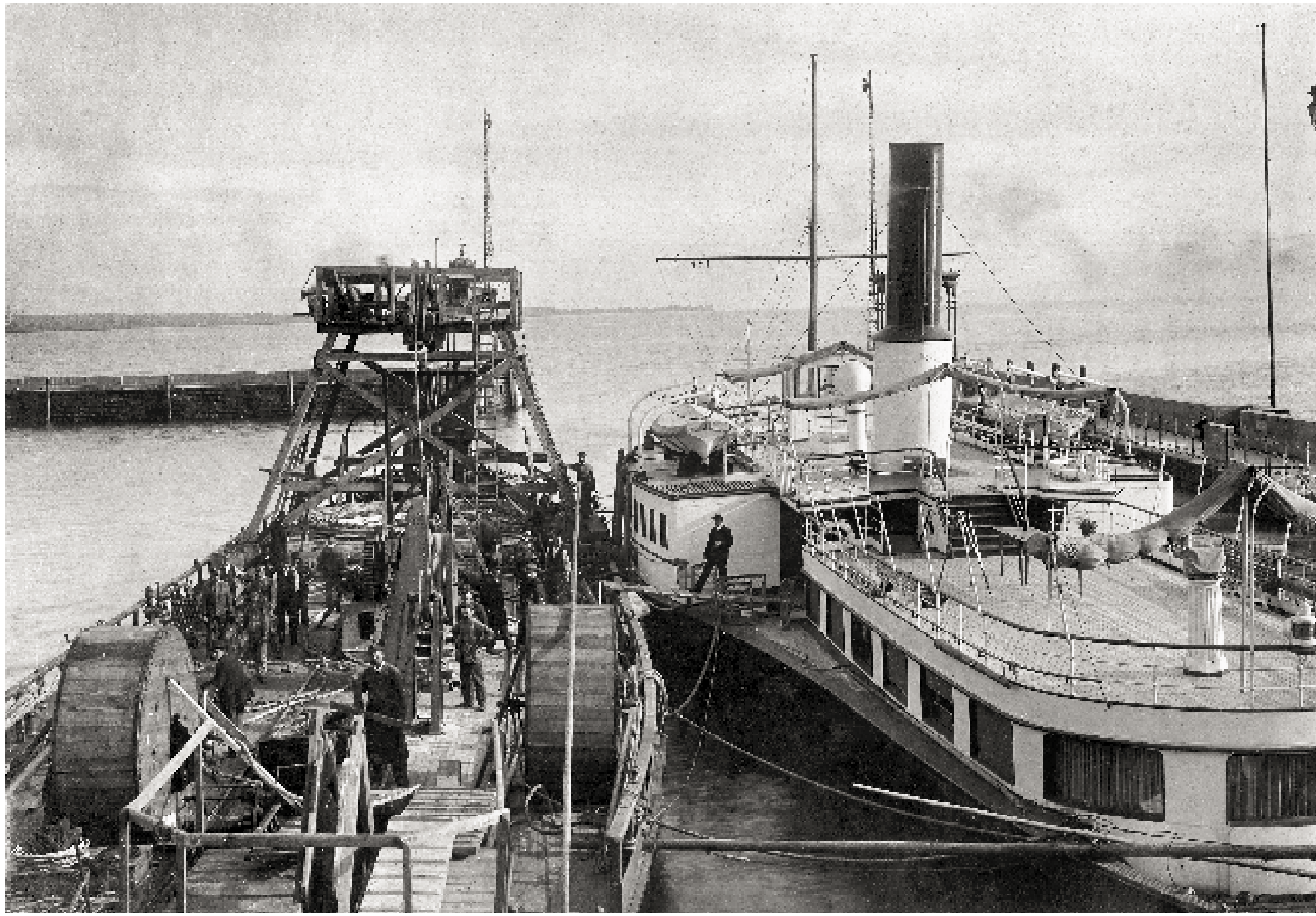
In 1905 the Württembergische Post- und Telegrafenverwaltung ordered a long-distance telephone cable, about 12 kilometers long, from the Berlin electrical engineering company. The cable would be laid through Lake Constance between Friedrichshafen and Romanshorn. Three of its total of seven pairs of copper wires would be used for long-distance telephone calls between Württemberg and Switzerland; four would be for calls between Switzerland and Bavaria. The cable was designed for a range of nearly 350 kilometers.

A Pioneering Achievement, but with Obstacles

Until now, Siemens & Halske had laid Pupin cables only on land, where the loading coils could readily be installed in protective cases and easily spliced into the cable along the line. The situation with the Bodenseekabel was different. Here the total of 22 coils had to be incorporated or spliced in before the cable was laid; they were an integral structural part of the telephone cable. This meant that a coil sleeve had to be developed that was small and flexible enough to be fitted into the lead-sheathed cable without significantly increasing the diameter. At the same time, the lead-sheathed cable had to be flexible and stable enough to withstand the strong tensile forces that would arise as it slipped into the water. In solving these problems, the researchers at Siemens & Halske could draw on the skills and many years of experience of their colleagues at the company's English branch. As early as the successful laying of a telegraph cable more than 3,000 kilometers long between Europe and America (1874/75), Siemens Brothers & Co. had earned a worldwide reputation as experts in the submarine cable business.

Nevertheless, the first attempt to lay the Lake Constance cable, in the fall of 1905, fell through. One problem was that the diameters of the delivery roller and stern sheave on a laying machine specially borrowed from England were too small for the lead-sheathed Pupin cable to be unrolled evenly. Before the work could be attempted again, a modified cable-laying machine had to be built. The project was postponed to the summer of the next year. The cable installers and splicers used the intervening months to make repairs and structural improvements on the cable.

The final attempt took place — successfully — on August 9, 1906. With numerous guests and onlookers in attendance, the sensitive coil sleeves slipped into the water undamaged. The world's first submarine Pupin cable remained in service for decades.

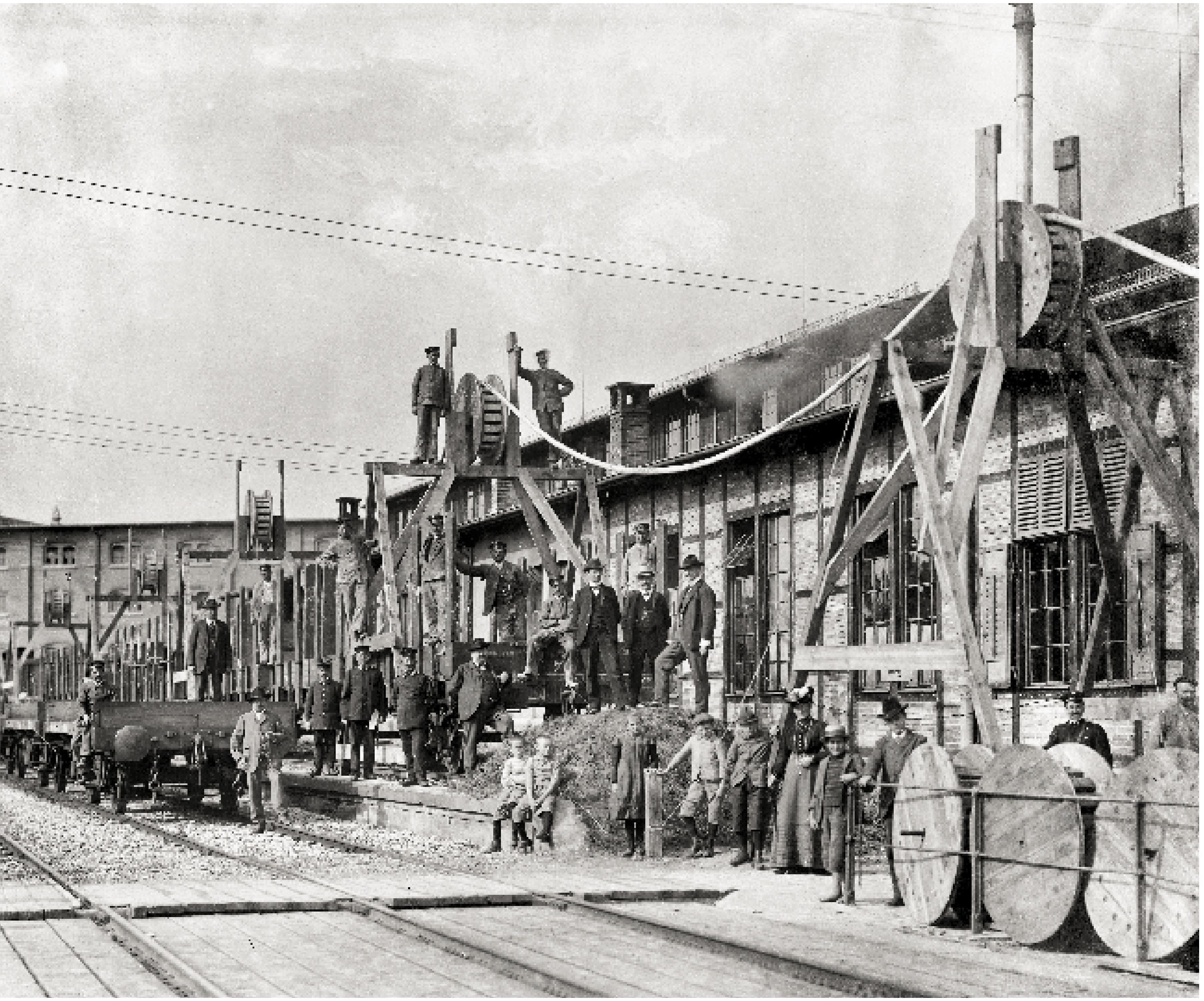


Twin boat, 1906

To lay the telephone cable, one of the barges that was used to carry railroad freight cars across Lake Constance was retrofitted as a cable-laying boat. Since this ferry barge had no propulsion mechanism of its own, it had to be coupled with a saloon steamer to form a single rigid unit.

Friedrichshafen harbor rail station, 1905

The telephone cable, produced at Siemens & Halske's Kabelwerk Westend (Westend cable plant), was shipped from Berlin to Friedrichshafen in open freight cars. On arrival, the cable had to be loaded on board the cable boat via an elaborate wooden contraption.

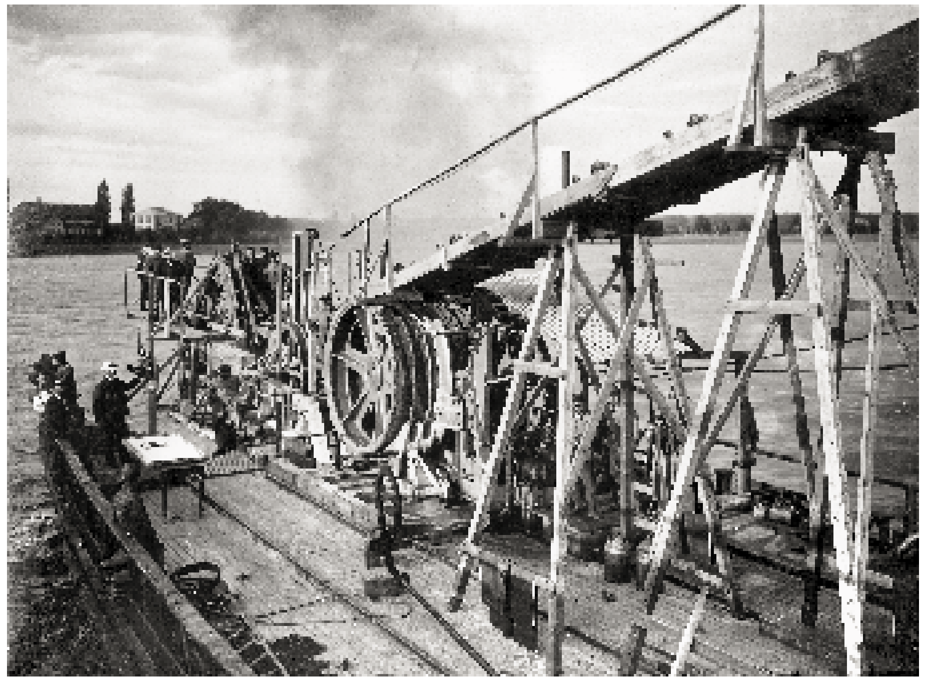


Workers armoring the cable, 1906

The Bodenseekabel ran at depths of as much as 250 meters, where water pressure reaches 25 atmospheres. So the Pupin cable had to be duly protected from mechanical and chemical stresses as well as leaking water. To armor the cable core, a pressure-resistant spiral composed of individual round steel wires was applied under the lead sheathing.

Laying the cable to shore at Romanshorn, 1906

Since the cable-laying boat could not sail all the way up to the shore of Lake Constance, smaller auxiliary boats were used for the last few meters in both Romanshorn and Friedrichshafen.

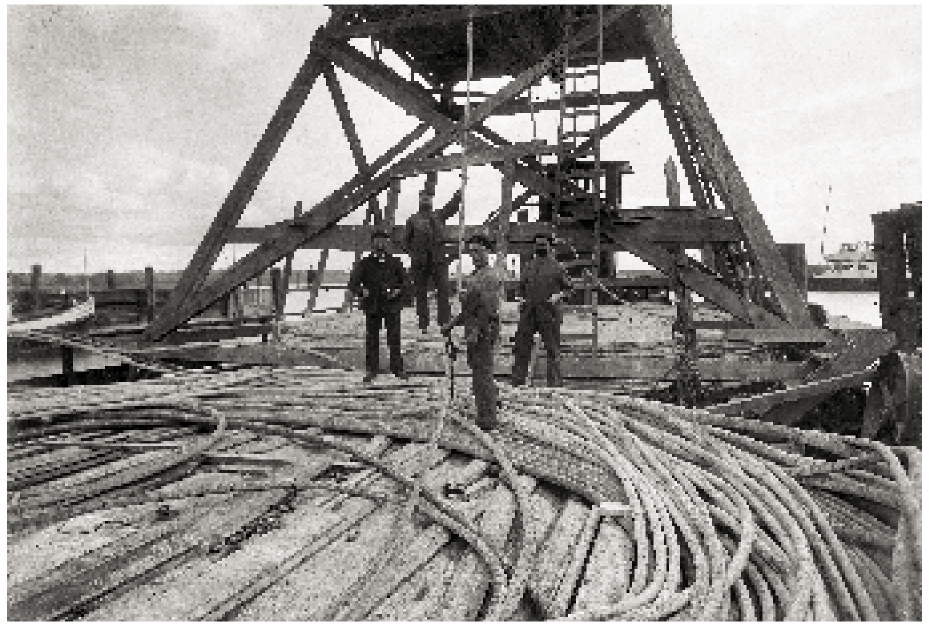


Cable-laying machinery, 1906

The Bodenseekabel, at only a bit more than 12 kilometers, was relatively short. Nevertheless, it had to be laid with the same cable brake that was used for deep-sea cables. The tensile forces on the cable as it slipped into the water could not have been controlled with a simpler braking device.

Laying the cable, 1906

For laying, the telephone cable, weighing a total of some 110 metric tons, was stored in a ring nine meters in diameter in the bow of the cable-laying boat. The laying machinery was mounted on the stern.



Laying the shore end of the cable in the dredged channel off Friedrichshafen, 1906

The local population took a lively interest in the work. Numerous onlookers watched the process from the jetty in the harbor.

Project managers and workers on laying day, 1906

The cable was laid with officials in attendance from the Bavarian, Württembergian, and Swiss telegraph administrations, as well as numerous guests from Berlin. The photo shows Siemens cable pioneer August Ebeling sawing off a piece of the Bodenseekabel as a souvenir of its successful laying.