HISTORY OF THE HOUSE OF SIEMENS

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GEORG SIEMENS

VOLUME II

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VOLUME II

THE ERA OF FREE ENTERPRISE

TRANSLATION BY
A.F. RODGER
AND LAWRENCE N. HOLE

1957

KARL ALBER · FREIBURG/MUNICH

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THE FIRST WORLD WAR

The war into which Europe bungled in that fateful August of 1914, owing to the stupidity of its statesmen, proved as it went on to be one of the greatest forces of destruction that the World had ever known. Moreover, it was not only material values that were destroyed, but the social and economic foundations of civilization were themselves grievously undermined. Right at the commencement stands a monumental piece of folly fraught with truly immeasurable consequences. In the first few days of the war, namely, the parliaments of the countries engaged passed laws by which the issuing banks were relieved of their obligation to cover their notes in gold. Gold was thus divested of its character as a commodity with a value of its own, and replaced by paper notes which derived their value merely from the credit of the State concerned. Whereas the currency had hitherto been autonomous, because founded on the gold in circulation, and in this way above the power of the State, it was now subject to it, and open to debasement. The States were not slow to make use of these possibilities by borrowing from the issuing banks, which financed these loans simply by issuing new notes. In England, the Government endeavoured to put the brake on the resulting inflation by drastic taxation; the continental countries simplified matters by issuing loans to cover their requirements. If they had been operating with real money, the war would have been finished in three months at the latest, in the same way as earlier potentates, notwithstanding their incomparably more modest requirements, had in due course been compelled to cease fighting.

The mobilization took German Industry somewhat unawares; in particular, very few firms had considered which of the employees were necessary for the maintenance of essential production, and thus exempt from military duty. After all, the last war which Germany had fought was more than forty years ago, and technical and economic development had meanwhile brought about so many changes that no one had any real conception of the demands of a modern war, and a world war, too, on the national economy. Thus many Siemens men also went to the front, who came to be the more sorely missed as military requirements grew in urgency. Attempts to obtain their recall encountered the greatest difficulties, even supposing they were alive at all.

At first, only a small section of the Siemens Works was engaged in war production proper. The Wernerwerk was faced with large demands for field telephones and wireless telegraphy equipment, which Telefunken ordered from the Measuring Instrument Department, X-Ray equipment for field and base hospitals, and, of course, the requirements of the fighting fleet, in particular, the further development of fire control installations. The Cable Works was fairly flooded with orders for field cable, and there was also a big demand for telegraph cables for fortifications on the land and sea frontiers. Soon there was a call for large numbers of high-speed telegraphs. Following the discovery by the Army that communication between their widely dispersed Staff Headquarters in the East, West and South-East and the homeland, was incomparably speedier and more reliable by means of the new high-speed telegraph, they developed and extended the network at a pace that was only limited by the ability of the Wernerwerk to supply.

On the other hand, the big turnover in hand with the Post Office and automatic telephone stations nearly came to a stand-still; the Fire Alarm Department seemed to have no option but to write off a large proportion of promising enquiries from Germany and abroad; the Water Meter Department was in difficulties; the Railway Signalling Works feared that no further orders would come in. In the business year 1913/14, which happened to close just before the outbreak of the war, the production of the Lamp Works was 19.5 million lamps; for 1914/15 the total was only 12.1 millions, although the home consumption had only dropped from 7.2 to 6.9 millions. The main decrease from 7.8 to 2.0 millions was accounted for by "territories not within reach."

In the case of Siemens-Schuckert, the brake on production exercised by the war seemed initially to be still more severe. At first, no one had the courage to build new power stations or to extend supply networks—nor the money, it was said. Business in tramway electrification was practically dead, and there could be no question of further extension of the electrified railways. With the exception of a few armament works, the customers of the Industry Department likewise held back further orders for the time being. The Overseas Department was cut off from the bulk of its customers, and as for the daughter companies in England, France and Russia, all that was known was that they had been sequestrated. The Small Accessories Department, which was also responsible for the sale of lamps and carbons, was faced with the same shrinkage of business as the rest. The one exception to the rule was the War and Marine Equipment Department, hitherto the smallest of the so-called "Balancing" Departments, which was now inundated with orders. Its chief customer was the Navy, whose main pre-occupation, the high-pressure development of the submarine, completely absorbed its constructional and manufacturing capacity.

In view of the foregoing position, it appeared that Siemens, in particular Siemens-Schuckert, but also to a lesser degree the Wernerwerk, would have to look round for other business in order to keep the Works employed. At the beginning of 1915 these reflections began to assume more definite shape, as it became clear that the original estimate of a few months' duration of the war was totally erroneous (due to the introduction of trench warfare, and the new devices for "creating money"). For the same reason Government Departments now began to change their policy in requisitioning supplies. In particular, they had learnt meanwhile that the consumption of artillery ammunition had assumed proportions hitherto undreamt of by military experts. The same applied to everything else: infantry ammunition, arms, means of communication, pioneer equipment, accoutrements, transport and technical auxiliaries of all kinds had to be provided and replaced on a scale hitherto unheard of, and which could not have been imagined in peace time. The factories which had so far produced all these things sufficed to cover only a fraction of these gigantic demands. It was obviously necessary to harness the whole of the Nation's industrial capacity to the task.

Having commenced, as a temporary measure, to make cooking utensils, tent pegs, cartridge cases and ammunition belts, the Wernerwerk engaged in the large-scale manufacture of detonators, which kept a large part of the Works busy for a number of years. A large business also developed in gun-lock tubes for infantry rifles, whilst ultimately the manufacture was commenced of complete gun-locks for machine guns. The Signal Works commenced to extend its motor manufacture so as to include aircraft engines, and soon achieved notable success in this field. The Dynamo Works, the Electromotor Works and the Small Accessories Works took up the turning of shells in large quantities. In addition, they also manufactured detonators, mortar bombs and components for sea mines. The Cable Works, situated at some distance from the others, even installed a plant for the manufacture of gunpowder.

Gradually, however, there was a recovery in the demand for "peace" goods. If everybody was to turn shells, and press field flasks and Iron Crosses they would require motors, cables, lamps and installation materials, and the generating plants would have to be extended, likewise the supply networks. The converted factories soon ceased to be able to cope with the demand, new ones had to be built, requiring transformers, cranes, and electrically driven machine tools. The demand for iron and steel increased enormously; the ironworks had to extend their plants considerably, and in addition to all the rest there was an urgent demand for more electric steel furnaces. In peace time, the production of electric steel had not exceeded a couple of thousand tons; in 1916 the figure was 180,000 tons. Besides considerable generating plant, cabling and drives, all these new and extended Works required telephones, fire alarms, clocks and other weak current installations. Within a couple of months the whole situation in the Electrical Engineering Industry had unexpectedly become reversed, but the strangers had settled in and could not just be turned out. In the first place, the male workers had been released from service in the field in order to turn shells and assemble breech-blocks for machine guns, but not to manufacture telephone installations for new Company Head Offices. In the second place, the big customer, the Government, was not willing to be turned out of the newly converted workshops, which were found to be very efficient. The consequence was a very awkward situation for Siemens: a lack of space and shortage of man-power at every turn.

Raw materials also soon came to be in short supply, the most acute scarcity being in copper and cotton, as far as the Electrical Industry was concerned. Germany was cut off from the overseas markets by the blockade of the British fleet, whilst the British law concerning "Trading with the Enemy," in conjunction with the system of "Black-lists," gradually dissuaded the Neutrals from acting as intermediaries. The result was the early development of a grievous shortage in these and many other commodities which had hitherto been imported from abroad.

The distribution of the scanty supplies amongst the consumers was the business of the "War Raw Materials Department" of the War Office, acting through subsidiary companies, such as the "War Metal A.G.," the "War Chemicals A.G.," the "War Lubricating Oil A.G.," etc. etc. These War Companies made a distinction between "war orders" and "peace orders" (the former being required to be substantiated by documents), with different prices for the two categories. In 1916, for example, copper for war-work was priced at 350 Marks per 100 kg, but if required for a "peace" contract the price was 450 Marks. By comparison, the average price of electrolytic copper in the last few years before the war was 120 Marks. For copper bought abroad on the black market, however, the price was 800—1,000 Marks. For cotton yarns costing on the average 1.5 Marks per kg in peace time, the official maximum price was 6 to 8.5 Marks according to counts and quality. Cotton smuggled in from abroad, on the other hand, cost from 70—100 Marks.

Since the introduction of the telephone, i. e., since about 1879, inventors had been grappling with the problem of devising a telephone relay (as a counterpart of the telegraph relay), by means of which the attenuated currents arriving at the end of a long section could be amplified before being sent on their way through the next section. In principle, the solution seemed to be very simple. All that was necessary was by some means to connect the membrane of a telephone mechanically to a microphone, and thus to cause the latter to vibrate in consequence of the oscillations of the telephone membrane, in the same way as it would under the influence of the sound waves set up by the human voice. The current supply to the microphone would then provide the required amplification energy. In spite of all the brains of the inventors, however, the idea would not work. Speech was distorted by the relay past recognition, due, no doubt, to the fact that the mechanical transmission between the telephone membrane and the microphone was too clumsy. Ultimately, S. G. Brown developed an arrangement, which he had patented. In this, a thin metal tongue, which carried a small platinum-iridium contact at its tip, was caused to vibrate by the telephone magnet. Opposite the contact, and at a microscopically small distance, was a fine point of the same material, the distance of which was capable of adjustment. This apparatus worked satisfactorily when correctly adjusted, but it was much too sensitive for every-day use. Siemens & Halske acquired the Brown patents and, working on the same basis, developed a mechanically improved and more robust arrangement, which proved itself reliable in service in a number of long-distance telephone lines. This was shortly before the outbreak of war.

Eight years previously, in 1906, a patent for Germany and elsewhere had been applied for by Robert von Lieben in Vienna. The inventor took advantage of the discovery made in 1904 by A. Wehnelt. Using the well-known evacuated gas-discharge tube, Wehnelt fashioned the cathode of platinum in hairpin form, and connected the ends to a heating circuit. He then observed that even at the low potential of 100 volts between anode and cathode, electrons issued from the glowing wire in the form of cathode rays, whereas otherwise, e. g., in the Röntgen tube, it was necessary to apply at least 30,000 volts to entice the electrons from the metallic surface of the cathode, and so to produce cathode rays.

In his patent application, von Lieben therefore described a "cathode-ray relay," in which the ray was diverted from its otherwise straight-line path by some peculiar action of the current to be amplified, e. g., by exciting a magnet. That the cathode ray, which is of course a part of the total current in the circuit, can be diverted by a magnetic field like any other, had been known for a long time. By causing the ray to strike the anode squarely, then less and finally not at all, the resistance of the circuit was varied, and consequently the current. The "massless" relay had the advantage over all others hitherto devised, that the moving parts were without inertia and were thus able to follow at once all variations of the current to be amplified.

Four years later von Lieben applied for a second and third patent, this time in conjunction with two collaborators. Whereas the second was only a modification of the first, the third was based on a new idea. He proposed to interpose a metallic network or grid in the path of the cathode ray, the grid to have a low negative voltage. Since the electrons, as the smallest units of negative electricity, were impeded and partly repulsed in their flight by the repellent action of the grid, only a portion of them was able to pass the grid, and if the grid voltage were high enough, they were all repelled. In this way, the stream of electrons was controlled by the action on the grid of the potential of the original current. Provided the arrangement and dimensioning were correct, the "anode current" produced by the electrons was a true, but materially amplified, copy of the original current.

The early Lieben tubes were still rather imperfect. Moreover, they contained low-pressure mercury vapour, since von Lieben was of the opinion that the amplifying action of the tube could thereby be increased. However, the fundamental importance of the invention was not to be denied, and both Siemens & Halske and the AEG endeavoured to gain exclusive possession of the patent. Since both firms had already carried out research work with similar objects in view, and were faced with the prospect of an interminable patent dispute, they agreed to purchase the patents jointly with Telefunken and the "South German Telephone Wire and Cable Works," and to found the so-called Lieben Syndicate for the purpose. Each of the members then went to work on the development of the Lieben tube into a serviceable amplifier, and in 1912 the AEG was the first to submit to the Post Office a number of tubes for trials.

In wireless telegraphy, as already described, it was originally the custom to use the Branly coherer to detect the waves arriving at the receiver. This was a pretty awkward instrument; efforts were soon afoot to register the signals acoustically, i. e., by means of the telephone. It was then the function of the telegraphist to transcribe the Morse signals into longhand, which was obviously much speedier than the previously existing procedure. Unfortunately, the high-frequency oscillations are much too rapid for the telephone membrane to be able to follow in the same rhythm, quite apart from the fact that the human ear is incapable of hearing them. If, however, only the half-waves of the one direction of a train of waves were registered and those of the other direction suppressed, it would be possible to use the exceedingly short current impulses to charge a condenser. When this was done, and the condenser discharged through the telephone, a short crackling sound was produced in the latter. When a train of these unidirectional waves, e. g., one thousand per second, was allowed to act on the telephone in this manner or, in other words, when the crackling sound was repeated one thousand times per second, it resulted in a musical sound corresponding to the frequency of one thousand. Such a sound could be used for signalling. What was necessary, therefore, was a device in the receiver which would suppress the high-frequency half-waves of the one direction, i. e., a "rectifier."

According to a discovery by Ferdinand Braun, a co-worker of Siemens & Halske in Strassbourg, certain semi-conductors in crystalline form are suitable for this purpose when used in conjunction with a needle-point contact. They allow the current to pass in one direction only. Under the name of "detector," they were in the first place used in large numbers in wireless telegraphy apparatus. They had one disadvantage, viz., that due to some unknown cause the contact between the metal point and the crystal frequently failed, necessitating re-setting of the detector. A search had to be made for a more reliable rectifier.

Lee de Forest, who was originally an engineer in the service of the Western Electric Co., Chicago, had set up in business for himself at the beginning of the century, with a view to exploiting certain inventions relating to wireless telegraphy. In searching for a rectifier, he hit upon the Wehnelt discovery of the slow cathode rays. Due to the presence of electrons, the path between anode and cathode is, of course, a conductor, but only for a current flowing in the direction from anode to cathode. The two cannot be reversed, since the cathode is part of the glowing wire which discharges the electrons. The tube allows only the one set of half waves of an alternating current to pass. De Forest therefore used the Wehnelt tube as a detector with every success.

In the course of his experiments he conceived the idea, independently of Lieben, of placing a grid between anode and cathode and applying the high-frequency oscillations to be rectified to the grid and cathode.

He thereby achieved not only the rectification of the oscillations, but obtained them in amplified form between anode and cathode. The "Audion," as he called the arrangement, was thus the combination of a rectifier and an amplifier. He was granted an American patent in 1907, and the device gradually came into general use in wireless telegraphy. Apart from this, however, as de Forest was aware, the tube was capable of being used as an amplifier for telephone cables.

In the same year as the German Post Office received the first Lieben tubes from the AEG, the American Telephone and Telegraph Co. received the first tubes from de Forest for testing as telephone amplifiers on their long-distance lines. They differed from the Lieben tubes only in that they did not contain the small quantity of mercury vapour, which von Lieben had introduced with a view to improving their action, and because of the difficulty in attaining the desired ultra-high vacuum. The de Forest tubes had this high vacuum, however, and were consequently less sensitive to temperature fluctuations.

In the following year, 1913, Alexander Meissner, who collaborated with Telefunken, was experimenting with electron tubes (the name now given to these discharge tubes with grids on the von Lieben and de Forest principle), and thereby made a further important discovery. The tube separates the incoming circuit, which carries the weak input, from the outgoing circuit, which carries the power which has been amplified by the relay action of the tube. If a part of the output is now returned by suitable connections to the input side, it passes through the tube for the second time and is amplified again, and so on; this was later called "feed-back, or reaction, coupling." Since the incoming circuit always contains capacity and self-induction, it is capable of oscillation, although the oscillations are quickly damped out by the action of the resistance. If, however, this damping is continually compensated by energy from the output side, the oscillations do not die out, and the whole combination becomes a wave generator—an alternator. In wireless telegraphy, therefore, it was no longer necessary to generate oscillations through closing and opening an oscillation circuit by means of a rapid succession of sparks, only to produce a series of damped wave-trains which quickly died out. The engineer now had at his disposal a continuously flowing source of undamped oscillations, which could be tapped out in any way desired to transmit a signal. On the 20th of August, 1914, the German Post Office installed a temporary telephone line with Lieben tubes between the Central Headquarters in Luxembourg and the Staff Headquarters in East Prussia, over which the telephone conversations were held which led to the dispatch of Hindenburg to the Eastern front, and to the battle of Tannenberg. It was the first experience of long-distance telephony. Five months later, on the 25th January, 1915, Carty in the United States, using the de Forest tubes, demonstrated to a circle of invited guests a telephone conversation between the aged Bell and Watson, one of his old Assistants—Bell in New York, and Watson in San Francisco. Bell said: " Mr. Watson, do you recollect that evening, 38 years ago, when we spoke over the telephone for the first time? . . . We are speaking now across 3,400 miles just as easily and clearly as in those days across two."

These were only the beginnings of a development which has made the little magic tube into one of the most revolutionary creations in the history of human inventions. In territories outside the American sphere of influence, the Lieben patents were destined to acquire an importance in no way inferior to that of the famous Bell patent of 1876.

As has been mentioned once or twice already, Wilhelm von Siemens was given to following up all manner of technical novelties in the seclusion of his private laboratory in the Wernerwerk. As he took a keen interest in matters of national defence, the idea occurred to him in 1905 of constructing a large torpedo to be launched at an enemy ship from the coast. As compared with other missiles of its kind, it was to have the advantage that it could be guided during its run, in accordance with observations on land, to render an escape of the target impossible. To this end, the torpedo was to unwind a thin cable in its wake, through which control impulses could be transmitted from land. This presupposed that the missile would be of considerable size, and that it would not travel under water, like the real torpedo. It was thought that a small boat travelling at high speed would, after all, be difficult to hit; on the other hand, the boat, which eventually attained a displacement of six tons, was able to carry an enormous load of explosives. The chief difficulty was to prevent the trailing cable from reducing the speed and interfering with the steering of the boat, but in shallow waters, at least, the influence of the cable was fairly well eliminated. Years had been spent in perfecting the device, and it was still not ready when the war broke out. However, following their occupation of the coast of Flanders and the ensuing need of the German troops to secure their flanks against attacks from the sea, the inventor succeeded in 1915, by a demonstration of the now completed "Remote Control Boat," in awakening the interest of the Admiralty. The boat was driven by a 400 h. p. petrol engine, travelled at 30 knots and had a radius of 12.5 nautical miles, which was later raised to 30. It proved to respond perfectly to the controls. Twelve of these boats with cable control were supplied up to April 1918. By virtue of the great strides which had meanwhile been made in wireless telegraphy consequent on the development of the discharge tube, a further number of speed boats were built for wireless control from aircraft. The first of these boats was taken into service in May 1918.

As to their effectiveness, opinions were divided. Two of the speed boats were sunk by the enemy, and one enemy monitor is said to have been destroyed. This much is certain, that the presence of these remote-controlled boats compelled the British fleet to proceed with circumspection when operating off the Flanders coast.

Whereas the remote-controlled speed boat was the fruit of the personal initiative of Wilhelm von Siemens, he was requested in 1907 by the Chief of the Prussian General Staff to give his assistance in the building of a dirigible balloon. At that period the plans of Count Zeppelin were very popular in Germany, but certain military circles considered a balloon of the non-rigid type to be more promising. Wilhelm immediately fell in with the suggestion and instructed Otto Krell, the Manager of the War and Marine Equipment Department of Siemens-Schuckert, to take the necessary steps. Krell's father had been a friend of Sigmund Schuckert, and Krell himself had joined the Schuckert firm as an engineer at an early age. Together with Robert Friese and other less spectacular personalities, he belonged to that group of technicians who, apart from material assets, must be regarded as the most valuable contribution of the Nuremberg House to the joint undertaking. As a designer Krell was imaginative, and the design of a large non-rigid airship fired his imagination. Along with his assistants, he developed a type of ship without supporting framework or stiffening members, which was maintained rigid solely by the gas pressure of the filling. The gas content was 15,000 cubic metres, and the ship was propelled by six engines carried in pairs in three nacelles, the latter suspended by slings of fabric. With a speed of 20 metres per second, the airship long held the record of being the fastest of its kind in the world. For stowing away the airship, a rotatable hangar, also designed by Krell, was erected on Wilhelm von Siemens' estate at Biesdorf near Berlin. This enabled the airship to enter the hangar with safety independently of the direction of the wind. This rotatable hangar was really the only part of the undertaking to be preserved for any considerable time, for in spite of having made nearly seventy trips of shorter and longer duration, the airship succumbed, even before the outbreak of the war, to the high-pressure competition of the rigid Zeppelin system, until this, in turn, was compelled to strike its colours before the aeroplane.

As soon as Wilhelm von Siemens realized that the aeroplane was much superior to the airship as a weapon of war (and this was already borne in on him in the first few weeks of the war), he took measures to ensure that Siemens-Schuckert utilized the experience gained in airship-building to produce aeroplanes. In opposition to the general opinion of the day, he insisted on building large and heavy aircraft for correspondingly heavy bomb loads—heavier than anything so far built at home or abroad. Already in October 1914 he pressed Krell to develop an aeroplane with two engines, something as yet unheard of. The task of producing these machines was given to the Dynamo Works. After surmounting enormous difficulties, partly technical, and partly arising out of the indecision of the War Office, the first few prototype machines were completed after considerable delay. The idea of placing the design with the War and Marine Equipment Department and the construction with the Dynamo Works also proved to have a retarding effect. It was therefore decided to place the whole of the work, including design, with the Dynamo Works, a task which Reichel took in hand with customary energy. Since the Army had meanwhile taken a fancy to the large aircraft and now began to increase its demands, six of the machines were converted into 3-engine craft, each with a total output of 780 h.p. and capable of carrying a load of 1,810 kg. These machines operated successfully on the Eastern front. Based on these good results, the War Office finally commissioned Siemens-Schuckert with the construction of two "Giant" aircraft, with six engines each, of together 1,680 h.p. These machines were not completed until the Armistice, however, but were the largest machines in existence at that date.

In between, single-seater fighters with rotary engines of the Signal Works were built for the most part in the Transformer Works, Nuremberg, to designs worked out by the Dynamo Works; machines of medium size were manufactured in accordance with a prototype of the Gotha Waggon Works, the so-called "Gothas," and various other machines under licence. As a result, a Siemens aircraft factory came into being beside the Dynamo Works, complete with its own airfield, a curious incursion of a totally alien spirit into the hitherto so peaceful atmosphere of electrical engineering.

In all this aircraft construction work, an outstanding part was played by the Signal Works engines, particularly in connection with the high-speed fighters. This Works had, in fact, turned its attention to the construction of aircraft engines as early as 1912, and had taken a special interest in a design of the firm of Gnôme, in which the engine cylinders are arranged in star fashion in one plane, to ensure a uniform cooling effect of the propellor air-stream. To further increase the cooling, Gnôme also made the cylinders rotate round the stationary crankshaft, thus arriving at the rotary star engine. The Signal Works added the new idea of causing the cylinders and crankshafts to rotate in opposite directions, by the interposition of an ingenious bevel-wheel transmission. In this way the effective speed of rotation of the engine, and thus also the output, was doubled. This aircraft engine with 11 cylinders and an output of 240 h. p., and with an unparalleled weight/power ratio of 0.8 kg/h.p. was known the world over as type Sh 3, and for long held the record amongst the aircraft engines of the warring nations.

The heavy battles of the summer of 1916, with their prodigious destruction of material, had shown the German Staff that the enemy was determined to throw every ounce of productive effort into the scales of victory. It followed that Germany would have to achieve an enormous increase in the production of war material, if it were to prevail in the struggle. The extensive plans which emerged from these deliberations came to be known as the "Hindenburg Programme." Apart from the actual factories for arms, ammunition and other equipment, these plans covered not only numerous auxiliary plants, for instance, for machines and apparatus of all kinds, but also for the production of raw materials. Of interest to the Electrical Industry were, above all, the manufacture of calcium cyanamide and aluminium, both of which consumed large quantities of electricity. The calcium cyanamide was not only required as a fertilizer, but also as a raw material in the manufacture of explosives. Electrical generating stations of a capacity hitherto unknown in Germany were erected in the Central German lignite coalfields at Zschornewitz and at Chorzow in Upper Silesia, to the plans of Georg Klingenberg of the AEG. In both places the newly founded "Reichsstickstoffwerke," an offshoot of the "Bayerische Stickstoffwerke," put up carbide factories with ancillary plant for the production of calcium cyanamide. Even the first stage of these plans was productive of orders to Siemens-Schuckert to the value of almost twenty million Marks. The very extensive Lautawerk of the "Vereinigte Aluminium-Werke," which had been founded jointly with the "Chemische Fabrik Griesheim-Elektron" and the Government, was also built on the Central German lignite coalfields in the extreme corner of Lower Silesia. For these Works, Siemens-Schuckert were called upon to supply six large rotary converters of 4,000 kW d. c. each. A further eight motor-generators of the same individual output were supplied to the large Aluminium Works "Erftwerk" near Grevenbroich in the lignite coalfields of the Lower Rhine. To cope with the power supply of this and other new consumers, the

"Rheinisch-Westfälische Elektrizitätswerk" in Essen extended its generating station built shortly before the war in the so-called foothills, near Cologne. This station was situated in close proximity to a lignite mine, and was powered by two steam turbines of 15,000 kW each. In the first place, four further machines of the same type were added, to be followed by two turbo-generators of 50,000 kW each, and two transformers of 60,000 kVA each, to correspond. One each of the generators and transformers were ordered from Siemens-Schuckert. At the time they were the largest units in existence, and the "Goldenbergwerk" the largest power station in Europe.

The expansion of the raw materials production programme was also the source of several orders to Siemens & Halske for electric steel furnaces, so that the proportion of their furnaces to the total number of electric steel units in those years rose to about 40%; from Austria they received an order to supply two fairly large electrolytic copper refining plants, working from copper scrap; several large plants were on order for the production of alkali-metal-chloride on the Siemens-Billiter system, and in the last year of the war Siemens & Halske commenced the erection of an extensive plant for the electrolytic deposition of pure iron. It was intended to use this, on account of its toughness and malleability, in place of copper for the sealing rings of artillery shells, but the plant could not be finished in time.

Under these circumstances, it was no wonder that the workshops were becoming congested, that overtime was a matter of course, and that it was often necessary to work in two or even three shifts. Overcrowding was worst, as always, in the Wernerwerk. In 1914, before the outbreak of war, an extensive new building had been begun to the West of the original Works, but work on this was stopped in the initial atmosphere of panic when war broke out. When the dreaded recession did not materialize, however, that part of the building already raised (up to and including the first floor) was temporarily roofed over and the interior completed. All manner of sheds and huts began to grow up around the new building, and a small factory nearby was rented, offices and stores took possession of the empty shops of the main street of Siemensstadt, and in a word, there was a repetition of the state of affairs familiar in the days of the Berlin Works. In February 1917, a large two-storey building for the manufacture of wireless apparatus was burnt to the ground, with resulting heavy loss of material and output. It was now decided to continue with the unfinished extension of "Wernerwerk II," later called "Wernerwerk M," in view of the fact that it accommodated the Measuring Instrument Department, which had meanwhile greatly increased in size, and the water meter production. The new building did not as yet cover the whole of the area originally planned, but was even so an enormous pile with a massive tower 66 metres high, to carry the water tank for the water meter test-bed, and an immense electric clock —the landmark of Siemensstadt. A considerable number of the sheds and huts now disappeared—for the time being.

Rasehorn, the experienced Chief of the Measuring Instrument Department, was not destined to see the completion of the new building; he died in 1915. His assistant, Heinrich von Buol, was selected to succeed him. Von Buol was descended from an old Graubünden family which had made its home in Austria. He had joined Siemens & Halske as a young engineer, and by reason of his gifts had soon attracted the attention of his superiors. He took over the management of the new Wernerwerk M, now that the old Wernerwerk had been divided up into two separate, independent units: Wernerwerk F (Telecommunication) and Wernerwerk M (Measuring Instruments).

A third factory under Wernerwerk control was that of the former "Telephone Apparatus Works Zwietusch & Co. G.m.b.H." in Charlottenburg, at one time a subsidiary of the Western Electric, Chicago. By an agreement concluded with this Firm shortly before the war, the Zwietusch business was acquired by Siemens & Halske. About the same time, Siemens-Schuckert increased their manufacturing capacity by the purchase in 1917 of the Paper Mills of Marggraff & Engels, Wolfswinkel near Eberswalde. For years past this firm had supplied nearly the whole of its output to the Cable Works at Gartenfeld, so that the production of the factory was scarcely affected by the change of ownership.

The enormous pressure on the Works of the Hindenburg-Programme not unnaturally aggravated the existing difficulties in obtaining raw materials. For the Electrical Industry the crucial problem continued to be the shortage of copper. In many cases the fulfilment of new orders was conditional on the substitution of the existing old slow-speed machines by modern high-speed types, and the re-using of the much more liberal quantities of copper recovered from the former. Copper conductors were replaced by conductors of iron or aluminium, and even old, disused d. c. cables were dug up. Attempts were made at first to replace the copper in machines and apparatus by zinc, but in consequence of the treacherous characteristics of this metal, all these attempts ended in complete failure. Aluminium windings in machines and transformers were more successful, but did not permit of the full type-output being obtained. A serious catastrophe was the total lack of mica, which could only be purchased in the desired quality in India, and for which there was no real substitute. Shellac, too, was unobtainable, likewise serviceable cable compound. Substitutes proved to be worthless, with the result that cables could no longer be manufactured for potentials higher than 10,000 volts. Lubricating oils became progressively scarcer and poorer in quality. Leather for belts was soon no longer available, and the cellulose belting, which was to be used as a substitute, was totally inadequate. At the same time, prices rose from day to day, while the quality of the workmanship deteriorated. So many of the old experienced hands were with the colours that the remainder were too small in number to steady the mass of new auxiliaries engaged. The women, who contributed the largest quota, were often enough very unreliable through frequent absence from work, with the consequence that their numbers fluctuated continuously. Conditions became more hopeless as time went on.

When in the first decade of 1900 Germany decided to build the Grand Fleet, it was explained that this fleet was required to keep open the approaches to overseas markets in the event of war. This it failed to do. The far-flung cordon of the British blockade of the German coasts remained, generally speaking, effective, with the result described above. In view of the secret as well as open dissatisfaction of wide circles in Germany with the Government policy of timid restraint, the Admiralty obtained in 1916 the Kaiser's sanction to an attempt to challenge the enemy to a full-scale naval battle. With this object in view the German High Seas Fleet left its base in the Jade Bay on 31st May, 1916, and proceeded in a northerly direction. In the late afternoon its vanguard, consisting of torpedo boats, light cruisers and five battle-cruisers, sighted the enemy vanguard about the level of Jutland at the exit of the Skagerrak. In the engagement which followed, the so-called cruiser action, the British Admiral sought, in spite of fairly heavy losses, to draw the Germans within range of his heavy ships, of which one division of ships of the line had meanwhile moved up to his support. The main body of heavy German ships of the line arrived on the scene about the same time. This was the signal for the main engagement, in which the whole of the British Home Fleet soon became involved with six divisions of battleships. The attempt of Admiral Jellicoe at encirclement of the enemy from North, East and South was foiled by the oncoming darkness, and in the misty weather which followed, the Germans succeeded in re-forming further to the South whence they sailed for home on the following morning. Total losses in big ships of the British fleet were two battle cruisers and four heavy cruisers, these four forming a squadron, which went down with its admiral. On the German side, they were one of the older ships of the line plus a battle cruiser, which was abandoned on the way back to base, and four light cruisers. The tonnage loss of the Home Fleet was about twice that of the Germans.

The number of heavy calibre shells, i. e., 28—38 cm (11—15 inch) fired on the British side was 4,600, as against 3,600 by the Germans. In this connection it must be remembered that the heaviest German calibre was 12 inches. The British registered 100 and the Germans 120 hits. The fact that, of every 100 shots, only two or three found their target may seem surprising, but it must be taken into account that the British opened fire at a range of 20—22,000 yards which, as far as the big ships are concerned, was never shortened to less than 5,500 yards, that mist, smoke and approaching darkness rendered the enemy almost invisible, and above all, that a hit in naval parlance means a "direct hit." Of the ships taking part in the engagement, the battle cruisers suffered most, since they had already fought the cruiser action before becoming involved in the main battle. The British lost two of this class, viz., "Indefatigable" and "Queen Mary," each having sustained five direct hits and going down during the action. The Germans lost one battle-cruiser, "Lützow," which sank on the homeward journey after having received 24 direct hits.

Immediately after the return of the fleet, the Siemens & Halske engineers Braunersreuther and Schollmeyer were at the dockyard in Wilhelmshaven to render assistance in the necessary repair work, and to note what lessons were to be learnt from the "test of fire." Braunersreuther, as Grabe's chief assistant, had been the Liaison Officer between his Firm and the Navy, whilst Schollmeyer was the Engineer-in-charge of the erection staff which had been concerned with the installation and modification of the fire control equipment for several years past.

The severest damage had been sustained by the battle cruiser "Seydlitz," which was practically a cripple, and only limped into Wilhelmshaven in the evening of the following day, with 21 direct hits and 7,000 tons of water in the forepeak. The battle cruiser "Derfflinger," with 17 direct hits, did not look much better; the battle cruiser "Moltke," with 4 hits, had got off comparatively lightly. With the exception of what was completely destroyed, however, the equipment supplied by Siemens & Halske was still in full working order, and the Commanders and Artillery Officers of the battered ships were loud in their praise of the fire controls. It was to these, in their opinion, that the undoubted artilleristic success was due.

The Navy of the Kaiserreich was destined to live under the shadow of a tragic fate. It was the favourite child, not only of the Kaiser, but of the Nation, which was attracted by the idea of seapower with a kind of romantic enthusiasm. The ablest talent had been applied to making it as far as possible the perfect instrument of war, with what measure of success was demonstrated when it eventually went into action. Officers and men were carefully selected and trained, and their self-sacrificing bravery was also acknowledged by the enemy. In spite of this, the Navy has done the country more harm than good. Its growth called forth the embittered enmity of the British people, and when it came to war, the Navy not only did not solve the problem for which it was built (the battle of Jutland did not influence the further course of the war in any way whatever), but the declaration of ruthless submarine warfare drove the United States into the enemy camp, thus deciding the outcome of the war. That the Navy was subjected at the finish to the severest humiliation which a victor can mete out to the vanquished, was nevertheless undeserved.

When, in due course, the ships to be handed over were assembled in the Jade Bay in preparation for their last journey, Schollmeyer appeared of his own initiative, and went from one high officer to another in order to obtain their sanction to a plan which he had conceived in the meantime. The officers shrugged their shoulders—they were no longer in a position to give orders, and suggested that he should act on his own responsibility.

Eventually he went to the officers' mess of the flagship of the fleet, "Friedrich der Große," where he found the Supreme Council of Workers and Soldiers in convivial session. Discussion was somewhat promiscuous. Some of the members listened to what he had to say and agreed that the most important thing was that the rate of pay was two shillings per hour. Schollmeyer now called his men together, explained his purpose, and engaged the required number of helpers from among the unemployed dockyard hands and artificers, on the authority of the Workers' and Soldiers' Council. He divided up the men into as many groups as there were ships, and placed each group under the leadership of one of his men. The groups went on board the ships, and in the course of a few days of strenuous work carefully dismantled the whole of the fire-control equipment, leaving only the empty housings, properly sealed, in their place. As much of the equipment as could be taken ashore was stowed away in railway waggons, the rest was thrown overboard.

Thus ended the business in fire control equipment between Siemens & Halske and the Kaiser's Navy.

XXI.

THE LIQUIDATION OF THE WAR

November 1918 brought the Armistice and the end of the war. At the same time, it brought about the collapse of the hitherto existing form of government in Germany. The ensuing disturbances, which lasted several months before the new order of things began to take shape, have somewhat pretentiously been called a revolution. Certainly, the backsurge of soldiers from the front, and political agitation among the masses, were the cause of much unrest in the ranks of the workers. This took the form of numerous strikes, often for the most trivial reasons. The progressive depreciation of the Mark led to the well-known spiral action between wages and prices, which always accompanies inflation. The shortage of foodstuffs and raw materials continued, as the blockade remained in force during the armistice. When, on the conclusion of peace, in June of the following year, the frontiers were opened, the hopeless deterioration of the German currency was still a serious obstacle to the import of sorely needed supplies. The Siemens Directors were thus faced with a mountain of difficulties, to tackle which called for a large measure of courage and self-reliance.

For the House of Siemens the issue of the war meant the loss of the whole of its possessions in enemy countries, in particular, its Branch undertakings in Russia, England, France, Italy and Belgium. The Branches in Italy and Belgium were primarily sales offices, in which no great capital values had been sunk, whilst the French business could never have acquired great proportions. The undertakings in Russia and England, however, which had so largely contributed to the growth of the Firm in the early decades of its existence, were in a different category. The loss of these two Branches, measured in terms of manufacturing capacity, turnover, branch organization and skilled personnel was such as scarcely seemed possible to overcome.

Immediately after the outbreak of war the Russian Government began to take an interest in the two Siemens Firms as alleged German property. The attention of the Government was drawn to the fact that the main shareholder, Carl von Siemens, had been a Russian subject, and that this continued to apply to his sons-in-law and heirs, viz., the Baltic Barons. The effect of this was that the two Companies were allowed to carry on in the meantime, particularly as their production became of growing importance to the Russian war effort, and had to be increased as the war went on. After about a year, however, the Government appointed two Commissars to supervise the business. Later, this State supervision was extended by the appointment of an Administrative Council, coordinated with the Management and having the rights of a Shareholders' General Meeting, but which, in general, refrained from interfering in the affairs of the Works. It was not until the Bolshevist Revolution that Workers' Committees seized the management of the Works, with the result that soon confusion reigned, and output sank to about a tenth of its former value. Finally, the new Government decreed the expropriation of all industrial property without compensation. Thus assets to the value of about 50 million gold Roubles, the result of nearly sixty years' enterprise in Russia, were lost to the House of Siemens for ever.

Expropriation of the Capitalist without compensation was one of the main points in the Bolshevist creed. It affected Russians and foreigners alike, also the Titles to the State Loans contracted under the Czar and placed abroad, which were declared invalid in spite of the strongest protests of the foreign Governments. In view of the victorious outcome of the Revolution, the world just had to put up with this high-handed act, especially as all attempts to overthrow the Bolshevist Government by force had failed. What took place in England, however, and, in consequence of the English example, in the other countries of the enemy coalition, was basically something much worse.

During the whole of the nineteenth century it had been an accepted principle that wars were conducted between governments only. For the private individual, legally speaking, the war did not exist. Consequently it was out of the question for a government to seize property in its country, merely because it belonged to a national of a country with which it was at war. After all, what had this individual to do with the war? "Hostile" private property did not exist.

An exception to this rule, of course, was the traditional right of blockade and capture at sea, to which Great Britain clung tenaciously, notwithstanding the strenuous efforts of other countries to secure its abolition. Immediately on the outbreak of war Britain extended this practice very materially by continuously lengthening the contraband lists until they covered practically everything which could be carried by sea. Moreover, the British Government forbade "trading with the enemy," not only to its own nationals, but also to Neutrals through the system of "black-lists." On the 4th of February, 1915, the German Government as a reprisal proclaimed that it regarded the territorial waters around Great Britain, including the Channel as belonging to the war zone, adding that every trader encountered in this zone flying the enemy flag would be attacked and sunk. Taken in conjunction, these measures were equivalent to the final throwing overboard of the principle of non-participating private property. There was no longer any holding on the slippery slope. Immediately after the commencement of the war, Great Britain had forbidden the transfer to Germany of income from German undertakings on British soil; it now sequestrated the private property of foreign nationals. Siemens Brothers were thus placed under Government Administration after Köttgen, the only German on the Board, had been compelled to resign (and was shortly afterwards interned). Finally, on the 21st of January, 1916, a law was passed empowering the Custodians to sell "enemy property" for the benefit of the State. The shares of Siemens Brothers found their way into English hands and the new owners sold Siemens Brothers Dynamo Works to the English Electric Co. Again, all that remained to be done in Berlin was to write off the whole of the Siemens property in Great Britain.

What the Siemens brothers resented most, was the fact that the sequestrated Firm continued to be run under the old name. For this purpose, therefore, the German name was good enough. Altogether, the brothers were inclined to take the events in England more seriously than in Russia, and not without a certain amount of justification. In Russia it was a kind of earthquake, the complete upset of the existing social order; in England, however, it was the undermining of concepts, the preservation of which they were defending against the revolutionary Russians. Carl Friedrich von Siemens, in particular, for six years Chief of the English House, with many English friends and a certain predeliction for the English way of life, was unable to overcome the shock of these events as long as he lived. "They have even stolen our name," he was wont to say with bitterness.

Apart from the direct losses abroad, the war dealt the German Electrical Industry another very severe indirect blow. A large number of foreign countries, European in particular, had meanwhile found their own feet as manufacturers. During the war it had been impossible to obtain much from Germany, either owing to the blockade or because the parts in question were required for German armament. The export of machines and apparatus manufactured for foreign account was often enough stopped at the last moment. One consequence was a vigorous expansion of the Swedish Electrical Industry, with a corresponding acquisition of new customers. The same applied to the Swiss. In Italy, too, as also in the newly established countries of Austria, Czechoslovakia and Poland, a national electrotechnical industry took shape. In most cases, the firms in question specialized in the manufacture of motors, wiring materials, meters, telephones, measuring instruments and also cables. These new factories not only covered home requirements, with a corresponding loss of business to Germany, but they exported as well, mostly to the Balkan countries. In addition, the United States had found their way into the extremely important South American market, and now appeared as competitors in Spain. Japan had grown up, and was already exporting electric lamps at prices which, thanks to its cheap labour, were below those of any competitor. Then there was the dislike of everything German as a consequence of four years of war-psychosis. With all this lost, what, it might be asked, was there left of interest in the world?

Wilhelm von Siemens emerged from the war a broken man, almost envying his brother Arnold (who died in the Spring of 1918) the merciful destiny of having escaped these latter events. In addition to the mental stress, there was the circumstance that he had held it to be his duty scrupulously to observe the rationing regulations, although it would have been an easy matter for him to have evaded them. In this sorely depressed condition, the doctors sent him in the summer of 1919 into the mountains to recuperate, where he himself hoped to recover sufficiently to enable him to resume his duties. But the hope was deceptive; in October 1919 he died as the result of an internal hemorrhage.

In the course of the long years of collaboration on the part of Wilhelm and Raps, a feeling of warm friendship had grown up between them. It had occasionally been compared to the relationship between Wilhelm I and Bismarck. Raps admired the sincerity of character of his Chief, and his sense of duty and loyalty towards those whom he trusted. Wilhelm von Siemens admired in Raps the inventive genius which was characterized by a streak of artistry, as well as his energy and tenacity in carrying through what he considered to be right. The result of the war had also struck Raps a heavy blow at the root of his being, in particular the scuttling of the fleet—his fleet. On receiving the news of the death of his Chief, Raps experienced a nervous breakdown which confined him to his bed. In spite of every effort to restore him to vigour, he died in April 1920 in consequence of a stroke.

It thus fell to the lot of Carl Friedrich von Siemens as the last surviving son of the founder of the House to take over the parental heritage. He was fully conscious of the magnitude of the task. Something had to be found to take the place of war work; the shops had to be re-educated in rational and competitive methods of working; the workers had to be sorted out again into cohesive groups; reorganization was inevitable in numerous directions; in particular, the sales organization abroad had to be built up again; above all, the main problem was how to deal with the depreciation of the currency, the effects of which were daily assuming more threatening forms. His two brothers had previously divided the formal responsibility between them, in that Arnold was Chairman of the Board of Directors of Siemens & Halske, whilst Wilhelm occupied the corresponding position on the Siemens-Schuckert side. Carl Friedrich was now obliged to assume both posts in person. Actually, this was nothing else than the position which his brother Wilhelm had always occupied. In consequence, he laid down his existing office of Chairman of the Managerial Board of Siemens-Schuckert. The choice of a successor caused him some difficulty. Candidates were Köttgen and Henrich, a couple which had sometimes jestingly been called the Dioscuri. Köttgen, certainly, had only just returned from internment in England, and had been abroad since 1908, whilst Henrich had been in charge of the largest and most important department, i. e., the Industry Department, throughout the war. Carl Friedrich, therefore, decided in favour of Henrich, although not without certain misgivings. In contrast to Köttgen, Henrich's manner did not make him exactly popular with his fellows.

Since Bödiker's retirement and the founding of the Siemens-Schuckertwerke, there had no longer been a Chairman of the Siemens & Halske Managerial Board. Due to the circumstance that numerous Directors were on the Managerial Boards of both Companies, there was a certain amount of vagueness in the matter of seniority, which Wilhelm had permitted (perhaps intentionally) to continue. Thus Raps had never occupied the Chair of the Board of Management, but had always been just the Manager of the Wernerwerk. Franke, who had been his deputy and presumptive successor for many years, now took his place as Chairman of the Board. On the Siemens-Schuckert side Henrich, who had suddenly been compelled to retire for personal reasons, was just as naturally replaced by Köttgen as Chairman of the Board of Management. Carl Friedrich thus had the support of two men who were equal in every way to their tasks, who enjoyed the respect of their colleagues, and were deserving of his complete confidence.

In 1922 he was in his fiftieth year and in his prime. In 1920 he had been elected a member of the first Reichstag of the Republic, where in accordance with his pronounced liberal view he took his seat with the "Democratic Party." In this he acted in contrast to most others of his own rank, who preferred the "People's Party." In Parliament he soon discovered that he was regarded by the politicians as one of the leading figures in the German economy, and that, not so much by virtue of the undertaking over which he presided, but of his personality. He himself was no longer in doubt that he would succeed in mastering the task which fortune had meted out to him.

Changes had meanwhile also taken place in the Management of the AEG. Emil Rathenau had died in 1915 in his seventy-seventh year, although only a few years earlier he had still guided the undertaking of his creation with a firm hand. His two sons, Erich and Walter, had the reputation of being exceedingly gifted, and it is probable that in spirit the father had seen the growth of a Rathenau dynasty beside that of Siemens. But Erich died at an early age before he was fully mature, leaving the hopes of the family concentrated on Walter, who advanced rapidly as a young electrical engineer in his father's firm. Engineering and business, however, were not enough to fill his life; his active mind was engrossed with all manner of problems which were continually coming to the surface of the agitated spiritual life of those days in Berlin, and it was not long before he discovered his literary talent. During the war, he took an interest in the organization of raw material supplies, and in this connection developed numerous ideas of economic planning which were foreign to those hitherto held by pre-war capitalism. When, after the demobilization, he took over the Management of the AEG in his late father's place, he soon found himself in disagreement with other authoritative personages in the Firm, who did not share his views. A public speech with a political tendency, in which he made several rather pointed allusions, was badly received in certain quarters, and severely criticized within the Management and the Board of Directors. He resigned from his Office in consequence, and Felix Deutsch, his father's old companion in harness, was made Chairman of the Board of Management. Walter Rathenau entered the field of politics, which in any case suited his temperament better than business. He became Foreign Secretary, and was one of the promising lights of the young Republic when he was struck down by an assassin in June 1922.

The Peace Treaty, amongst other things, placed German industry under a number of restrictions regarding the manufacture of war materials, and arranged for these to be supervised by an Allied Commission. Since the Commission consisted only partly of professional soldiers, but also of members who in earlier life had been engineering experts, industrial circles in Germany were not unnaturally apprehensive lest this supervision should develop into a dangerous organization for industrial espionage. Firms which had put their Works back on a 100 % peacetime basis could, after satisfactory test, obtain an official certificate exempting them from further inspection. Now, most of the Works in Siemensstadt and Nuremberg had ceased the production of shells, detonators, machine-gun parts and other alien objects immediately on demobilization, whilst the whole of the aircraft paraphernalia disappeared from the Dynamo Works and the Nuremberg Transformer Works. The manufacture of submarine motors and their accessories ceased at once, the more so, as in any case these had been forbidden to Germany for the future. It was only in the Wernerwerk that the separation of the war material presented any difficulty, since the retention of a small navy had been sanctioned, for which a certain amount of specialized electrical equipment was necessary. In order to start with a clean slate, it was decided, on Franke's suggestion, to establish a separate Firm to deal with this equipment. Since 1908 a Company had figured in the Berlin Official Commercial Register called the "Gesellschaft für Automatische Telephonie." After Siemens & Halske had decided to buy out the other members of the Research Company and to develop the automatic telephone business on their own responsibility, the telephone company had become an empty shell. It was therefore re-named "Gesellschaft für Elektrische Apparate," and a disused workshop rented in Marienfelde, near Berlin. Since there was practically no demand for such equipment at first, the Company, in order to keep it in being, was given the assignment to develop and manufacture corresponding apparatus for the Merchant Navy. Contact was also made with a small Dutch engineering Works in Hengelo, one of the partners of which, a certain Mr. Hazemeyer, had founded a new undertaking which he named "Hazemeyer Signal." In these Works, which soon commenced to flourish, the further development of the fire control equipment was taken in hand, and it was found to be of considerable interest to the navies of the smaller neutral countries. In this way it might be hoped to reap some reward for previous labours. Amongst those engaged in this branch of the business, there were also some who were thinking in secret that things could not remain as they were for ever; one could never know what the future had in store.

A further much more important change in the scope of the Siemens products was not due to the Peace Treaty, but to a transaction which, as in 1903, forced the House of Siemens rather unexpectedly to take a decision which it would certainly have preferred to avoid. In the manufacture of incandescent lamps, the exchange of patents in 1911, followed by the introduction, two years later, of the gas-filled lamp with coiled filament, had left little room for noticeable technical differences between the lamps of the three main German producers, viz., Siemens, the AEG, and the Auer Company. For all practical purposes, the lamps made by the three Companies were the same, apart from differences in the scale of ratings, external shape and modifications to meet special requirements. The obvious thing would have been to re-constitute the Syndicate for carbon filament lamps (which was dissolved shortly before the war), but for metal filament lamps. At least, the Syndicate could have included the three above-mentioned partners, who had already adjusted their respective outputs by mutual consent. It was agreed to discuss the matter at a convenient time. In the late summer of 1919, when Wilhelm von Siemens was spending his last holiday in the mountains, from which he was not destined to return alive, the world was startled by the announcement that the Auer Company had sold its Lamp Works to the AEG. To be more precise, it meant that Arthur Koppel, Geheimer Kommerzienrat and practically sole owner of the Auer Company, had joined with the AEG to form a new Company, to whom the two partners had assigned their respective lamp works. The share of the AEG was stated to be 72 %, that of the Auer Company 28 %, thus securing to the AEG undisputed majority rights.

However, the agreement contained a further clause: Siemens & Halske were to be given the option of joining the new Company with the provision that, in the event of their also bringing their Lamp Works, the ownership ratio as between the AEG, Siemens and Auer should be 40 : 40 : 20.

What was to be done? Here, for the third time, the Firm had been manoeuvred into a position which meant renouncing the independent pursuit of an important branch of electrical engineering. The first time the matter had ended with the establishment of the Accumulator Factory, the second with the birth of Telefunken. Siemens, however, preferred to be free from such ties as far as possible. Their only advantage was that they usually proved to be quite lucrative, but otherwise they were the cause of constant annoyance and a continual reminder that one had relinquished the right to participate in the scientific development of the product in question.

Should they refuse, then? In that case they would find themselves opposed by a considerable superiority in output. The proposed ratios corresponded roughly to the actual manufacturing capacities, and in the event of Julius Pintsch later joining the others, the scales would be still more heavily weighted against them. To this a psychological factor of internal import must be added, which in these times of general foment carried greater weight than would ordinarily have been the case. The more the large undertakings had split up into individual specialist firms, the looser had the contact between the Heads of the undertakings and those of the specialist members become; the latter soon began to regard themselves as manufacturers in their own right. The more numerous, on the other hand, were the points of contact between those of equivalent status representing different undertakings. Men met in standardization committees, at price control meetings, syndicate meetings, exhibitions, etc., and the greater the similarity and standardization of the products, and the more closely they answered to the appellation of "goods," the fewer were the divergencies of opinion; a community of interests grew to a corresponding extent. Politicians and economists are in error when they believe that greater efficiency and economy are always the motives underlying industrial fusions; in many cases the personal inclinations and interests of the executives concerned also supply part of the driving force.

Thus, in the second half of 1919 the "Osram G.m.b.H. KG" came into existence, comprising Siemens, the AEG and the Auer Company with their respective lamp factories. It was agreed that the Partner Firms should continue to supply users (mostly large firms) directly, whilst dealers (which represented the majority of the customers) should be supplied through a new marketing organization of the Osram Company. And so, after a life of some forty years, the incandescent lamp departed from the House of Siemens.

Since the introduction of the metal filament lamp, the technical pioneering work had been continued in Germany and the U.S.A. Here, too, were the leading figures of international lamp business, in spite of the fact that quite substantial lamp factories had meanwhile been built in Great Britain, France and Austria-Hungary. Whilst the bulk of their output was for the home market, it was often the case that the national façade was a camouflage for the participation of the big German and American houses. All this changed radically as the result of the war. To some extent, particularly in England, the German factories had been transferred after sequestration to English ownership, and were now competing with Germany under their own name, i. e., Siemens or Osram. For the most part, however, since something had to be done, and German lamps were unobtainable, the existing small lamp factories were considerably extended and re-established under national-sounding names, with which the public presently became familiar. In Italy, Spain, Sweden, Switzerland and the Netherlands there were now also lamp works of some importance, and in Japan the hitherto meagre Lamp Industry had shot up as in a hothouse. Not only had Japan become independent during the war, but had even begun to export, at first to the Far Eastern countries and later to Europe. In 1925 Japan had about 75 lamp factories with a total output of 85 million lamps per annum. Of these factories one was large, several of medium size and the rest small, many of the latter employing the cheapest class of home labour. The quality of these lamps, usually small units, was the poorest imaginable, but at the low prices charged they found a sale.

The most remarkable newcomer to the ranks of the international lamp manufacturers, however, was an undertaking in the Netherlands. In 1891 Frederik Philips and his son G. L. F. Philips, an engineer, had jointly established the firm of N. V. Philips' Gloeilampenfabrieken in Eindhoven, with an initial capital of 150,000 Guilders. A few years later they were joined by Anton F. Philips. In the first decade of the new century the business had already attained considerable proportions, especially as, by agreement with the German Firms, they had acquired the right to manufacture tungsten filament lamps. In 1912 their share capital amounted to almost six million Guilders. Nevertheless, up to the war Philips did not manufacture the whole of the ancillary parts himself, but imported some of them from Germany. The war compelled Philips to become self-supporting, and to establish his firm on a very broad basis. He bought up other Dutch lamp factories, and either acquired or built further factories in Belgium, Spain, Switzerland and Poland. He took up shares in a large firm in Sweden, commenced the manufacture of amplifier tubes, whence it was but a short step to wireless broadcasting apparatus, which was just then commencing to be popular. He systematically trained a large staff of technical assistants for the development of this business, built well-appointed laboratories, and spared no expense to secure a scientifically commanding position for his firm in this sphere of interest. Thus, almost overnight, a factory of world repute had grown up on Dutch soil, in which the manufacture of lamps was no longer the sole object, although Philips ranked after the General Electric Co. and the Osram Company as the third largest producer in the world.

Under these circumstances, it was not long after the end of the war before the idea cropped up of combining the price control arrangements for lamps of the various countries, to form one international price ring. This succeeded only within a fairly restricted area, however; only the most important undertakings in Europe became members, excluding Great Britain, France, Belgium, Spain and Sweden. Since, in view of its recently introduced system of State Capitalism, Russian participation was out of the question, it meant the restriction of the organization to Central Europe, Holland and Italy. The "International Incandescent Lamp Price Association" was established in 1921 with its headquarters in Berlin (significantly). It endeavoured to fix uniform prices for the individual countries, the maintenance of such prices on the part of the members being made compulsory by fines. Since it is difficult in the case of such a mass product as the incandescent lamp to fix prices without quotas, several attempts were made to control production by mutual agreement. These, however, never got beyond the initial stages. It soon became apparent that the powers at the disposal of the Association were insufficient to compel compliance on the part of the members. The collapse of the various currencies, that of Germany in particular, provided the contraveners of the Association Rules with cheap excuses for their selfish attitude. The Association thus succumbed to anarchy, and was dissolved three years later.

When it became clear that there was no prospect of success along these lines, a number of the larger companies, not limiting themselves, as hitherto, to Central Europe, attempted to come to an agreement amongst themselves, which also included exchange of patents and experience. Following the patent agreement concluded before the war between the American G.E.C. and German firms, to which Philips very soon added his signature, agreements of this kind had become increasingly frequent. There was much manufacturing experience which could not be sealed off by patents, and the preservation of Works' secrets was proving more difficult as the operatives grew in numbers. Many works preferred, in consequence, to discuss production methods with competitors in the hope of thereby reaping some advantage, instead of a doubtful policy of secrecy. Man's craving for light was great, lamps were always in demand, so that poor quality of the product could do more harm to the common interests of all manufacturers than it could help the competitor. This had been proved most clearly in the case of the cheap Japanese lamps. Seeing the "Big Ones" thus playing with their cards on the table, the smaller manufacturers gradually followed suit, the result being the establishment in 1924 of a new body, viz., the "Phoebus S. A. Compagnie Industrielle pour le développement de l'éclairage" in Geneva, which was one of the most interesting known attempts to control a branch of world trade.

The "Phoebus" Company was the organization which was to give effect to the "General Patent and Development Agreement" to be concluded simultaneously between the contracting parties. As the title of the Agreement states, its object was to effect a general exchange of patents and experience by way of licences, although this was not compulsory. Indemnification for the handing over of experience to another was settled by a court of arbitration if the parties could not agree amongst themselves. The far-reaching standardization of manufacturing methods went a long way towards levelling the manufacturing costs of the various manufacturers, which is one of the most important conditions of a uniform price policy.

Phoebus was also an Association for controlling prices and sales. Selling prices within the individual countries were laid down at meetings of the members, it being left to members to decide whether or not to establish joint sales organizations.

The United States and Canada remained formally outside the Agreement, but for a long time past there had been a series of agreements in existence between the chief members of Phoebus and the big American firms. In practice, therefore, the agreements were respected by the Americans, the more so as care had been taken when they were formulated not to prejudice American interests.

When it was stated above that Phoebus was "also" an Association for controlling prices and sales, this meant that it had outgrown the original object of a price ring, which is to secure satisfactory conditions of production for its members. It had developed into an economic system, to which the favourite Anglo-Saxon term "co-operative" can properly be applied. It is this system which is nowadays being recommended in the form of supra-national organizations for joint economic planning, as the best means of overcoming political differences. Whether such an amalgamation of certain branches of Industry is brought about by Governments, or on the initiative of the parties concerned, is probably immaterial as far as its ultimate success is concerned. As things are to-day, Government leadership is likely to be preferred, in order to allay at the outset any fears as to the misuse of private economic power. This does not alter the fact that the Phoebus Association can be regarded as a kind of pace-maker for ideas which are being looked upon to-day as the epitome of wisdom in the quest for international understanding.

One of Wilhelm's last organizational acts was the founding of the Research Laboratory. From the earliest times, laboratories had been looked upon by Siemens & Halske as one of the most important factors in development work. The first large laboratory to be established, in addition to Werner Siemens' private laboratory, was that of Frölich, who studied all manner of things, from the torsion dynamometer to ozone. Later, the electro-chemical laboratories of Engelhardt in Vienna and of Erlwein in Besselstrasse, but above all the incandescent lamp laboratory, came into existence. Schuckert, too, before the fusion with Siemens & Halske, also possessed a development laboratory for meters and instruments. When the various works came to be built in Siemensstadt, each unit had at least one Works' laboratory for day-to-day material testing, the Cable Works being particularly well equipped in this respect. The Wernerwerk maintained quite a number of development sections with laboratories, both for tele-communication work (the Schwennicke laboratory for teleprinter development has already been mentioned) and, especially, for measuring instruments, all of which eventually occupied an entire wing of the Works. Each of these laboratories, however, was designed for a specific purpose. One, for instance, would be working on amplifier valves, another on a. c. instruments, a third on pyrometers. In addition to these, and quite separate from the manufacturing side, there was the physical-chemical laboratory, which was originally installed at Bohneshof near Charlottenburg, later moving into rather primitive temporary quarters in Siemensstadt, known locally as the "Doctor's Dungeon." It was here that Bolton had succeeded for the first time in producing tantalum, and here that all problems came to be dealt with, which went beyond the scope of any one Works. Budde, who was formally in charge of research, retired in 1911, and Bolton died a year later. Wilhelm von Siemens then appointed Bolton's colleague, Dr. Hans Gerdien, to be Chief of Research. Gerdien was a former lecturer at Göttingen University, and had been called some years earlier by Wilhelm to the laboratories. As Chief of Research his position was by no means an easy one, for amongst the Works Managers, the majority of whom were members of the Managerial Board, there were few who were prepared to admit the necessity for such laboratories. It required the full weight of Wilhelm's authority to reach agreement on the essentiality of "free" research in Industry. Based on a proposal by Gerdien, the research laboratories, collectively, were henceforth called the "Research Laboratory of the Siemens Works," and an extensive building plan was agreed to. Work on this commenced in the Summer of 1914, but was interrupted by the war and not completed until 1919. Wilhelm von Siemens thus did not live to see the birth of one of his favourite children. Carl Friedrich, who under Henrich's influence had at first taken a somewhat sceptical view of the matter, now regarded it as one of his principal duties to watch over and promote his brother's heritage, having learnt meanwhile how "free" research could be productive of results, which were destined to be of the greatest economic importance to his House.

The building of the Berlin Elevated and Underground Railway gave rise, as has already been told, to the formation of a section which, contrary to the accepted rules of speech, called itself the "Electric Railway Department," and was not to be confused with the "Department for Electric Railways." The former had, amongst other things, brought the system of ground-water lowering by means of numerous artesian wells to a high state of perfection, and maintained a large staff of constructional engineers. These disposed of a fund of experience in difficult foundation work, the erection of hydraulic structures, the building of tunnels and bridges, the laying of railway tracks, and the raising of ferro-concrete structures. The engineering staff was supported by numerous competent foremen and craftsmen, not to mention equipment of all kinds. The decline in building activity in Berlin, however, rendered it necessary to find other work, and this actually lay at hand in connection with reparation contracts, and other projects at home and abroad. It was no longer possible, however, to run the business under the name "Electric Railway Department," and it was therefore decided in 1921 to form a new company called the "Siemens Bauunion G.m.b.H., Komm. Ges.," in which Siemens & Halske and Siemens-Schuckert held equal shares, and which took over the personnel, equipment and business of the former Company. Contrary to expectations, deliveries on the reparation account did not amount to any substantial proportion of the new Firm's turnover, but it nevertheless soon commenced to flourish. It began its activities with the building of hydro-electric power stations, weirs, inlet ducts, penstocks, high-pressure pipelines, turbine rooms and tail races, all of which placed great demands on the skill of the engineer. It also took up the construction of harbour works, locks and bridges, designed underground railways, water works, sewage plants, factory buildings and skyscrapers, and quickly acquired a high reputation abroad, particularly in South America.

The first few years in Germany after the conclusion of peace were characterized by continual changes in the ownership of property, brought about by the tremendous industrial convulsion of the war. One of the most notable examples was connected with the name of Hugo Stinnes. Following the establishment of the Rhine-Westphalian Electricity Undertaking (RWE), in which he was partly instrumental, he acquired the assets of the "A.G. for the Iron and Coal Industry, Differdingen-Dannenbaum," in liquidation. This Company owned a small ironworks in Luxembourg, and a colliery at Bochum in the Ruhr. Stinnes converted it into a new Company with the title: "Deutsch-Luxemburgische Bergwerks- und Hütten-AG." (German-Luxembourg Mining and Ironworks

Company). This Company now became a 'collecting box' for his further purchases. Almost every year a further Ruhr colliery or a small ironworks was added to the bag, until in 1910 the old and respected, although not always well-managed "Union A.G. für Bergbau, Eisen- und Stahlindustrie" in Dortmund, with its extensive properties, brought the capital of "Deutsch-Luxemburg" up to 100 million Marks. Two years later the capital was again raised by 30 millions. But Stinnes did not confine himself to 'collecting for his box.' Possessed of practical working knowledge and with a happy knack of choosing the right men, he reorganized the various Works and arranged for their production to dovetail into each other, so as to achieve an overall balance. The process of expansion continued unabated throughout the war, with the result that at its close Stinnes was the master of one of the largest mining concerns in Germany.

Another large agglomeration of a similar kind was due to the initiative of Emil Kirdorf, although belonging to an earlier period. In 1873 the two collieries Rheinelbe and Alma, both near Gelsenkirchen, were amalgamated to form the "Gelsenkirchener Bergwerks-A.G.," under the management of Emil Kirdorf. Around this nucleus Kirdorf grouped a large number of other collieries, acquired the Works of the "Aachener Hütten Aktien-Verein zu Rothe Erde," near Aix-la-Chapelle, the "Schalker Gruben- und Hüttenverein" in Gelsenkirchen, and the "Gesellschaft Vulkan" near Duisburg; shortly before the war he built a large-scale ironworks at Esch in Luxembourg, and linked this up with ore mines, blast furnaces, steel and rolling mills in Siegerland, tube mills in Düsseldorf, shipping companies on the Rhine, and coal merchanting firms. An extremely powerful combination had already grown up in this way before the 1914 war. As Head of the combine, and also founder and controller of the "Rheinisch-Westfälisches Kohlensyndikat" Kirdorf was looked upon as the Nestor of the much-admired and much-hated mining lords.

In 1920 Stinnes, then in his prime, succeeded in convincing the seventy-three year old, and socially reactionary, Kirdorf that the best way to meet the onrush of the Unions and leftist trouble-makers was by a powerful association of the employers. The two undertakings therefore concluded a pooling agreement, to last 80 years, which they called the "Rheinelbe-Union." The Rheinelbe-Union shortly afterwards acquired a majority holding in the "Bochumer Verein für Bergbau und Gußstahlfabrikation A.G.," in Bochum (a Company owning two large ironworks as well as coal, ore and potash mines), thereby controlling almost a quarter of the production of the Ruhr district. Hugo Stinnes, as the actual Principal, thus had the control of this mighty economic machine in his hands.

Beside the Rheinelbe-Union Stinnes had his own private Concern, the origin of which were the inherited collieries, to which a considerable number had since been added. In addition, he owned or controlled electrical generating stations, engineering workshops, shipyards, shipping companies, hotels, iron and coal merchants businesses, oil companies, forestry concessions, timber merchants businesses, cellulose and paper mills (these in great numbers), chemical works, publishing firms, printing works and newspapers. Several large German press publications voiced his political principles (incidentally, he was a Member of the Reichstag).

Besides embittered opponents, mostly from left-wing political circles, an industrialist with such a record also has numerous admirers and heralds, who endeavour to explain to the public at large the secret of his success. In his case they believed they had found it in the principle of the vertical combination, meaning by this slogan that it was particularly advantageous to combine processes which follow each other naturally in point of time. From coal and ore we obtain iron and steel; from the latter, rolled sections and forgings, which are supplied to machine shops and shipyards, who use them to build ships, which in their turn ply in the service of shipping companies. Forestry, timber merchanting, cellulose manufacture, paper making and printing are a further example of a vertical combination. Now, the realization of this principle was not exactly new. Krupp, for instance, had commenced decades ago to make his steel products into finished cannons, and when the shops were grouped together, not only on paper, but in reality, it is probable that economic advantages accrued. Why it should be necessary, however, for a coal merchant to possess an overseas shipping line, or why a shipping line must at all costs have an hotel in Hamburg is no more convincing than that a newspaper publisher, to be successful, must have a pine forest at his back. When, however, such slogans as that of the natural importance of vertical concerns have once gained currency, they are repeated by the great majority without the slightest attempt at criticism.

One of the admirers of the great man was Otto Henrich, who had formerly come into contact with him in business. A suggestion of Stinnes to extend the principle of the vertical combination to embrace the Mining and Electrical Industries had, in Henrich's case, fallen on fruitful ground. Statistics for the last year before the war showed that the German Electrical Industry had a consumption of about 450,000 tons of iron and steel, as compared with 90,000 tons of copper and 80,000 tons of other metals. The figures for the remaining raw materials, such as textiles, insulation materials, porcelain, oil and chemicals were correspondingly low; much more than half of the raw material consumption was of iron and steel. Here, therefore, was another case in which an organized combination of the iron producer with the consumer would be of advantage to both: "From Coal to the Electric Lamp."

The figures were correct, but misleading, for it is not only the weight of the materials that matters, but essentially the use that is made of them, especially in a case like the Electrical Industry with its output of highly refined products. An oscilloscope, for instance, may cost several thousand Marks, according to type, but embodies hardly a hundredth part of its sale price in the purchase of iron and steel. Henrich, however, saw only the large machines to which he had been accustomed all his life. Moreover, the argument, quite right in itself, was put forward that an association between the Iron-producing and Electrical Industries could lead to common scientific study, in the course of which each would gain better knowledge of the needs of the other, and would profit by the experience gained. A widely-based plan was worked out for scientific collaboration between the House of Siemens and the Rheinelbe-Union, with which it was hoped to render the idea of a pooling agreement palatable to the Head of the House of Siemens. Financially, the scheme envisaged the independence of the partners and the formation of a Holding Company, into which they would pay their profits in accordance with an arranged scale. The contents of the pool would then be divided between the partners in an agreed ratio.

The combined efforts of Stinnes and Henrich finally succeeded in winning over Carl Friedrich von Siemens to the plan. His inward, perhaps unreasoned, resistance was met, in the first place, by the argument that the independence of the House was to remain unimpaired, as the only obligation to be undertaken concerned a division of profits. The second weighty argument was the idea of collaboration in scientific and technical research. Thus an extraordinary general meeting of Siemens & Halske at the end of December 1920 resolved to participate in the formation of the "Siemens-Rheinelbe-Schuckert-Union."

The occasion was taken to vote an increase in the capital, as it was felt that the existing 63 million Marks no longer corresponded to the scope of the undertaking for one thing, nor to the depreciated value of the Mark for another. The capital was doubled, bringing it to 126 millions; in addition, 4,000 further shares were issued, thus increasing the total of the Ordinary Share Capital to 130 million Marks. Preference Shares were issued to the same amount as the Ordinary Share Capital, so that the total capital now amounted to 260 million Marks. It must, of course, be remembered that the two categories of shares differed in intrinsic value, for the Preference Shares were, in fact, merely paper currency. With the object of further strengthening the capital basis, Siemens & Halske invited subscriptions to a debenture loan of 60 million Marks at 4½%.

The Firm's adviser in these transactions was Max Haller, in whom Carl Friedrich von Siemens had secured a Finance Director of very rare parts. Haller joined the Firm in 1911 as an engineer; five years later he was made a deputy member of the Managerial Board. This was not on account of particular brilliance as a technician, but because of the discovery that here was a man who regarded financial matters from a totally different angle to that of customary business routine. For Haller, money had no value in itself, but was merely a measure of other values and one which, owing to its own instability, was difficult of application. Through the figures of the balance sheet he always saw the real values. At the close of the war he became a full member of the Managerial Board. He was one of the first to realize the cause and meaning of inflation. Whilst others were still intoxicated by the big figures, Haller clearly saw the coming financial and economic collapse which these figures heralded. He did not cling to the Dollar, as others did, when it became the stable measure of currency in Germany, but had an imaginary currency of his own in which he was accustomed to reckon. In the most difficult period of galloping inflation and subsequent stabilization of the Mark, he became a master of finance who commanded the admiration of the whole German industry.

Hardly had the conclusion of the pooling agreement become known, than articles appeared in the daily papers and journals to the effect that Siemens, too, now belonged to the Stinnes Concern, just like some hotel, timber-merchant or paper mill. Although, of course, allowance had to be made for ignorance and stupidity on the part of the writers, Carl Friedrich von Siemens was nevertheless annoyed to find the essence of the transaction so misrepresented. Blunt denials were issued to the Press, but an uncomfortable feeling remained, which was strengthened by occasional criticisms heard within the House itself. The question was asked, for instance, as to the advantage of the agreement from the point of view of the Central Station Department, or the Traction Department. To the Wernerwerk, above all, with its wide interests centered chiefly in the Government Departments, e. g., the development of the inter-European telephone system, this combination appeared to be quite outside its sphere. What was the use of facing the rigours of competition with Sweden and the U.S.A. in order that the profits be handed over to the Steelmen? In this case Henrich appeared to have placed the interests of his Department on a level with those of the whole House.

Whilst considerable doubts were thus being expressed regarding the propriety of the intended division of profits, it soon transpired that it was not feasible until the German currency had been reformed. In an undertaking which uses a large proportion of imported raw materials, and exports about one third of its produce, the determination of the prime costs must proceed along other lines than in an industry whose chief raw material is the native coal. Even in the case of those electrical manufactures which are sold at home, the long delivery periods caused considerable difficulty in assessing the prime cost. Since the value of the Mark continued to sink from day to day, it was impossible to agree on a fixed price, as on the date of the order, for a large machine which might not be completed until a year later. Instead, it became necessary to resort to a complicated system of settlement involving many disputes, and one which, in addition, required frequent modification. It was impossible to arrive at an authentic figure for the profits from such an unstable basis. The idea of the Pool thus had to be deferred for the time being.

In the Spring of 1924, about the time of the publication of the Dawes Plan and the beginning of stabilization in Germany, Hugo Stinnes died. Had he been able, in person, to effect the transition of his combines to the new order of things, he might have succeeded in retaining the major portion under his influence. As it was, however, the bubble disintegrated under the pressure of the Gold-mark balances more quickly than it had been formed. The Siemens-Rheinelbe-Schuckert-Union had thus become meaningless; all that remained to do was to liquidate the structure which, in any case, had only existed on paper. The process of winding up took longer, however, than suited Carl Friedrich's impatience. The Gold-mark balance sheets for 30th of September, 1924, could not be prepared before the Spring of 1926. The statements of net profits presented by the several partners were as follows. The Gelsenkirchen Bergwerks-A.G.: 1,772 millions; the Deutsch-Luxemburgische Bergwerks- und Hütten-A.G.: 1,914 millions; the Bochumer Verein für Bergbau und Gußstahlfabrikation: 0,131 millions; together 3,817 million Gold-marks. By comparison, the Siemens figures were, Siemens & Halske: 6,245 millions; Schuckert: 1,970 millions; and Siemens-Schuckertwerke: 8,955 millions; for the whole Siemens group, therefore, a total of 17,170 millions Gold-marks net profit. Account must, of course, be taken of the fact that the period under consideration, the first year of the stabilized Mark, was still suffering from the effects of the Ruhr disorders, and that the losses occasioned by their suppression figured in the accounts of the collieries for that year. Even when allowance for all this was made, however, the discrepancy between the two sides was so wide that the Siemens group could not be expected to continue in such an unequal partnership.

Albert Vögler, for years past Stinnes' confidential adviser and executor of his will, admitted this freely when Carl Friedrich von Siemens suggested the early formal dissolution of the pooling agreement. It was the more justified, as in consequence of the dismemberment of the Stinnes Concern, the whole structure of the Rhine-Westphalian industry had begun to move in search of a new orientation. As the result of this process of re-formation, and after protracted negotiations, a new Combine came into being called the "Vereinigte Stahlwerke" (United Steelworks), the core of which was the former Rheinelbe-Union and the Thyssen undertakings. Associated with them were all the larger ironworking units of the Ruhr industry with the exception of Krupp, the Gutehoffnungshütte, the Hoesch Iron and Steel Works and the Klöckner-Concern.

The scientific collaboration and the combination of the research facilities of the two partners had, nevertheless, been found to be beneficial and productive of many new ideas. Criticism of each other's products had in many cases led to improvement in quality, and many useful improvements had been made and introduced into the manufacturing process. Vögler was a man with a very alert mind and astonishingly versatile, as engineers go; vivacious and courteous in manner, Carl Friedrich von Siemens found him congenial. Vögler's suggestion, therefore, that the Siemens group should transfer the former agreement regarding collaboration in technical research to the Vereinigte Stahlwerke was readily assented to. An agreement was concluded late in 1927 under the title of "Stahl-Elektro-Union," which gave legal effect to this resolve. In accordance with a sliding scale based on the distributed profits, annual contributions were to be made to a common pool from which certain branches of research and experimental work were to be financed. A number of expert committees from both sides were to decide upon the best use of the funds, and to issue regular progress reports. In this way, the intervening years have witnessed the investigation of many new ideas which might otherwise never have been possible. As is usual in such cases, each party sent delegates to the Board of Directors of the other. Albert Vögler joined the Boards of Siemens & Halske A. G. and Siemens-Schuckertwerke, where he gradually formed a friendship with Carl Friedrich von Siemens which, in course of time, came to exceed that of a mere business acquaintance.

The first few years after the war in Germany were darkly overshadowed by the question of reparations. In accordance with the Versailles Treaty, Germany was under obligation to pay a war indemnity in an amount yet to be fixed. The interminable bitter dispute as to the sum total and the annual contributions not only poisoned the relations between Germany and its former opponents, but was preventing the return of healthy conditions of world trade. Things reached a climax when French and Belgian troops occupied the Ruhr District at the beginning of 1923 as security for payment. The ensuing proclamation of passive resistance by the German Government reduced the Mark to absolute worthlessness, and brought Germany to the brink of economic and political collapse. The U.S.A., although not co-signatories of the Versailles Treaty, regarded these chaotic conditions with great concern, and succeeded in setting up a Committee of Economists from Great Britain, France, Belgium and the United States in order to examine the best way of stabilizing the German currency, and of restoring the national economy to equilibrium. The plan worked out by the committee, which has gone down to history under the name of its Chairman, Charles G. Dawes, was presented in the Spring of 1924. By virtue of an agreement concluded in London between the Allies and Germany, it came into force on the 16th August, 1924.

The London Agreement provided that the reparation payments, in the meantime tentative, should flow from three sources, viz., from the ordinary revenues of the State, from a forced mortgage on the German economy, and another on the Railways. The revenues of the Reich were absolved of all reparation payments for the first two years, to enable them to regain their balance. Payments were then to be made on an ascending scale until attaining 1,250 million Gold-marks in the first "normal year."

One of the most controversial of the objects investigated by the committee were the German State Railways, whose finance and tariff policy called forth the sharpest possible criticism. As required by the committee, far-reaching alterations had to be made in the Railway Administration. The fixed property of the Railways, estimated at a total value of 26 milliard Gold-marks, was transferred to a newly established Company with a capital of 15 milliard Gold-marks, and subdivided into 2 milliards of ordinary and 13 milliards of preference shares. The Management of the Railways was made subordinate to a Board of Administration of 18 members, one half of which was nominated by the German Government, and the other by the Custodian of the Reparations Commission. Of these, at least four were required to be Representatives of the Allies. One of them was the Commissioner for Railways, whose duty as a specialist was to keep the working of the railways under observation, and to intervene if the debenture interest payments threatened to fall in arrears. In that case he possessed extensive powers; under certain circumstances he could depose the Managing Director and assume the management in person, or appoint another.

It was stipulated that the Chairman of the Board of Administration, who possessed the casting vote, must be one of the members nominated by the Custodian, and that he must be elected by the Board. This meant that Germans and non-Germans had to agree in their selection of a member whom they both trusted. The election procedure quickly showed that the man to whom this applied was Carl Friedrich von Siemens, who thereupon gave up his seat in Parliament in accordance with regulations.

For the Head of the House of Siemens the office he had assumed was extremely onerous. In the settlement of reparations the Railways were the chief bone of contention. With mounting Chauvinism, many Germans were incensed at the idea of this national property being held as a pledge in the plundering of Germany. For the reason just quoted, the foreign creditors regarded the Railway Management with particular suspicion. To promote agreement under such circumstances seemed hardly possible, and the fear was very real that the Board of Administration would be continually reft by dissension.

Nothing of the sort took place. The dreaded Commissioner, M. Levere, was a French railway engineer of high standing. Since the debenture interest payments came in regularly and punctually, he proved to be a most genial individual, and the Germans began to take a calmer view of things when they saw that the technical equipment of the railways was not being neglected. On the contrary, it was apparent that much was being done under the influence of the Commissioner to raise their efficiency. The non-German members of the Board also began to experience pleasure in the development of the German Railways, as the neighbouring countries also benefited by the improvements. The result was that the Board worked together quite harmoniously. It even stood firm when the Reichs Transport Minister, acting under the influence of Parliament, endeavoured to bend the Railways to his will, by playing them off against the other means of transport.

There is a genius of intuition, such as is found in commanders in the field, artists, inventors and actively productive scientists. There is also a genius of industriousness, objectivity and common sense, however, which succeeds in harmonizing opposing interests, conciliating antagonisms, and securing their collaboration in a common cause. In this sense, Carl Friedrich von Siemens was a genius. To anybody who had not realized this, perhaps by reason of his comparatively brief period as Head of the House of Siemens, it would have become abundantly plain in watching him in action on the hotly contested railway line. He is the only Chairman of the German State Railways who has ever occupied this position as an independent individual.

There was only one group which was not quite satisfied with his labours, viz., those members of the House of Siemens whose business was with the Railways. In their opinion, the Chief could have done a bit better for his Firm. As things were now, it was even more difficult for them than before. Such scrupulousness went too far. In the interests of the railway business, it was desirable that he should relinquish his post in favour of another as soon as possible.

XXII.

WORLD TELEPHONY

That from the point of view of physics, human speech is a mixture of acoustic harmonic oscillations of widely varying frequencies, has been known since Helmholtz, and as long ago as the last decade of last century, telephone engineers were applying themselves to the study of the laws governing the propagation of the electrical counterparts of these oscillations over wires. This led to the discovery that frequencies of about 800 oscillations per second, or 800 cycles (c/s), to use the accepted unit of measurement, were those most commonly encountered. This figure thus came to be used as an average value when making approximate calculations.

The sound of the human voice contains, firstly, a fundamental oscillation; this determines the pitch of the sound in the musical scale. Besides this, it contains harmonic oscillations, i. e., whole multiples of the fundamental oscillation. These give the sound its characteristic tone colour. Finally, it contains "characteristic frequencies," oscillations which are quite unevenly distributed over the frequency scale and which transform the sound into speech. For any given sound, quite independently of pitch and tone colour, they retain the frequencies appropriate to that sound; an "O," for example, always remains an "O," no matter whether it be spoken or sung in the deepest bass or highest treble.

Prior even to the formulation of the laws governing the formation of speech from sound, telephone engineers had endeavoured to form a more accurate estimate of how the frequency of the speech-forming electrical oscillations affects their attenuation in their passage over the line. Originally it had been customary to consider attenuation in terms of one single average frequency, viz., 800 c/s; now however, it was required to ascertain the attenuation for every point of the frequency spectrum and to present the values in a system of co-ordinates, in which the scale of frequencies forms the horizontal axis, whilst the values of the attenuation corresponding to each frequency are represented by the ordinates. The ensuing curve was called the "frequency response;" for all the usual arrangements of the conductors it exhibited a more or less steep rise of the attenuation with increasing frequency.

The pupinization of existing telephone cables modified the frequency response by reducing the attenuation for the average frequencies, i. e., in the region of 800 c/s, to about one quarter of its former value. The character of the curve was also changed; over a large portion it remained almost horizontal, indicating constant attenuation, which was a decided gain. There came a certain point, however, at which the curve bent upwards and rose with increasing steepness, so that the cable became impermeable. This point of impermeability was termed the limiting frequency. It could be extended by reducing the spacing of the Pupin coils, which, of course, involved extra outlay.

The first German long-distance cable, meaning in this context a telephone cable laid in the ground, was the Rhineland cable, which was laid from Berlin via Magdeburg to Hanover shortly before and during the early stages of the first World War. It was conceived as a through line Berlin—Magdeburg—Hanover—Dortmund—Cologne, over 600 kilometres in length, with copper conductors of 2 and 3 mm diameter. The heavier wires were designed for full-distance, and the lighter ones for sectional operation. At that time, this cable was still operating without amplifiers; by virtue of its 3 mm conductors it had a limiting frequency of 3,000 c/s, and sufficed to meet any demands as regards attenuation which at that time were considered reasonable to make. Nevertheless, when the cable was completed soon after the end of the war, it became evident that long distances could not be bridged without the use of amplifiers.

Following the signing of the Peace Treaty, therefore, a start was made in Germany with the systematic development of the hitherto more or less experimental amplifiers with Lieben or de Forest tubes, and equipping long-distance telephone lines with these amplifiers. In this connection two groups of scientists met in the solution of a common task, their joint efforts leading in a few years to the achievement of results which were quite astonishing, although little noticed by the public. The two partners were the German Post Office and Siemens & Halske.

As long ago as 1888 the German Post Office had maintained a Telegraph Engineering Dept., which was staffed by a few competent scientists and some members of the Post Office staff who took an interest in telegraphy. About the turn of the century this rapidly expanding department, with its laboratories and experimental equipment, was re-named the "Experimental Telegraph Office," finally, in 1920, becoming the "National Technical Telegraph Office." Judged by the standards of a State enterprise, the output in technical and scientific research of this institute was very remarkable. It was here that Franke had won his scientific spurs before joining Siemens & Halske, and names like Arendt, Breisig and K. W. Wagner had acquired international repute. Apart from the staff of the research centre, the Post Office had a number of very experienced and alert officials in its employ, such as Feyerabend, Craemer, Kruckow and others, who kept a close watch on developments in other countries, the U.S.A. in particular, and whose ambition it was to make the German telephone service a model for other countries, at least in Europe. A further member of this fraternity was Fritz Lüschen, whose services Ebeling had secured for Siemens & Halske in connection with the laying of the Rhineland cable. Numerous ties of a personal nature had thus existed for a number of years between the German Post Office and the House of Siemens. From these there grew after the war a degree of collaboration which reminded one of the former happy relationship with the Navy, except for the fact that efforts were this time bent, not on achieving destruction, but on the work of restoration and assisting the peoples to live together.

In view of the peculiar nature of the subject matter, it was essential to bring about a certain international conformity in the technical basis of long-distance telephony. This led to the formation in 1924 of the "Comité consultatif international pour les communications à grande distance" (C.C.I.), which was affiliated a year later to the International Telegraphic Union, and has been instrumental from time to time, frequently at the instigation of the German members, in initiating most fruitful international cooperation.

The connection of the amplifier tubes in circuit resulted at first in a number of difficulties. A voltage applied to the amplifier between grid and cathode is reproduced in the circuit consisting of the anode and cathode in amplified form. In this direction the valve is, therefore, permeable, but not in the opposite direction. Hence, if the amplifier is connected in the circuit of a twin conductor leading from A to B in such a manner that grid and cathode are connected to the conductors coming from A, whilst anode and cathode are connected to those leading to B, it is possible to speak from A to B, but not from B to A. Two amplifiers are thus required, one for the direction A—B, and the other for B—A. The resulting arrangement resembles that of a single-track railway, in which a length of double track with suitable points must be provided at one station to enable trains coming from opposite directions to pass each other. When the energy coming from A has passed the amplifier I on its way to B, part of it can enter the amplifier II by the rear points, is further amplified, re-enters I by the front points, and so on. The direction of flow of the energy describes a complete circle at these points, the energy being continuously amplified. In consequence of this "feed-back" the amplifier commences to "sing." To prevent this the arrangement must be such that the entire energy from A, which is amplified in I, is compelled to enter the conductor leading to B at the rear points; in other words, the entry to amplifier II must be blocked. On the other hand, the entry to amplifier II must be open to the energy coming from B. It is possible to solve this problem by an artificial connection which splits the currents from one or other of the amplifiers into two equal parts. The trick consists in the two halves opposing, i.e., neutralizing each other in the prohibited direction (suicide of the current), whilst in the desired direction the components combine again to form the full value.

For the division of the current into two equal parts, it is necessary to have an exact reproduction of the physical conditions of the section through which the current has to pass. i. e., a combination of coils to represent self-induction and condensers to represent capacitance, so arranged that the electrical values are the equivalent of those of the natural conductor at all frequencies. If this condition is fulfilled, the current has no choice but to split at the branch into equal proportions.

The artificial reproduction of the characteristics of the conductors did not serve the stated purpose only. Since the attenuation of the various frequencies by the cable was not uniform, but increased at higher frequencies, the resulting speech distortion was met by the introduction between amplifiers of an artificial conductor with the opposite response to that of the real conductor. The same result can be obtained by arranging for the amplifier not to raise the frequencies uniformly, but in accordance with a curve which corresponds to the frequency response of the line-attenuation compensator.

The name given by long-distance telephone engineers to the arrangement compared above with a single-track railway was "two-wire connection." While the war was still in progress, and the rate of advance in the new methods of telephony slow, it had already been proposed to employ two twin wires, i. e., one pair for each direction, corresponding to the double track railway. With this arrangement there would be no need to entertain fears in connection with the feed-back at the amplifier points. All that was needed was to connect the four wires at the ends of the line into pairs with the appropriate substitutes for self-induction and capacity. At first sight, the expenditure of double the quantity of wiring would seem to be sheer waste; it was soon found, however, that where the line was longer than about 700 kilometres, the four-wire cable was the more economical, as it permitted the use of wire of smaller cross-section, of wider spacing of the amplifiers, and of lighter Pupin coils. As time went on, the two-wire connection with 1.4 mm conductors for distances up to a maximum of 900 km, and for greater distances the four-wire connection with .9 mm conductors came to be standardized for German long-distance telephone cables.

The introduction of the amplifier, in turn, stimulated the development of the still indispensable Pupin coil. As is generally known, the ring-shaped cores of the early Pupin coils had been built up of dynamo sheets. With a view to further reduction of the losses and eddy currents, the thickness of the sheets had been successively reduced to 3/100 mm, i. e., the thickness of tissue-paper. When even these were found to be no longer adequate, cores were fashioned out of thin ring-wound wire of special quality steel. Coils of this kind were used for the Rhineland cable, but the sensitiveness of amplifier operation rendered the results unsatisfactory. This caused Siemens & Halske to revert to an idea which had occurred to them soon after the introduction of the Pupin system, but which had never taken practical shape, and was now re-appearing as the latest American invention. Finely powdered iron of a special quality was mixed to a paste with insulating compound, care being taken that every particle of iron was completely encased in compound. The plastic mass was compressed under high pressure into the desired ring form. These powder cores fulfilled, above all, the essential and most insistent requirement, that any sudden rush of current induced, perhaps, by neighbouring power cables, must on no account result in a permanent change in the magnetic properties of the cores.

Thus it happened that, building on the foundation of its cables, Pupin coils and amplifier stations, the German long-distance telephone network commenced as early as 1920 to stretch its limbs. The driving force behind this development on the Post Office side was the above-mentioned engineer (later Ministerial Director) Craemer, and in the House of Siemens Dr. Ebeling, who had meanwhile become Manager of the Gartenfeld Cable Works, and Fritz Lüschen. The latter was successful, in particular, in uniting the elements of this specialist department, which by reason of its development had become somewhat scattered, to form the staff of a "Central Laboratory for Long-distance Communication" under his own management. Amongst these specialist engineers was Bruno Pohlmann, who had distinguished himself by a wealth of inventive ideas. It was only when the personnel of the laboratory, comprising more than one hundred engineers and physicists as well as hundreds of assistants, filled the whole of the top storey of the extensive Wernerwerk building that the magnitude which the problem had meanwhile acquired was realized. It was no longer possible, of course, for the supply of the equipment to remain the monopoly of one firm, particularly as both the AEG and Felten & Guilleaume had successfully solved some of the auxiliary problems in their respective cable works. On its part, the Post Office energetically furthered the development of the long-distance telephone network. It was anxious to apply the experience gained to the improvement of each successive line, and, above all, not to be frustrated in this respect by patent disputes between its suppliers. For this reason, a semi-public undertaking was formed in 1921, known as the "Deutsche Fernkabelgesellschaft," of which the Post Office, Siemens & Halske, the AEG and Felten & Guilleaume were the original partners. The Fernkabelgesellschaft undertook the supply and laying of the long-distance cables, was responsible to the Post Office for any legal obligations arising out of agreements, in particular, the fulfilment of guarantees, and distributed the work amongst its three manufacturing members. After a period of successful operation, the membership was extended to four further cable manufacturers.

Simultaneously with the development of the long-distance telephone system, the German Post Office pressed on with the conversion from manual to automatic operation of the existing exchanges. It may be remembered that, having built the first large experimental exchange in Hildesheim, the Post Office was proceeding before the war with the conversion of individual exchanges, the largest being in Dresden with a pre-war roll of 17,000 subscribers. Here, however, an arrangement had been adopted, which at first sight seemed to be a retrograde step. Automatic telephony presupposes a subscriber's instrument with a rotatable dial, i. e., an instrument which differs materially from those previously in use, both as regards outward appearance and internal connections. The cost of replacement of all the instruments in a large telephone network would run into many thousands of pounds. With a view to spreading the cost, therefore, Dresden and other large cities adopted the expedient of equipping the exchange in the manner required for eventual fully-automatic operation, subscribers meanwhile retaining their existing instruments. When a subscriber lifted his receiver, the exchange would ask in the usual manner for the required number. The operator then set up the connection by means of selector equipment which, however, did not consist of dials (which would have been too slow in operation) but of rows of keys, of ten each, there being as many rows as there would have been numbers to dial. Depressing the keys after the fashion of typewriter operation was so speedy (everything else being performed by the selectors) that only half the personnel was required as compared with the fully hand-operated exchange. When all subscribers had been provided with dial instruments, and the period of transition came to an end, it was possible to switch over to fully automatic operation without further changes of any consequence.

Approximately fifteen years of combined effort by the Post Office and Siemens & Halske had produced a definite Post Office pattern of selector exchanges. Siemens & Halske might with equal justice have called the system by their own name, since the external design and method of connection of the instruments and apparatus were essentially theirs and were covered in all directions by numerous patents in the sole name of Siemens & Halske. As far as automatic exchanges were concerned, the position had therefore been reached in which, by reason of Siemens & Halske's technical monopoly, other firms were precluded from taking part in the further development of the German telephone network. It was clear both to the Post Office and to Siemens & Halske that a situation of this kind could not be maintained indefinitely, and in 1924 the Post Office was instrumental in inducing all the firms which were desirous of supplying automatic telephone equipment for public use to form a Company to be known as the "Automatische Fernsprechanlagen-Baugesellschaft." Siemens & Halske undertook to place their patent rights and designs at the disposal of the Company without charge as far as equipment for the German telephone network was concerned.

With the growing number of automatic exchanges for local calls, the question arose as to the best system of operation between exchanges. The matter was of particular urgency in large cities, which usually had several local exchanges. It was, of course, out of the question to have two different systems in operation in one city, i. e., automatic for communication between public and exchange, and hand-operated from one exchange to another, especially as it was of no interest to the subscriber to know by which of the exchanges his or his correspondent's call had chanced to be handled.

In large cities with several exchanges, therefore, above all in Berlin, which can count approximately fifty, interconnection between these is automatic. The consequence is that the subscriber, who in the case of Berlin has to select a six-figure number, does not realize that the connection he is dialling might be involving several exchanges. On the contrary, he has the feeling that he is in an enormous telephone network with one equally vast exchange. It was thus quite natural to conceive the plan to equip the whole of Germany in this manner, even if it should take several years to complete the work.

There were considerable technical difficulties to be overcome. In the case of short distances, such as those within the confines of a town, the same current impulses usually sufficed to operate the selectors of a neighbouring exchange as were habitually used in the home exchange, i. e., interrupted d.c. Where the distances were longer, however, direct current was bound to fail, one reason being that which had led to its abandonment for long-distance power transmission. It frequently happens, too, that for various reasons small transformers, known as repeating coils, are inserted in long-distance lines. Whilst these present no obstacle to the speaking currents, which are alternating currents, they constitute a barrier to direct current. The selectors, therefore, had to be a. c.-operated at the usual power-current frequency, the waves of which were chopped up into individual sections by the dialing procedure. Still more difficult was the problem of the actual long-distance cables with their amplifiers. It was in the nature of things that these could only be traversed by currents having the character of speaking currents. The selectors, therefore, had to be operated by alternating current of sound frequency, which led to the further difficulty that such sounds, and possibly speech itself, might result in unintentional movements of the selectors. Siemens & Halske succeeded, however, in overcoming all these pitfalls, and in producing systems which rendered it possible to operate the selectors over the same distances as applied to speech transmission. Individual large private telephone networks in Germany, such as that of the "Vereinigte Stahlwerke," took advantage of these developments, and were eventually operating fully automatic telephones with unattended exchanges hundreds of kilometres apart. The most extensive of these private telephone systems was that of the State Railways, for whom Siemens & Halske had built up a network in the 1930's which permitted the automatic setting up of telephone connections between a railway station near Constance and a station near Oppeln or Königsberg, without the assistance of any operator whatsoever. In the event of the selectors finding the direct approach to the desired terminal station blocked, they set about exploring other channels to find a by-pass, without the subscriber being aware; the fact is that they were fully developed robots.

Whilst, therefore, the technical problem could definitely be regarded as having been solved, even prior to the above-mentioned Railway network, and although the Bavarian Post Office had successfully carried out a large-scale test in 1933 in the Weilheim sector of their network, the Reich Postal Authorities still could not see their way to convert the whole German long-distance network to automatic operation. In dealing with long-distance calls it had hitherto been found to be an advantage to make a note of subscribers' requests for calls at special booking positions in the long-distance exchange, these notes being passed on to the telephone operators to be dealt with in rotation. Since it was usual for the calls to accumulate during the main hours of business, the capacity of the available lines had to be utilized to the utmost by switching through the next call, for which preparation had already been made, immediately the existing call was finished. Preparation consisted in alerting the two subscribers wishing to speak. The Post Office considered this procedure indispensable, since if it had been left to subscribers to set up their own connections, the result would have been that during the rush hours the lines and selectors would have been hopelessly blocked by incomplete connections. The only solution would have been far-reaching duplication of the system, and as extra facilities would not have been in use during the greater part of the day, the additional capital investment would not have been justified. The Reich Post Office thus preferred as a matter of principle to carry on with manually operated exchanges for long-distance traffic. The system was modernized, however, by the building of large new exchanges in which the fullest possible use was made of semi-automatic operation. In this connection Siemens & Halske found ample occupation for the manufacturing plant of the Zwietusch Factory, which they had acquired in the meantime, and which was specially designed for the production of automatic equipment. Further expansion of this business led in 1926 to the erection of an imposing new Works on the Salzufer, Charlottenburg.

The vast increase in turnover which Siemens experienced in the telephone business in the ten years following the first World War was due considerably to the development of the extension telephone systems, i.e. private branch exchanges. As defined by the Post Office, an "extension station" was one which existed alongside the subscriber's actual telephone, or "master station," installed, possibly, in another room of the same business, and which can, if required, be connected up to the incoming Post Office exchange line in place of the master station. In the early years of telephony in Germany, approximately until 1900, no great significance was attached to these stations. There were only a few of the large undertakings which felt the need of being able to telephone from several places within their premises. On the other hand, there were numerous subscribers, such as large factories, business houses, banks, hotels and Government offices, which had expressed a desire for a private telephone installation to enable individual departments to communicate with each other. Harry Fuld in Frankfort on the Main endeavoured to cater for this requirement by installing the necessary telephone equipment for internal communication, which was not subject to the telegraph and telephone monopoly of the Reich as long as it remained within the confines of the property. Fuld did not sell the equipment, however, but charged a fee for the wiring and fixing of the instruments and apparatus. These remained his property; the subscriber paid a rent for the use of the installation, which also covered inspection and maintenance. These rental contracts were usually concluded for a period of fifteen years.

Shortly after its establishment, the "Deutsche Privattelephon-Gesellschaft H. Fuld & Co." received a powerful fillip through the surrender by the Reich Post Office in 1900 of its monopoly of the installation of private branch exchanges. From then onwards private undertakings were permitted to lease or sell PBX's to telephone subscribers. The PBX's could, of course, also be combined with the private intercom systems, but had to conform to the regulations which the Post Office issued for the safety of the installation and to safeguard the collection of its dues. Almost all of the ensuing PBX installations were of the combined type.

Unfettered industrial competition proved to be an advantage, not only from the point of view of the technical development of the instruments, but as regards the wider use of PBX's as such. The various specialized manufacturers of telephone equipment were able with the help of their publicity material to demonstrate the value of having reliable and extensive possibilities of telephone communication throughout their Works. As regards this type of publicity it has to be admitted that up to the 1914 war, Siemens & Halske were not exactly in the van. They contented themselves with offering their services to the larger customers of the House, leaving the small business to others.

Amongst these others, Fuld was by far the most enterprising. He had at first purchased the materials he required from his competitors, including Siemens & Halske; as his business expanded, however, he built a factory in Frankfort and began to manufacture telephone equipment to his own designs, which were decidedly good. Above all, he established numerous subsidiaries up and down the country, who were pledged to sell his products, and operated eventually with an army of commission agents who swept clean the most remote corners of industrial Germany. In this way even the smallest customers were gathered in, and many a small customer grew in the course of fifteen years to be a large one.

Following the war, the importance of the PBX business grew in Germany from year to year. The machinery of local and national Government expanded at an enormous rate, likewise that of the supply services; the fusion of industrial units formed undertakings of ever-increasing size; during the inflation period the Banks themselves were not exempt from the same influence, and where formerly one telephone had been sufficient, several were now required. Private exchanges with several hundred connections were to be counted by the dozen in every large town, and in

Siemensstadt the Firm had had its own private exchange for an initial number of 600 extensions since 1913. At the end of 25 years the number had grown to 12,500. It is therefore not surprising that the special attention of the Branch Offices of Siemens & Halske was drawn to the importance of the PBX business.

At a conference of the outside representatives in Berlin the complaint was raised that it had become well-nigh impossible to counter the competition of Fuld in particular, as he operated with rental contracts which, in spite of the obligations entailed, were preferred by many on account of the smaller capital outlay. The demand was therefore made that Siemens should also enter the rental business—up to now the Firm had refused to do so.

The Heads of the Wernerwerk were reluctant. In consequence of the practices introduced by Fuld, the rental business did not seem to be in keeping with the general Siemens principles. Now that Fuld had been operating for a number of years, however, the prospect of bringing about any change appeared to be doubtful. Things had meanwhile reached the point that the other firms, determined to prevent the whole of the medium and small business falling into Fuld's hands, adopted the same policy, and therefore the House resolved to take over a recently established rental business which was heavily indebted to Siemens & Halske and to run it under another name. The object of this company, therefore, was to transact business in rental contracts for telephone extensions. Potential buyers of the apparatus were to be turned over to the Siemens & Halske and vice versa.

This was the starting point of a comedy, the like of which had never been seen in the long history of the Firm. The prospective customer would be most strongly advised by the salesman of the rental company not to buy a private branch exchange, as he could have the use of the equipment on much more favourable terms under the rental contract. A few days later he would be warned by the Siemens & Halske representative from the Branch Office against having anything to do with a rental contract. All exhortations from above to work hand in hand were without effect. This was due not merely to the fact that the salesman's commission was involved, but in a much greater degree to the annoyance of the Siemens & Halske engineers in the Branch Offices at what they considered unfair competition. The disputes between salesmen penetrated to the higher levels of the Wernerwerk, where each party had its supporters, and where repeated attempts were made to discover a formula which would put an end to the interminable squabbles. There was the additional difficulty that a fusion of the two groups would have entailed dismissal, or lower ranking, of redundant personnel, which it was desired to avoid as being undeserved. It was not until the great depression, and the issue of new Post Office regulations governing private branch exchanges, that it became unavoidable to combine the two departments within the framework of the Branch Offices. An unhappy experiment was thus brought to a close; the result demonstrated that any attempt to introduce a foreign organism into the House of Siemens is apt to call forth an explosive reaction.

When in the year 1928, after twenty years of systematic salesmanship, a count was made of the turnover in automatic telephone installations, it was found that the number of exchanges supplied to Public Authorities —and these alone—covered approximately 1½ million subscribers. This represented about one quarter of the world production figure. Included in this were about 400,000 subscribers abroad. As this section of the business was as important as it was difficult, it is proposed to devote to it a few further words at this juncture.

The year 1920 witnessed in New York the establishment of the "International Telephone and Telegraph Corporation" with the strong support of J. P. Morgan & Co. and the National City Bank. The object was to build or acquire, but in any case to operate, telegraph and telephone lines, either with wires or wireless, primarily in Central and South America, but also in other countries. A few years later the Corporation purchased the "International Western Electric Corporation of New York" and changed the name to "International Standard Electric Corporation of New York." By doing so, the Corporation acquired a number of factories manufacturing telegraph and telephone components, and amongst them, the "Bell Telephone Manufacturing Co." in Antwerp.

The very powerful I.T.T. was one of the two principal American competitors with whom Siemens & Halske had to cross swords in the world market, the other being the "International Automatic Telephone Co.," an offshoot of the Strowger Co. in Chicago. Prior to the war Siemens & Halske had concluded licence agreements with this firm, and also with the International Western Electric. These old connections were revived after the war, resulting in a certain accord between the three firms with the object of mellowing competition. Instead, however, the result was a series of embittered disputes, which dragged on for years and finally led to litigation before the Court of Appeal in London.

Siemens & Halske already realized that it was not possible in the international telephone business just to manufacture in Germany and sell the instruments abroad like other wares. As a rule, the telephone service was a State, or at least municipal, monopoly, and all those obstacles would have to be taken into account which are raised by champions of the public interest in the name of "national economy."

The procedure which had been followed in the electrical manufacturing industry from the early days of its expansion, i. e., towards the close of the nineteenth century, was to establish factories abroad. A manufacturing branch, in which foreign capital was usually invested, with representatives of the country in question on the Board, employing mainly home labour and paying taxes like any other, could hardly be reproached with not being a part of the national economy. Thus in 1922 Siemens & Halske acquired a Works in Albisrieden near Zurich for their Swiss representatives, "Siemens Electrical Products," and fitted it out for the manufacture of communication equipment, primarily telephones. In 1924 the undertaking was given the name "Telephonwerke Albisrieden," and in 1935 renamed "Albiswerk A.G. Zurich." With the support of this Works the Zurich House of the Firm was soon campaigning with eminent success against its competitors, in particular the Antwerp factory of the "Standard" Company.

A second company was founded in 1935 in Japan in connection with the already existing Fusi Denki K. K. (about which more will be said later) to equip a Telephone Works in Kawasaki. This was known as the Fusi Tsushinki Seizo K. S. In addition to the already heavy demand of the expanding national economy, there was the necessity of making good the losses due to the 1923 earthquake. Since the House of Siemens had been firmly established in Japan for a number of years, and also had a lively participation in the development of the long-distance telephone network to its credit, the telephone business proved here, too, to be very satisfactory.

Finally, in 1930, the "Electrotechna A.G. für Schwachstromtechnik" was founded in Prague at the instigation of the Czechoslovak Government, with a capital of 16 million Crowns. The undertaking possessed a factory in Prague-Karolinenthal with an initial personnel of some 600 workers, and its own sales organization. In technical matters it was managed from Berlin, and its object was not merely to serve the Czechoslovakian market, but to cover those of the other Eastern European countries. The most important of these was Yugoslavia, where the market for Siemens telephone equipment and cables appeared to be especially promising.

On the other hand, the I.T.T. and its subsidiary, the International Standard Electric Corporation (to which the factories belonging to the I.T.T. were transferred) had meanwhile been continually increasing their manufacturing capacity in countries outside the U.S.A. In addition to the above-mentioned factory in Antwerp, they possessed similar large Works in Paris and London, apart from smaller workshops in almost all the European Capitals, which either manufactured components only or confined themselves to assembly work. In Germany, too, they had built up a strong position by the purchase of existing Works. The I.T.T. had founded the "Standard Elektrizitätsgesellschaft" in Berlin, the function of which was to be a Holding Company, and to control the various firms absorbed, viz., A.G. Mix & Genest, Berlin; Telephonfabrik Berliner A.G., Berlin-Schöneberg; Ferdinand Schuchhardt, Berliner Fernsprech- und Telegraphenwerk A.G., Berlin, and Süddeutsche Apparatefabrik GmbH, Nuremberg. In 1930, moreover, the I.T.T. acquired C. Lorenz A.G.,Berlin, which it kept under its own immediate control.

A second factor in the international communications business was the activity of the large contractor working under a concession. The centre of gravity of the I.T.T. business was in the region of Central and South America, viz., Mexico, Portorico, Havana, Peru, Southern Brazil, the Argentine and Chile. Siemens & Halske had therefore to follow this lead unless they were prepared to forego much lucrative business from the outset. It was similar to the development of power current business in the last decade of last century.

In the northern provinces of the Argentine bordering on Paraguay, a small firm was manufacturing and installing telephones, but found the capital required for modernization and extension of the plant beyond its power to provide. By buying up the shares, Siemens & Halske were able to acquire the rights of the concessionaires. The name of the firm was changed to "Compañia Internacional de Teléfonos," and soon it was flourishing on the renewal of local and development of long-distance networks. A little later Siemens & Halske succeeded in purchasing a small offshoot of the "Deutsch-Atlantische Telegraphengesellschaft" (the only German transatlantic telegraph company remaining after the 1914/18 war), viz., the Compañia Telegráfica-Teléfonos del Plata. This Company operated a submarine cable between Buenos Aires and Colonia across the estuary of the River Plate, connecting the Capitals of the Argentine and Uruguay. Although traffic on this cable was insignificant and still dwindling, a footing had been obtained on both banks of the La Plata, which ultimately enabled the Firm to establish itself at Montevideo, and to obtain the contract for the conversion of the telephone system to automatic operation. Simultaneously, the Firm was able to purchase the majority rights of the Montevideo Telephone Co., which was thereupon amalgamated with the Compañia Internacional. Concession activities were extended to the southern provinces of Uruguay until, finally, the La Plata system represented quite a sizeable undertaking. Later on, the I.T.T. were given an interest in the concern for the sake of ensuring friendly relations with its subsidiary, the River Plate Telephone Co., in Buenos Aires.

In 1930, Siemens & Halske succeeded in obtaining from the Greek Government and Parliament the concession for the supply and installation of local telephone-networks; a simultaneous contract covered the long-distance lines and exchanges, the operation of which the Authorities reserved to themselves. After some initial difficulties, which the company formed to operate the networks was able to overcome, the new installation proved to be a great success. A considerable part of the necessary capital, however, had to be provided by Siemens & Halske. As happened in the case of the Argentine concessions, the Greek concessions became the property of the State following on the second World War. In itself, of course, that is inherent in the conception of a concession: the object is to educate Public Authorities in the use of new technical methods until they have acquired sufficient knowledge to enable them to operate alone. It is wrong, however, to make the concessionaire suffer for the sins of his partner, the State.

In the case of concessions operated in conjunction with large manufacturing concerns, there is always the danger that the manufacturing works will bring pressure to bear on the concessionaires to introduce to their customer the very latest developments immediately they appear, and that they subordinate the welfare of the undertaking to their interests in driving up the turnover. In order to meet this possibility, Siemens & Halske opened a "Central Office for Concession Business" under the direction of Richard Diercks, a member of the Managerial Board. It was jocularly known as the "Limited Company on Paper," as it operated like a completely independent undertaking. It had a Committee, called "The Board," on which the departments concerned, in particular, the Finance Department and the Central Accountants Department, each had a representative. In this way security was provided against the concession schemes being overloaded with extraneous plans and wishes to the point of endangering their commercial success.

When it is a question of introducing to the world a new technical achievement such as the telephone with its far-flung network, this cannot be left to small firms. The foregoing narrative has probably made it clear that the ability to deal with the concomitant technical problems and commercial propositions presupposes the wide experience only available in the trained staff of a large undertaking. Apart from this, ample capital is essential. It would also seem unnecessary to argue that undertakings of this kind must have a correspondingly large share of the turnover if they are to exist. This knowledge, however, does not restrain certain circles from at once crying "Monopoly." In Germany, too, there had formerly been some talk of a practical Siemens & Halske monopoly during the development of the German telephone network. This was not the case; their share of the Post Office orders amounted to about 60%. Nevertheless, Carl Friedrich von Siemens took the occasion of the Annual General Meeting on the 17th January, 1930 to refer to these allegations in the following terms: "You may have read recently in various publications that our position in several directions amounts to a monopoly, and must therefore be attacked. When an industrial monopoly comes into being as the result of hard work, not having been established by law or through exclusive access to raw materials, but founded only on the principle of producing the best at the lowest possible cost, I consider this to be a very gratifying industrial phenomenon. Should performance slacken, competition would immediately make itself felt. It is not my intention in this connection to discuss the usefulness and necessity of rings; there is no doubt, however, that a monopoly which has grown as the result of work and performance is preferable to a ring, in which provision must always be made for the protection of the weaker members . . ."

This characterizes the three kinds of commercial monopoly in existence: the monopoly granted by law or ordinance (Railway, power supply or —not to be overlooked—the dominating position of an industry against foreign competition built up on import duties); the raw material monopoly, usually confined to a limited area (exploitation of fuel beds or sources of power); the monopoly based on performance. Before attacking this latter, it should be remembered that it is the offspring of invention protected by Patent Laws. Whoever is against the performance monopoly must first abolish patents.

Logically, he must then abolish copyright, both for the artist and writer. Not until that has been done, have these any right to inveigh against the performance monopoly.

XXIII.

ELECTRIC HEAT AND ELECTRO-MEDICINE

The heating of a conductor by an electric current flowing through it is one of the earliest reactions observed by physicists engaged in the study of electrical phenomena, and doctors had already begun to take advantage of it about the middle of the nineteenth century. A thin platinum wire bent to a loop with a handle affixed, and raised by the current of several cells to a bright red heat, was employed in minor surgical operations, such as the removal of growths. The treatment was called galvanocaustic. "Electric Heat" and "Electro-Medicine" are thus twins. As long as battery cells were the only source of current, however, there was little prospect of the use of electric heat on a large scale, and it was not until 1883 that it was possible to demonstrate a few practical applications at the Vienna Exhibition of that year. Amongst these were water heaters, curling tongs, cigar lighters, heating pads and similar appliances which were looked upon by the man-in-the-street as sheer luxury for rich folk. Reliability and durability, moreover, left a lot to be desired.

Simple as it appeared to be in principle to use the passage of a current through a wire as a source of heat, the practical application was attended with difficulties. In the majority of cases the conductor must have a temperature of at least 600°—700° Centigrade, corresponding to medium red heat, if the desired effect is to be achieved. At this temperature, however, base metals commence to oxydize; the heating wire disintegrates and very soon burns out. Since in the majority of cases the cost of platinum rendered the use of this metal prohibitive, the question of a suitable metal for the heating element seemed to be well-nigh insoluble. The insulation of the glowing wire presented considerable difficulties. Textile and rubber-based materials were clearly unusable; glass in a viscous state decomposes at these temperatures and becomes an electrolytic conductor; porcelain also loses a great part of its insulating properties, and is very sensitive to changes of temperature; mica, too, is unreliable when heated. The early examples of such heating apparatus were thus no recommendation for the use of electricity as a source of heat, and Siemens & Halske in consequence felt no inclination to give the matter much thought. The delivery of an electrical heating and boiling plant to the State-owned opium factory in Batavia was noteworthy as regards its place of destination and uncommon application, but it remained an isolated example.

Heinrich Voigt, however, whose name has already been mentioned as founder of the Firm of Voigt & Haeffner, had as a young man devoted a good deal of attention to the problem of the heating element. He conceived the idea of covering strips of precious metals, which do not oxydize, with enamel and baking them in a stove, thus forming an insulating coating. Heating elements of this type were superior to all others then in existence, and so with Voigt's participation a factory was opened in Frankfort on the Main, under the name of "Prometheus," for the manufacture of electric heating apparatus. This firm existed until after the first World War and had the reputation of being one of the leading undertakings in this sphere. It did a considerable export business, and contributed with its high-grade products to the successful development of electric heating as a whole.

The Voigt solution was, of course, not suitable for apparatus of large capacity, where the heating elements must consist of non-oxydizing wire. It was in the U.S.A. that the idea was first conceived of using an alloy of iron, chromium and nickel (so-called chrome-nickel steel) for the heating elements. There are many kinds of chrome-nickel steel, depending on the proportions of the ingredients, and some, indeed, which contain no iron at all. These steels do not oxydize, and have therefore been used successfully for heating elements for temperatures up to about 900° C, especially as it had been learnt, meanwhile, how to produce ceramic insulators capable of withstanding widely fluctuating temperatures.

About the same time as the discovery by Moissan of calcium carbide, CaC_2, Acheson, an American inventor, produced silicon carbide, SiC by melting a mixture of sand, coke and salt in an electric furnace. In view of its great hardness, it was first used as an abrasive under the name of Carborundum. Having further mastered the art of disintegrating the coarse crystals, it was found possible to treat the material in the same way as a ceramic mass. In 1903, Gebr. Siemens & Co. in Lichtenberg used this material to produce rods and tubes for industrial heating resistances which they introduced under the name of "Silit." These Silit resistances were able to operate at temperatures up to 1,400° C, thus opening the way to the construction of electrically heated resistance furnaces, in which copper and its alloys could be melted, steel raised to forging temperature, and porcelain fired.

In the last few years before the first World War, electrical science had reached the stage where it could have satisfied industrial and domestic requirements in the field of electric heating. The conversion of electric current into heat met with the prejudice, however, that of the energy expended in its generation in the steam power station, only one tenth is recovered.

Those who spoke thus overlooked the fact that in the direct heating of a stove or range by coal or gas, the greater part of the heat of combustion is also lost, either through radiation or up the chimney (in domestic fires the kitchen grate usually also heats the kitchen). The above objection is therefore not valid. Apart from this, moreover, it often happens that fuel economy is of less importance than cleanliness, handiness, and the ease of regulation of electric heat. As compared with coal, there is a saving of transport and bunkerage, and as compared with gas, electric heating is not dangerous, and does not pollute the atmosphere. Many industrial processes, such as annealing, hardening and heat-treatment, necessitate the maintenance of definite, pre-determined temperatures over considerable periods, a task which is not easy to fulfil with coal firing. The above objection regarding the efficiency of electrical heating is also no longer true if current is generated in a water-power plant.

This became particularly evident during the 1914/18 war and in the early post-war years, when there was a severe shortage of coal, and Switzerland and the Scandinavian countries, especially Norway, were compelled to fall back on their water power. It thus happened that Switzerland and Norway came to be the originators of the electric kitchen in Europe, whilst in the Western Hemisphere much had been done in the United States to introduce electric heating in the home. This was to some extent consequent on the development of social conditions, which permitted only a few of the well-to-do the luxury of domestic servants.

The attitude of the electric supply companies towards the general introduction of electric cooking was at first one of scepticism, at least in Germany. The charge to the small consumer for the kilowatt-hour was from 40 to 60 Pfennigs (approximately 5^d—7^d). The current consumption required to cook a dinner for a family of five, observing every possible economy, and not including "washing up," is about 1.7 kWh at a price of 6^d per unit, this would amount to more than 10^d for "fuel charges" alone. With all the advantages in its favour, charges like these rendered electric cooking beyond consideration. Simple calculations showed that the unit cost of current must not exceed $1^d$to $1\frac{1}{4}^{d,}$ if electric cooking were to compete successfully with its main rival—gas. A reduction in the price of the unit to one fifth of the existing level, however, appeared to the supply companies to be out of the question.

It should not be overlooked, of course, that the then existing tariff charges were based on a lighting load, which is very unfavourable from the point of view of the supply station, viz., a brief peak morning and evening in the winter, and little or even nothing in the summer. Would not the power station calculation acquire a totally different aspect if numerous households, instead of using 20—30 kW/hours per month, were to consume five to six times that amount, and if this load were to be distributed evenly over the day by the use of storage heaters? Such a consumer, who is no longer a "small consumer," would have a right to treatment on the same lines as the large consumer. The interested parties resolved to press for action along these lines.

A recent addition to these "interested parties" was the House of Siemens. Up to the outbreak of the war, the Firm had confined itself to the manufacture of a few flat irons and hot-plates at the Small Accessories Works; sales were not supported by publicity. In the event of a customer wishing to have further domestic appliances from Siemens as part of a large order, the items in question would be procured from Prometheus. After the war, due to the scarcity of coal, and to the makeshift nature of the domestic arrangements in numerous families, there arose—also in Germany—an increased demand for electrical heating and cooking appliances. It was part of the business of the Small Accessories Sales Department to market the products of the Works of that name. The new Manager of the department, Julius Laufer, had joined the Firm as a young engineer, but had soon proved himself to be a most energetic and resourceful man of business of the American type. His plan was to raise the manufacture of electric domestic appliances to a place of commanding importance in the Firm. In the course of his activities he unexpectedly came upon a kind of competitor within the Family, of whom nobody had hitherto taken any notice, viz., "Friedrich Siemens, Maker of Patent Heating Equipment" in Dresden. This firm, founded by Werner's brother, Friedrich, who died in 1904, had recently commenced to take an interest in electric heating, and built space heaters, temperature-controlled baths for special purposes, and incubators. The business was not extensive, but was an obstacle in the path of Siemens-Schuckert aspirations, nor could it be truly regarded as a "friendly" firm. At Laufer's suggestion, it was agreed in 1920 to amalgamate this business with that of the Small Accessories Works to form the "Siemens Elektrowärme GmbH," with headquarters in Berlin, for the time being. The new firm was placed under the management of Dr. Johannes Wolf, whose first step was to set afoot extensive design and development work as the basis of subsequent manufacture.

It soon transpired that the Small Accessories Works was not suitably equipped for this kind of production. On the one hand, there were many household products, such as stoves and warm water storage heaters, which were quite outside the scope of the Works, and on the other, enquiries began to multiply for muffle furnaces for annealing and hardening, melting crucibles, baths, air-heaters, drying equipment and similar apparatus which were foreign to the manufacturing programme of the Works. Laufer now initiated an active publicity campaign for electric domestic appliances, as part of which he sent Berlin-trained specialists to all the branch offices. The result was that he secured for the Firm a share of more than one third of the combined turnover of the whole body of German manufacturers. Soon, the Small Accessories Works was literally smothered with orders for these appliances, and Laufer therefore found little difficulty in consequence in convincing his colleagues on the Board of Management that the Elektrowärme-Gesellschaft required a Works of its own. In view of the unsettled state of the building market at that time (1922), there could be no question of erecting a new factory in Siemensstadt. Under the circumstances, it was decided to purchase a suitable factory which was being offered for sale in Sörnewitz, in the neighbourhood of Dresden, whither also the Head Offices of the company were transferred.

In Sörnewitz, a commencement was made with the flat-iron. This simple domestic instrument would at first sight hardly appear likely to attract the attention and skill of the designer and production engineer. Before it is possible, however, to realize the sum total of engineering planning required before a finished iron comes off the conveyor belt, it must be seen how the half-inch steel soleplates are stamped out under 250 tons pressure, flattened under a second press, milled on all surfaces, then polished on the grinder, being kept meanwhile under close observation; then, how the domes are pressed out of 16 gauge sheet steel at one stroke, ground, polished, degreased, copper plated and finally nickel plated; how the heating elements, handle supports, and handles and contact pins seem to appear almost automatically; then how the components for five irons are collected in small trolleys running on rails to enable them to travel alongside the work on the conveyor belt for assembly; how, then, following the assembly, the iron is connected in passing to a source of current and heated up, any faulty parts shown up by instruments and pilot lamps, being taken out of the train by the inspectress for closer examination; and how, finally, the finished irons proceed automatically to be greased, packed and delivered to stores or to the Despatch Department, as the case may be. With this almost uncanny machinery and 100 hands, the output to commence with was 1,400 irons per day, rising later to 3,000. By constant improvement of the manufacturing process, the Management succeeded within five years in reducing the selling price of the iron by half, at the same time raising the average earnings of the workers by 10%.

In the meantime, the battle of the kitchen between the protagonists of gas and electricity had flared up all along the line in Germany. The first sallies of the electrical engineers into the disputed territory, which took place soon after the war, had not been taken too seriously by the gas people. They relied on the efficiency calculations referred to above, but in the main on the fact that in most cases the gasworks were owned by the municipalities, who therefore had a strong interest in resisting any change. Even in cases where the electrical power plant was in the hands of the municipality, the gasworks were the "senior service," the existence of which was being threatened by electric cooking, whilst the electricity works had been quite prosperous without the cooking load. Moreover, the agitation on the electrical side amounted to such a drastic reduction in the price of current as to render it dubious whether any surplus would remain for the city coffers. In Berlin, where the "Berliner Elektrizitätswerke" had meanwhile come under municipal ownership, the Corporation issued strict directives to the Management of the electricity undertaking to refrain from publicity in support of electrical cooking. Other cities followed their example.

The champions of the electrical side, however, were not to be dismayed, and it was here that the experience of the propaganda machine and sales organizations of the industry made itself felt. Besides, not all supply undertakings were municipal; there were still some upon which influence could be brought to bear. Electric cooking only a luxury for the rich? On the contrary, the middle-class man, including the manual worker, was intended to enjoy the benefits of clean, hygienic and labour-saving cooking; it was precisely the housewife who does her own cooking who was to be relieved of the necessity of inhaling the combustion gases of the open gas fire.

It began with a few industrial or public housing estates; no gas pipes were laid, either in the houses or the road approaches, thus economizing in building costs. Gas was thus beyond argument from the outset, and it was made easier for tenants to acquire electric cookers and storage water-heaters on the instalment system; favourable terms were negotiated with the electricity supply company on the basis of fully electric households. Siemens-Schuckert undertook a joint publicity campaign with a well-known manufacturer of baking powder—himself well-versed in advertising. For a considerable number of years electric cooking and baking were demonstrated all over Germany, and tasty samples of the products distributed. Even municipal supply undertakings caught the infection, especially on it becoming evident that, owing to the increased consumption, the reduced tariff charges for cooking current had not led to bankruptcy. Tardy Managements were finding themselves more and more harrassed by the insistent demands of consumers. The "Association of Power Suppliers" decided, at length, in 1928 to relinquish its opposition to the electric kitchen, whilst stating that there was no intention of ousting gas from positions where it had become firmly established. When, however, the "Rheinisch-Westfälisches Elektrizitätswerk" suddenly decided, in its usual revolutionary manner, to open its vast network to the electric kitchen by the grant of preferential tariffs, the ice was broken. Progress throughout the rest of Germany was now assured. Whereas at the beginning of the campaign in 1925 there were barely 1,000 domestic cookers in Germany, these had increased in 1929 to 30,000, in 1930 to 45,000, and in 1931 to 70,000, notwithstanding the intervening depression. Of these cookers, approximately half were supplied to working-class families, one fifth to office staffs of all grades, a further fifth to farms and small craftsmen, and only one tenth to wealthier families. The pace of development of the large cookers was even greater; the demand for the equipment of restaurants and hotels, ships and canteens was insatiable, the march of the electric cooker irresistible. In Sörnewitz efforts were unceasingly directed to the maintenance of the Firm's lead by the design of new models and continual improvement of existing ones; hot-plates, cookers from the domestic pattern to the largest multi-ring hotel models, saucepans, frying pans and baking ovens, and it was a source of satisfaction to see that the Works grew to be the largest and most productive of its kind on the Continent.

This success was in no small degree due to the work of Hanns Benkert, who had been Production Engineer in Sörnewitz since 1925. Amongst engineers there are those whose constructive energies are interwoven with an artistic temperament. In the choice of an occupation a mere chance, perhaps, has started a man of this type on a technical career, where under slightly different circumstances he might have thrown himself into the arms of the muse. Such a man was Benkert. The design and equipment of the factory also appealed to him as a formative task, whilst at the same time, with his warm temperament, the ideal of uniting all ranks of his subordinates in a common endeavour was a goal which fired his enthusiasm. In his work in Sörnewitz he attained a stature which, six years later, demanded a much wider scope for its further development.

Some considerable time before the advent of the electric cooker, another application of electric heat had brought about a revolution in the metalworking industry.

If it was required to join the edges of two sheets of metal, it was usual to rivet them together, this being one of the joints most commonly used by the engineer. Riveting was used in boilers, shipbuilding, bridgebuilding and constructional iron-work of all kinds. In a large industrial country countless rivets were used every day; the hull of a large vessel was studded with thousands of rivets, which, taken together, represented a very considerable weight. About the middle of last century it was already known that by burning hydrogen in an atmosphere of oxygen it is possible to produce a flame of great heat. The appliance, in which the two gases meet at the combustion nozzle, is known as a blowpipe. Acetylene can be used in place of hydrogen with a similar result. Following on the large-scale production of these gases by the Linde process and electrolytic methods, it became common to store them in steel bottles capable of transportation, and to use the gas flame for "cutting" steel plates. The sharply defined flame very soon caused the metal to melt, so that a steel girder could be cut through as if by a saw. Very shortly afterwards attempts were made to weld metals together, the first experiments being undertaken on cracked castings. In carrying out the repairs fresh weld metal, melted in the blowpipe flame, was fed into the cracks. The next step was to use this process for building up wrought-iron structures instead of riveting them. "Autogenous" or gas welding soon came to be applied to all kinds of objects, and it became possible to fabricate from individual pieces constructions which, on account of their complicated form, would formerly have had to be cast.

In 1885 Bernardos and Olszewski in St. Petersburg took out patents in the chief industrial countries, including Germany, covering a welding process in which the electric arc was used instead of the gas flame. An arc was kindled between a carbon electrode and the work, each being connected to one of the poles of a source of direct current. A feed electrode consisting of heavy iron wire was held in the flame of the arc. The molten metal dropped on to the weld-hot work piece and combined with it. A few years later Slavianoff simply replaced the carbon electrode by the weld-metal feedwire, and thus inaugurated the process now known and almost universally used under the name of "arc-welding."

Admittedly, a considerable time elapsed before this stage was reached, since gas welding was firmly established. It was not until the beginning of the present century that the Americans commenced to use arc-welding to repair tramway rails and, in particular, to weld the lengths of rails together. The tramways were predestined to be selected for a practical experiment of this kind, as the rails were in any case connected to one pole of the supply system, so that all that was necessary was to connect the welding electrode to the overhead wire through an adequate resistance to choke down the excess voltage and to damp the intermittent short-circuit. From the tramways, arc-welding spread in competition with gas-welding to other branches of engineering. Since these were usually connected to a. c., it was necessary to provide a small mobile a. c.—d. c. converter, as d. c. was considered essential for welding on account of the steadier arc. The direct-current generator could then be designed to cope with the short-circuits resulting from the striking of the arc. From repair work, arc-welding came to be increasingly used for new construction work, until it finally became possible to weld a seam joining two sheets or a junction point between sectional iron members as well as by the autogenous method.

In striking the arc it frequently happened that the movable electrode would stick to the stationary one, which indicated that there was a further method of electric welding. If two metal rods, each connected to a pole of an electric supply of sufficient capacity, are brought into contact with each other and then drawn slightly apart, a small electric arc will be produced. On repeating this a number of times at short intervals, the contact surfaces will heat up until reaching welding temperature. If the two surfaces are then pressed firmly together, allowing the current to flow for a short time whilst the pressure continues, the ends of the rods will be found to be welded together. This is called "resistance welding," as the main source of heat is the contact resistance of the weld surface.

If it were required, on the other hand, to weld together two large surfaces, e. g., two metal sheets, a different method of resistance welding would have to be adopted. In this case the sheets are laid with the edges overlapping, as in riveting. Current is fed through two copper electrodes arranged opposite each other above and below the sheets and pressed together by mechanical means. When the current was switched on, it gave rise to intense local heating of the sheets at the points where they were pressed together by the electrodes, with the result that they were welded together. This was called "spot welding," and the process was repeated at every point where a rivet would otherwise have been placed. The effect was the same as in the case of a riveted seam. The process was, of course, confined to sheets of medium thickness. If the sheets were very thin and of good conducting material, e. g., aluminium, roller electrodes could be used in place of the pencil type, and the edges of the sheets drawn between the rollers in a continuous movement. The result was a continuous welded seam similar to that made in fabric by a sewing machine. All the above welding processes, whether butt, spot or seam, required very heavy current of low voltage. This was obtained from a transformer, connected to the electricity supply and controlled on the high-tension side. On the low-tension side the transformer possessed only a few turns of a very heavy, in some cases water-cooled, conductor, the ends of which were connected directly to the jaws which, in the case of the butt-welder, held the pieces to be welded together, or to the electrodes in the case of the spot-welder. The current was switched on and off automatically in unison with the movement of the electrodes. Stepping on a pedal first pressed the electrodes on to the work and then switched on the current; releasing the pedal was followed by the reverse action, and the weld was made. In the time required to drill a dozen rivet holes, heat up the rivets, place them in position and hammer the heads, it was possible to produce a hundred spot welds and more.

That was roughly the state of the art of electric welding shortly before the first World War. Arc-welding was brought to greater perfection, and the first butt, spot and seam welding machines were being built, with the Americans in the van of progress. In Germany there were a few manufacturing firms which took up this new application of electric heat. Foremost among the larger firms was the AEG, stimulated by the lively activity of their American namesakes. Siemens surveyed the field from time to time, but nobody took a serious interest in the matter. The "Siemens Elektrowärme-Gesellschaft" was not yet in existence.

Meanwhile, the 1914/18 war had broken out, its special demands administering a powerful fillip to creative technical activities of all kinds. In the further course of events, soon after the entry of the United States into the war on the side of the Allies in 1917, the activities of the German submarines created a situation of no little danger for the enemy. The wholesale sinking of shipping could only be made good by building activities on the same scale, based on the building in England and America of series of vessels to standardized designs, and at a pace that in the light of existing experience seemed impossible. In the opinion of the experts, the new ships would have to be electrically welded, not riveted, thus rendering them not only lighter, but speeding up their construction very considerably.

A start was therefore made in England by building a number of all-welded ships, the ribs being fabricated by butt and spot welding, whilst the hull plates were secured in position by arc-welding. When it transpired that these new ships could be built in a surprisingly short time, and that they were seaworthy in every respect, the Americans threw themselves into the fray with their characteristic enthusiasm for all technical problems, and bent all their energy to the production of electrically welded ships.

Welding machines began to be made all over the country; the General Electric Co. and other firms opened training shops for welders, who were then drafted in great numbers to the shipyards, where seven times as many men were at work as under normal conditions. It was found that welding showed a saving of 10% in building costs, and of 25—40% in time. The replacement fleet was completed according to schedule, and enthusiasts claimed with pride that electric welding had won the war.

At the time when the Siemens Elektrowärme-Gesellschaft was founded, the question arose as to whether the development and manufacture of industrial heating equipment, primarily electric furnaces, and electric welding machines should be included in the manufacturing programme of the new undertaking. The decision was in the affirmative, at least, as far as furnaces were concerned, but it soon became apparent that domestic appliances on the one hand and industrial furnaces, arc and resistance welders on the other were too diverse in character, both from a manufacturing and sales point of view, to make a rational partnership. As a result, the decision was taken in 1925 to confine the Sörnewitz Works to the production of heating and cooking appliances for domestic use only, the responsibility for sales remaining, as hitherto, with the "Small Accessories Sales Department." The industrial heating business was allotted to the Industry Department, its supporting Works being mainly the Transformer Works in Nuremberg. This was to be the seat of development and manufacture of the resistance welding machines and other apparatus requiring electric heat for their operation, in particular, electric furnaces.

In the House of Siemens it had come to be realized that "Electric Heat" had been neglected for at least a decade. Not only had the Americans gained an enormous lead (which might have been considered pardonable), but also British manufacturers and competitors at home. As the gap was not going to be easy to close, the Transformer Works took the task in hand with all the greater energy. The management at that time lay in the hands of Karl Kurda, an old Schuckert man, who forthwith set a number of the best brains in the design department to work on the interesting problems involved. When eight years later in Essen the "Electric Heat" Exhibition presented a broad survey of the state of development in the industrial uses of heat in Germany, Siemens-Schuckert had nothing to be ashamed of.

Amongst other things, they had developed many kinds of drying furnaces, some in the form of long tunnels, through which freshly enamelled motor car bodies were drawn slowly on a conveyor belt, passing through graduated temperature zones to ensure even drying of the enamel without cracking. During the Exhibition it was learnt that an automobile manufacturer had received delivery of an electric furnace of this type having a length of 91 metres and an electrical rating of 1,000 kW. For a number of years this was the largest electric furnace in Germany. Other furnaces for the heat treatment of steel by annealing and hardening were in some cases of the tunnel, and in others of the ring type. A most important feature of these furnaces was the maintenance by precision regulators of the exact temperatures required in the treatment.

Particularly stringent conditions were attached to the process of bright annealing, in which scale must not be allowed to form on the surface of the work. The equipment required for this purpose was frequently extenvise, annealing being performed in an atmosphere of protective gas, and there was often no alternative to the electrical solution of the problem. Pusher furnaces heated a number of blocks of steel, the last of which, when introduced at the charging end, expelled the first at the discharging end. Walking-beam furnaces, by means of an ingenious reciprocal motion of rising and falling beams, slowly propel the charge through the furnace. A chrome-nickel tube, heated by the passage of electric current, itself forms a furnace which is traversed by a steel strip. After heat treatment in this way, the strip is eventually worked up into safety razor blades. Salt bath furnaces with molten salts are used for hardening cutting tools, and others with Silit heating rods for firing porcelain. If the various kinds of welding machines, viz., butt, spot and seam welders, many of them fully automatic, are added to the furnaces, some idea will be gathered of the part played by electric heat in industrial processes.

Among the products shown by Siemens at the Essen Exhibition was a steel furnace of special design, viz., the high-frequency or induction crucible. This furnace operates on the principle that the transfer of the energy of an alternating current from one conductor to another, physically separate conductor, is made possible by the existence of the joint magnetic field, which "couples" them electrically. In order to render this coupling as effective as possible, the two conductors (in the case of an ordinary transformer) are mounted in the form of coils on the transformer cores, which are built up of sheet iron laminations and arranged to form a yoke, in order to provide a closed iron circuit for the magnetic field. If the iron yoke is omitted, the inductive action continues to be present, although much weaker, since it is greatly amplified by the iron; a considerable proportion of the lines of magnetic force stray, moreover, from the desired path and are lost, as far as the energy transmission is concerned (loose coupling).

The transfer of energy in a loose-coupled system of this kind also depends on the frequency, rising rapidly with increasing frequency. It would, therefore, be possible to use transformers without cores if, instead of being 50, the frequency were raised to 500 or 5,000 cycles per second. This is, however, not feasible for other reasons.

In 1917, Dr. E. E. Northrup in Princetown, New Jersey conceived the idea of using high frequency currents of this kind for local heating. He visualized an arrangement in which the primary coil consisted of a spirally wound conductor, and the secondary of a fire-proof crucible filled with pieces of metal and placed in the space enclosed by the coil. If high-frequency alternating current were passed through the primary coil, it must produce currents of the same frequency in the metal in the crucible, and, as the resistance would be low, of considerable magnitude. Laboratory experiments with small crucibles demonstrated that steel could be melted in this way with ease.

To generate high frequency current, Northrup commenced by using an oscillating circuit consisting of coils and capacitors connected through a spark gap to a source of electric current, in the same way as in the beginnings of wireless telegraphy. For higher outputs, it became necessary to build special single-phase alternators for frequencies of 3,000, 2,000 or 500 cycles. The circuit had a capacity, the amount of which was adjusted to correspond to the self-induction in order to produce a natural frequency equal to that of the generator. In this case (resonance), the energy of the generator could be transmitted without much loss through the oscillating circuit to the furnace coil, and thence to the contents of the crucible. About 1925 Northrup was beginning to supply furnaces of a few hundredweight capacity to the American steel-makers.

The Electro-Chemical Department of Siemens & Halske had gradually given up the manufacture of the Röchling-Rodenhauser induction furnaces in favour of the Héroult arc furnace, the former having been found difficult to operate. The Northrup idea appealed to them very strongly, however, and they lost no time in securing manufacturing rights under the Northrup patents. As the capacity of the furnaces increased, new problems cropped up, as always in such cases, but step by step the sizes increased, so that the furnace shown at the above-mentioned Essen Exhibition had a capacity of five tons, whilst some of the furnaces completed later were the largest of their kind in existence. Where it was a question of maintaining the exact composition of the alloy, the induction furnace was unsurpassed. With the arc furnace there was always the danger of broken pieces of electrode dropping into the charge.

The principle of the induction furnace, viz., the generation of eddy currents in the bath by means of a high-frequency magnetic field, found a further interesting application. In certain cases it was not required to melt the material, but only to heat it. The charge might consist of semi-finished parts which only required heat-treatment. A portion of a spindle could be heated up locally by a suitably dimensioned coil passed over it, or flat surfaces could be treated by disc-shaped coils fitted in plate holders. Depending on the duration of the process, the parts can be heated evenly throughout, or the heating can be made to penetrate to a certain depth only. This is the object in view in so-called case hardening, where the interior of a spindle or shaft must remain soft and tough, whilst the surface is required to be hard to withstand wear. The higher the frequency of the magnetic field, the less was the penetration of the current in consequence of the "skin" action. Siemens-Schuckert, who made a special study of this technique, succeeded, by using frequencies of 200,000 to 300,000 cycles (produced in special tube generators) in heating a surface to a depth of one millimetre or less in fractions of a second. The effect of the saving in time in mass production as compared with former methods will be easily understood.

Notwithstanding the competition of the induction furnace, the arc furnace had secured a commanding position as regards electrically produced steel, and the number and capacity of these furnaces grew from year to year. Furnaces of 25 tons capacity, or even more, were no longer uncommon. The consumption of carbon electrodes increased in proportion. In addition, it was learned that the Swedes were experimenting with the direct production of steel from the ore in arc furnaces. The carbide industry was busy extending its production, mainly by the cyanamide process; the alkali-metal-chloride electrolysis industry required large slabs of particularly resistant carbon, and the largest consumer of carbon electrodes was the aluminium-producing industry. It was therefore not surprising that the manufacture of carbon electrodes came to be of increasing importance.

In Nuremberg there were two firms of this kind which had originated as makers of lead pencils; the pressing and firing of arc-lamp carbons, which started here and at the Works of Gebrüder Siemens & Co., had been copied from the manufacture of the cores of lead pencils. The brothers Fritz and Moritz von Hardtmuth, who about the middle of the 1880's had founded a carbon works in Vienna under the style: "A.G. für Fabrikation von Kohlenstiften vorm. F. Hardtmuth & Co.," also started as pencil manufacturers. It was their intention to extend their famous pencil trademark "Kohinoor" to their carbon electrodes. The AEG and the Banking House of Jacob Landau were partners in the new venture. In order to enable anthracite to be used in place of the more expensive lamp-black and retort graphite, a process had been worked out for separating the anthracite ash by means of hydrofluoric acid. To operate the process, Works were built at Ratibor, close to the coalfields. However, the process was not a success; by the middle of the 'nineties the whole of the capital had been used up, and the Hardtmuth brothers compelled to resign. The firm was now taken over by the majority shareholders and renamed "Planiawerke A.G. für Kohlefabrikation." After a number of years the undertaking was restored to health, but the AEG appeared to have but little liking for it, for the majority of the shares were sold in 1912, with the acquiescence of the AEG, to the Rütgerswerke, who were specialists in coal refining processes. The Planiawerke A.G. and the Rütgerswerke amalgamated in 1916 under the name "Planiawerk."

It had long been a matter of common knowledge that the graphite electrode was superior to the carbon, but that it was very difficult to produce it in the necessary quality. The raw material had to be mixed with a binding agent, pressed into a form and fired. In this process the binding agent is reduced to carbon, so that the final product is a mixture of graphite and carbon. For many purposes this was by no means an advantage. In steel making, for instance, the carbon was consumed, while the graphite fell unburnt into the bath, thereby altering the composition of the steel. On the other hand, Siemens-Billiter baths and other methods of alkali-metal-chloride electrolysis called for the purest possible graphite for their electrodes, since carbon was attacked by chloride.

The only solution of the problem was, as suggested in 1896 by Moissan, to manufacture the electrodes from carbon as hitherto and to convert them into graphite by treatment at very high temperature. All attempts to put this suggestion into practice, however, failed completely.

In 1899 Acheson, the inventor of carborundum, working along the same lines as Moissan, took out a patent for the production of graphite electrodes. The process was similar to that by which he had produced carborundum. He packed the carbon in a heat insulating jacket and raised its temperature to about 2,400° C by the passage of an electric current. A number of details, in particular the materials employed as catalytic agents to accelerate the conversion process, were kept secret. Using the water power of the Niagara, and protected by a comprehensive patent and carefully guarded secrets, the Acheson Company manufactured graphite electrodes for the whole world, including Germany.

During the war, the denial of American supplies gradually became extremely serious for the alkali-metal-chloride electrolysis industry, as it depended entirely on graphite electrodes. Under these circumstances, Gebr. Siemens & Co. undertook the attempt to copy the Acheson process, especially as the basic Acheson patent had just then lapsed. As a result they succeeded in 1916 in supplying up to 70 tons of graphite electrodes per month to the chemical industry. When it was learned after the war that the Americans had been using these graphite electrodes for their steel furnaces for some considerable time, Siemens resolved to exploit the experience gained by building a special graphitizing plant of their own. On account of the heavy power consumption which the process involved, they were anxious to avoid paying for current at the Berlin rates, and therefore looked round for a suitable source of hydraulic power. They found one at Meitingen on the Lech, not far from Augsburg. Here in 1921 they built a graphitizing plant, the capacity of which was doubled three years later, with a total of 22 furnaces and a power consumption of 5,000 kW. The rough pressings were supplied by the Lichtenberg Works.

The Works at Meitingen was the largest of its kind in Europe, so that Gebr. Siemens & Co. held a commanding position amongst the electrode manufacturers. In the face of this the Rütgerswerke were beginning to feel their position somewhat insecure; they had a number of other interests, moreover, which they considered more important than the manufacture of electrodes. They therefore dropped their original plan to build a graphitizing plant in Ratibor and approached Gebr. Siemens & Co., with the result that in 1927 the "Siemens-Planiawerke A.G.," Berlin, was formed to represent the joint interests of the two companies. Gebr. Siemens & Co. contributed the whole of its works, i. e., its factories in Charlottenburg, Lichtenberg and Meitingen, and the Rütgerswerke the Planiawerk. The majority of the shares lay with Siemens, so that the new firm, like its predecessor, could count as a member of the great House.

A similar occurrence (the absorption of a hitherto independent body by an organism with greater assimilative power) also took place in another sphere of the Firm's activities, viz., electro-medicine. In the earlier pages of this account, the narrative ceased for the time being with the situation as it was some years before the war. In order to join up the broken ends, it is necessary to insert a few words of explanation.

The vacuum tubes used in those days to produce Röntgen rays still contained a certain residue of gas. On the one hand, the attainment of extremely high vacua occasioned considerable difficulties, which were not overcome until later through improved pumping plant, and then the residual gases were found to be useful. Amongst these there were always sure to be a number of molecules which were ionized, i. e., which carried an electric charge. These were accelerated by the electric field, thereby bombarding the cathode and dislodging the electrons in the metal surface. Since the consequence was a continual decrease in the number of ions,

i. e., the quantity of residual gas, the tube would have become useless for want of ions, if traces of gas had not been introduced by a regeneration apparatus. This, however, was not physically a clearly defined condition, and the tubes were consequently uneven in their action.

Even before the war Siemens & Halske had ceased to use spark inductors, as was the original practice for the operation of the tubes. Since alternating current had meanwhile become the prevailing source of public supply, they generated the high tension for the Röntgen tube by means of a special transformer, which differed from the spark inductor in that the magnetic flux was provided with a closed iron circuit. The transformer, however, produces on the secondary side alternating current of the same wave form as that which is fed to the primary side, that is to say, two consecutive and equal half-waves but of opposite direction. Of these, only one can be used; the other half-wave must either be suppressed or reversed, so that it has the same direction as the first. This is one of the hoary problems of electrical science; it occurred for the first time, as will be remembered, when alternating current was generated in the first magnetelectric dynamos, and the direction of the second half-wave was reversed by connecting the ends of the coil to the halves of a split slip ring (commutator).

On these lines Siemens & Halske developed a high-tension commutator consisting of a spider capable of being rotated on a spindle, and arranged to brush past stationary contacts, thereby rectifying the second half wave. Since this had to be in the exact rhythm of the alternating current, the rotating part was driven by a synchronous motor which was connected to the same source of a. c. supply. On account of the noise and the ozone generated by the sparks, the rectifier had to be installed in a separate room.

Following the already chronicled discovery by Wehnelt in 1904 that electrons emanate in large quantities from a glowing cathode (a discovery which von Lieben and de Forest exploited in the development of their amplifiers), efforts were immediately made to apply this discovery to Röntgen tubes. Alongside German researchers like Lilienfeld and Rosenthal, as well as a German patent in the name of Fürstenau, W. D. Coolidge and his assistant, Irving Langmuir, perfected a tube in 1913 in the laboratories of the General Electric Co., Schenectady, which soon became known the world over as the Coolidge tube. This was made with the highest attainable vacuum, and the cathode was heated by a spiral filament, so that only thermally produced electrons were used in its operation. The number of electrons, in other words, the current, was easily controlled by varying the heating, whilst the applied voltage and hence the penetrative power of the rays (their hardness) could be varied independently of the current density, or dosage. From the point of view of the doctor, this mutual independence of hardness and dosage was a considerable advance.

For the anti-cathode, which when struck by the electrons gives rise to the Röntgen rays, and which in all later tubes was identical with the anode, it was desirable to have an element of high specific gravity, or, to be more precise, high atomic number, since, all other things being equal, the output of rays increases with the atomic number. The material of the anode, moreover, must have a high melting point, as the bombardment by the electrons is liable to bring it up to white heat in a short time. For this reason Siemens & Halske, at Rasehorn's suggestion, had already applied for a patent in 1904 for anti-cathodes of tantalum, and in a second application in the same year for a patent for anti-cathodes of niobium and tungsten. Tungsten was included at the instigation of Fischer, the Head of the Patent Department, against the wishes of Rasehorn and Bolton. The former, in particular, objected on the ground that nobody had so far succeeded in producing a piece of tungsten of the required size. Fischer prevailed, however, and a patent was granted for a design which it was as yet impossible to produce. The first Röntgen tubes with tungsten anti-cathodes were manufactured in 1910. Apart from its high melting point, tungsten differs from all other metals, including the heavy metals, in that after formation it liberates no further gas when under vacuum. In view of the fact, however, that the Coolidge tube depends for its efficiency on the vacuum being as near to perfect as possible, and not spoilt subsequently by gassing of the anti-cathode, it obviously needs an anti-cathode of tungsten.

Prior to the entry of the United States into the war, the General Electric Co. granted the AEG, with whom it was on friendly terms, manufacturing rights for the European market. The AEG would thus have been in a position to manufacture Röntgen tubes, had it not been that Siemens & Halske were sole owners of the patent covering anti-cathodes of tungsten. Up to this point, the AEG had not taken any interest in electro-medicine, but the Coolidge tube seemed to fit into the manufacturing programme of its incandescent lamp factory, and it was not prepared to forego the advantages which the patent rights conferred. The result was that the AEG and Siemens & Halske concluded an agreement, in virtue of which each partner granted the other the use of both patents, and in which the AEG reserved to itself the right to manufacture certain definite quantities of tubes for Siemens & Halske. The agreement was subsequently modified and extended on several occasions.

The advent of the Coolidge tube solved at a stroke the problem of the rectification of the high-tension current obtained from the transformer. The direction of the current is unmistakably laid down by the construction of the tube. The terminal where the heating drives the electrons out of the metal is the cathode; the other terminal is the anode, and since there is no residue of gas in the path of the discharge, the tube permits only that half-wave of the alternating current to pass which travels in the direction of the current from the anode to the cathode. The other half-wave is completely suppressed. A rotary rectifier is thus no longer necessary. If it is required to make use of the suppressed waves, which is important in cases where it is desired to intensify the action of large sets for radiation treatment, this can be done by the use of simple supplementary tubes, similar in design to the Röntgen tubes, but differing in that they do not emit any Röntgen rays, while acting as suppressors for one direction of the current—so-called hot-cathode tubes. When connected to the Röntgen tube and the transformer in suitable combination, they feed the high-tension alternating current to the tube in such a way that the whole of the half-waves pass through it in the same direction.

Although Röntgen rays have been the most important contribution of electricity to medical science, there have been others. Some of these, incidentally, were among the earliest problems with which the newly established Firm of Siemens & Halske found itself confronted. At the request of du Bois-Reymond and in accordance with his instructions, Halske made an induction apparatus with interrupter for Faradisation, as it was then called, which led to the discovery of the du Bois Law concerning the effect of electric currents on the human body. Siemens & Halske also supplied him with supersensitive galvanometers for investigating electric currents in the muscles. Doctors, in general, were beginning to prescribe electrical treatment with alternating or direct current (Galvanisation or Faradisation), and for these also Siemens & Halske supplied the necessary apparatus, in the main fine-step regulators for controlling the exact dosage.

The turnover did not amount to much, particularly as there was no active sales organization. The electromedical business can be said to have dated from the introduction of the Röntgen tube. A further form of electrical treatment which came into use during the war was that known as diathermy, in which a high-frequency alternating current, which has no irritant action on the nervous system, is used to achieve local heating of internal parts of the body. A remarkable piece of apparatus which was developed about the same time was a hearing-aid known by the name of "Phonophore." It consisted of a microphone, a dry battery and a telephone, the combination being a miniature work of art, so small that it was capable of insertion in the auditory canal. The business in hearing aids expanded after the war to very considerable dimensions.

The electro-cardiograph, an instrument almost the same in principle as the oscillograph, was also a considerable achievement. Its purpose is to record the functional currents of the heart, which present a clear picture of its action. The two instruments differ, however, in the much greater sensitiveness of the cardiograph, since the heart currents are so weak that they can only be picked up and recorded with the most sensitive of instruments. The metering system of the cardiograph (a coil in a magnetic field with small mirrors cemented in position) was manufactured in the Wernerwerk and was a work of art which obstinately defied all attempts at rationalized production; it could only be made individually by specially skilled mechanics. On account of its liability to damage, the instrument was at first to be found only in the larger hospitals and clinics, but in both cases has rendered inestimable services, both in connection with research and with the therapeutic treatment of diseases of the heart. Later, an amplifier was inserted between the receiving transmitter and the measuring instrument, which enabled the heart action voltages to be recorded instead of the less clearly defined currents. The instrument itself was also made mechanically more robust, and there is now a portable model available for use even in sports grounds.

The development of the cardiograph after the war pointed to the advisability of taking it out of the Measuring Instrument Department and transferring it to an independent "Sales Department for Electromedical Apparatus." As a result there was greater activity in the matter of publicity, in maintaining contact with well-known doctors, and in the equipment of a special show-room in the Langenbeck-Virchow Hospital, where the Annual Congress of Surgeons and other assemblies were in the habit of meeting.

Apart from Siemens & Halske there were other firms in Germany who manufactured electromedical apparatus, the chief of these being Reiniger, Gebbert & Schall A.G. in Erlangen, and the Veifawerke in Frankfort on the Main. Of more recent date was the firm of C.H.F. Müller in Homburg, which concentrated primarily on Röntgen tubes, and had gained a first-class reputation for their quality. Beside these large undertakings were a number of small ones, and amongst these were firms which made apparatus and instruments for the medical profession and for hospitals and, as a side line, electromedical apparatus. Except in the case of makers of very simple apparatus, it was only the large and financially well-established houses which could stand the strain of competition. In that period of rapid development, the Röntgen apparatus, in particular, was of such a nature that in the event of a breakdown, there was little a layman could do about it, and in this respect doctors were to be regarded as laymen. It was only in the large hospitals that personnel was available with sufficient technical knowledge to attempt to put matters right—and then not by any means in every case. The doctors in small hospitals and the independent specialists, however, were dependent on the manufacturers coming speedily to their aid in an emergency. It lay with the manufacturers to give their clients detailed instructions on the operation of the sets, and to maintain close touch with clients, in order to apply the experience gained to the further improvement of their designs. The same thing was noticed as had happened a generation earlier during the rapid development of power current, viz., that commercial advantage can only be taken of all the possibilities if the manufacturer has a large number of well distributed Branches at his disposal. To keep abreast of competitors it was necessary to have a staff of qualified engineer-salesmen, well schooled in the service of customers. Considerations of this kind and war-time difficulties led Dessauer, who had meanwhile become Professor of Experimental Physics at Frankfort University, to sell his holding in Veifa shares in 1916 to Reiniger, Gebbert & Schall. This alone made that firm a very serious competitor of Siemens & Halske, and the situation became more difficult still when the Chairman of the Managerial Board of Reiniger, Gebbert & Schall, a certain Mr. Zitzmann, embarked on a policy of expansion on the Stinnes pattern by buying up numbers of smaller firms. Only a minority of the firms absorbed were manufacturers of electromedical apparatus or their components, such as Phönix Röntgenröhrenfabriken A.G., Rudolstadt, or the Polyphos GmbH, Munich (which also produced Röntgen tubes); Zitzmann bought up any firm which catered for the requirements of doctors and hospitals in scientific apparatus, such as surgical instruments, dentists' chairs, invalid furniture and sterilisers. In the post-war period the position of all these firms had become insecure and they were an easy prey for an inflation speculator of the type of Zitzmann. Admittedly, he confined his speculations to the sphere of medical equipment, relying for his information on the technical knowledge of his co-director, William Niendorf. In this way he had ultimately forged a block of 20 large and small undertakings (including his own firm and Veifa), which he amalgamated in 1921 into a Holding Company called "Industrieunternehmungen A.G., Erlangen (Inag)." Soon after the stabilization of the German currency it became obvious that Zitzmann's speculations were not based on sound business principles and early in 1924, rumours of irregularities in the management of the firm began to circulate. The Board of Directors caused an enquiry to be made into these matters, with the result that Zitzmann was given immediate notice to leave. The management of the firm was taken over by two members of the Board of Directors, Dr. Müller and Dr. Sehmer, who were entrusted with the task of putting the firm on a sound footing again. As they considered it necessary, if the firm was to recover at all, to strive for a coalition with Siemens & Halske, negotiations were commenced with the House. To begin with, the negotiations led to no result. Carl Friedrich von Siemens was not in favour of a merger and had given his chief negotiator, von Buol (Manager of the Wernerwerk M), terms which the other side could not see its way to accept. In the first place, Carl Friedrich disliked the Inag, the "Chain Store," as he called it, and let it be known that he was, in fact, not at all desirous of forming a Trust, even in a limited sphere. In his opinion it was essential to maintain a state of healthy competition. It was whilst negotiations had thus reached a deadlock that a new offer was received. C.H.F. Müller was for sale. Siemens now had to make up their minds as to which offer to accept, as otherwise, if they refused both, they courted the danger of both undertakings falling into the hands of some strong financial group —perhaps foreign—and becoming a powerful competitor. The position was similar to that which had arisen twenty years before in connection with Schuckert. Siemens were at first disinclined to move but eventually found themselves compelled to do so in order to ward off greater danger. Thus it came about that negotiations were resumed with the Erlangen firm, with the result that late in 1924 Siemens & Halske acquired a majority of the Reiniger, Gebbert & Schall shares. With these in their hands they proceeded in 1925 to establish the "Siemens-Reiniger-Veifa Gesellschaft für Medizinische Technik m.b.H.," the three associates being Siemens & Halske, Reiniger, Gebbert & Schall and the Veifawerke. It should be noted, however, that the gudgeon had already been gobbled up by the carp, and the carp devoured by the pike before this took place. The "chain-store," Inag, was allowed to continue in business, but was shorn of such departments as would have led to a waste of energy through the pursuit of objects which were foreign to the purpose of the undertaking. All those departments, on the other hand, which were connected with engineering production, such as the manufacture of dentists' operating chairs and accessories, were retained and developed; in conjunction with electric control, these attained a high degree of precision of manipulation. Broadly speaking, the manufacturing programme of the combined undertaking covered the ancillary requirements of hospitals and clinics with electromedical equipment. For the time being, the three factories in Siemensstadt, Erlangen and Frankfort continued in production so as not to disturb the work of reorganization; then, in 1932, everything was transferred to Erlangen with the sole exception of the Röntgen tubes, which continued to be made in the Phoenix Works, Rudolstadt. The erstwhile undertaking of the style and title of Siemens-Reiniger-Veifa GmbH was taken over by the Reiniger, Gebbert & Schall A.G. and 1927 renamed "Siemens-Reinigerwerke A.G., Berlin," quite evidently a somewhat complicated legal proceeding. The transaction was eminently successful, for within a few years the Siemens-Reinigerwerke had become the largest, most versatile and productive manufacturers of electromedical apparatus in the world.

As Manager of the Wernerwerk M, which was also responsible for electromedical sales, von Buol had not only to carry through the difficult negotiations with the Reiniger group, but later to guide the merging of the departments from heterogeneous units into a homogeneous body. In particular, the utmost care had to be taken to build up an efficient sales organization, upon which more depended than in most departments of the House. In all this he exhibited such exact knowledge, based on a close study of the subject matter, proceeding steadily yet with caution, that Carl Friedrich was repeatedly astonished. Although he knew von Buol to be a genius in many respects, he had always thought of him primarily as a technician. The way in which von Buol applied these gifts in the conduct of commercial negotiations, internal organization, and even in the formulation of legal statements was, however, unique. Carl Friedrich disliked nothing so strongly as dilettantism in business. He despised the juggler in Industry, whose hey-day was the inflation period, and he knew from the history of the House of not so long ago that the Firm had not always kept clear of people whose promises were greater than their performance. Here, however, was a man after his own heart, and when Franke, now ageing, should decide to lay down his burden, Carl Friedrich had a successor ready to hand.

XXIV.

ELECTRO-ACOUSTICS

Simultaneously with the increasing replacement during the first World War of the crystal detector by the electron tube for wireless reception, another development was taking place, which also raised the electron tube to a position of the first importance as an oscillator in wireless transmission.

As will be remembered, the object of the original spark-gap (Funkenstrecke), which in Germany gave its name, "Funk," to the whole procedure, was to open and close the oscillation circuit (consisting of capacity and induction) in rapid succession. The capacitor was charged during the interruption of the spark-gap, and energy thereby fed into the circuit; when the gap was closed by the spark, the capacitor discharged its energy into the circuit, giving rise to oscillations which were radiated as a train of electro-magnetic waves from the antennae. A train of waves of this kind is thus the result of the discharge of a limited amount of energy. The amplitudes of the waves die down very rapidly, similarly to the string of an instrument when plucked—they are "damped." If means are taken to feed energy continuously into the oscillation circuit, however, i.e., if the string is not plucked, but stroked with a bow, continuous, "undamped" oscillations are produced. It was soon discovered that these have a number of advantages as compared with damped ones.

It is possible to produce undamped oscillations with the original circuit by using an arc in place of the spark-gap. This is related to the fact that voltage and current in the arc do not conform to Ohm's Law, but that they assume a peculiar relationship to one another. This had been known for some considerable time. It was the telegraph engineer V. Poulsen in Copenhagen, however, who was the first to demonstrate that the electrical values must fulfil certain definite conditions for the apparatus to be of any use.

If a wave-train of undamped oscillations was "keyed," i.e., interrupted in the rhythm of the symbols, the work of the receiver was merely to rectify the high-frequency oscillations in the receiver circuits (by means of the crystal detector, perhaps, or later, the capacitor detector), and to register the resulting d.c. impulses. A telephone, of course, would not react to these current impulses, any more than it would have transmitted the Morse signals of the old d.c.-operated wired telegraph. If audible reception was required, it became necessary to chop the current impulses at an audible frequency, in order to produce a tone of the same kind as when generating damped wave-trains by means of the spark-gap.

Since it was possible to transmit more power by means of the undamped waves, these were at first adopted for long-distance traffic, e.g., for communication between Europe and America. In operating thus it was found that the electro-magnetic waves clung to the Earth's surface, as if it were a conductor, which was quite comprehensible as far as the oceans were concerned.

If the waves had radiated in straight lines, a European station could never have made contact with America on account of the curvature of the Earth's surface. On the other hand, this gliding of the waves on the surface entailed considerable losses which, incidentally, varied widely according to the time of day, i.e., the position of the sun. They also varied with the wave-length. Long waves were not damped as much as short waves. For transatlantic communication the tendency was, therefore, to use ever-increasing wave-lengths, i.e., lower and lower frequencies for the transmitter and receiver circuits. About 1910 a wave-length of approximately 7,000 metres had been achieved. A little later this was increased to 18,000 metres in special cases. This led to a corresponding increase in the measurements of the antennae, since the length of the aerial feeder must bear a certain relationship to the wave-length. This necessitated the erection of enormous pylons for the antennae.

The longer the wave-lengths, the lower the frequency in the oscillation circuits. A wave-length of 3,000 metres corresponds to a frequency of 100,000 cycles, and a wave-length of 10,000 metres to a frequency of only 33,300 cycles. Thus a reduction had gradually been made in the frequency figures from the millions of earlier practice to an order of magnitude which invited the question as to whether it was not preferable to generate these high-frequency currents in specially designed alternators. These would be very high-speed machines with a very large number of poles. E.T.W. Alexanderson of the G.E.C. (America) was the first to build a serviceable machine for 100,000 cycles and an output of 2.1 kW; a little later, in 1910, a second h.f. machine designed on another principle by R. Goldschmidt, and with an output of 12.5 kW at 33,300 cycles, was set to work in Germany. With machines like these a start was now made to equip stations for transmission overseas.

Meissner's discovery that electron tubes with grids could also be used to produce undamped oscillations, gave the nations at war the incentive to convert the crystal sets used in the field to electron transmission with damped waves. This took place more or less simultaneously on both sides in the course of 1917. These electron tube sets were suitable for use with the range of frequencies employed by the troops, viz., between 200 and 700 metres, and in view of the short distances involved their small output was in every case adequate for field requirements. It was a more difficult matter, of course, when the attempt was made after the war to use these transmitters for the heavy duty involved in wireless communication over long distances with long wave-lengths. In 1920, Telefunken commenced to use them for large transmitters with outputs up to 20 kW. Whereas with the output hitherto dealt with in these electron tubes, voltages and currents had been low and the bombardment by the electrons of the anode had not caused any appreciable heating, it now became necessary to employ anode voltages up to 15,000 v, and the cathode had to deliver a multiple of the quantities of electrons previously produced. This meant a considerable increase in the dimensions of the tubes and artificial cooling of the anodes, which now consisted of hollow cylinders of copper traversed by cooling water; a number of these tubes had to be connected in parallel. All this gave rise to many difficulties, but development nevertheless forged ahead with great strides, particularly in the United States, where the former American Marconi Company had meanwhile become the Radio Corporation of America, a subsidiary of the General Electric Co. This firm not only manufactured wireless apparatus but also operated the large wireless stations. In this way it practically held a monopoly of everything connected with wireless in the United States.

The war brought about a curious change in the attitude of the average man to wireless. Formerly it had been the concern of a few specialists; the broad masses, even in industrially developed countries, just knew of its existence, without having any knowledge of its scientific principles, much less its technical applications. As in so many other respects in our daily life, the war ushered in a wireless revolution. The belligerents on both sides were equipping their forces with this means of communication to an increasing extent. Every aircraft, every ship, every staff and every army unit of any size had its wireless station. Thousands upon thousands of wireless sets were installed on both sides and—without exaggeration—hundreds of thousands of men charged with their operation. The transmission and reception of Morse signals was practised, short instructional courses given on the general principles of waves, tuning, antennae and fault location, and above all, the men were given the apparatus and shown how to operate it. When the war was over, there were many who continued to take an interest in the subject, and with the help of text books, commenced to rig up wireless sets of their own with components obtained cheaply from the surplus stock of war-time supplies. This hobby attained considerable dimensions, particularly in the U.S.A., the El Dorado of the self-taught, and in the British Dominions, but there were not a few of those amateurs in Europe and especially in Germany, where, of course, it was not long before corresponding clubs were founded to cater for their interests. At first the amateurs went to work on wave-lengths between 200 and 700 metres, as they had been accustomed in the war. Since the growing density of wireless traffic resulted in increasing mutual interference, and it was difficult with their small sets to produce longer waves, the amateurs sought a way out in the direction of shorter wave-lengths. They had, of course, to take the disadvantage of the smaller transmission range of their set into account. Then, in 1920, there came the surprising news that amateur stations, working on wave-lengths between 12 and 50 metres, which according to all the rules could not have a range of more than 50 kilometres, had been heard at several hundred kilometres after passing through a belt of silence. Reception was reported to be perfectly reliable, and under favourable conditions it was even possible to bridge the ocean.

Careful experiments and deliberation led to the formation of the theory that in the upper strata of the atmosphere there is a zone in which (presumably under the influence of cosmic radiation from space, about which little was as yet known) the molecules of the atmosphere are ionized, i.e., separated into positive and negative particles. This zone is in consequence, an electrical conductor in the same way as a dissociated liquid, and acts, therefore, on electro-magnetic waves in the same way as a transparent and at the same time reflecting medium on light waves. The transmitter, of course, does not only emit waves which cling to the Earth, being considerably damped by absorption, but also waves which are directed upwards, i.e., skywaves. These strike the conducting strata of the ionosphere at any particular angle, and—in simple language—are reflected at a corresponding angle, with the result that they reach the Earth only slightly damaged and are strong enough to be received. If this theory proved to be capable of practical application, it was obvious that the days of the giant long-wave stations for overseas transmission were numbered.

As soon as it became possible to generate undamped electro-magnetic waves, i.e., since the introduction of the Poulsen arc transmitter, the means had also been available to give practical effect to an idea, about which much had been said, but for which the original chopped, damped waves of "spark" telegraphy were unsuitable. This was the wireless transmission of speech. If a microphone in the circuit of the antennae is spoken into, the antennae current will vary in the same rhythm as the speech oscillations, since the microphone is a variable resistance. If the antennae current is an uninterrupted alternating current of high frequency, as in the case of the undamped waves, the effect on the radiated waves of speaking into the microphone is to vary their amplitudes (the crests and troughs of the waves) in the rhythm of the speech oscillations. One says that the uniform fundamental oscillation of the transmitter, the carrier frequency, is modulated by the superimposed voice frequency. Human speech, however, is made up of the fundamental oscillation, the higher harmonics and the fundamental frequencies, so that the modulation of the carrier wave by speech produces a whole series of different waves, a wave-band, the width of which increases with the increasing length of the carrier wave. Long waves such as had hitherto been used in transoceanic telegraphy were therefore unsuitable for wireless telephony, as they occupied an excessive width of zone and were too easily prone to mutual interference.

In the closing years of the war a commencement was made in Germany with the telegraphing of news items of general interest, such as the front-line and other official reports, from a wireless station. The bulletins were directed "to all," and were thus used by the Press. Later on, weather reports, Stock Exchange quotations and similar information was included. in 1919, Dr. Hans Bredow (formerly one of the leading engineers of the Telefunken Company and now in the service of the Post Office) came forward with the proposal to replace wireless telegraphy by wireless telephony, which was simpler to receive. At a public meeting in Berlin he made propaganda for the idea, explaining that it would be possible to transmit instructive or entertaining lectures and music. He advised as many of the public as possible to join the "Broadcasting" scheme, for which he prophesied a great future. In the United States, where a few individuals had already been thinking along similar lines, the idea was taken up enthusiastically, and whilst the question was still under consideration in Germany as to how the organization could be mounted without infringing the monopoly rights of the Post Office Telegraphs, hundreds of broadcasting stations came into being in America as the result of private initiative. These, like the newspapers, earned their income by advertising and recommendations. The firms which had hitherto built wireless sets for the Army and Navy adapted themselves to the manufacture of broadcasting receivers, and flooded the country with their products. A regular broadcasting fever broke out. From America the craze spread to other countries. In Germany, the Post Office and other Government Departments were inundated with offers.

One of the chief reasons for the rapid spread of broadcasting was the introduction of the loudspeaker. At first the listener sat alone beside his set, equipped with earphones, just as the Army signaller had done before him. But these primitive sets were soon improved; both the high-frequency oscillations and the low-frequency sounds were amplified by tubes and soon there was enough output available to operate a loudspeaking telephone. This instrument was a great advance on its predecessors of the days of the fire control equipment, both in technical efficiency and purity of tone. The improvement was the result of systematic research into the complicated phenomena accompanying the origin and radiation of sound in membranes and other oscillating bodies. It may, in fact, be said that this became the occasion for a revival of the study of acoustics, a long neglected science. Hans Riegger and Ferdinand Trendelenburg, both Assistants in the Siemens Research Laboratory, each made important contributions to this revival. Riegger, who was extremely gifted, unfortunately died at an early age.

A component which was to profit by this development was the now 50 year old microphone, first propounded by Hughes in 1878. Hundreds of inventors had endeavoured to improve it, but had nearly all retained the idea of movable carbon contacts which varied their resistance under the influence of sound waves. Siemens & Halske now struck out in a new direction. Riegger developed a condenser microphone, in which a thin metal foil formed one side of the coating of a capacitor, whilst the other side consisted of a rigid metal plate, the two being separated by a small air-gap. The oscillations of the foil caused by incoming sound waves altered the capacity of the condenser. Provided that the condenser was in an alternating current circuit of sufficiently high frequency, these variations of the capacity gave rise to variations of the current, which, when rectified and recorded by an oscillograph, provided a copy of the sounds of speech and music with a fidelity hitherto unattained. A second microphone, in which a thin strip of metal was stretched across the field of an electro-magnet (originated in the Central Laboratory of the Wernerwerk). Oscillations of the strip consequent on the impact of sound waves gave rise to currents in the strip induced by its movement in the magnetic field. On the same principle, but in reverse, electrical oscillations could be re-converted into sound; with the necessary amplification of the current and the employment of a tape-type loudspeaker, results were obtained which at that time were little short of sensational. In a somewhat different form to that suggested by Gerlach this design, known as the "Riffel loudspeaker," found extensive use in large assembly halls, churches and even for open-air gatherings. A particularly efficient loudspeaker, developed by Riegger, was the "Blatthaller," in which a number of series-connected conductors are enclosed in magnetic fields and connected to a large leaf as membrane. The leaf was not fastened at the edges, but was free to move back and forth like a piston under the influence of the electrodynamic forces acting on the conductors, and was thus capable of causing an enormous agitation of air.

The instrument to which Edison owed his early fame, and which he called the Phonograph, had meanwhile undergone considerable improvement. The original wax cylinder in which the recording needle cut the sound track in spirals had been replaced about the turn of the century by a horizontal disc, as suggested by Berliner, on the surface of which the sound track was disposed in spirals, proceeding from the outside to the centre. Sound variations were no longer produced, as in the wax cylinder, by cutting more or less deeply into the wax, but by lateral deviation. The needle thus described a minute wave track. It was in this form that the instrument became popular, and that the recording and reproduction of records of the immortal performances of conductors and tenors grew into a very profitable line of business.

Here again, the introduction of the amplifier opened up totally new possibilities. If, when playing a record, the needle is no longer made to act directly on the membrane, but its minute oscillations used to operate a small moving coil in a magnetic field, the resulting current can be amplified and rendered audible in a loudspeaker. It was found that the quality of reproduction was thereby greatly improved, especially when this process was used to cut the matrix; it was also found that the volume of sound could be varied over a wide range. In the United States manufacturers began to give their attention to these improvements in 1924, and a year later the "Brunswick-Balke-Collender Co.," Chicago, and the "Victor Talking Co.," Camden, had already turned over completely to electrical recording. The first-named group, which co-operated with the General Electric Co., immediately got into touch with the so-called Talking Machine Concern in Germany, the leading partner in which was the "Deutsche Grammophon A.G." At the request of the General Electric Co., the AEG took an interest in the Grammophon A.G. and manufactured the electrical equipment required.

The next step was to design a low-frequency amplifier with loudspeaker, either as an adjunct to a broadcasting receiver or as an independent unit, so that it could be used, as required, for broadcasting reception, for a gramophone, or for a microphone. It was now possible to install the apparatus in public halls, restaurants and fun-fairs, hospitals and sanatoria; the whole equipment could be rendered mobile, and used for public announcements in the streets.

As far as Germany was concerned, these fundamental developments took place between 1923 and 1928. In those five years a new technique had conquered the world. The number of wireless subscribers in Germany rose to three millions, to whom must be added a considerable number of unlicensed listeners. In point of the number duly licensed, Germany came next to the United States. A new factor in the national economy thus came into being, in the shape of an industry which for years to come was going to be working to the limit of its capacity. The Post Office erected one transmitting station after another. Studios, usually at some distance from the antennae, had to be built and connected up by cable of a new type, specially designed for broadcasting. The stations were operated by companies under the control of the "Reichs-Rundfunk-Gesellschaft," in which again the State had the controlling interest through the Post Office. Supervisory and cultural committees became the battleground of political and philosophic antagonism; procedures had to be worked out with regard to public relations and to receive the juridical seal. Journals were published, some technical and others devoted to the broadcasting programme. Whole libraries of popular, semi-scientific books were published. Large numbers of people were given employment, amongst them administrative personnel, technicians, musicians and actors. The great majority of these, of course, found work in the factories that were springing up daily, offering sets with improved circuits, improved components, or of new and attractive appearance with which they sought to beat their competitors. Every year at the beginning of August the new "season" was ushered in by a large exhibition in Berlin, in which the world was shown the latest models (for the well-to-do it was a point of honour to buy a new set every year). In addition to the manufacturers, there were repair shops and thousands of dealers throughout the country. There was money in the business.

There was, however, one serious obstacle to its expansion, viz., the Lieben patents. Without electron tubes there was no convenient method of producing undamped waves, and thus of wireless speech transmission, no capacitor detector, no amplifier, no loud-speaker. And without the Lieben patent there was no electron tube. All attempts to shake the last decisive patent DRP 249 142 of 4th November, 1910 had proved ineffective; with the war-time extension the patent was valid until 3rd November, 1933. The owner of the patent was the Lieben Syndicate, i.e., for all practical purposes, "Telefunken." No one in Germany could manufacture, sell or use electron tubes without the consent of Telefunken—such was the legal position.

The Lieben Syndicate soon realized, however, that the ruthless exploitation of this monopoly would unleash a public storm, which might be followed by consequences which it were better to avoid. Telefunken let it be known, therefore, that it agreed to the manufacture of broadcasting receivers incorporating its patents by others on payment of a moderate royalty. This "Telefunken Sanction" was subject to the proviso that the manufacturer purchased the necessary Lieben tubes from Telefunken. The position was accepted by all the firms wishing to participate in the electro-acoustic business.

For Siemens & Halske and the AEG, the two founder members, the ensuing situation was rather peculiar. New electrical firms or extensions of existing ones were springing up all round, and capturing a considerable portion of the market. If the Telefunken agreement was to be observed in letter and spirit, the two parent firms would have to leave the business to the daughter company; on the other hand, it was bound to create a rather curious impression if these two large firms, which had always been regarded as the pillars of the electrical industry, were to take no part in this new promising development. This last consideration was decisive, and the two parent firms resolved to consider themselves as licensees of Telefunken like the others, and to participate in the wireless business on their own account. Their intention was, however, to standardize the development work as far as possible. At one period, they even went so far as to employ the same "chassis" for the sets of all three firms, only the cases being different. But this competition, which was not really supposed to exist, soon led to acute differences, and when one day shortly afterwards C. F. von Siemens was about to attend a meeting of the three parties he openly expressed his intention of killing the broadcasting business of his Firm (and consequently also that of the AEG), and of leaving it exclusively to Telefunken. At this point, however, he suddenly found himself faced by lively opposition from within his own House. It was agreed that as Telefunken had no factory of its own—except for an experimental workshop—the procedure would amount to manufacturing for the daughter company to the latter's designs (although it was common knowledge that a great part of the development work would fall to Siemens), and eventually to seeing the Siemens products going out into the world under another name. Whilst this had unfortunately always been the case even as it was, there was this difference, that they were now dealing with a mass product which was going to be in every household.

Apart from this, the apparatus was still in the development stage, and it was impossible to foresee how possible applications might affect already existing departments. Then, a "Company for Wireless Telegraphy" had been established, now, it was quite a different matter. Beyond all this, Telefunken had still no sales organization, whilst Siemens & Halske had its Branch Officers, and these objections were followed by others.

In considering the organization of the branch offices in an earlier chapter, we had arrived at a point, prior to the war, where Siemens & Halske had their own staff, which enjoyed the support of the much more strongly staffed Siemens-Schuckert organization, and was subject to a certain amount of supervision by the Siemens-Schuckert Management. After the war, the growth of the turnover in fire alarm and telephone installations, in measuring instruments, water meters and electro-medical equipment, pointed to the desirability of freeing the Siemens & Halske outside representatives entirely from Siemens-Schuckert tutelage, and of setting on their own feet. Although both their volume of business and staff were as yet less than those of their sister firm, they were expanding rapidly —more so than Siemens-Schuckert. They required mass sales, either to the public direct or through dealers, on the lines of the Siemens-Schuckert business in vacuum cleaners, refrigerators, irons, cookers and other domestic appliances. Here was wireless, with a prospect of similar lucrative business for Siemens & Halske, which it was now suggested to turn over to Telefunken. That must never be! Without a doubt, the mass sale of wireless apparatus to a vast number of individual customers presented a never recurring opportunity to display the name and trademark of the Firm. In the upshot, the associates agreed that, as regards wireless business, each should go his own way, and it thus came about that the two large Houses which had been linked together by Telefunken, now faced each other and their subsidiary as competitors. The solution might be quite good, however, in cases such as this, where a technical novelty is concerned which is in the early stages of development.

Based on the pattern of the Siemens-Schuckert "Small Accessories Sales Department," Siemens & Halske now set up a "Small Sales Department," the core of which was to be the sale of wireless apparatus and its accessories. Under the management of Carl Friedrich's only son, Ernst, whose first responsible assignment this was, the department threw itself with vigour into the struggle. This class of business was totally different from that to which Siemens & Halske had hitherto been accustomed. Now, for the first time, they found themselves confronted with those incalculable manifestations of the mentality of the masses which revolve round the words "fashion" and "good taste."

Even before the war the AEG had attempted, with the support of an artist of repute, to eliminate incongruities in the outward form of certain of their products, particularly, however, in matters concerned with publicity, such as trade-marks, nameplates, posters, advertisements, printed matter and exhibitions, etc. The underlying principle was to build up the edifice, of whatever style, on a foundation of the laws of good taste. One day—in the year 1932—Siemens also felt the necessity of giving expression to the inner character of the House, and with this end in view approached Hans Domizlaff, a successful advertising expert, who had made a reputation by a series of witty and informative studies on the psychological connection between taste, fashion and publicity value. It was considered necessary, however, to acquaint the artist and psychologist a little more closely with the principles of electricity and the spirit of the House, a task which von Buol undertook with his usual thoroughness. The pupil on his part had to adapt himself to the convenience of his tutor, who could only find time for such extraneous work in the late evening after disposing of his extensive daily duties. Two men could then be seen sitting in a room of the otherwise dark and deserted building, working with the aid of black coffee and strong tobacco until the early hours. Von Buol was very fond of such opportunities of undisturbed discussion, in which he could give rein to his rich and many-sided intellect. Under the stimulating effect of Domizlaff's activities, his suggestions and designs, the resulting improvement in the appearance of its products gave the House a "new look," which proved to be as practical as it was in good taste.

Experience, of course, had to be paid for. The task at issue was to design a wireless set for the House of Siemens with an attractive exterior. Owing to the multitude of wireless manufacturers, both in Germany and abroad, sets of the most widely differing types were on the market, some of them of very strange appearance; everybody was experimenting. In making its choice, the public was governed to a great extent by outward appearance, and by a natural desire that the wireless set should match the furniture. Into this jumble of ideas Domizlaff introduced the reflection that the wireless receiver, especially the larger and more expensive set, is the musical instrument of the modern home and destined to replace the piano, all the more so, as Siemens & Halske were increasingly directing their efforts towards the satisfaction of the most fastidious requirements by the sound-quality of their instruments. The piano, however, in its familiar form and its ebony-black case, belonged to no particular period, and fitted in with furniture of any style. The same must apply to the outward appearance of its successor: just a plain cabinet, rather higher than broad with folding doors, ebony-black with internal components ivory-white. When the "gentleman in evening dress," as it was jokingly called, was introduced to a panel of the House for criticism, the members were immediately divided into two parties. The one was enthusiastically in favour of the idea, and convinced of its success. This opinion was voiced by all those who considered they understood something of art and good taste. The others were sceptical and adopted a warning attitude; these were hardened salesmen, the business friends of the dealers and the travellers. The "refined" proved to be in the majority over the "primitives," and manufacture of the "gentleman in evening dress" was commenced on a large scale. The fact that there was no sale in the first season was explained by the need of the public for time to become accustomed to a novelty of high quality; after a second season with no sale, it was resolved to start a resounding advertising campaign, but when after a third season the Firm was left with unsold stocks of the third series, it had to be admitted that the "primitives" were right, and that there was no alternative but to write off a few million Marks. In order not to lose everything, the stocks were dumped abroad below cost, and thus many a "gentleman in evening dress" found his way to the Balkans and among the savages. But the incident had provided the Firm with a valuable contribution to its study of the "mentality of the masses."

The year 1928 marked the close of the five-year span, of which it has been said that in it a new technique had conquered the world, i.e., that of broadcasting and the cognate sciences; at the same time it ushered in a new period, in which another technical novelty took shape, viz., the sound film. In this case, the pace of development was even faster, in fact, well-nigh revolutionary.

Up to then, films had been silent. The birth of the film can be said to have taken place on the occasion of the public demonstration in March 1895 by the Lumière brothers in Paris. From then until about the year 1913 it had progressed through the stages of a fun-fair. In 1900 there were two "picture houses" in Germany, in 1910 they numbered 456. Whilst on the one hand the photographic technique appropriate to picture making and reproduction had reached a certain definite stage of development, seriously minded people on the other hand were beginning to take an interest in the new cultural medium, and to discover that it had its artistic, as well as its commercial possibilities. Besides much that was inferior, the post-war production of the larger countries included the large spectacular films, the quality of which was not to be denied by the severest critics. But the film was silent, and there were many whose word carried weight who claimed that this was one of its inherent qualities, and that attempts to make it talk rested on a misconception of its natural mode of expression.

This notwithstanding, Oskar Messter had attempted about the beginning of the century to couple the gramophone and the film projector in such a way as to synchronize the picture with the sound. By this method Messter produced several hundred sound films without being able to gain their acceptance by the industry. Both picture and sound were rough, but as long as the honours were about equally divided, one could still put up with this combination of flickering and squawking. Film technique however, was making rapid progress towards higher standards, whilst sound production lagged behind, and was therefore felt to be an inadequate partner. This resulted in the dissolution of the marriage.

Not long after the invention of the phonograph by Edison, incidentally, Valdemar Poulsen had proposed a further method of sound recording and reproduction. He connected an electromagnet in the circuit of the microphone, and drew a steel wire across and between the poles of the magnet. On speaking into the microphone, the resulting variation of the magnet excitation induced corresponding rhythmic variations of the magnetism in the steel wire. If this same wire were drawn at the same speed between the poles of a second magnet with wound coils, the corresponding variations of current would be induced in the magnet as those which bring forth the sound in a telephone. As long as the amplifier was unknown, however, the procedure was confined to the use of earphones.

Immediately after the war three men with inventive brains came together in Germany, viz., Voigt, Engl and Massolle, and formed a working party which they called "Triergon," the object of which was systematic research into the basic requirements of the sound film. They were convinced that the best way to ensure synchronism between sound and picture was to provide a sound track on the film strip beside the picture. The sound track would have to be exposed to the light of a projector in the same way as the picture, so that the sequence from the reception of the sound to the point of its reproduction would be: sound—current variations—light fluctuations—film—light fluctuations—current variations—sound. The amplifier was already known in principle, all that was required was to provide it with a suitable form. The essence of the task was, therefore, the conversion of the current variations into light fluctuations and vice versa.

Since all sources of light which depend on the heating-up of the medium were much too sluggish to be able to follow the rapid variations of the current, the Triergon people developed a glow lamp in which the light effect is caused by the luminosity of the residual gases in a vacuum under the influence of an electric current. The only difficulty was the condition that the light must be proportional to the current which produced it, and much thought and many experiments were necessary before a suitable modification of the glow lamp was evolved. The inventors called it the "Ultrafrequency Lamp." In recording the sound, the weak current generated by the sound waves was amplified and fed to the ultrafrequency lamp, the light of which, after passing through a narrow slit, was thrown by a suitable lens on to the film. Here it produced a continuous strip of 7 mm width consisting of a series of very thin lines of not more than 1/100 of a millimetre thickness and of varying degrees of density. Pictures and sound were recorded on separate negatives, the requirements regarding the density of the emulsion being different in each case, and were only printed together on the final positive film.

In sound reproduction the object was to convert the fluctuations in the brightness of the translucent track into variations of the current. Here, the inventors took advantage of a discovery by Elster and Geitel dating back to the beginning of the century. Certain metals, in particular the alkali metals lithium, sodium, potassium, rubidium and cesium, have the property of giving up electrons from their surface when exposed to light. This "photo-electric" effect is particularly noticeable when an alkalimetal is employed as a cathode opposite an anode in a vacuum tube, and a light is directed onto the cathode through a window. If a sufficiently high d.c. voltage is applied to the anode and cathode, the resulting current will under certain circumstances be proportional to the intensity of the light. In this way the fluctuations in the light intensity due to the sound track of the film are converted into current variations, amplified and fed to the loudspeaker.

All that sounds very simple, but from the conception of the idea to the stage of practical utility was a long and laborious journey, characterized by a long succession of patents. After five years of work, they were at length able in 1923 to demonstrate the result to invited guests in one of the large Berlin picture theatres. Everything went off successfully from a technical point of view, but the demonstration aroused no commercial interest. The art experts, in particular, continued to object that the sound film was foreign to the nature of the moving picture. A firm was established in Zurich to exploit the process, and for a time nothing more was heard of it.

Five years passed, in which individual inventors continued to grapple with the problem in the seclusion of their laboratories. Some wanted to revert to the old idea of coupling the gramophone with the projector, others followed Poulsen's idea of the magnetized steel wire; there were now possibilities in both processes since the introduction of the amplifier. In the Central Laboratory of the Wernerwerk, too, the development of a sound film apparatus was taken in hand at Lüschen's suggestion. Here, the idea had struck them to inscribe the sound track on the film—as in the Triergon method—not by means of the ultrafrequency lamp, but by causing a sharp ray of light to fall on a small mirror attached, after the fashion of the oscillograph, to a sensitive measuring loop. This was actuated by the current generated by the sound waves. The ray of light described a curve on the film which formed the limit of the translucent track on one side. As in the Triergon arrangement, the result was a continuous band built up of parallel strips, but differing from it in being of variable width instead of variable translucency. The AEG also turned their attention to this problem. They endeavoured to dispense with the ultrafrequency lamp by making use of a property of nitrobenzol which had been discovered by Kerr, and was later used by Karolus with great ingenuity in the construction of an electric cell. When this liquid is exposed to an electric field it becomes doubly refractive, i.e., a ray of light is split into two rays having particular qualities (they are said to be polarized; the electro-magnetic wave, which is the ray of light, oscillates in only one particular plane, depending on the arrangement) and this effect bears a certain relationship to the intensity of the electric field which is subject to definite laws. The Kerr cell consists of a condenser with two parallel metal plates, between which is nitrobenzol. The ray of light passes through the liquid parallel to the plates. A prism of special construction is arranged before and another behind the cell, these prisms also having the effect of polarizing the light. Since the optical axes of the two "Nicol" prisms are at right angles to each other, the ray of light is extinguished when the Kerr cell is not excited. If, however, an electric field is created between its coatings, the ray lights up with a definite functional relationship to the intensity of the field. It is thus possible to convert current variations into light variations, i.e., to inscribe the sound on the film.

In the United States, too, the incubation period of the sound film was a time of intense study. The Western Electric Co. founded a subsidiary, the "Electrical Research Products Inc." which, in collaboration with the Radio Corporation of America, evolved several solutions of the sound film problem. Some of these were of the same nature as those produced in Germany. Other suggestions, sometimes pursued by the smaller firms, amounted to the combination of the gramophone and film strip, whilst endeavouring to improve the quality of the sound to such an extent (as compared with the original Messter apparatus) as to be acceptable to more fastidious tastes. In the end, a group which advocated the "Vitaphone" method of employing a gramophone, took the plunge, and commenced to equip some three hundred cinemas on these lines. Their first film was "The Singing Fool," and with the easily awakened enthusiasm of the American public the result was a mass hysteria of rapture. The picture was one of the very big events in the United States. All doubts as to the artistic possibilities of the sound film were swept away by this judgement of the people as by a whirlwind, and now all those in any way interested, e.g., the big film producers, the development laboratories, the factories, the theatres and, not least, the Stock Exchange, rushed in to participate in the new boom. Within a year the conversion from the silent to the sound film in America was complete—technically and in point of organization a very considerable achievement. It was not long before the enthusiasm reached Europe, and England in particular, which, in view of the common language, the Americans regarded as their domain.

This broke the ice in Germany. The simile is not inept, for in the same way as a sudden warm wind causes the pack ice on a frozen river to pile up in wild confusion, so the news from America created a veritable tumult in Germany. Messter, the Poulsen Patentees, the so-called "Küchenmeister" Group, Triergon, the AEG and Siemens & Halske—they all descended on the unfortunate film producers and theatre-owners with offers and warnings against possible infringements of patent rights. What were they to do? Not one of them had the slightest idea as to what all this to-do of advertisement, patent rights, and law-suits was about. What was the cinema proprietor to know about the talking steel wire, ultra-frequency lamps, Nicol prisms and amplitude processes? His concern was to show sound pictures, the public were demanding them, but as soon as he launched his canoe in the drift-ice, he was threatened with being crushed between the floes. Whichever way he made his decision, he found himself threatened with patent proceedings. In short, it was an impossible state of affairs.

Since this soon came to be recognized, an enterprising individual of the name of Brückmann succeeded in bringing the various parties together. With the Triergon group as the core (they being the most powerful on account of their patents) he brought together the other competitors mentioned above, with the exception of the AEG and Siemens, and formed the "Tonbild-Syndikat A.G." (abbreviated "Tobis"). He then approached the two large firms individually with an invitation to join the Syndicate.

Both firms refused. Tobis, with its twelve million Marks capital, appeared to them to be heavily over-capitalized, an opinion which later proved to be justified, as the capital had to be repeatedly written down. Their own development work had meanwhile progressed so far, moreover, that they could now count on being independent of Tobis, i.e., Triergon. Besides, the two firms felt an urge to form a united front against Tobis, especially as their work and patent rights were found to be largely complementary. The result was the founding in 1928 of the "Klangfilm GmbH," to which Siemens and the AEG each contributed half the capital. The articles of association were drawn up on the same lines as in the Telefunken agreement, except that the technical development work was to remain in the hands of the patent companies. Klangfilm was thus to be a pure sales organization. This soon proved to be impracticable, however, as it is very difficult for two parties who are competitors to join hands in carrying out development work for a third party. The consequence was that, after a few years, development work was handed over to Telefunken.

This was the fourth joint undertaking of Siemens and the AEG, the earlier three being the Accumulator Factory, Telefunken and Osram. But Klangfilm was in a different category. In the first case, the fusion was the work of financial interests operating, as was usual at that time, through the Banks. In the second case, politics played a leading part, whilst in the case of Osram, the step was suggested by the necessity for the rationalization immediately following the war. The Klangfilm partnership, on the other hand, was a sociological necessity. The retention of completely unregulated competition between three or more firms, with the brake of lawsuits and temporary injunctions, was completely alien to the nature of the film, which must have freedom of movement. Such conditions would have rendered the introduction of the sound film into Germany impossible, and would have resulted in a public demand for legislation.

Needless to say, the expected clash between Tobis and Klangfilm occurred immediately, occasioned by a film produced by the General Electric Co., and shown by Klangfilm to an invited audience in Berlin, which Tobis conceived to be an infringement of its development patent and copyright. After a dispute lasting about six months the parties concluded a pooling agreement. They exchanged their patent rights in the form of licences, whilst they apportioned their business interests by allocating manufacture and sales of the equipment to Klangfilm, and exploitation of the patent rights covering the film production to Tobis. Each partner had an interest in the other's turnover. This threw open the doors to the introduction of the sound film in Germany.

Not so, however, in the rest of the world. A violent dispute arose between Tobis-Klangfilm, of the one part, and the American groups on the other, mostly concerning the validity of the respective patents in the various countries, and continued until 1930. Since the victims in this war were mainly the customers, i.e., the film producers and distributors, these ultimately compelled the combatants to come to terms which culminated in the "Film Peace of Paris." It was based on an extensive exchange of patents and experience, as well as on an agreement concerning friendly competition, and furnished proof of the contention that, in some cases, agreements between large manufacturers are unavoidable in the interests of the consumer.

Although the maintenance of relations with customers devolved on Klangfilm, it was inevitable that the two parent firms, i.e., also Siemens & Halske, should come into closer contact with this new branch of the business. The development laboratories, production departments, patent offices, legal and commercial departments, but above all, those whose task was the discussion of questions of principle, got a glimpse of a world which they had hitherto only known from hearsay. It was a peculiar kind of business, this, so different from that with Government Departments, municipalities, industrial firms or even the Theatre, with which business contacts were made from time to time. The mentality of this new clientele was incomprehensible until one realized from whom they drew their income, to whose favour they owed their existence. It is the million-footed creature which every evening files past the ticket-offices of the cinemas, and sits in front of the shimmering screen, gazing rapturously at its idols and letting itself be carried away by cheap sentiment. These are the masses, whom their first modern biographer declared to be incapable of rational thought, and who obey only their own unbridled impulses. When Carl Friedrich—now not merely the titular Head of the House, but in every respect its true and unchallenged representative—thought of his father (no soulless money-maker, but an idealist), he would hear him expatiating upon the blessings of the telegraph in linking up the nations, of the dynamo, which unlocks the forces of Nature, and of the arc lamp which makes bright the darkness. In every case, his work ministered in some way to the essential requirements and well-being of mankind, i.e., to progress. Could this still be said of that complex of electro-acoustics which had developed in the course of the last ten years with the active participation of the House of Siemens? Was it not possible that these developments concealed certain indefinite dangers of a serious nature? Carl Friedrich was far too cautious by nature to answer these questions in a spirit of care-free optimism, but he was also conscious of the fact that, even as Principal of the House, he had neither the right nor the power to turn back the hands of the clock. For some considerable time past developments had been in progress which followed their own laws. Here again, as in so many other matters, man had unleashed forces which he soon found himself unable to control.

XXV.

HIGH TENSION CURRENT AND ELECTRIC DRIVES

Hand in hand with the increasing capacity and voltage of the large three-phase generating and distributing stations, the problem of ever-increasing magnitude was how best to switch the power on and off. At the beginning of the century the general practice in dealing with alternating current was to employ the oil circuit-breaker. This proved satisfactory as long as outputs remained within the limits customary in the first decade of this century.

In the meantime, however, tensions had been increased to 110,000 volts, and this called for oil circuit-breakers which, together with their bushings, were already over four metres high and consisted of separate tanks for each phase. The use of one tank common to all three phases was too risky owing to the close proximity of the phases and the danger of short-circuiting between them. Even at lower voltages, however, experience of the performance of oil circuit-breakers had given rise to misgivings. This was due to the fact that in the event of short-circuits in large distribution systems, which are usually fed by several power stations, the energy flowing into the short-circuit can attain enormous proportions. For this reason it could happen that at a distribution point for a few small consumers which would be considered to be amply protected by a 350-amp circuit-breaker—in those days a popular standard size—the current to be interrupted in the case of a short-circuit might be several thousand amperes, due to the inrush of current from neighbouring stations. It might happen, in consequence, that the tank of the circuit-breaker would burst with a dull roar, drenching the switchgear in burning oil and possibly plunging the whole station into fume-laden darkness.

It was, therefore, not surprising that the oil circuit-breaker came to be regarded with suspicion, and immediately following the war the problem of the oil circuit-breaker was to be found on the agenda of every important meeting of electrical engineers, not only in Germany, but also in the United States.

The AEG, incidentally, already had an experimental station for oil circuit-breakers at its switchgear works in 1912, the first of its kind in the world. A three-phase alternator of specially robust construction, with an output of 15,000 kVA—a very large machine for those days—and capable of withstanding a momentary short-circuit of 150,000 kVA, was brought up to speed by a motor and suddenly short-circuited. It was the function of the test circuit-breaker to rupture the circuit again. The test-bed was equipped with numerous instruments, and so designed as to permit observation of the behaviour of the circuit-breaker without danger. After the war, this example was copied by various manufacturers. Amongst others, the Ateliers de constructions électriques de Delle, Villeurbonne, equipped at their own expense an experimental station, in which oil circuit-breakers of up to 500,000 kVA rupturing capacity could be tested. The company made this station available to the University of Grenoble for experimental purposes. The General Electric Co. built an experimental testing station on these lines in 1925-26. Finally, the American Gas and Electric Co., Canton (Ohio) resolved to undertake tests on its own distribution system, in which four large power stations were arranged to feed a centrally placed short-circuit point. At a transmission potential of 132,000 volts, this gave rise in certain cases to a short-circuit output of one million kVA, which one single circuit-breaker was called upon to rupture.

As has already been stated, the whole of the machine construction (generators and motors) had gradually been withdrawn from the Siemens-Schuckert Charlottenburg Works and taken over by the Dynamo Works and Electromotor Works; the manufacture of small components for switchgear and accessories had been incorporated in the programme of the Small Accessories Works. Even before the war, therefore, the Charlottenburg Works was left with only the large switchgear, of which the oil circuit-breakers occupied the most space, and the motor-starters and all kinds of regulators. The latter, of all shapes and sizes, were very difficult to arrange in some kind of order and to manufacture in accordance with rational mass-production principles. It happened only too frequently that the regulators had to be designed to suit the special requirements of a particular machine. When, however, owing to the large industrial expansion in the second half of the war, the demand for switchgear, and oil circuit-breakers in particular, began to exceed all bounds, the space question and other shortcomings of the Charlottenburg Works pointed to the desirability of finding a new home for these circuit-breakers. In 1917, therefore, the manufacture of switchgear was transferred to a site in Siemensstadt to the west of the Head Office building, where a plain shed-roofed building was erected, in the wide bays of which the greater part of the space was taken up by oil switches. To these were added in 1913 the manufacture of an insulating material which had been used for some considerable time instead of porcelain for pin insulators, bushings, operating rods and similar purposes. This synthetic material, known as "Repelit," is obtained by wrapping together layers of hard paper under high pressure and temperature. Since switchgear was its principal "consumer," the Repelit Works, together with its ancillary furnaces, was erected alongside the Switchgear Works.

By the end of the war the centre of gravity of switchgear manufacture was in Siemensstadt. The management of the new Works was entrusted to Hans Beiersdorf, who had grown up in the Siemens-Schuckert school during the period of its initial vigorous expansion. Immediately, it was found essential to transfer what remained of the switchgear production from Charlottenburg to the new Works, and definitely to close down the former. It might have seemed natural to accomodate this not inconsiderable remainder, together with the offices, in a shed-roofed building adjoining the existing one. It proved to be more expedient, however, to articulate the manufacturing process in a vertical direction, the result being the first electrical manufacturing works in Germany to be housed in a "skyscraper."

Hertlein, who had meanwhile become Architect-in-Chief to the Firm, and had shown himself to be possessed of both originality and good taste, erected a total of ten floors above the basement, each with a clear space of 175 metres length and 16 metres width. The only exceptions were the two uppermost floors, the width of which had to be restricted to 12 metres as a safety measure in case of fire. Two covered-in staircases were built on to the outside of each of the long walls, giving the impression of massive towers jutting out of the facade. The structural steel columns were encased in red brick and appeared as pilasters pleasantly breaking up the enormous surface of the walls. This building, which forthwith became a landmark for miles around, was completed in 1928, and found the approval of all those with an eye for the beauties of modern industrial architecture.

The new Works was equipped with laboratories on a scale commensurate with the current level of technical development. The so-called high-tension test-field, in which the finished products were subjected to routine test voltages corresponding to their use, but in which research problems connected with new designs could also be handled, included a separate structure comprising two darkrooms and housing one large and one small transformer. When connected in series, these two transformers were capable of producing a potential to earth of 800,000 volts. Alongside these was a circuit-breaker test-bed of the conventional type, but incorporating the most up-to-date features of test-bed design. A specially designed motor-driven test generator for 40,000 kVA could be short-circuited by the test-piece, either directly, if a test voltage of 12,000 volts were sufficient, or in series with a transformer. The machine room, together with the test-beds, observation rooms, offices and a well-stocked instrument room, occupied a whole group of buildings and demonstrated the scale of the outlay considered necessary to cope with a task which, after all, formed only a small part of the activities of the House.

In discussions on the problem of the oil circuit-breaker then taking place, Dr. Fritz Kesselring, a Swiss engineer domiciled in Germany, had attracted a good deal of attention by his skill in experimenting and the weight of his deductions. Siemens-Schuckert decided, therefore, to engage his services, and placed the facilities of the new Switchgear Works at his disposal in the pursuit of his further research. In 1930 he published the results of his research in a lecture which caused a sensation throughout the electrical world. He demonstrated that the extinction of the flame of the electric arc depends on totally different factors from those which had hitherto been believed to be involved. As was already known, the charge-carriers in the form of ions and electrons still present in the path of the arc when the current passes through zero brought about the rekindling of the arc as the potential recovered. If this is to be prevented, the charge-carriers must either be forcibly removed from the path of the arc (this the AEG had already succeeded in doing by means of an air-blast circuit-breaker which directed a powerful current of air or gas on to the path of the arc at the contacts opened) or they must be "arrested." Kesselring proved that the action of the oil circuit-breaker is already based (although imperfectly) on the "arresting" of the charge-carriers by the gas bubble which forms in the oil, and demonstrated how the same result could be achieved by very much better and simpler means. As is well known, steam, when suddenly cooled, has a tendency to condense. Small drops of moisture begin to form, particularly in places where fine specks of dust or even ions or electrons are present to act as nuclei of condensation. The mass of the charge-carriers is thereby increased a hundred-thousand fold, with the result that they can no longer be accelerated by the field of the recovering voltage and hence cannot rekindle the arc. Later investigations point to the probability that the quenching of the arc is also due to a great extent to the reduction of its diameter caused by the sudden cooling.

Kesselring designed one of the two contacts of his circuit-breaker in the form of a chamber, through a circular opening in the roof of which the other, rod-shaped contact was withdrawn when breaking circuit. The chamber was half filled with water, which was converted into steam during the first phase of the rupturing action. As the withdrawal of the rod contact proceeded, the opening was gradually uncovered, thus allowing the high-pressure steam to escape from the chamber and thereby to expand and cool down. This, in turn, brought about the condensation of the steam; the drops of moisture arrested the charge-carriers, and the arc was unable to re-kindle. By comparison with the clumsy and frequently unreliable oil circuit-breaker, the "expansion circuit-breaker," as Kesselring named it, was a veritable "Columbus' Egg," and at once commenced to bring in a rich harvest for Siemens-Schuckert.

The introduction of the expansion circuit-breaker and of its very formidable rival, the air-blast circuit-breaker, coincided with the search on the part of switchgear designers for new solutions of the problems confronting them. Apart from the continual raising of the transmission voltage on the main power lines, for which the pre-war experimental potential of 10,000 volts had gradually come to be recognized as a standard, the power generated in the individual stations and flowing together through the arterial lines had also increased as time went on. The linking together of the various supply systems had rendered them so interdependent in the case of faults that the highest standard of safety had become essential. Greater safety, however, meant increased insulation, wider spacing of the conductors, larger switches, more subdivision of the circuits, and in short, continually increasing dimensions of the switchgear installations. For a time, therefore, the argument continued as to whether the switchgear should be housed in a number of separate cubicles, with a view to confining the risk of damage to the narrowest possible limits, or whether it was preferable to build large, hall-type switchgear houses without intermediate floors and partitions. A point in favour of the latter was the better supervision which this type of structure rendered possible. In the U.S.A. the hall-type switch-house predominated, and when in 1913 the Southern California Edison Co. (just as Germany had decided to risk 110,000 volts) raised its supply voltage to 150,000 volts, the question was also thrown up as to whether a switchgear installation was not possible without walls and a roof. The first to answer this query in the affirmative was the Pacific Gas and Electric Co., from whom San Francisco takes its supply. It was with incredulous astonishment that the news was soon afterwards received in Germany of open-air switchgear installations. Their indubitable success was at first attributed to the mild Californian climate. After the war, however, a few venturesome power station managers, mainly in Switzerland and France, made friends with the new idea, although the first of these installations conveyed the impression of having been installed in a building, the walls and roof of which had subsequently been removed. The "A.G. Sächsische Werke," the supply undertaking of the Free State of Saxony, being the first German electricity supply company to realize the full implications of the new system, placed the whole of the equipment on one level at a convenient height above ground. Having thus become familiar with the idea of the open-air installation, and having learnt how to make the transformers, circuit-breakers and smaller apparatus weather-proof, the designers themselves, including those of Siemens-Schuckert, were surprised that this simple solution of the arrangement of high-tension apparatus had not occurred to them before. And the travelling public became increasingly familiar with the sight from the carriage window of these strange and often extensive groups of large and small tanks on concrete foundations, carrying enormous ribbed insulators arranged in rows and surmounted by a maze of wiring which glowed mysteriously in the dark.

This glow, the radiation of high-tension electricity from conductors, is known to the electrical engineer as the corona. Mention of the phenomenon will be found in old seafaring yarns; more was learnt about it in experimental physics laboratories, e.g., that it bore a definite relationship to the radius of curvature of the surface of the conductor. The smaller the radius, the greater the corona losses. The first rule which the designer of high-tension gear thus had to observe was to avoid sharp edges, corners or, most important of all, points. When, therefore, in 1923 the above-mentioned two Californian power supply companies ventured to step up the tensions in their systems to 220,000 volts, it was soon discovered that the difficulty did not lie with the insulation between phases or to earth, but in controlling the corona effect. Careful measurements carried out by the Pacific Gas and Electric Co. disclosed the fact that on the 325 kilometre San Francisco feeder there was a "leakage loss" of 2,000 to 2,500 kW, depending on the weather; part of the power was simply dissipated into the air. And this notwithstanding the circumstance that the conductors consisted not so much exclusively of steel-aluminium cable (a stranded aluminium cable with a steel core to take the strain), as for the most part of pure copper stranded cable of more than 23 millimetres diameter. Obviously, therefore, the diameter would have to be increased and, for the sake of the corona, made much larger than was necessary to carry the current. What was going to be the resulting weight, however, and the effect on the design of the masts? These Californian experiments, said the German electrical engineers, had demonstrated that a transmission potential of 110,000 volts should not be exceeded, especially since, as far as Germany was concerned, there were no distribution problems which were incapable of being dealt with easily within this maximum.

Arthur Koepchen, the Technical Manager of the Rheinisch-Westfälische Elektrizitätswerke in Essen, was of a different opinion. He had begun his career with the company as a young engineer during the Stinnes era, and had advanced rapidly. He possessed the rare combination of sound technical knowledge and outstanding business ability, in many respects reminding one of Emil Rathenau. In 1917 he succeeded to the management of the company, following the sudden death of its Manager Goldenberg, after whom the large RWE power station on the Rhenish lignite coalfields is named. For all practical purposes this meant that he controlled the policy of this peculiar semi-public utility undertaking. The original share capital of the RWE had been privately subscribed, but as time went on, an increasing number of municipalities and other communal bodies had become shareholders, so that eventually the majority of the seats on the Board of Directors came to be occupied by Lord Lieutenants and Lord Mayors who, however, left the Management a wide measure of freedom in the conduct of affairs.

One by one agreements were conducted with the smaller and larger electricity supply undertakings—whether private or municipal was immaterial—which brought them under the influence of the RWE. A start was made in the Rhine Province and Westphalia; the River Main was then crossed to open the way to South Germany and eventually to Switzerland and Austria.

As already mentioned, Koepchen had not believed in the 110,000 volt limit from the outset, and a visit to the United States in 1924 was for the sole purpose of obtaining visual proof of the correctness of his opinions. On his return he commenced immediately the construction of a "busbar" for 200,000 volts stretching from Northern Westphalia to Vorarlberg.

For the technical realization of its plans the RWE was, of course, dependent on the two large electrotechnical Firms in Germany; the others had neither the staff, the manufacturing facilities, nor the capital resources essential in carrying out a programme of this nature. If it was a question of overcoming the natural inertia of the two firms, the RWE would call on their pride of achievement and play one off against the other. It was accustomed to deal sternly with suppliers and to insist on a high standard of performance, reinforced by extensive guarantees. The periods allowed for delivery were invariably short. Every large tender for the RWE became a matter of prestige for the sake of which the supplier must be prepared to make a sacrifice. Siemens used to groan at every large order received from the RWE, but if the order went past them they groaned much more.

Meanwhile, Siemens had also been giving some thought to the matter of the corona, since this was evidently the main problem accompanying the use of very high tension. As early as 1919 Rüdenberg had applied for a patent for a large-diameter conductor consisting of two stranded layers of flat wire which formed a hollow cable with a smooth outer surface. Internally, the cable was supported by a diametrically arranged steel strip twisted spirally about the axis of the conductor. Koepchen had already dicussed conductors of this type with his American friends so that he now called upon Felten & Guilleaume, the AEG and Siemens-Schuckert to develop suitable hollow conductors of about 42 mm external diameter.

Whilst Felten & Guilleaume and the AEG were devoting much thought to the solution of this problem, Werner, the Chief of the Siemens-Schuckert Central Station Department, found on his return from a lengthy sick-leave that practically nothing had been done on the part of Siemens during his absence. Werner was not a brilliant and inspiring personality of the type of Raps, or an unchallenged master of power station design, like his late colleague Klingenberg of the AEG, whose works, in particular the Golpa Power Station, had lent him undisputed authority in this domain. Werner, by contrast, had devoted himself less to the problems of power operation than of its distribution, and as the result of many years' experience had acquired a sound judgement of the possibilities, but also of the risks involved. Now, in the situation resulting from Koepchen's initiative, he realized instinctively that much was at stake, and that much ground had already been lost to competitors. With an energy amounting almost to brutality he galvanized the somewhat disordered ranks of his assistants, re-formed them and led them anew to the attack. In the shortest possible time the rough designs drawn up in accordance with the Rüdenberg patent had been developed into workshop drawings, sample lengths of wire rolled and stranded in the Metal Works, a new suspension insulator designed, and an erection programme worked out. As a result of this intensive preparatory work the RWE decided to award Siemens-Schuckert the contract for the supply of 40% of the transmission line stretching from the Rhenish lignite fields southwards to the temporary terminal on the river Main. Felten & Guilleaume and the AEG each received an order for 30% of the remainder with the stipulation that the Siemens design of conductor was to be used. The line was to be so arranged that the potential could later be raised to 380,000 volts (arrived at by multiplying the original figure by $\sqrt{3}$, a factor peculiar to the three-phase system). The equipment included the necessary switchgear for which, pending the completion of the expansion circuit-breaker, oil circuit-breakers had to be used initially. The fact that these monsters with their bushing insulators were over six metres high demonstrated the necessity of finding a better solution to the switchgear question. An interesting problem arose with regard to the transformers for stepping down the tension from 220,000 to 110,000 volts, or lower with suitable interconnection on the l.t. side. The RWE attached importance to these transformers being suitable for rail transport after removal of the terminal bushings in order to facilitate modifications which the continual expansion of the supply system might necessitate. The oil-filled transformers were therefore fitted at both ends with lattice outriggers, the ends of which each rested on a 16-wheel railway truck, so that the 168 ton weight of the transformer for 60,000 kVA was suspended between the trucks a few inches above rail level. Siemens-Schuckert were instructed to supply 14 of these transformers simultaneously. With pride it was recorded that this was the largest order for transformers which had ever been placed up to that time. Werner, however, had the satisfaction of seeing his Firm sharing in the development of Koepchen's plans to an extent which was commensurate with its importance. The basic idea of the undertaking was no less than the interlinking of the Vorarlberg and Swiss water power plants with the thermal power stations of the Rhenish lignite and Westphalian anthracite coalfields in order to feed into an 800 kilometre transmission line, from which electricity could be distributed as required. There was no other comparable supply line in Europe, and even the Americans had to admit that this was no mean achievement.

If overhead transmission lines and cables were to be regarded as competitors in the carrying of electric current, it had to be admitted that for voltages of the magnitude here involved cables were hopelessly out of the running. During the war, as will be remembered, the inferior quality of the impregnating compound rendered it impossible to risk higher working voltages than 10,000 volts; after the war the former limits of 25,000 to 30,000 volts were re-introduced, and experimental cables manufactured for still higher voltages. Designs for three-phase high-tension cables, of which Siemens-Schuckert also manufactured experimental lengths, were regarded with considerable distrust. This was justified, since these high-tension cables appeared to be anything but reliable. A cable of this kind could have been tested with twice its working voltage, and have operated faultlessly at its full normal voltage for a year or more, only to break down suddenly for no apparent reason.

Continuous tests, exact measurements and mathematical investigation into the structure and interaction of the electrical fields of the individual cores (in which the Siemens-Schuckert Cable Works played a leading part) led, finally, to the conclusion that the behaviour of the high-tension cable was not connected with the tension at all, but was a question of heat. In other words, it is the heat generated in the cable which in the course of time leads to its destruction.

In the first place, as in all conductors, this heat is caused by the passage of the current; to this must be added the heat produced by the alternating field in the insulation (displacement current), the so-called dielectric losses. This heat is only imperfectly carried away by the surroundings of cables laid in the ground. The consequent rise in temperature causes the impregnating compound to expand and stretch the lead sheathing, which may be the cause of fine hair cracks in the lead, through which moisture can penetrate. In spite of every care, too, it is impossible to ensure absolute uniformity in the distribution of the impregnating medium throughout the insulation. When the current is switched off, and the cable cools down, the cracks in the unelastic lead sheath do not close again. New cavities are added to the existing ones, so dreaded by the high tension engineer on account of the formation of nitric oxide following glow-discharge. In course of time the nitrous gases destroy the whole of the impregnating compound, the insulation deteriorates more or less rapidly, depending on the operating conditions, and is finally punctured by the high tension. At voltages under 35,000 volts the action was so slow as not to affect the life of the cable appreciably, but above that limit the rate of deterioration increased rapidly. It appeared, therefore, that the sphere of really high tension was definitely closed to cable.

The use of high-tension overhead transmission lines in and near towns, however, was attended by much inconvenience. The idea of high-tension conductors suspended from high masts crossing the roofs and crowded thoroughfares was somewhat awesome; an unlucky coincidence or a stroke of lightning could have serious consequences. The increase in air traffic, moreover, necessitated the situating of airfields near to the large towns, and overhead high tension wires could be a source of danger to aircraft on taking off and landing. It was clear that these overhead lines would have to be removed from the vicinity of large towns.

Following on a suggestion by Schoettke the Siemens-Schuckert Cable Works developed a fundamentally new type of high-tension cable. This took place about the same time as new designs were appearing in the United States—these, in turn, being along the lines of a suggestion coming from Italy. The first examples of the new cable were of the single-core type. For three-phase transmission three of these cables would be laid in the same trench. The conductor was again hollow, although of smaller diameter than that of its overhead counterpart, insulated in the usual way with paper, encased in a lead sheath, served with jute and armoured with steel wire. The impregnating liquid consisted of low-viscosity transformer oil, which was introduced through the hollow conductor, and filled the layer of insulation between it and the lead sheath. When the cable heated up, the oil was forced back into expansion vessels at the end of the cable or at intermediate points. There was no appreciable rise of pressure in the interior of the cable, and hence no expansion of the lead sheath and no cavities. The insulation remained saturated with oil at constant pressure. In July 1928 Siemens-Schuckert laid a cable after this pattern to connect two sub-stations of the Franken power supply in Nuremberg for the purpose of linking up the municipal supply system with the Bayernwerk. Success encouraged the further development of the underground cable. It was not long before three-core cable, as hitherto customary in three-phase systems, was available in the form of oil-filled cable and was in use for all potentials above 35,000 volts. It was also used as submarine cable, as in 1932, when a section of the cable supplied to the city of Zurich was required to cross the lake under water. Electrical engineers throughout Europe took a keen interest in this new development, and as very few cablemakers were at first prepared to face the difficulties of manufacturing and laying such cables, the result was a very lucrative business for Siemens. As an example, Siemens-Schuckert in conjunction with Pirelli of Milan received the order for a 54 kilometre transmission line from Buenos Aires to La Plata, comprising 216 kilometres of single-core oil-filled cable for 66,000 volts. For a number of reasons, business of this order represented a considerable asset in the German economy.

In cases where, in addition to the all-pervading three-phase current, d.c. was also required, it was generated in convertors, the various forms of which have already been described. In this branch of electrical science, too, however, the knowledge gained of the phenomena accompanying the so-called gas discharge was already being turned to account.

In 1892, long before electronic tubes and the like were thought of, L. Arons, the Berlin physicist, published the results of experiments with an electric arc and a mercury cathode. In an evacuated glass tube with two current terminals was a small quantity of mercury which covered the terminal acting as a cathode. A suitable a.c. potential was applied to the terminals, and the tube tipped over until the mercury formed a bridge across them. If the tube were now righted again, so as to break the mercury bridge, an arc was formed between the anode and the mercury cathode as when the two carbons of an arc lamp are drawn apart. The mercury vaporized by the heat of the arc filled the tube in the path of the current, and after striking the electrons, produced the necessary ions as charge carriers. In the cooler parts of the tube the vapour re-condensed into drops and collected again on the cathode. This mercury vapour lamp, as Arons called it, produced an unpleasant yellowish-green light which spoilt all colours and caused people to look like corpses. It was in consequence unfit for the purpose of illumination, but was rich in rays outside the visible spectrum, and therefore of interest to physicists and medical men. Arons did not take out a patent for the lamp, and about twelve years later the firm of Heraeus in Hanau, with special experience in the melting of quartz, took up the idea and replaced the glass tube by one of clear quartz. This tube was able to withstand a higher internal pressure than the glass tube and thus enabled the gas pressure to be increased. The quartz tube also withstood higher temperatures and was permeable for the invisible long-wave heat rays. The Quartz Lamp, as it came to be called, was much used for therapeutic purposes.

An arc lamp with carbon electrodes can also be operated with alternating current, but the mercury vapour lamp only with direct current, and in addition, mercury is required for the cathode. With alternating current the current reverses its direction twice in every period, passing each time for a brief instant through zero. This means that the arc is extinguished and would require to be re-ignited. This would be possible as long as the electrode, which was the anode and is now to become the cathode, were aglow, i.e., emitting electrons. If this is not so, as in the case of the mercury vapour lamp, the anode of which does not glow, no current is produced in the next half-period, whereas in the next but one, when the mercury should act as a cathode, it has cooled down in consequence of its great heat conductivity to such an extent that it no longer emits electrons and is unable to re-ignite the arc.

About 1902, Cooper Hewitt, a very gifted American engineer, had also experimented with the quartz lamp, but in spite of all efforts had failed to persuade it to work on alternating current. This was annoying, as a.c. was beginning to predominate and the utility of the lamp would suffer in consequence.

Eventually it occurred to Hewitt to provide the lamp with two anodes instead of one. He tapped the secondary winding of the transformer (which was in any case required to give the proper lamp voltage) in the centre and connected this point C to the cathode, whilst joining the ends A and B to the two anodes. In this way he had formed two separate circuits having one limb in common, viz., the connecting piece from the centre of the coil C to the cathode. If the current in the transformer secondary flowed from A to B, only the section CB of the coil would be traversed, and the anode connected to B was in play. When during the following half-period the current flowed from B to A, the other half of the transformer secondary with the point A connected to the other anode was in action. In every case, therefore, the current left the coil at one or other of the ends A or B, and always entered at C. Since C was connected to the mercury-covered electrode, this was consequently always the point where the current left the lamp or cathode. The lamp now, therefore, operated on alternating current.

When Cooper Hewitt came to consider the flow of the current in the connection between the cathode and the centre C of the coil, he realized that the current was an alternating one, but only as regards its strength and not its direction of flow. If, therefore, a piece of consuming apparatus, such as a run-down accumulator battery, were connected in circuit between the cathode and C, the accumulator could be made to absorb the greater part of the total energy, whilst the lamp consumed only a small part; it acted merely as a switch after the fashion of a commutator. As in every switch, there was a movable element, viz., the arc, the root of which, like the fulcrum of a knife switch, was centred on the cathode whilst the other end whipped rhythmically from one anode to the other with the periodicity of the current.

The radiation qualities of the lamp had now become of minor significance, its purpose was the changing of the direction of the current. Hewitt therefore called it a "rectifier." It was evident that he had made a very important invention, for which he immediately took out patents, also in Germany.

The next step forward was to operate with three-phase instead of single-phase current. This necessitated the use of three anodes, which were connected to the three conductors, whereas the cathode was connected to the star point. This resembled in effect that of the multi-part commutator of Pacinotti's machine, in which the half-waves of the individual currents overlap and the resulting rectified current consists of a basic direct current with superimposed alternating currents. By suitable connection of the transformer Hewitt succeeded later in converting the three-phase current into six-phase and in making the rectifier with six anodes; with this and the addition of reactors, which further smoothed the residual current, he finally succeeded in producing a continuous current which could no longer be distinguished from machine-generated current.

Before this point was reached, however, there was much discussion among electrical engineers concerning the uses to which the new device could be put. At first, the only material available for the rectifier vessel was glass, for it was soon discovered that faultless operation presupposed an absolute vacuum in the discharge space, which was only thought to be obtainable with glass vessels. The pear-shaped vessel with the neck pointing downwards was furnished with the mercury cathode at its lowest point. Higher up, wide tubes radiated from the parent body, at the ends of which the anodes entered the vessel, this arrangement protecting them as far as possible from mercury splashed from the cathode by the action of the arc which dances about on its surface. In the dome of the vessel, which had to be kept cool, the mercury vapour condensed and flowed back to the cathode. It was hardly surprising that the electrical engineer of those days, particularly the power-current engineer, regarded this fragile structure of glass with a mixture of scepticism and contempt. It was all very well in a physics laboratory, but not fit for use with machines in a power station. It was possible to consider its use on occasions for charging batteries, especially as its d.c. output seldom exceeded 10—20 amps. When some optimists, however, began to talk of building glass rectifiers for higher currents and using them to operate the tramways, it was obviously phantastic nonsense. It was particularly at Siemens-Schuckert that talk of this kind could be heard.

In 1909 Bela Schaefer, a young Hungarian engineer employed in Germany who had spent some time experimenting with rectifiers, conceived the idea of replacing the fragile glass vessel, which in the case of large outputs also became very awkward to manufacture, by one of iron (iron being the only non-precious metal which is not attacked by mercury). Since an iron vessel of this kind would have to comprise at least two parts, the main difficulty lay in designing reliable gas-tight joints. It was only after protracted efforts that a satisfactory solution was found. A further major difficulty was the insulated bushing of the anode connections in the iron cover of the vessel. Since almost all metals, iron in particular, give off gas when heated to high temperatures, thus spoiling the vacuum, it was found necessary to equip the set with one of the new air pumps for very high vacuum, running continually in order to maintain the requisite degree of vacuum in the tank. Schaefer was assisted in his work by Hartmann-Kempf, partner in the firm of Hartmann & Braun in Frankfort on the Main. At the close of 1911 he installed the first mercury-arc rectifier with steel tank in the Rödelheim Foundry near Frankfort. The output of the rectifier was about 80 kW at 240 volts on the d.c. side, and worked quite satisfactorily, apart from a few teething troubles. The inventor had applied for several important patents to cover his invention, and these, as also the fundamental principles involved, impressed the German Patent Office to such an extent that on his application they awarded him a "licence as of right" on the German Cooper-Hewitt Patent, without which the whole of Schaefer's work would have been useless.

It was certainly undeniable that it was due to Schaefer's hard work and inventive genius that the problem of the iron tank mercury-arc rectifier was solved in principle, and it was not long before representatives of the various interested parties appeared in Rödelheim, amongst them emissaries of the AEG and Brown Boveri, to inspect the invention. Since Hartmann & Braun had meanwhile come to the conclusion that further activity in this sphere would interfere with the pursuit of their real objective, viz., the manufacture of electrical measuring instruments, they withdrew from the discussions in favour of the AEG and BBC. The latter immediately entered into negotiations with Schaefer; the AEG also let it be known that it was their intention to acquire licences. Robert Friese, the Manager of the Siemens-Schuckert Charlottenburg Works, on the other hand, continued to hold back. As recently as the end of January, 1917, he had reported to Carl Friedrich von Siemens, who was at that time Chairman of the Board of Management, that he had no great opinion of the whole thing. He drew attention to the fact that Feuerlein had brought back from the United States a glass bulb rectifier which had been tested exhaustively in the Charlottenburg Works. The much larger and more complicated apparatus of Bela Schaefer presented no radically new features, but would be attended with difficulties proportional to its size. No further progress had been made in America. "In that country where the rotary convertor is used to a prodigious extent, there is not, to my knowledge, a single case on record in which the mercury-arc rectifier has been used in place of a rotary convertor or with the idea of superseding it."

Even before the results of Bela Schaefer's work had become known, however, the two competitors had already devoted considerable research to the development of a practical and reliable apparatus on the basis of the Cooper-Hewitt invention. Brown Boveri, in particular, had shown much initiative. It was soon discovered that in comparison with the machine convertor (motor generator or rotary convertor) the efficiency of the rectifier was superior at higher voltages of the d. c. current, the reason being that its losses are represented by the voltage drop in the arc, which is fairly constant. It was therefore for traction duty with its fairly high voltages that the rectifier was pre-eminently suitable. It had the further advantage of having no movable parts, thus requiring less supervision and maintenance. It was not long before glass-bulb rectifiers were being built for 500 amps; at 600 volts this represented an output of 300 kW, whilst a little later steel-tank rectifiers were available for outputs up to 1,000 kW and more.

Before this stage was reached, Siemens-Schuckert had become conscious of the fact that their attitude to the mercury-arc rectifier had been a huge mistake, and that they had missed the connection with regard to a promising field of development. They had given their competitors a 6 years' start, since the Cooper-Hewitt patent was valid until the beginning of 1918. Soon after the commencement of the war, therefore, the Dynamo Works was given the assignment to develop a mercury-arc rectifier, and Walter Reichel applied himself with customary energy to the recovery of the lost territory. Experimental apparatus of drawing-office design was built in the shops and tested there under working conditions, sometimes with unexpected results. Reichel's most gifted assistant in this undertaking was Max Schenkel, an extremely quiet and unassuming, scientist-type of man with a very clear brain, quick to penetrate spheres hitherto unknown to him. Prior to the rectifier problem he had shown his skill in unravelling the complicated phenomena of the alternating-current commutator motor, and of the traction motor in particular. He now tackled the rectifier with the same energy.

In a few years the Firm had caught up with its competitors, and scientific articles in "Scientific publications of the Siemens Works" bear witness to the fact that the reputation of the Firm in this sphere had been restored.

As to the future of the rectifier business, Siemens considered it would be unwise to entertain great expectations. To all appearances continuous current had had its day. It was still unrivalled for traction duty (tramways, city and suburban railways, Works' sidings and mining railways). Furthermore, d.c. was indispensable to certain electro-chemical processes, and much more suitable than a.c. for arc-welding. Beyond this, there were still a certain number of private and public electricity supply networks not yet converted to a.c., although it was agreed that it was only a matter of time before this took place. With the continual spread of alternating current on the one hand, and the increasing use of individual drives on the other, the demand for economic speed regulation of the three-phase motor was again becoming insistent.

In an earlier chapter an account has already been given of the means adopted to solve this problem for large motors. With the continued progress of industrial electrification, however, the electric motor, from being used to drive the main shaft, was being applied progressively to the drive of subsidiary shafting and, finally, of the individual machine. The greater the number of small motors called for in comparison with the few medium-sized and large motors, the more insistent became the demand for a variable-speed three-phase motor on the lines of the d.c. motor, the speed of which could be regulated without complicated auxiliary apparatus and without wasting a considerable proportion of the energy in resistances, producing undesirable and often injurious heat.

The solution of this problem was provided in due course by the alternating current commutator motor. As early as 1895 Siemens & Halske applied for a German patent which was based on an invention by Görges. Görges proposed to provide an ordinary a.c. motor with a commutator and brushes in place of the usual slip rings, and to connect the stator and rotor in series. It was found that the motor possessed the fundamental characteristics of a d.c. series-wound motor of the type in general use in the tramways and on hoisting machinery. In a motor of this type the speed drops rapidly with increasing torque. This, of course, was not speed regulation in the accepted meaning of the term, which is intended to indicate the ability to vary the speed as desired at constant torques. This was found to be possible by shifting the brushes out of the so-called neutral zone, thereby altering the current distribution in the rotor. At constant torques, each position of the brushes corresponded to a definite speed.

As so often happens, the invention was ahead of its time. In practice, apart from other disabilities, the motor could only be wound for a maximum of 100 volts, as otherwise, sparking at the brushes could no longer be kept under control. The fact was, however, that everybody was so taken with the simplicity of the three-phase motor, that nobody would have anything more to do with the commutator, the most sensitive part of the d.c. machine, which it was hoped was a thing of the past. And so the patent was allowed to lapse.

Soon after the turn of the century, when the idea of an electric railway to operate on single-phase alternating current was being discussed in engineering circles, it was recollected that a motor for this purpose had been proposed as early as 1886 by Elihu Thomson. A special feature of this motor was its simplicity. The stator was connected to the supply in the ordinary way, whilst the rotor had a commutator with movable brushes which were connected together by a cable, i.e., short-circuited. By displacement of the brushes, the rotor current could be varied within certain limits and a corresponding variation achieved. The idea, which at the time had attracted no attention, was taken up and improved upon by Déri, who equipped the motor with two sets of brushes, one of which was stationary and the other adjustable relatively to the first. For traction purposes the Déri motor was not very suitable owing to the necessity of a mechanical connection between driver and motor. As against this, however, Brown Boveri Cie. were very successful in introducing the motor into industry, mainly, for the individual drive of ring spinning frames, the output of which could be considerably increased by varying the speed in accordance with certain definite laws. It was a certain disadvantage of the single-phase motor, particularly of higher rating, that it drew its current from one phase only of the supply, thus causing a certain amount of unbalance in the three-phase system.

The consequence was that thoughts were again directed to the three-phase motor and in 1908 Rüdenberg reverted to an old invention of his predecessor, Görges, having meanwhile acquired the mastery of the difficult problems of commutation in various types of single-phase commutator motors, frequency changers, and the like. Together with Schenkel he produced a series-wound three-phase commutator motor, a distinctive feature of which was a small transformer connected in series with the stator and the brushes, the purpose of which was to reduce the voltage at the commutator. This motor was more expensive than the ordinary three-phase motor, but solved the problem of speed regulation in elegant fashion, always provided the series characteristics of the motor, i.e., the inverse relationship of speed and torque could be utilized. Where this was not the case, or where it was desirable to be able to set the motor to run at any desired speed (within its speed-range) and to maintain that speed practically constant for varying values of the torque, this called for a shunt-wound motor. For a motor of this type, data had been jointly published in 1910 by Winter, Eichberg and Latour. In this solution, mains current was supplied to both stator and rotor, which was furnished with a commutator. A step transformer was connected between rotor and supply, by means of which the voltage and consequently the speed could be regulated. A still more ingenious solution was that published by H. K. Schrage in Stockholm in the following year, according to which the connections of an ordinary induction motor were reversed: the rotor is fed through its slip rings from the supply, whilst the stator windings are considered to be short-circuited. However, a variable voltage applied to these windings enables the speed to be varied. The voltage is taken from the commutator by means of two sets of brushes, one fixed and the other adjustable. Independently of Schrage, this arrangement was discovered by Rüdenberg and Buff at Siemens-Schuckert and was extensively applied after the war in industrial drives.

With the introduction of the three-phase commutator motor, large numbers of which soon came to be used in Germany, electricity had overcome the last resistance to its use for machine driving, particularly in the light industries. In this connection the lead lay indisputably with Siemens-Schuckert. The United States soon followed the German example. In Europe, however, with the possible exception of Switzerland, the electrical manufacturers were not at once in a position to satisfy the home demand for these variable speed motors, well protected as they were by patents, which therefore became a not insignificant item of export for the homeland.

About the same period, following the initiative of Siemens-Schuckert, an important improvement was achieved in the performance of the "ordinary" three-phase motor, which continued to be used for the vast majority of industrial drives. The necessity for starting up the motor by means of rotor resistances, which are cut out on the attainment of full speed, is in many cases a nuisance and not without an element of risk in situations in which explosive gases might be present and become ignited by sparks at the slip rings and starter contacts. In 1919 Rüdenberg proposed an arrangement in which the rotor, even in the case of large motors, could be of the so-called squirrel-cage type, i.e., without slip rings and starting resistances as had always been the practice for the lower ratings. For motors of higher output this had hitherto not been possible owing to the heavy current surge and low starting torque of motors switched directly on to the line. Rüdenberg demonstrated that by making the slots in the rotor narrow and deep in conjunction with a special design of the windings, an additional resistance was produced during starting (when the frequency of the rotor current was still high) which took the place of the separate starting resistance. The "additional" resistance faded out automatically as the motor came up to speed and its rotor frequency decreased, rendering a switching operation unnecessary.

The development of new types of electric motors and the continual adaptation of their outward form to suit specific working conditions (which will not be discussed in detail here) would not in itself have sufficed to account for the enormous change brought about in the industrial world during the inter-war years by the increasing popularity of the electric drive. There was a further circumstance: the conscious and systematic endeavour of the exponents of the electric drive to apply it as closely as possible to the last stage of the manufacturing process. Cotton spinning and weaving provide a ready example. In the centre of the mill was a large steam engine, from the flywheel-pulley of which the power was transmitted by ropes to the main transmission shafts in the various departments. From these it was distributed to countershafts and thence to the machines, which in most cases incorporated further belt or rope drives to their various components. In the first scheme for the electrification of a spinning mill, however, the electrical engineer applied his motor to drive the main shaft in the spinning room; in the next scheme the spinning machines were divided up into groups, each driven by a separate motor, and finally, each spinning machine was driven by its own individual motor.

For ring spinning machines this degree of sectionalization was considered to be adequate for the time being, as the individual drive of each of the 400—500 spindles of a frame by a tiny motor would have involved additional expenditure which would have outweighed the advantages obtained. When it was a question of spinning hard fibres such as flax, jute and hemp, however, where spinning is still performed by means of flyer spindles as in great-grandmother's days, the individual electric drive of each spindle was worth considering. An enterprising textile specialist entered into an association with Siemens-Schuckert to develop suitable small spindle motors of an output of about 175 watts at a speed of 5,000—6,000 r.p.m. Large numbers—it might be hundreds—of these motorized spindles mounted side by side on the spindle rail were at first greeted by a dubious shaking of heads in the industry. Doubts were quickly dispelled, however, by the excellence of their performance in practice. The conversion of the opponents was due to their realization of the fact that the individual drive is not so much a machinery problem as a production problem. As the result of individual driving, the quantity and quality of the product is improved. This is due to the adaptation of the drive to the requirements of the final phase of manufacture, which thus takes place under optimum conditions.

This is the case, not only in the textile industry with its manifold branches, but in paper-making, printing, the foodstuffs industries, woodworking, the immensely diverse machine-tool industry, in the chemical industry, as well as the iron-producing and consuming industries. Everywhere in industry the specialized individual electric drive has opened up new possibilities and, in fact, put industrial production on a new basis.

Of course, this would not have come about so quickly and thoroughly, had it not been the case that the electrical engineering firms, and the House of Siemens in particular, disposed of large staffs of engineers who could not only deal efficiently with the mechanical and electrical side of these drives, but were capable of grasping the technological side of the problem. In this connection the sub-division of the Siemens-Schuckert Industry Department according to trades proved to be very suitable. To the Heads of Departments like Wilhelm Stiel, in charge of the Textile, Papermaking and Printing Departments, a scientist by nature, who had studied the technological foundations of these industries more deeply than many self-styled specialists—to him and others is due much of the credit for the unquestionable lead held by Siemens-Schuckert in Europe in the field of individual electric drives.

The industry which offered probably the most obstinate resistance to the electrification of one section of its equipment was that of coal mining. As far as Germany was concerned, it was the Rhenish-Westphalian sector. This does not refer to open-cast mining. The electric drive of the coal preparation, comprising screening and washing plant with their conveyors, was a matter of course. The same applied to the briquette and coking plants with their ancillaries. Electric driving was also in evidence underground in deep mining. Electrically driven pumps for mine drainage had already been introduced in the last decade of the nineteenth century, and after the war there were no other than electrically driven drainage pumps in existence. Electrically driven main winding engines superseded steam driven engines to an ever-increasing extent as time went on, and the compressed-air driven haulages in the blind shafts gradually followed suit. Mining locomotives, too, large numbers of which were formerly petrol or compressed-air driven, were replaced by electrically driven machines as far as possible, having due regard to fire-damp conditions. When, however, the electrical engineer had penetrated in his wanderings through the mine to the point where the coal is won, i.e., to the coal face, he found himself confronted by no mean problem. On reflecting that in a large mine more than one thousand men in each shift may be working at the coal face, that their work is arduous and fraught with danger, and therefore calls for particularly good lighting, one cannot help wondering how it was possible that as recently as the 1920's the only illumination was that provided by the Davy safety lamp, an oil-dip with a luminosity of about one candle power. The obvious idea to light the coal face electrically was untenable on account of the possible presence of fire-damp, the risk of which, of course, is much greater at the coal face than elsewhere. The lamp bulb might be broken, and although the filament would be burnt out instantaneously, it might be possible under unfavourable circumstances for an explosion of fire-damp to occur. If a lamp is unscrewed from its socket in order to change it for another, the tiny spark on breaking contact may suffice to cause a catastrophe, likewise if a circuit is broken through damage to a cable, or if a fuse blows, or a short-circuit occurs anywhere in the system. The very strict Inspectorate of the German Ministry of Mines well-nigh drove the electrical engineers to desperation with their "ifs" and "buts," and it is not surprising that mine managers were reluctant to incur additional risks involving them in still further safety regulations, and that they therefore preferred to leave things as they were. For the drive of the auxiliary machinery underground, such as the additional ventilation, the coal cutters, loaders, shaker conveyors and main conveyors, compressed air was always available and was in most cases preferred by the miner to the electric cables. And as regards electric lighting, the old-type Davy flame lamps were in the process of being superseded by the more powerful portable accumulator lamps. Under these circumstances the introduction of electric power driving at the coal face made little or no progress.

One of the various sections of the Siemens-Schuckert Department of Industry dealt with mining. This was in charge of Wilhelm Philippi, who for decades past had devoted himself tirelessly to the introduction of electricity in the mines. At home and abroad he was an acknowledged authority on the subject, and had published a journal called "Electricity in Mining," which gave accounts of his own experience and that of others in this field. With the task of popularizing the use of electricity at the coal face, however, he, too, was unable at first to make much progress. There was, therefore, no other way but to design and produce prototypes of each of the elements involved, such as lamp sockets, protective housings, tough rubber cable, plugs and sockets, switches, fuses, motors and transformers—a task involving years of work—in such a way as to meet the objections and satisfy the safety regulations of the Mining Authorities and collieries, and to install numbers of these prototypes under working conditions. Had it not been for the fact that the Siemens engineering staff included a number of former mining engineers who had grown up with the miners and spoke their language, it is doubtful whether the Firm would have attained its object. However, its efforts were finally rewarded by the agreement of first one, then another of the collieries to a large-scale test, as the result of which they were at length convinced that better lighting meant fewer accidents, greater production and less dirt. At last the way was open to the introduction of power-driven machinery at the coal-face, and Siemens were able to reap the fruits of their long years of patient efforts. The Chief Assistant in the Mining Department, Bohnhoff, who later succeeded Philippi in the management, was posted missing in Russia after the second World War and has not been heard of since.

These and other innovations are merely examples of the many-sided development work which the Firm pursued. In the eyes of the layman, to whom one may endeavour to explain them, many of the details may seem to be trivial. Taken together, however, they represent the mighty wedge which electrical engineering has driven more and more deeply each year into the industrial structure, and which is the outcome of assiduous team-work on the part of specialists of many kinds. It was the task of the Management of the "Department of Industry" to co-ordinate the labours of these specialists to the best advantage.

This task was entrusted to Rudolf Bingel, who for a number of years had been Technical Manager of the important Mannheim Branch of the Firm. It was a rare occurrence for a Branch Manager to be placed in charge of one of the large Head Office Departments. There was usually a suspicion that the Branch representative had lost touch with creative development work. Bingel, however, had acquired such a good reputation that Carl Friedrich von Siemens considered it permissible in this instance to make an exception from the rule. The fact that in this as in other cases the candidate had not acquired his technical training at a University, but only at a Technical School, did not trouble Carl Friedrich.

In Bingel's case the difference was compensated by quite a number of special gifts. His creative ability bordered on the artistic (recalling to mind the names of Raps, Bolton, Erlwein and Benkert); he possessed remarkable foresight with regard to the tasks of the future and perceived almost instinctively the direction of coming technical development. His skill as a negotiator was quite out of the ordinary, as was also the courtesy and patience with which he would succeed in the face of apparently hopeless odds in gaining his object. On the other hand, he was often a heavy burden to his subordinates whom he well-nigh drove to desperation by his persistent alteration and remoulding of letters and other documents presented for his signature. It might well have been beyond the power of his assistants to bear with their "amiable tyrant," as they called him, had they not made allowances for his Rhenish-Frankish temperament and realized that in most cases he was right.

XXVI.

ELECTRIC POWER SUPPLY

The generation of electric power in Germany in 1913, the last year before the first World War, can be estimated to be about 5,100 million kW/hours. Less than half of this was produced in public generating stations, the greater part having been generated in consumers' own works. In 1925, the first year of "peace" in Germany after the reparations crisis which followed the first World War, the total production of current was 20.3 milliard kW/hours, i.e., four times as much as in 1913. In the next few years the figure had grown to 31 milliards. At the same time the proportion supplied by the public stations increased, as more and more consumers gave up the idea of generating their own current. In 1932 this only amounted to 43%. All this was only made possible by great building activity on the part of the supply companies, which had begun about 1921 and with the help of foreign credits in the last four years of the period under review, had assumed an exceedingly brisk pace.

About 1907, based on the experience of the steam turbine, it had become the common practice in building power stations to forsake the former rules in favour of steam pressures of at least 15 atmospheres and steam temperatures of 325° to 375° C. This rendered it possible to increase the rating of the turbo-sets considerably. As against a "normal" output of some 5,000 kW at the beginning of this period, it was not uncommon during the war to find units of about 16,000 kW. Ten such sets were installed in the famous Klingenberg generating station at Golpa-Zschornewitz in 1917. At full load the steam consumption of one of these turbines was about 80 tons per hour. Since the steaming capacity of the largest boilers of those days was 12—15 tons per hour, each turbine would require 6—8 boilers, or 8—10 including reserves, which practically meant a boiler house for each turbine. To all appearances, therefore, it was the steam supply which was going to place a limit on the size of the turbine, an increase of which seemed to be otherwise feasible.

The inability to increase the boiler output was due to the types of boilers in use at that time. In spite of attempts made in the U.S.A. it had not been found possible to increase the size of the inclined water-tube assembly beyond certain limits; this also applied to the area of the travelling grate, as the task of stoking became unmanageable beyond a certain size. Trials were made with steeply inclined, almost vertical tubes of considerable length with several drums above and below, which achieved a higher rate of evaporation, but that still left the problem of the grate unsolved.

This led about 1922, also in Germany, to the revival of an idea which had proved a success in the U.S.A. at the beginning of the war, viz., to grind the coal to a fine powder and to feed the resulting viscous mass together with the air required for combustion through a pipe into the furnace. This results in an enormous jet of great heat, which is easy to control; several such jets together by far exceed the heating effect of the largest travelling grate. It was not surprising, of course, that the existing furnace brickwork was unable to withstand this extra heat; the refractor brickwork had to be cooled by water-piping, so that the combustion chamber was more or less enclosed by the heating surface. Building on these lines, boilers were ultimately designed which were capable of producing 50 and more tons of steam per hour, to be followed quickly by turbine units for 20,000—25,000 kW, whilst plans for new power stations were already being based on units of twice that size. Simultaneously, steam pressures were being raised to 35 atmospheres and temperatures to 450° C.

The era which commenced with the introduction of pulverized fuel and lasted until about 1933 can be regarded as the third in power station design. The second is the Klingenberg period from 1907—1922. At the beginning of the second era, the heat consumption in the power station was about 7,000 metric heat units (kg/cal) per kilowatt-hour, falling at the end of the era to 6,000. Since 1 kg of good anthracite produces about 8,000 metric units of heat, the quantity of coal required to generate one kilowatt-hour is about .875 or .750 kgs respectively. In the third period, however, thanks to the increase in steam pressure and temperature and the greater attention paid to the conduct of the evaporation, but, above all, to the considerable increase in the size of the boiler and generator units rendered possible by the introduction of pulverized fuel, the heat consumption had dropped to about 4,000 metric thermal units; in other words, the coal consumption for 1 kWh was now only ½ kg. The improved steam-generating technique had thus saved the nation about 150 million Marks per annum.

Familiarity with the idea of exceeding the hitherto existing limits in steam pressure and temperature lent new impetus to the endeavours of those who advocated the use of 100—120 atmospheres and temperatures of 450—500° C. These suggestions were by no means new; in Germany itself suggestions on these lines had been put forward by venturesome pioneers a generation ago, and small-scale plants put into operation. These had led to the discovery that for many of the components there were no suitable materials available.

It was not until alloy steels, molybdenum steels in particular, came into use in the construction of machines and apparatus that it was thought possible to risk (as many still considered it) building a steam generating plant for 60 atmospheres or more. The difficulties centred chiefly round the boilers. In evaporating the water it was important to drive the steam bubbles from the inner walls of the tubes as quickly as possible, to prevent uneven heating consequent on the insulating action of the bubbles. This had for long been the bugbear of boiler designers, and had led to the development of the vertical-tube boiler with all kinds of devices for accelerating the water circulation. The raising of the evaporation to its peak value was now responsible for a sheaf of the most uncommon suggestions for the prevention of steam bubbles in the tubes.

In England, Mark Benson propounded in 1921 the following theory. The process of evaporation consists of two parts. To commence with, the water must be heated to boiling point, which depends on the pressure, before evaporation can commence. Correspondingly a distinction is made between the sensible heat, which must be conveyed to the water up to the point where evaporation commences, and the latent heat which is used in converting the water into steam. At the low pressures used at that time the latent heat is much greater than the sensible heat; at about 93 atmospheres the two are equal, and the higher the pressure, the less becomes the latent heat; at 225 atmospheres it becomes zero. This is known as the "critical" pressure; the corresponding "critical" temperature is 374° C. The meaning of this is that if the water is subjected to 225 atmospheres pressure and heated to 374° C, there will be no evaporation before the critical temperature is reached, and that when the critical point is exceeded, the whole of the water is converted immediately into steam. Under these conditions there ceases, therefore, to be a state in which water and steam are present at the same time; below the critical point there is only water and above it only steam, i.e., steam bubbles cease to exist. If, then, the steam consumer, e.g., a steam turbine, is not required to operate with steam at 225—230 atmospheres but at a lower pressure—say, half that figure—the steam can be throttled down correspondingly, but the work entailed in so doing must be written off as a loss.

In the spring of 1923 an article in an English engineering journal dealing with this subject came to the notice of Siemens-Schuckert, who thereupon communicated with Benson. Following on an inspection of his experimental plant, an agreement was concluded between the parties, in accordance with which Siemens undertook to carry out further large-scale studies and to develop the process to the commercially operational stage. It soon became evident that these extremely high pressures and temperatures were the cause of a series of difficulties, the elimination of which entailed systematic research into the fairly complicated processes involved. On completion of the initial studies on a small plant in the Works' power station, a full-sized Benson boiler of Siemens design was erected at the Firm's Cable Works in Gartenfeld and put into operation with the rest of the steaming plant. This boiler was not really a boiler in the strict sense of the word, but simply a tube of several hundred metres length in numerous coils, so arranged that the water flowing through it was first pre-heated in a relatively cool zone, then evaporated in the hottest zone, and the steam finally superheated in a zone of medium heat. A sensitive governor was provided to control the water, fuel and air feed accurately in accordance with the varying load of the consumer, i.e., a steam turbine. The boiler had become a steam-producing machine. Concerning the governor equipment there will be more to be said later on. In passing, let it suffice to say that Siemens-Schuckert had profited enormously by the experience meanwhile gained by the Wernerwerk in the development of thermo-technical instruments.

Having now in the course of their development work become more familiar with the new principles of steam generation, it was discovered that the essential core of Benson's invention, viz., the evaporation of the water at the critical point, was not so important as had been thought. It was also found to be possible below the critical point, although not so smoothly. There was some formation of steam bubbles, but in consequence of the much higher rate of the forced flow of the feed water as compared with boilers featuring natural circulation, the bubbles could do no harm. This being so, subsequent Benson boilers were frequently designed with feed pumps for pressures just suitable for the working pressure of the boiler steam. This pressure was also not rigidly maintained, as formerly, but was allowed to fluctuate in unison with variations in the load (sliding pressure system). The credit for the successful development of the Benson system must, in the main, go to the Siemens-Schuckert engineers, and of these, in the first place, to H. Gleichmann.

In speaking above of the Klingenberg era of power station building, meaning approximately the period between the general introduction of the steam turbine and the year 1922, this did not refer merely to the general lay-out of the stations and the type of boilers employed, but also to the distance between the main bearings, thereby keeping the rotor as short as possible in order to ensure that the dangerous critical speed, at which every fast-rotating body commences to vibrate, should be kept higher than the working speed. The consequent reduction in the number of stages was taken into account, since it was then thought possible to raise the velocity of the steam-flow to that of sound without materially affecting the efficiency (as was formerly believed); for the inlet steam pressures then normally in use, from 8 to 12 stages, depending on the design of the turbines, were considered sufficient for the purpose. Some AEG turbines had as few as 5 stages.

In these turbines a distinction was made between a high-pressure and a low-pressure section, although the two were not always clearly separated from each other. The former was reckoned from the inlet pressure down to 3—0.5 atmospheres, the latter from the lower limit down to condenser pressure. It is remarkable that the high-pressure stages, although comprising the greater part of the pressure drop, only account for the utilization of two to three-tenths of the input, whilst the remainder is converted in the low pressure stages. For this reason, the greater care was usually given to the low-pressure section in which, for instance, a large number of stages were provided in order to attain maximum efficiency of conversion. The high-pressure section very frequently consisted of one single stage.

As is well known, the steam which enters the condenser on issuing from the turbine possesses a considerable heat content, which is lost as far as the conversion into power is concerned and is to blame for the fact that, according to the size and quality of the plant, only a fifth to a quarter of the heat is converted into power. In a case where a manufacturer requires large quantities of process heat in the form of steam of a few atmospheres pressure distributed over the Works, the best plan is to raise the whole of the steam required for power and processing together at fairly high pressure. The steam is fed to a "back-pressure" turbine to generate the required amount of power current, after which it is extracted at the pressure most suitable for the processing plant. The turbine in this case has only a high-pressure part and a lower efficiency than that of a condenser turbine. This does not represent an ultimate loss, however, since the cost of raising the process steam to the inlet pressure of the turbine is not great. The boiler-house is necessary in any case, and the electric power generated by the back-pressure turbine is obtained, so to speak, as a by-product of the manufacturing process.

Success, of course, depends on very careful planning and dimensioning to suit the working conditions of each plant. It is no longer sufficient to install a generating plant for a certain output and to leave the rest to the consumer. In these cases power and heat are so interlocked that one is dependent on the other. If a local disturbance is to be prevented from spreading to the whole of the system, provision must be made to deal with every occurrence imaginable. This was a branch of engineering science in which Siemens-Schuckert were in their element. Bingel, in particular, incessantly urged his assistants to make a thorough study of the collective requirements of the Works in each individual case, even if the time occupied by the investigations and the conduct of experiments should run into months, before submitting their proposals to the customer as his consultants. This practice was rewarded by success; a particularly high proportion of the industrial power plants of those days was built by the House of Siemens.

Since the majority of the turbines in these industrial power plants consisted of a high-pressure section only, it seemed advisable to devote more attention to this section than had hitherto been the case, and in view of the tendency to raise the inlet steam pressure from the customary 12—18 atmospheres to 30—35, and later to 100 atmospheres and more, the high-pressure side of the condenser turbine, i.e., the public supply turbine, also acquired increasing importance. Its neglect was no longer excusable, and multi-stage design again became the rule. Since turbine outputs furthermore continued to increase unceasingly in the period between 1922 and 1933, mainly due to American influence, rising to 30,000, 40,000, 60,000, and in isolated cases even to 100,000 kW and higher, the designer had no option but to divide the turbine into two sections to prevent its assuming inadmissible proportions. In this case the steam from the high-pressure part was carried over to the low-pressure cylinder by piping.

As far as possible, the high and low pressure cylinders were mounted on one shaft, which was supported in several bearings and also carried the generator (single-shaft type); in the case of the largest machines, the high and low pressure cylinders were mounted separately, each driving its own generator (multi-shaft type). Thus we find embodied in one machine twenty times the amount of power which a generation ago was the practical limit of the reciprocating steam engine.

In 1912, Ljungström, a Swedish machine designer with an extraordinary gift of inventiveness, published proposals for a new type of steam turbine which were at first met with smiles. His idea was to mount a number of concentric rings of turbine blading on the plane surface of a circular disc. The distance between two rings was to be rather more than the width of the blades. A second disc was also to be furnished with concentric rings of blading, so arranged that when the two discs were placed concentrically face to face, the rings of blades of the one fitted into the spaces of the other. The two discs, each mounted overhung on a shaft, were able to rotate in opposite directions. If high pressure steam was fed to the centre of the assembly, it was able to escape in a radial direction, finding, as it expanded (increased in volume), a progressively larger diameter of the rings, i.e., larger channels, without the necessity for increasing the size of the blades, as with ordinary turbines. The runner blades of each disc were at the same time the guide blades for the other, and since the two discs rotated in opposite directions, the resulting speed for each disc for a given velocity of the steam-flow was only half that of the hitherto orthodox turbine. Here, then, was a design of staggering simplicity and neatness, but one calling for a high degree of precision in manufacture.

As early as 1914, notwithstanding their connection with the "Zoelly Syndicate," the "Maschinenfabrik Augsburg-Nuremberg" (MAN) had been in touch with Ljungström with a view to obtaining a licence under his patents, and had ordered two generators required for an experimental set from Siemens-Schuckert. The generators were more than ever an integral part of the set, since the turbine wheels were mounted overhung on the ends of their shafts. The war interfered with the completion of the work, and it was not until 1924 that MAN was able to put into operation in their own Gustavsburg Works the first turbo-dynamo to be built completely in Germany in accordance with Ljungström's design, and to test its qualities.

Carl Friedrich von Siemens had paid close attention to post-war developments on the steam side, such as the use of high pressures, new types of boilers and the continually increasing size of the turbines which, of course, was reflected in the output of the generators. This was the more natural, as these questions were matters of continual study in his own House, which had from time to time contributed materially to their advancement. In the case of the turbine, which was the core of the whole movement, it was very irksome to be confined to working with the firms of the Zoelly Syndicate, particularly in view of the growing tendency of each to go his own way, of which the case of the MAN and the Ljungström turbine was a typical example. The decision not to engage in their manufacture, taken by his brother Wilhelm years ago at the commencement of the steam turbine era, may have been sound. It had, however, brought numerous disadvantages in its train, which were making themselves felt to an increasing degree. It was time to look around for manufacturing facilities of one's own.

The opportunity offered itself in connection with the founding of the "Vereinigte Stahlwerke," the final act in the liquidation of the Stinnes legacy. A part of the Thyssen industrial property which was scheduled to be absorbed by the Vereinigte Stahlwerke was the "Maschinenfabrik Thyssen A.G." in Mülheim on the Ruhr. The manufacturing programme of this factory included steam turbines and electric generators. These, on the other hand, did not fit into the intended programme of the "Vereinigte Stahlwerke." It was therefore decided in connection with the dissolution of the Siemens-Rheinelbe-Schuckert-Union to transfer that particular part of the factory to Siemens-Schuckert, a decision which was facilitated by the fact that the particular shops could be separated from the rest without difficulty. Siemens-Schuckert set to work at once with zest to re-model the somewhat out-of-date workshops and to re-furnish them with high-capacity machine tools and testing equipment, and this was one of those cases in which the accumulated experience of the Central Works Administration Department was of very obvious value. In accordance with the programme it was intended that in addition to the steam turbines, the generators hitherto manufactured in the Dynamo Works in Siemensstadt should now also be made in Mülheim. The Mülheim Works of the Siemens-Schuckertwerke were opened in April 1927. Trusted personnel transmitted the experience of the parent Works to the new seat of production.

This infusion of new blood made itself felt immediately in important orders received. Thus, early in 1930 the Société Générale de Production d'Electricité in Antwerp placed an order for its Schelde power station for a turbogenerator to operate at 35 atmospheres, 425° C steam temperature and 3,000 r.p.m. and to give an output of 60,000 kW. The steam was expanded in one high pressure and two low pressure cylinders, all in line with each other and with the generator on one common shaft. The total length of the set was 30 meters. Voices could be heard saying that a machine of that length was an impossibility, but by this time it was already under construction. When it was set to work it was the largest single-shaft turbo-set in the world. Descriptions in technical journals under the heading: "The Largest Steam Turbine in the World" were quite good publicity.

The MAN had meanwhile been successful with their experimental Ljungström turbine, and was occupied with the development of the system for larger outputs. Siemens-Schuckert, too, having become independent turbine makers, began to turn their attention to the radial-flow turbine.

On the one side, they were anxious to obtain a licence for the Ljungström turbine, as the AEG and Brown Boveri Cie (BBC) had also shown interest in it. In 1930 Siemens-Schuckert succeeded in founding the "Internationale Ljungström-Turbinen Union A.G." which included, in addition to Siemens-Schuckert and the MAN, the AEG and BBC. On the other hand, they pushed forward with their own development work by designing a simple radial-flow turbine, not with oppositional rotation of the runners, but with one wheel stationary as a guide-wheel. This solution was above all very suitable for small units working at high initial steam pressures without a condenser, but supplying (back pressure) steam for processing purposes or other forms of heating. In turbines of the usual axial-flow type, these high initial pressures and corresponding temperatures had given rise to many difficulties in the way of internal heat stresses, which were avoided in the radial turbine.

Notwithstanding the many doubts expressed by interested parties, Siemens went ahead vigorously with the radial turbine, which proved a success, and led to considerable business. Simultaneously they developed the Ljungström turbine for large outputs. In a short space of time the Mülheim Works had taken its place as an equal beside the corresponding Works of the AEG which until then had been acknowledged to be the largest and most up-to-date turbine works of the Old World.

In 1928—1930 a large task fell to the lot, not only of the Mülheim Works, but of the whole of the Central Station Department, in the building of the Berlin Power Station "West," which the Berlin Electricity Works had planned to erect on the banks of the Lower Spree, immediately adjoining the Siemens Works.

This proximity, as also the circumstance that AEG had built the Klingenberg Works, naturally suggested that the new station should be the work of Siemens. Effect was given to this idea by the conclusion of an agreement between the "Bewag" (Berlin Electricity Works, A.G.) and Siemens-Schuckert whereby the latter undertook as Consulting Engineers the planning and erection of the complete station against payment according to a mutually agreed scale of fees. At the same time the order for the steam turbines with generators and the whole of the electrical equipment was placed with Siemens. For the remaining work and supplies, such as the difficult foundations, the docks, railway sidings, coaling plant, ash disposal, the structural steel work and the chimneys, it was the duty of Siemens to invite tenders and to recommend the most favourable ones.

The generating plant comprised six turbo-alternators of 34,000 kW each at 3,000 r.p.m. and two further sets of 12,000 kW each for house service. The turbines received their steam from eight boilers, each with a maximum output of 150 tons of steam per hour at 32 atmospheres. The smoke from the boilers was discharged through two chimneys of novel design; they rested on the roof of the boiler-house and were 110 metres high in all. Taking everything into consideration, the power station was regarded as a remarkable technical achievement, particularly in view of its rapid completion.

As compared with the development of steam-power generating plants, that of corresponding hydro-electric stations had for some time taken place on a modest scale, the reasons being as stated in an earlier chapter. Of the large hydro-electric plants supplied by Germany before the war, the majority went abroad, to Scandinavia, Austria, Northern Italy and Spain; Switzerland had already become independent in this connection. Central and South America were pretty good customers, but entry to the North American Continent was barred. In Germany itself it was really only in the South that opportunities for hydro-electric schemes presented themselves on a larger scale than the mere catering for local needs. In Bavaria, Oscar von Miller had, prior to the war, advocated that the supply and distribution of electricity should be placed in the hands of a State authority, pointing to the potential sources of power available in the water of the Bavarian Alps and the right-bank tributaries of the Danube. After the war, these suggestions crystallized in the building of the Bayernwerk (Bavaria Works) with its 110,000-volt distribution system, and the linking up of the large steam-power stations in Franconia with the Walchensee Werk (in operation since 1924) and three (later four) other power stations erected at the same time on the middle reaches of the Isar between Munich and Moosburg. These groupings represented a considerable volume of power. When fully operative, the Walchensee Werk could generate more than 100,000 kW, although the output depended on the widely fluctuating flow of water. The same applied to the stations on the middle reaches of the Isar, where maximum output was 112,000 kW. Both stations supplied three-phase current for general purposes, and, in addition, single-phase current at 16⅔ cycles for the railways. About the same time an industrial power station took shape at Töging on the river Inn which supplied current to aluminium works and the calcium cyanamide industry. In one vast generator house were assembled no less than 15 turbines, side by side, seven of which were driving d.c. generators and the remaining eight coupled to three-phase alternators; the total output was in the region of 28,000 kW. Somewhat later, in connection with the canalization of the Danube, the so-called Kachlet Step in the river approaches to Passau was completed, and a power station built into the river comprising eight generators of 6,000 kW each. Orders for a substantial share of the electrical machinery for all these stations fell to Siemens-Schuckert, as, indeed, there was scarcely a water-power plant of any size in those days for which Siemens-Schuckert did not supply part or even the whole of the electrical equipment. In computing the turnover it must be remembered that the water-turbine invariably runs at a slower speed than the steam-turbine. With large heads of water the speed may approach 500 r.p.m., whilst with low heads and correspondingly larger volumes of water, the speed may be as low as 75 r.p.m. This was actually the case in the Danube power station at Kachlet, where the 80-pole magnet wheel and shaft of one generator weighed 110 tons, and the complete machine 260 tons.

The power supply to the State of Baden was in the hands of the "Baden Works," a nationalized Joint-Stock Company founded in 1921 with the object of developing the hydraulic energy of the Black Forest. Of the power stations built within the scope of this plan, the Schwarzenbach Works, to the building and equipment of which the House of Siemens made a major contribution, is worthy of note.

In particular, the masonry dam was built by the Siemens-Bauunion, who also bored the intake tunnel of 1,800 metres through the granite of the mountain, blasted the surge-tank, and built the penstocks, whence the head-water plunged downwards through cast-iron pressure pipes to the turbines 360 metres below.

In generating electric power, it has always been felt to be a disadvantage that electricity cannot be stored, and that only just as much current must be generated as is actually required at the moment. As long as direct current was the only current used, the accumulator battery provided a certain amount of relief; in going over to alternating current, even this was denied. The assumption that the fluctuating day-load of the power stations would be smoothed out by the increasing use of electricity for manufacturing purposes, such as electro-chemical processes (metal-alkali electrolysis, calcium cyanamide, carbide manufacture, aluminium production), and by the introduction of industrial and domestic heating, had only been partially fulfilled. A look at the load curve of any large power station supplying one or several cities of any size always showed the same result, varying merely according to the season of the year: a high peak in the morning, a trough during the dinner interval, a second peak in the afternoon, and a period of low consumption during the night. The generating capacity had to be sufficient to cover the winter evening peaks, although two hours later consumption had fallen to less than one fifth of the rated load, a condition which persisted until the next morning. If it were possible to fill the troughs even partially by charging an accumulator and to reduce the peaks by its discharge, an increase in the overall efficiency of the plant could be expected, even if in consequence of unavoidable losses a part of the energy stored in the accumulator were irrecoverable.

Thinking along these lines the Swedish engineer Ruths hit upon the idea of introducing, as part of the steam-raising plant, large vessels with good heat insulation which were partly filled with water. During periods of low load, part of the steam was not fed to the turbine but to these vessels, where it was used to heat the water with the object of supplying the extra steam required in the peak-load periods. As part of the extension of the Charlottenburg power station of the Berlin Electricity Works, for which the contract was placed with Siemens-Schuckert, a battery of 16 vessels of the Ruths Accumulator type was installed, capable of supplying more than 600 tons of steam over a period of three hours. In conjunction with two special lighting sets the evening lighting peak was thereby covered at less cost than would have been incurred by the installation of boilers of the usual type. At the same time, the thermal efficiency of the steam-raising plant was appreciably improved by the resulting steadier load on the boilers.

As long ago as 1894 similar considerations had led to an experiment with a hydro-electric station at Luino, on Lake Maggiore. At night, when current consumption was a minimum, water from the lake was pumped into the reservoir higher up the mountain, to build up a sufficient supply for the next day. Owing to the smallness of the plant, measured by present-day standards, and the low efficiency of the machines of those days, the realization of a commercial advantage was out of the question. The idea was shown to be capable of development, however, and plants built in Upper Italy and Switzerland up to the outbreak of the 1914/18 war showed that it was possible in this way to obtain a commercially profitable balance of the load. In nearly all cases, including the Murg Station (the first large pumped-storage plant in Germany), the stations were basically river-operated, only part of the natural volume of water being pumped back into an upper reservoir to augment the flow as the load demanded. After the war it became increasingly common practice in Germany to build pure pumped-storage stations, which have no natural head of water (river). In these it is only necessary to have a river or large lake at the lower level from which to take sufficient water for the upper (usually artificial) storage basin. The power-house at tail-race level includes a three-phase synchronous machine, which can operate either as a generator or motor, and is connected to the supply network. On one side it is coupled to a turbine, and on the other to a pump. During periods of low consumption, usually at night, the synchronous machine takes current from the supply and drives the pump, which fills the upper reservoir. During load peaks, the contents of the upper reservoir are returned to the turbine through the same pipe, and the synchronous motor, now operating as a generator, delivers its output to the supply system. Although only 60—65% of the electric power taken from the supply system for pumping can be recovered during operation of the synchronous set as a generator, the advantage of being able to cover the load peaks is so great that quite a number of these pumped-storage stations were built in Germany in the years following the war. Most of them, moreover, were fairly large stations, for if there was to be any point in helping the supply systems, it was of no use to offer them a few thousand kilowatt-hours.

The RWE, for instance, built a power station at the Hengsteysee at the confluence of the Ruhr and Lenne rivers, the level of the Hengsteysee having been raised by a dam for the purpose of purifying the water. The storage basin was 160 metres above the lower level of the Hengsteysee, and each of the four turbo-sets had an output of 48,600 HP. One has to realize what it meant to the pump builders to design pumps each capable of converting 36,000 HP into the energy of flowing water. At that time there were no pumps in existence of even approximately comparable size. To the electrical industry, too, these pumped-storage stations presented special problems. Owing to the wide range of its activities, the House of Siemens participated in almost every case where power plants of this kind were built in the supply of important sections of the equipment. Thus at Hengstey, it fell to Siemens to design and supply the gear for automatically starting and changing over the pumping sets. With this equipment it was possible, in case of failure of another power station, to provide an instantaneous reserve by connecting the pumped-storage station to the main RWE supply system. Changing over from pumping to generating was initiated by the manipulation of a small two-way switch and completed within the space of 50 seconds. It is only when one remembers that each pump was raising 15 cubic metres of water per second through the two 3.2 metres diameter pipes to a height of 160 metres, and realizes the enormous forces involved in the reversal, that it is possible to appreciate fully the magnitude of this feat of engineering.

The creation of such power distribution networks as were characteristic of the third decade of the twentieth century in all countries also raised a number of problems which, whilst they had already existed in principle, now acquired crucial importance. It is easy enough to envisage the power supply of the whole of Bavaria, Thuringia or Saxony from a few large stations; to stipulate that consumers with their own generating plant must operate in conjunction with the public supply on a power exchange basis; to lay down that the regional supply networks must be coupled up at adjacent points for their mutual support; to envisage an 800 kilometre busbar supplying to wherever required the power generated in the anthracite and lignite coalfields or from the white coal of the Alps; but the practical realization of these schemes was beset, at first, with considerable difficulties. These were fundamentally due to the fact that a fault occurring at any point in a large interlinked supply system would at once spread throughout the network and endanger its operation.

The steps taken in the interests of safe operation of the distribution systems led to the collaboration of the specialists of the whole world in the step by step evolution of a many-sided system of protection known as "selective protection," so called because it operates by cutting out the faulty portion of the network without interfering with the remainder. To this end, a circuit-breaker was introduced into the system at every point where a branch conductor issued from a junction—usually identical with a distribution sub-station—or where the subdivision of a main feeder seemed desirable. Each of these circuit-breakers, of a rating corresponding to the short-circuit energy to be cleared, was provided with a metering system capable of tripping the breaker automatically should this be warranted by the metering results. These meters have widely varying tasks to fulfil, depending on the configuration of the supply system and its pattern of operation. The simplest type measures only the current flowing, others measure the voltage, others the quotient of voltage and current, i.e., the resistance of the section controlled, which usually undergoes a considerable change on the occurrence of a fault; other meters integrate the product of current and voltage, i.e., the power. Of these latter, some also register the direction of flow of the power. Many meters "operate" immediately on detecting dangerously high (or low) values of the quantities measured within their section, others are equipped with delayed-action devices, the operation of which may under certain circumstances depend on the value of the quantity measured, they may also wait to see whether some other circuit-breaker which is nearer to the fault may not trip first. Finally, there are meters which are connected to their neighbours by a pilot wire, by means of which they inform each other as to the nature of suspicious phenomena. By way of an example: a longish cable connects two junction points in the distribution system, there being no consumers between these points. The circuit breakers at each end of the line are provided with metering devices which determine the direction of flow of the current. If energy flows from the junction point into the cable, a contact A is closed, in the reverse case a contact B. A pilot wire connects the two junction points by way of the two contacts A. If they are both closed, it means that energy is flowing into the cable from both junction points. This will indicate that something is seriously amiss since there is no legitimate consumer between the junction points. It can therefore only be a case of short-circuit, into which the energy of the power station generators is flowing via the two junction points. The circuit formed by the pilot wire, the two closed contacts A and a source of current trips the circuit-breakers at both ends of the cable, and disconnects the faulty part from the system.

When this section is so situated that the station personnel is able to see at once which part is affected, the purpose of the protective equipment has been achieved; further measures must be left to the intelligence of the station attendants. Not infrequently, however, the faulty section is so placed that the attendant in a power station or large distribution substation is unable to determine which kind of automatic switching operation has taken place. In that case the occurrence must be automatically signalled to the control room. This leads up to the part played by automatic signalling in conjunction with power station operation, and to a brief survey of the development of control room practice.

Anyone entering the machine room of a power station of about the year 1910 would usually find one wall occupied by a marble panelled switchboard raised a couple of steps above floor level and surrounded by an ornamental ironwork frame. Mounted on the panels were the switch handles and instruments of the individual circuits. The use of marble for the board dated back to the old d.c. days, when the switch contacts were mounted directly on the board, which therefore had to be an insulator. The advent of three-phase current and higher voltages brought the oil-switch in its train, which, together with its "live" parts, was at first enclosed in a cage behind the board, and operated by a lever from the front of the board. This rendered the marble senseless, but it was nevertheless retained because of its good appearance. Gradually, however, with increasing voltage and output, the high tension panels grew to be of such a size that they could no longer be accommodated behind the switchboard; they came to be installed in separate rooms, where they were soon occupying several stories, until eventually, in the case of the highest voltages, they found themselves in the open air as outdoor switchgear. From the switchboard, which presently exchanged its marble for simple sheet-iron panels, and began to take the form of a number of separate switchdesks, the oil circuit-breakers were remote-controlled by electromagnets or small motors. More recently, compressed air has also been used for this purpose. To begin with, the "control room" remained within the four walls of the machine room, as it was considered essential that in an emergency the switchboard attendant should be in direct contact with the machine minder. Gradually, however, it came to be realized that this was more of a nuisance than an advantage, and the switch control gear was therefore installed in a separate room, which was made soundproof as far as possible. From here it was possible for one or two attendants, as time went on usually engineers, to control the whole station, issue their instructions to personnel in the remotest parts of the widely distributed organization and keep in touch with remote distribution points and other power stations which might be linked to the system. Thus, the control room came to consist of a spacious hall containing a large curved switchboard of many panels, in the centre of which were two desks with instruments, push buttons and telephones, at which were seated engineers of the watch like spiders at the centre of a web. In very large networks the control rooms came to be entirely separated from the generating plant and were placed where most convenient from an administrative point of view. In such cases where it might be that the electricity supply of a whole province was controlled, those in charge of these control posts were called "load despatchers," and wielded very great power. Power stations and distribution points had to follow their instructions implicitly.

In view of the nature of this task the load despatcher had, of course, to be kept informed at first hand of the more important occurrences in the supply network. This meant that the electrical quantities measured at certain points in the system had to be transmitted to his desk, frequently over distances of one hundred kilometres and more. Moreover, he had to be able to see from the position of the most important switches which sections of the network were disconnected, either intentionally or automatically, owing to a fault. For this purpose the appropriate section of the supply system with its generating stations, sub-stations and main connections was represented by a luminous diagram on the panels of the large switchboard, the symbolic representations of the generators, busbars, transformers, circuit-breakers and connections lighting up when the units in question were connected in circuit; parts not in circuit remained in darkness. Unpremeditated disconnection from the circuit caused the indicator lamps to flash, thus arousing the immediate attention of the supervisor. An important feature of the luminous mimic diagram was that the symbols representing the circuit-breakers were themselves miniature switches, the closing of which operated the circuit-breakers. The operator was therefore unlikely to make a mistake in the choice of switch. In more recent installations the illumination of the complete diagram was frequently dispensed with, and confined to the handles of the small check-back control switches. Such mimic diagrams were termed non-luminous.

The transmission over long distances of the switch position indications, but more particularly of the instrument readings, is a problem which has exercised many brains. It was out of the question, of course, to provide a wire for each instrument, of which there might be a hundred or more, quite apart from the fact that the weak currents concerned could not be transmitted over a long wire of variable conductivity without falsifying the results. All kinds of expedients were tried. To begin with, an attempt was made to apply the experience gained in communication engineering with the multiple use of conductors, in particular with duplex connections in telegraphy and phantom circuits in telephony, and with Baudot's distributor disc, above all, however, with the methods which had produced a number of channels in a single conductor by means of different carrier frequencies. In order to transmit the reading along these channels, it had to be "telegraphed," i.e., it had to be converted into current impulses, the mutual distances between which, or their frequency, expressed the value of the reading. The transmitter, therefore, was a measuring instrument which converted its readings into telegraph impulses, and the receiver an instrument which converted the impulses and passed them on to a measuring instrument with scale and pointer on which the values could be read off in the usual manner as volts, amps or kilowatts. In contemplating these cleverly designed electro-mechanical measuring telegraph instruments in their compact black cases in operation, one could not help being surprised that in spite of the complicated nature of the conversion, the error of transmission was so small.

As a rule, the load despatcher refrains from actual operation of the switches, but issues his instructions to the various points of the network. It is a different matter when the control centre covers one power station or a small group only; in that case it might be advisable for the load despatcher to operate the controls directly. Where long distances are involved, as, for instance, in controlling a distant unattended sub-station, it is out of the question to install a separate control line, it might even be with check-back connection, for every circuit-breaker. The suggestion was therefore made to use the selector lines of the automatic telephone system. Every switch, in fact every piece of remote-controlled apparatus, such as the water-gates, slide valves, steam valves, couplings and other units in the machine room, was given a number under which it could be called like a telephone station. In this way, one line sufficed to cover the whole of the remote controlled apparatus of a group. One had to be certain, of course, that no error had occurred in transmitting the call, and for this reason it was not until the switch which had been "called" had confirmed its number that it finally received the instruction. The whole of this procedure was automatic.

All these measures in conjunction rendered it possible to master problems which at first appeared quite impossible of solution. Belonging to a large hydro-electric station, for instance, was a smaller one further upstream, making use of another part of the total head of water. In that case the upper plant could be left entirely unattended, to be set in motion from the main station as required. From there, following the pressing of the master button in the luminous mimic diagram, it was possible to follow the opening of the water-gate, the running of the turbines up to speed, and the excitation of the generators until reaching synchronism with the main station, when the incoming machines connected themselves automatically to the supply system. To a layman it all looked a little like witchcraft.

The development of the required equipment on which, as already remarked, electrical engineers of all countries with the necessary industrial resources were now engaged for the first time, gave some idea of the difficulties ahead in the continued specialization in electrical engineering. The equipment and operation of electrical power plants was essentially the design and operation of power-current apparatus. The majority a good many mechanical problems. Now, however, the situation called for the extensive cooperation of the metering and communication branches of the weak current side, which were required to be closely acquainted with the design and operation of the power-current apparatus. The majority of electrical manufacturers, however, produced only one or the other, and there was really only one firm in the whole world which as a matter of principle gave equal attention to both sides, i.e., the House of Siemens. But even here, the individual departments had to such an extent lost touch with, not to say become isolated from each other that collaboration in the form now demanded by developments had become difficult. Internal disputes were not uncommon as to which department was most closely concerned in a particular case, obviously to the detriment of business.

In this situation it was exceedingly fortunate that at Siemens the hierarchic pyramid was carried through to a head, added to which was the fact that Carl Friedrich von Siemens was an industrial leader of a very different type to that of his brother Wilhelm. Rather than try his hand at inventing, as Wilhelm had done, a rôle which in no wise suited his temperament, Carl Friedrich was wont to spend some time quietly but intently observing the development of things, both within the House and elsewhere. Then he would speak out in his courteous but firm and resolute manner. Nothwithstanding the resistance of the departmental managers concerned in the squabble just mentioned, he constructed a bridge between Siemens-Schuckertwerk and Siemens & Halske, in the shape of the "Siemens Relay Association," not a new firm, but a department outside the existing framework. It was to be supervised by a Board consisting of Directors of the two companies under the Chairmanship of Dr. Manfred Schleicher, a versatile and skilful engineer, who was supported by a staff of picked specialists from the various groups involved. Schleicher proved to have a pronounced gift of coordinating the efforts of these workers and of leading them to the common goal. As the result, Siemens came within a few years to be recognized as the leading House where this class of equipment was concerned.

With the exception of a few large municipalities, the builders and owners of the power stations of the public supply in Germany were usually undertakings covering whole districts or provinces. They were either semi-private Joint-Stock Companies, after the fashion of the Rhein-Westphalian Electricity Works, or companies, the whole of whose capital was publicly owned. The last of the privately-owned undertakings of any importance was a relic of the former Trust Companies, viz., the "Gesellschaft für elektrische Unternehmungen" ("Gesfürel"), which had been founded by the Loewe Group. This undertaking still owned extensive plants, particularly in Silesia. Otherwise, power generation and distribution in Germany was nationalized, if the term is acceptable. Of the total production of electricity in Germany which, in 1929, was the second largest in the world (following the United States), 38% was from lignite, 37% from hard coal, 15% from water power and 10% from gas and oil.

In the majority of other countries private capital had maintained its hold on the power supply industry. That this was the case in the U.S.A. goes without saying, but also in the most important countries of the European Continent, private ownership still predominated. In the two countries of the Scandinavian Peninsula and in Switzerland and Austria, however, the State was beginning to play an active part.

A characteristic common to the countries named was that their electricity supply was based on hydraulic power. Whilst these sources of energy could be regarded as private property, depending on the legal situation in each case, it was nevertheless easier to accept the idea of placing their development in public hands rather than the building of steam power stations, if only on account of the inevitable interference with the rights of others.

In Italy and Spain, on the other hand, notwithstanding the prevalence of hydro-electric stations (in consequence of the scarcity of coal), the great majority of these are in private hands. This is even more the case in France, where the State refrains on principle from building public supply stations, but insists on conformance with the minutest details of bye-laws governing their operation. In particular, the State reserves the sole right to grant concessions, which in most other countries has been left to the initiative of autonomous bodies.

In Great Britain, the position of the electric supply industry had gradually come to resemble that of coal mining, in that it consisted of a large number of independent and diverse units. After the first World War a start was made by the passing of somewhat complicated laws to introduce a certain amount of uniformity into the industry, culminating in 1926 in the creation of a self-governing body with the sole right of dealing with electricity supply in bulk.

The undertakings doing business in the countries already named, those in the newly created States in Eastern Europe apart from Russia, those in the Balkan Peninsula, in Central and South America, and in any other part of the world where electrical power plants are built, were known under a wide variety of names. They owned subsidiary companies and were themselves interrelated, often enough to such a degree as to render the connection between them obscure. If one took the trouble to unravel these relationships, as far as was possible on the basis of the published data, and to plot them diagrammatically, the result was a confused network, but one which evidently contained a number of nodal points. The most pronounced of these, in which nearly all the threads came together, was in Brussels, the capital of one of the small European countries which had so far played no part in the history of electrical development.

In 1898 the AEG and the Deutsche Bank had together founded the "Deutsche Überseeische Elektrizitätsgesellschaft" with a view to exploiting concessions in Buenos Aires. A little later Siemens & Halske also joined the undertaking through their Trust Company, with the result that the business spread fairly rapidly throughout South American. After the war it was impossible to obtain the capital required for further development from German sources, and it was therefore decided to convert the undertaking into a Spanish Company with foreign capital under the title "Compañia Hispano-Americana de Electricidad" (Chade). The foreign share-holders were in Spain, Switzerland and the U.S.A., but above all in Belgium.

There, also before the war, the AEG, by virtue of its fusion with the Union Elektrizitätsgesellschaft, had acquired an interest in the "Société financière de transport et d'entreprises industrielles" in Brussels (Sofina), and had more or less come to control the small undertaking, as it then was.

After the war the AEG was ousted from this position, as in the case of "Chade," and under the Chairmanship of the uncommonly energetic Dannie Heinemann, and with the backing of the powerful Banque de Bruxelles, the Sofina advanced step by step to the position of largest Holding Company for electrical undertakings in Europe or perhaps even in the world. Banks in Basle and Geneva were considerable shareholders, as also the "Bank für elektrische Unternehmungen" in Zurich, of which the AEG had likewise lost control, and the "Gesfürel," the last remaining German Trust Company of any standing. In 1923 the Sofina found itself faced with a competitor in the "Société internationale d'énergie hydro-électrique" (Sidro) in Brussels, which Heinemann's opponent, the financier Loewenstein, had regarded as the nucleus of a giant electricity concern. There followed years of bitter struggle behind the scenes, in which Loewenstein, having acquired a large block of shares of the Banque de Bruxelles on the Stock Exchange, endeavoured to get Heinemann unseated. Heinemann, however, succeeded in retaining the upper hand and Loewenstein died shortly afterwards. Sidro now became a subsidiary of Sofina in the same way as Chade and "Electrobel," which had been founded by the Belgian banks in 1929. Threads existed between the Heinemann group via the Belgian Baron Empain, who had founded three small Holding Companies in Belgium, and Schneider & Cie. in Le Creusot (although originally a child of the Steel Industry, Schneider had felt the urge to expand with the electrical business). Other threads led to the "Société française pour l'exploitation des procédés Thomson Houston," a creation of the General Electric Co. which had become the largest firm in the French Electrical Industry, and which through its numerous subsidiaries controlled about 60 % of the electrical equipment production and 50 % of the current supply of the country. It was particularly in the electricity supply companies originally founded by Thomson Houston, the largest of which was the "Société central pour l'industrie électrique" in Paris, that the influence of the Sofina was most felt. It was impossible, however, to discern the exact connection between the various members from without, the more so, as the whole system was in a continual state of flux.

Consequent on this state of affairs the German electrical industry and the House of Siemens, in particular, found themselves faced with almost insuperable difficulties in doing business with power supply companies abroad. If an attempt was made to unravel the skein in the case of a particular enquiry, the thread was nearly always found to end in a French, Belgian, Italian or Czech factory or with one of the European subsidiaries of the General Electric Co. of America. It was only when the others were confronted with technical problems, to the mastery of which they did not feel equal, as in the case of the turbo-set for the Schelde power station near Antwerp, that one had a chance of competing.

That technical achievement is still the most effective argument in soliciting orders was demonstrated most impressively about that time in connection with the planning of the electricity supply of Ireland.

Having gained its independence at the end of the war after a bitter struggle, the study of the country's natural resources was one of the first tasks of the new Irish Government. Inter alia it was desired to improve the flow of the Shannon, the largest river of the island, and it thus happened that Siemens-Schuckert, Berlin, one day received an enquiry for the supply of certain machines.

In handling numerous hydro-electric enquiries in recent times a section had been developed within the Central Station Department which did not merely confine itself to working out formal quotations, but made a close study of all the features connected with such a project. These included the geographical and climatic conditions of the country, the recorded rainfall, statistics of the flow of the rivers and geological data on the composition of the river beds. The section was also acquainted with any other schemes which might have been under discussion concerning the river in question. In reply to their enquiry the Irish Government received a quotation with full information, but in addition, fully elaborated proposals for a much more extensive scheme, together with the necessary maps, charts and calculations.

If full advantage were taken of all possibilities, it was stated, the Shannon would be fully able to cover the foreseeable power requirements of the whole of Ireland for some years to come. To this end it was suggested that the three large lakes, through which the Shannon flows in its upper reaches, be converted into storage basins, thereby at the same time reclaiming for agriculture the areas hitherto subject to annual flooding. From the point where it emerged from the last of the lakes to within the neighbourhood of the mouth it was proposed to carry the river in an artificial, levelled bed with little gradient. In a power station at the end of this sector the resulting head was calculated to produce about 150,000 kW (when fully developed); a lock would be provided for shipping. Plans were also worked out for the distribution of the power overland. In conclusion, it was pointed out that the whole of the work would be executed by the House of Siemens exclusively with its own personnel, from the preliminary survey to the completion of the last transformer station. The overall cost was estimated to be from 100 to 120 million Marks.

These proposals, which in their essentials were due to the initiative of

H. Wallern, Werner's deputy, made a strong impression in Dublin, where they occasioned no little surprise at the wealth of information at the disposal of Berlin concerning conditions in Ireland. Discussions in Dublin and Berlin crystallized in March 1924 into a preliminary contract, according to which Siemens-Schuckert should now undertake a thorough investigation of conditions on the spot and submit detailed proposals. These were presented in September 1924 and submitted by the Irish Government to a panel of four Engineering Consultants of international repute, two Swiss lecturers at the Technical University, one Swede and one Norwegian, for their opinion. These recommended the adoption of the plans with minor alterations. Thus, after the receipt of parliamentary approval, and the grant of the necessary funds by the Shannon Bill, Siemens-Schuckert were awarded a contract which, in point of scope and importance, but also as regards technical difficulties in execution, was reminiscent of the famous Indo-European contract.

As on that occasion, it was to commence with again a question of large-scale transport. Siemens Bauunion chartered three vessels of 2,000 gross tons each, which plied continually between the German harbours and Limerick, at the mouth of the Shannon. The first items they brought were three cranes, which were installed in Limerick Harbour to enable the heavy building tackle, scaffolding, etc., to be unloaded in the first place. The next to be unloaded were 15 chain and bucket dredges, 16 shovel excavators, several large depositing machines, 28 cranes, 3 cable cranes, 115 steam locomotives, 8 electric locomotives, nearly 2,000 trucks, approximately 100 km of rails and 36 lorries. A portable light railway was constructed, an auxiliary power plant comprising 9 Diesel-electric generators with a total output of 4,200 h.p., a workshop with over 50 machine tools, a brass foundry, a rope splicer, a belt shop, an acetylene plant, an oxygen plant, a sawmill, a carpenters' shop, a central store, an explosives store, living quarters for 4,300 Irish staff and manual workers, and corresponding quarters for 450 German engineers, foremen and skilled workers. As some of these had brought their wives and families, a school and teaching staff also had to be provided. It was not until all the foregoing equipment was on site that a start could be made with the shipment of the building materials, the piling, the steelwork and piping, and later on the turbines, generators, transformers, switchgear, transmission masts, insulators and the overhead transmission cables. After rather less than four years the complete plant was handed over to the Irish Government in working order. In the first development stage the power house contained three turbines with generators for 30,000 kVA each; space was provided for doubling the capacity of the station. The supply network for 110,000, 38,000 and 10,000 volts of a total length of 3,400 km, with numerous switching and transformer stations, three of these of considerable size, distributed the current throughout the length and breadth of the Free State. The undertaking proved to be a complete success, both from a technical and commercial point of view.

When after seven years of war, revolution and civil strife the former Russian Empire, bled white and starving, had at length found its way back to an orderly, if very much changed, pattern of life, the new masters of the State drew up a plan to mobilize the resources of the land within five years, and to apply these to the creation of a flourishing home industry. Since in Russia both planning and execution have to pass through a dovetailed system of ministries, commissions and courts, and their rate of progress is consequently exceedingly slow by Western standards, there was an inclination outside Russia, particularly in Germany, to look upon the five-year plan as a piece of propaganda bluff, not to be taken too seriously. This applied especially to the electrical part. However, the judgment was erroneous. Slowly at first, but gathering speed as time went on, the work of rebuilding existing power stations and raising new ones went on apace. Amongst the latter were some which as regards size and equipment would bear comparison with the most modern stations of the western world. The establishment of new industries proceeded hand in hand: the sinking of new shafts in the Don Basin, the development of naphta production on the Caspian Sea, the building of iron-producing plants, as also of those producing yellow and light metals; new shipyards were opened, new machine construction workshops and new factories for electrical machines and goods; the existing textile, paper-making and foodstuffs industries were considerably extended. Little wonder that countries were to be found soliciting orders from Russia which a short while ago were in the ranks of the interventionists. The only countries amongst the great industrial nations who were not involved in this respect were Germany and the United States, which was the reason, apart from their productive capacity, why they were able to skim the cream off the Russian business.

This business was very difficult to handle, and fundamentally different from what had hitherto been understood in free countries by "export." Formerly, the manufacturer sold through a representative to the user in the latter's country; here, the reverse applied. The Russian Government had a monopoly of the export trade and purchased through trade delegations, which it maintained in all the more important countries, directly from the producer. It consequently also had a trade delegation in Berlin with whom Siemens now had to negotiate, if they wished to sell to Russia. As opposite number to the Russian trade delegation, Siemens opened an office in Siemensstadt known as "Technisches Büro Ost," in which all the threads of the Russian business came together. The first concern of this office was to receive the constant stream of Russian visitors which came to Siemensstadt on the introduction of the Russian trade delegation to discuss business, to consult the Firm on technical matters and to see the Works. In the course of its activities, the Technisches Büro Ost dealt with about 80 different commissions, more than 1,000 engineers, about 200 professors and 300 doctors, in addition to Generals and diplomats. The Soviet Ambassador of the day was also wont to pay his respects in Siemensstadt.

The turnover achieved on these lines in the decade between 1923 and 1933 was quite considerable. Deliveries included several steam turbogenerators for 44,000 or 50,000 kW, a number of large three-phase motors for rolling mills, the complete driving equipment for a tube mill, electric steel furnaces, more than 1,000 variable speed three-phase commutator motors for 9 large textile mills, drives for paper-making machines, switchgear installations, broadcasting cable, telephone amplifiers, heat measuring and control instruments for steam power stations and enormous quantities of measuring instruments of all kinds to an aggregate value of approximately 30 million Marks, including literally masses of oscillographs and hundreds of X-ray units. In view of the aggregate value of all this equipment it is probably correct to say that Soviet Russia was the largest individual customer which the House of Siemens has ever had.

In the negotiations preceding each of the orders the Russians showed themselves to be fussy, suspicious and pedantic, requesting details which were never otherwise asked for, demanding the most farreaching guarantees, and more than once bringing the German negotiators to the verge of despair by their "wearing down" tactics. When the first few orders were placed, the Russians usually engaged the services of engineers and erectors for the assembly and placing in operation of the equipment. As time went on, this became more rare and the entry into Russia of our personnel was rendered increasingly difficult. However, when the goods had been delivered and erection (if any) completed in accordance with the contract, payment followed immediately and, as a rule, nothing further was heard; serious differences were a rare occurrence.

Amongst the numerous schemes forming part of the five-year plan was one which was outstanding on account of its size and boldness: this was the building of a dam across the Dnieper with a power station and chain of locks in the neighbourhood of Saporoshie, the scheme with which, during the constructional period, the world came to be familiar under the name Dnieprostroi. The idea of damming up the Dnieper, the third largest of the rivers in Europe, with a view to rendering the rapids in the upper reaches commercially navigable, had already occupied the ruling Russian despots of the eighteenth century. By the time the idea was revived by the Soviet Government, the scheme worked out by Prof. Alexandrow was the seventeenth since the year 1900. For reasons of prestige, the Government resolved not, as originally intended, to let the contract go to a foreign contractor, but to carry out the work under its own auspices. To be safe, however, it decided to approach the most competent experts abroad with a request for an opinion as to the best way of carrying out the Alexandrow plan in detail, above all, as to the best method of tackling the earth and masonry work. It was, of course, realized that before work commenced, provision would have to be made for housing the men and machinery, of which the latter were of greater importance, since the more difficult of replacement. Then there was the Russian winter to remember, which usually ended with enormous flooding by the river. There was no doubt that the task was one of great difficulty which called for extensive and most careful preparation on site before the first sod was turned. The Russians therefore turned to Col. Cooper, President of the American firm of building contractors of that name, which had made a reputation for itself as the builders of the Wilson Dam, and to the Siemens Bauunion, for their work in harnessing the Shannon. The Firms in question submitted a lengthy memorandum with numerous plans, in which the preparation and execution of the building work was described in detail. The Russians ordered a large number of copies of the memorandum, but in the Russian language, which were studied closely by the Russian engineers.

At the request of the Russians the two Consultants, whose views frequently differed, but who nevertheless worked together in the closest harmony, remained on site until completion of the work. It was due to their influence that the enormous collection of building machinery and tackle was purchased almost exclusively from Germany and America. On the other hand, the Germans could not prevent five of the nine turbo-generator sets being ordered from America. The three-phase alternators of these sets had an output of 77,500 kVA at 88.2 r.p.m.; the salient-pole rotators alone weighed 4.38 tons each. The Russians decided to build the remaining sets themselves, by copying the originals. The finished power plant, comprising at that time the largest dam and the largest generating station in the world, was ceremonially inaugurated on the 10th October, 1932, the anniversary of the revolution, the two Consultants being present as invited guests. They were in no doubt that they were witnessing the completion of a Work not only of major technical and commercial importance, but also of great political significance. But no one present could foresee the frightful happenings which centred round the mighty buildings barely ten years later.

XXVII

LONG-DISTANCE CABLE AND TELEGRAPHY

As compared with the pre-1914 scientific achievements of the power-current engineers, reflected in the continuous development of alternating current, the contribution of telecommunication engineering could hardly be said to possess a scientific background, and this notwithstanding the importance of the inventions connected with the names of Hughes and Baudot or of the Siemens high-speed telegraph. The same applies to telephony: neither the hand-operated multiple switchboards nor the automatic exchanges were based on scientific foundations. The originators of all these telegraph and telephone systems (not excluding Raps and his fire alarms) were essentially inventors of mechanical apparatus in combination with electrical switching devices, often of a complicated nature. With keen insight and inventive imagination they tinkered about (if the expression is permissible) with electro-mechanical gadgets, so that it was sometimes said in fun that the communications engineer was the offspring of an illegal union between physical science and a mechanic. The first to approach the phenomena on the telephone lines from the mathematical angle, instead of concentrating, as the inventors had hitherto done, on the apparatus, was Oliver Heaviside, but he proved to be years in advance of his time. In contrast to Raps, Franke had long since realized the importance of this matter. However, the first to demonstrate by his invention the real significance of these long-distance transmission problems was Pupin, who also showed how they could be successfully solved by mathematical means. In an earlier chapter an account had already been given of the importance of the development work carried out by Siemens & Halske under Ebeling's management in its bearing on the eventual success of Pupin's idea, and one is therefore justified in regarding Ebeling's "Cable Sales Department" and its later development, the "Central Laboratory," as one of the earliest seats of research into the science of long-distance communication. The other, at least as far as Germany was concerned, was the "Telegraph Department of the Reich Post Office" which later took the name of "Central Department of the Reich Post Office" and for many years collaborated closely with the Central Laboratory. Alongside these two research centres it was the Americans, in particular the Bell Telephone Laboratories of the American Telephone & Telegraph Co., who contributed in an outstanding degree to the scientific penetration of the subject. It will be scarcely an injustice to any other nation to claim that in the period between 1915 and 1930, leadership in fundamental research in this sphere lay with Germany and America.

One of the big strides which communication engineering took into the new territory is connected with two well-known electrical elements. From its earliest days electrical science had been aware of the opposing physical properties of the coil and the condenser. The inductance of the coil multiplied by the frequency (neglecting its ohmic resistance) is the measure of its impedance; the capacitance of the condenser multiplied by the frequency equals its conductivity. In other words, the higher the frequency of the current, the greater will be the resistance of the coil, but the less that of the condenser.

Power current engineers, who were the first to study alternating current phenomena, did not turn the above frequency law to account. No doubt this was due to the fact that they were in the habit of using one frequency only in their network. When, however, the communication engineers began to develop their art into a science, the frequency phenomenon began to acquire greater importance, since the communication networks, particularly the telephone networks, employed all manner of frequencies. The phenomena resulting from the combination of a number of coils and condensers were particularly interesting.

If, for instance, a number of coils are connected in series in one branch of a twin line, and connections made from the junctions between coils to the second branch, each with an interposed capacitor, this line will allow low-frequency current to pass, but not high-frequency current, since the chain of coils offers a resistance to the passage of current in the direction of flow, which increases with the frequency, whilst opening a convenient side-channel for the return of the current to its point of origin. If the coils and condensers are made to change places, the line becomes a good conductor for high frequencies, but the reverse for low.

The circumstances connected with these "recurrent networks" were clarified for the first time in 1915 by K.W. Wagner, an assistant at the "Telegraph Department of the Reich Post Office," in an exhaustive mathematical investigation, and since the time was evidently ripe for the assimilation of new ideas, G.A. Campbell applied in the same year for an American patent which was built up on the same foundation. Both publications provided the incentive to numerous other scientists, both in Germany and the U.S.A., to pursue further research in this direction. It was now found to be possible to calculate accurately the so-called frequency response, i.e., the variation of the conductivity of such a combination, in advance, and conversely, to design "filters," as they were called in Germany, with definite characteristics. It was thus possible to design combinations of coils and condensers which offered an almost free passage to alternating current of low frequency, whilst above a pre-arranged frequency the curve of the attenuation, the frequency response, rose steeply. In America such arrangements were called low-pass filters, whilst those which only become permeable above a certain frequency limit were termed high-pass filters. Finally, a combination was designed which allowed only a specific group of frequencies to pass, whilst below and above this group everything else was cut off.

It was after the first World War and the introduction of the amplifier into telephony that the conception of an all-European telephone network began to take shape (with Germany as the obvious core). The question arose simultaneously as to what should be done with regard to telegraphy in view of the fact that the cable network was in the first place provided for telephony. Although telegraphy seemed to have been overshadowed in its importance by the rapid growth of telephony, it nevertheless continued to be an important branch of the means of communication, which demanded to be taken into account under the proposed new scheme. To lay a separate telegraph network alongside the telephone system was out of the question. But was it not possible to use the telephone cables for telegraphy as well?

It would, of course, have been an easy matter to appropriate a few of the 98 pairs, which at that time represented the standard form of German long-distance telephone cable, for the purpose of telegraphy. However, if the attempt had been made to operate the telegraphs with d.c. impulses in the usual way, no matter whether on the Morse, Hughes, Baudot or Siemens high-speed systems, the transmission of speech by the same telephone cable would have been distorted beyond recognition by inductive action, since in those days the currents required for telegraphing were a multiple of the very weak telephone currents. Moreover, these d.c. impulses would have had to by-pass all Pupin coils, repeaters and amplifiers, through which they were incapable of passing. In a word, the problem would have to be solved in a different way.

The matter assumed a different aspect when it was decided to telegraph with alternating currents of about the same value and frequency as those used in telephony. No modification of the telegraph instruments was required. The d.c. signal produced, for instance, by a Morse instrument would be made to operate a relay, which sent the alternating current of a small dynamo or valve generator into the line, at the other end of which it was picked up by a corresponding receiver relay and re-converted into d.c. Whilst this idea was receiving active consideration in Germany after the war in connection with the planning of the new long-distance cable network, another suggestion came to be remembered which had been put forward by Mercadier in the 'eighties of the previous century, and which had been unsuccessfully tried between Paris and Lyons.

This inventor's idea was to produce alternating currents of varying frequencies by means of a tuning fork, to feed them into one and the same line, and to receive them by telephones at the end of the line which were designed to respond to one frequency only and were in consequence called Monotelephones. In this way, it was claimed, several telegrams could be transmitted over one line simultaneously. A similar idea is mooted in the description of Bell's famous telephone patent of 7.3.1876. Mercadier's experiments were unsuccessful, as it proved to be impossible to tune the monotelephones to one definite frequency. Later attempts of other inventors in the same direction also failed. The technical means of those days were not yet equal to the task. Now, however, having discovered the filter characteristics of the recurrent networks and the possibility of their mathematical calculation, it was possible to separate the currents at the end of the line according to frequency. At the same time it was now possible to follow up Mercadier's idea with some prospect of success.

In collaboration with the Telegraph Department of the Reich Post Office, which at that time had just been renamed the Central Department of the Reich Post Office, a system of "alternating current telegraphy" had been developed by the Central Laboratory of the Wernerwerk under the guidance of Lüschen and his able assistant Karl Küpfmüller. Under this system a valve transmitter produced six different frequencies between 400 and 1,590 cycles. As will be observed, these frequencies are all within the range of human speech, so that instead of a conversation, it was possible to transmit six different telegrams. At the receiving end, the frequency mixture was first of all amplified, then separated into its components, i.e., the six telegrams, by means of six parallel wave-filters, each component being finally converted in a valve rectifier into the d.c. impulses which operated the receiver relays of the individual telegraph instruments. A little later, a second system was developed in which twelve carrier frequencies were accommodated within a range of 300—1,700 cycles. The twelve carrier frequencies were generated in a machine with twelve pole-wheels; in other respects the arrangement was the same in both cases. With this equipment six or twelve telegraph channels were available on one line, and it was said that by using twelve Siemens high-speed telegraphs simultaneously, the editorial part of a fair-sized daily newspaper could be telegraphed any distance over one pair of lines in two or three minutes. Whilst this, of course, was obviously nothing more than a theoretical calculation, it pointed to the fact that alternating current had raised the speed of telegraphy to such an extent that all the artificial connections formerly used in duplex working, with which the engineers of the previous generation had wrestled, had lost their significance. Above all, the age-old distinction between telegraph and telephone cables had ceased to exist. There was now only one uniform pattern of long-distance communication cable, and which of its cores were used at any particular moment for telegraphing or telephoning was a matter of no consequence.

In reality, a.c. telegraphy was the same as what had been the practice in wireless telegraphy since the advent of undamped waves. The wave radiated from the transmitter was chopped and the resulting impulses picked up by the receiver after tuning to the wavelength of the transmitter. The means of tuning the receiver circuit thus corresponded to one of the wave-filters at the end of the line. As in this case, so also in that of the wireless receiver, the surrounding ether is filled with a mixture of frequencies, from which the desired communication is filtered out by tuning.

As already described in an earlier chapter, further progress in the development of wireless telegraphy was due to the discovery that in generating and sending out undamped waves it was possible, by speaking into a microphone in the aerial circuit (the original arrangement), to modulate them so as to transmit speech. By suitable "demodulation" they could be reproduced in the receiver. In the early stages of these experiments it was imagined that the amplitudes of the undamped oscillations, the equal peak values of their waves, were rendered unequal by the modulation. The connection of unequal peak values in a diagram produced a curve, the envelope, which represented the communication. It was a condition, of course, that the oscillation frequency of the original undamped waves (the carrier) must be higher than that of the communication, since it is essential to have numerous peak values of varying height if the curve of the envelope is to be accurately traced. This is particularly the case when dealing with the complicated nature of speech sounds.

The foregoing conception was right as far as it went, but it was incomplete. One element was missing which later on proved to be of essential importance in multiple-circuit operation of the individual cores.

This element was only found as the result of a close mathematical analysis of the problem.

In giving a brief description of the process, let it be remembered that it was generally agreed that frequencies between 300 and 2,400 cycles were suitable for good speech transmission over long distances. A range of frequencies of this kind is called a frequency band with a width of 2,400—300 = 2,100 cycles. What happens if this band is used to modulate a carrier frequency of, say, 6,000 cycles, by connecting the microphone in an aerial circuit which radiates undamped waves of 6,000 cycles? In considering this arrangement, however, it is not necessary to confine oneself to wireless operation; the principle applies equally if an undamped oscillation of the stated frequency produced by a tube oscillator is transmitted through a telegraph line, and modulated by speaking into a suitably connected microphone. The surprising result of a mathematical evaluation is that in modulating a carrier frequency by a frequency band, this band disappears, its place being taken by two new bands of equal width, one on either side of the carrier frequency. The upper band contains the original frequencies in the correct order, whilst in the lower band the order of the frequencies is reversed. The two new bands are termed "side bands." If, for the moment, only the upper band, having the frequencies in the correct order, is contemplated, the process can also be described by saying: in modulating a certain frequency, the modulating frequency band is displaced to another part of the scale. That was the cardinal fact, and its discovery had economic consequences which were little short of revolutionary. This displacement by modulation of the band of speech frequencies from its natural location of 300—2,400 cycles to the position of 6,300—8,400 cycles means that one and the same line can carry two speech bands, one in the natural position and the other in the displaced position. At the end of the line the two bands can be clearly separated by wave filters and taken to two different receivers; in doing so, the displaced band is returned by demodulation to its natural position. In this way it is possible to carry on two conversations simultaneously on one line without mutual interference. It is a condition, however, that the line will allow the displaced band of high frequency to pass without excessive damping. It has already been noted that damping increases with the periodicity; in general, the "frequency response," i.e., the relationship between damping and frequency, is a rising curve. In the case of overhead lines the rise is moderate, and the curve almost a straight line. It was on this account that the new method was first tried out on overhead lines. As to where the idea originated, it is significant that it was taken up in Germany by the firms which specialized in wireless telegraphy, i.e., Telefunken and C. Lorenz A.G., the latter, a Berlin firm, having in 1880 commenced to manufacture telephone and telegraph instruments on a small scale. During the war it had turned its attention to wireless telegraphy.

To the Post Office, carrier-frequency telephony did not at first appear to have any great future. In accordance with what they considered to be their duty, however, they purchased a quantity of equipment from both firms in order to try it out on their lines. At the same time the Post Office let it be known that the intention was gradually to incorporate the still existing long overhead lines into the cable network which was in course of development. This was planned on a scale, moreover, which would ensure its capacity to meet all requirements likely to be felt in the foreseeable future. In the estimation of the Siemens & Halske Central Laboratory the position in the so-called undeveloped countries looked very different. With the exception of Central and Western Europe and the United States, this appellation covered actually the whole of the world. In these regions telephone and telegraph facilities were as a rule few and far between, and there could be no question in the near future of laying underground cables. For a long time to come important long-distance communications would have to operate as overhead lines. Siemens & Halske also took up the manufacture of this equipment, therefore, and sold them to Eastern Europe, South America and India, doing their best to perfect them as time went on in the light of working experience.

The foregoing discussion of telephony has been based on the assumption that we are dealing with land connections. Where the sea has to be crossed, the conditions are very different.

Up to the turn of the century submarine cable had been employed exclusively for telegraphy. The use of such a cable for telephoning was out of the question. The embedding of a pair of cores in the guttapercha covering resulted in such a high capacitance of the cable and consequent attenuation that the cable would have been practically impervious beyond a length of twelve kilometres. The only way to overcome the difficulty would have been to use abnormally heavy cores, as in the case of the world's first submarine telephone cable laid in 1897 across the English Channel, over which reception was only just possible. It may be remembered that Heaviside had stated, long before Pupin, that the ill effects of capacity in a cable could be overcome by distributing inductance, equally spaced throughout the length of the cable; as the simplest method he had, indeed, already suggested encasing the copper conductor in a wrapping of magnetic material. When early in the new century a cable was to be laid between Helsingfors and Helsingborg to join up the Danish and

Swedish telephone networks, Karl Emil Krarup, at that time Telegraph Engineer to the Danish Government, suggested coiling a thin iron wire round the cable. The cable was made accordingly by Felten & Guilleaume, who at the instigation of the German Government had already been experimenting on these lines, and proved to be a complete success. One year later a German-Danish cable of the same kind was laid between Fehmarn and Laaland by Felten & Guilleaume with the same success, to be followed by a whole series of cables across the numerous straits in the coasts of Northern and North-Western Europe, as also two through the English Channel.

As compared with the almost contemporary Pupin cable, the Krarup system had the disadvantage of requiring more material in order to achieve the same result: each core had to be spun individually with the iron wire, the cost of which was considerably greater than the provision of a Pupin coil every two kilometres, and the cable was heavier and of larger diameter. The consequence was that the Krarup cable was unable to hold its own on land; as a submarine cable, however, it was not to be beaten, as no coil boxes were required.

Ebeling's pride could not suffer the rebuff inherent in the fact that the Pupin system, so carefully fostered, and, indeed, developed by him, should have been surpassed at the outset in one of its applications by a rival. He designed a long flexible sleeve, into which he introduced the Pupin coils one after the other, and which could be spliced integrally into the cable. The sleeve had long, tapered ends, to that the cable was somewhat thicker at the places containing the coils. In order to reduce the capacity, Ebeling discontinued the use of guttaperdha, which was in common use for marine cables, in favour of the loose paper insulation employed in land cables. This, of course, had to be protected by a lead sheath, which had not hitherto been used for submarine cables for fear of the increased difficulties in laying. In attempting to lay lead-sheathed cable with loose paper insulation in any appreciable depth of water the sheathing would have been crushed in by the weight of the water wherever there was a hollow space inside. It was therefore essential to introduce an arch-like internal support for the sheathing, which represented a structure at once complicated and untried. Little wonder that the Post Office turned a deaf ear to Siemens & Halske's suggestions, all the more, as it had meanwhile decided in favour of the Krarup cable.

Siemens & Halske therefore approached the Württemberg Postal Authorities, who at that time were independent, with a request to be allowed to lay a Pupin cable from Friedrichshafen across Lake Constance to Romanshorn. In this region the Lake has a maximum depth of 250 metres, i.e., greater than any waters thus far crossed by Krarup. The contract was duly placed, but the cable-laying in the Autumn of 1905 was a failure, due to the fact that the diameter of the paying-out cable drum was too small, having regard to the stiffness of the coil-sleeves. When the attempt was repeated in the following year everything went smoothly, and the twelve kilometres of water were crossed in two hours; the cable was in service for forty years.

Notwithstanding this success, the Reich Post Office refused for a long time to have anything to do with submarine Pupin cable, fearing the difficulties of carrying out repairs in the event of damage. It was not until 1926 that Siemens & Halske were commissioned to lay a telephone cable between Germany and Denmark, which was also to carry international traffic. The cable was to be laid between Warnemünde and Gjedser, a distance of 46 kilometres, and to comprise 48 cores in four-wire operation giving twelve speaking circuits. A year later Felten & Guilleaume received an order for a Pupin cable of 116 kilometres length between Stralsund and Malmö to link up Sweden and Germany. This cable also had 48 cores and 12 speaking circuits. It was already the third cable between these terminals; the two previously laid were Krarup cables with two and six pairs of cores. All three were the common property of the two States concerned. With the new Pupin cable it was thought that the requirements of the foreseeable future had been covered.

This belief turned out to be erroneous, for only three years later there were renewed difficulties on the Malmö-Stralsund line. The expansion of trade in those years had been exceptional. The laying of a fourth cable, however, would have exposed the two Authorities concerned to considerable public criticism.

At the suggestion of their Assistant, Dr. H.F. Mayer of the Central Laboratory, Siemens & Halske, although they had had nothing to do with this cable, approached the Post Office with the suggestion to operate the cable on the carrier-frequency system developed by them for overhead lines and, by opening a second channel for each speaking circuit, to double their number. It has, of course, already been stated that when the carrier-frequency system was developed, it was thought to be applicable to overhead lines only, owing to the fact that in cables damping increases so rapidly at higher frequencies that it is no longer possible to accommodate a second speech band in the comparatively narrow pass range. This applies much more to Pupin cable than to those of the usual kind, since the insertion of the Pupin coils greatly reduces damping within the range of ordinary speech frequencies (which is their object, of course) but causes it to rise steeply beyond a certain frequency, viz., the cut-off frequency. If the coils are given a lower inductance (lighter loading), the cut-off frequency is deferred, but the damping within the permeability range is also increased.

With the perfection of the amplifier it was permissible to allow increased damping in the speech band, since the volume could be restored by the amplifier. The lighter loading was also accompanied by a number of advantages which were particularly evident when telephoning over very great distances. The above-mentioned German-Swedish cable was designed in accordance with these principles. Its cut-off frequency of 5,400 cycles was appreciably higher than that of the earlier Pupin marine cables. This just permitted the accommodation of a second speech band above the normal, the second being the lower side band of a modulated carrier frequency of 5,500 cycles. It was found possible to give effect to the Siemens & Halske proposals with only a small outlay for additional apparatus at the cable terminals, and thus to double the number of speaking circuits whilst saving the millions of Marks required for the laying of a new cable.

The success of the so-called Sweden cable had far-reaching effects. In the first place, both Siemens & Halske and Felten & Guilleaume had found the collaboration in improving the Sweden cable as profitable as it was pleasant, and this led to a series of talks on the subject of submarine telephone cables, with the result that it was decided in 1930 that Siemens & Halske should acquire a 50% share in the Felten & Guilleaume subsidiary, the "Norddeutsche Seekabelwerke," Nordenham. In this way, and for the first time since the loss of Siemens Brothers, S&H were able again to lay submarine cables with their own cable ship, the "Norderney."

Still more important, however, was the effect of the Sweden cable on the shaping of the whole European communication cable system. Mention has already been made of the circumstances leading to the gradual reduction in the inductance of Pupin coils. Alongside the oldest type with "heavy" loading, it became customary to distinguish between "medium heavy," "light" and "very light" loading. The last incentive to reduce the pupinization was the observation that the speed of transmission of the waves along the line was reduced by inductance, and that a transmission period of speech of half a second between microphone and receiving instrument was sufficient to interfere with the free exchange of conversation. In cases where the speakers are several thousand kilometres apart, however, heavy pupinization will result in such periods. The greater the distances over which it was desired to speak, therefore, the further one had to depart from the original Pupin idea; the higher, also, was the cut-off frequency of the line (a further advantage) but the closer the spacing of the amplifiers (a serious economic disadvantage). For these reasons light loading was not resorted to except in cases of real necessity and for very important international lines of great length.

In this predicament the advent of carrier-frequency telephony was a welcome aid to the more efficient use of the costly cables. "Light" loading permitted the introduction of a second speech band to each pair of cores, and "very light" loading of three further bands, so that in the first case the "output" of the cable was doubled, and in the second case quadrupled. Eventually, the Pupin coils were discarded altogether, Great Britain being the first to take this step in 1935, and it was found possible to transmit twelve conversations simultaneously per pair of "unloaded" cores—at the cost, of course, of a corresponding number of amplifiers.

About the time that these developments were taking place, telephone engineers in Germany and the U.S.A. had taken the logical decision to construct a cable with exceedingly low natural damping as compared with those hitherto in use. The damping depends, in the first place, on the ohmic resistance and the capacitance, and in the second on the leakance (leakage losses) of the cable. Endeavours therefore had to be directed to the production of a cable with very low ohmic resistance, i.e., with a large cross-section of the cores, and with very low capacitance, i.e., wide spacing of the conductors in conjunction with low dielectric losses of the separating medium, and excellent insulation. The result was a concentric cable with, in the German version, a 5-mm central core surrounded by a tubular sheath of 18 mm inside diameter, and held in position by discs or spirally-wound strips of Styroflex, one of the more recent large-molecular synthetic products of the Chemical Industry. The whole cable comprised only this one concentric pair, and its damping was so low that it was possible to transmit no fewer than two hundred speech bands within the range of 30,000 to 690,000 cycles. Above this range and up to a limit of 3 million cycles, it was possible to transmit the high-frequency impulses required for television, which it was now intended should also be introduced into Germany, using cable transmission in the first place. The broad-band cable thus represented the crowning achievement in the development of long-distance telephony.

Whilst the long-distance cable had been designed to meet the requirements of telephony, it had, as we have seen, also included those of telegraphy as soon as the latter had learnt how to transmit its signals by means of alternating current with a frequency of audible sound. This brings us back to the development of telegraphy, from which we had digressed after describing the Siemens high-speed telegraph.

In demonstrating his original design in November 1903, Wilhelm von Siemens had also mentioned the names of other inventors who were engaged in the study of the high-speed telegraph. The chief of these were Murray and Creed.

Donald Murray, a native of New Zealand, had commenced by designing a type-setting machine, from which he evolved a telegraph on the principle of the five-unit alphabet in which transmitting was effected by punching a strip of paper by a kind of typewriter. In passing through the transmitter the perforated strip was scanned by feelers, with the result that corresponding combinations of current impulses were sent along the wire. The receiver, in turn, produced a perforated strip which was identical with that of the transmitter. Independently of the time of transmission the perforated strip at the receiving end could be run through another machine in which it was de-coded (translated). It was this machine which embodied Murray's original invention. Instead of a type-setting machine, it was a typewriter which translated the combination of perforations in the strip into the corresponding letter of the alphabet and typed it on a sheet of paper in the usual manner.

About the same time as the Murray Telegraph took shape, Frederic George Creed, a native of Canada, developed a decoding machine which differed from the one invented by Murray in that each letter was printed by a revolving type wheel in the same way as with the other telegraph printers. As both inventors had worked along much the same lines and with more or less the same end in view, they decided to pool their patents, and created together the Murray-Creed Telegraph, which, however, did not advance beyond the trial stage, for Murray was a restless spirit and was soon pursuing other ideas. He therefore parted company with Creed, who thereupon founded the firm of Creed & Co. Ltd., Engineers, in Croydon near London, in order to exploit his inventions on his own. About 1911 Murray entered into association with the Western Union Telegraph Co. in New York, the largest American Land and Sea Telegraph Company. They were interested in his patents and other schemes and put means at his disposal to enable him to develop a high-speed telegraph, which appeared in 1914 under the name of the "Western Union Multiplex" and was manufactured by the Morkrum-Kleinschmidt Corporation in Chicago.

This machine incorporated all the features of the previous models. The message was first punched onto a strip by means of a perforator working on the typewriter principle and then scanned by the feelers of the transmitter, which sent combinations of current impulses on the principle of the five-unit alphabet over the wire. These were immediately decoded on receipt in a translating machine of the Creed design and printed by means of a type wheel on the usual telegram strip or, in a different model, onto a sheet of typewriter paper. In addition, this machine was fitted with a distributor disc, so that up to six machines could transmit along the same line. As the war broke out shortly after the appearance of this machine, and prevented the introduction of the Siemens high-speed telegraph in all but a few foreign countries, it was relatively easy for the Western Union Multiplex to be brought onto the market as "the" high-speed telegraph. However, the days of the high-speed telegraph were numbered anyway. Wilhelm von Siemens had foreseen developments correctly when he said, in the lecture mentioned earlier, "As a matter of fact, the telegraph administration is not so much lacking in telegraph machines as in telegrams." Unfortunately he did now draw the proper conclusions from this diagnosis of the situation, but obstinately stuck to his plan to create a show piece, which experienced a short period of favour under the emergency conditions created by the war, to be in demand shortly afterwards in only a few countries abroad. Whereas the two big forerunners, the Hughes and Baudot telegraphs, both hailed in a new era on their appearance, and thus managed to maintain their position for almost half a century, the Siemens high-speed telegraph and its rival, the Western Union Multiplex, were brought out too late and soon lost their importance, as a new age had broken in and conditions had changed.

A few figures will show the reason for the change in the situation. In the period from 1900 to 1925, the number of telegrams handled by the Reich Post Office rose from 46 millions to 50.3 millions, i.e., by about 10%. The number of telephone calls—not including local calls—rose in the same period from 18.5 millions to 243.6 millions, or to more than 13 times their original number. All this in spite of the fact that by and large, calls were twice as dear as telegrams. But there was nothing to be done about it, the position of the telegraph was hopeless.

As the telegraph and telephone services were both administered by the State in practically all of the European countries, the new developments were accepted there as being in the nature of things. The telephone covered the losses on the telegraph several times over and the money from both of these sources flowed into the same coffer anyway. Nobody racked their brains to think of a way of making the telegraph more popular and convenient for the public. Telegrams were handed in at the desks of the Post Offices as before, and only gradually did it become customary to send and receive telegrams over the telephone, which merely served to encourage people to use the telephone for all forms of communication. Whereas the Post Office had allowed anybody interested to compete in the telephone business, they jealously guarded the telegraph service and administered it themselves, on the grounds that it could only be attended by specially trained staff anyway.

Things had developed rather differently in the United States. After the signing in 1879 of an agreement between the Western Union, which handled about 85 % of the telegraph traffic in the United States, and the Bell Company, by the terms of which the one was entitled to consider the telegraph business its sole domain whilst the other had similar rights in the telephone field, a solution of the problem with which other firms interested in the telegraph business mutely or expressly concurred, the struggle between telephone and telegraph became a matter of life and death for the companies involved. In view of the vast distances to be covered and the speculative nature of many business transactions, the telegraph had admittedly from the very beginning played a different role in business life in America than in Europe, for from the pionier time onwards it was taken for granted by Americans that all agreements were laid down in writing, but here too the telegraph was nevertheless hard pressed by the competition of the telephone. The telegraph companies soon found themselves obliged to devote more and more attention to advertising and customer service. It soon became a matter of course for every station and every good hotel to have a telegraph, in the operation of which members of the staff were specially instructed. It was but one step further to connect up all the newspapers, stock exchanges, brokers, shipping companies, insurance companies, shipping agents, trading companies of all kinds, as also the large industrial concerns to the telegraph network.

It would of course be wrong to speak of connecting them to the network in the same sense as the telephone. One telephone subscriber can call any other subscriber he desires, but a Morse telegraph cannot communicate with a Hughes telegraph. Moreover, the operation of the telegraph office presents much greater difficulties, as the customers' wishes, so easily expressed and acknowledged over the telephone, must here be passed on to the telegraph office in writing by a much more complicated process. It became usual, therefore, to equip certain frequently used connections with the same kind of machine and to elaborate a simplified system of exchange operation, or in other cases to set up permanent connections wherever this was justifiable by the circumstances, as in the case of connections between the central offices of the large shipping agencies and their warehouses. This practice had become quite common in the years immediately prior to the outbreak of the war and provided the incentive for the Morkrum-Kleinschmidt Corporation in Chicago to develop from the component parts of the Western Union Multiplex manufactured by them a simplified telegraph machine, which could be installed in the office of anybody interested in subscriber telegram traffic.

Shortly after the outbreak of the war, Ehrhardt, the constructor of the Siemens & Halske high-speed telegraph, also applied himself to the task of simplifying the telegraph and lowering the cost of production by retaining the basic elements whilst reducing the telegraph speed, so that it could also be used on lines with a lower traffic density.

It was clear from the beginning, both in Chicago and Berlin, that if the system were to be simplified at all, the first step would be to abandon the preparation of the message on a perforated tape. The message would have to be transmitted straight into the line by the keyboard. Furthermore it would be necessary to break with the system of telegraph synchronization in use at the time.

Readers will no doubt remember the peculiarity of this synchronization. At the precise moment in which the combination of signals required for the printing of a certain letter was transmitted, the corresponding letter on the type wheel had to be already situated in front of the typing mechanism, in other words, the transmitting mechanism always had to "know" the position of the type wheel of the receiver, which was only possible if this position corresponded exactly with that of its own type wheel. This was still the case in later models in which the type wheel had been dispensed with, the letters being printed by typewriter arms in the manner originated by Murray; somewhere in the machine was a revolving shaft which fulfilled a similar function. Maintaining the machines in perfect synchronization had so far provided the worst headaches for the constructors. Reliable speed regulators and special pulses for the mutual control of receiver and transmitter complicated the mechanism immensely. Above all, the two stations corresponding first had to be "played in" at every fresh operation, which called for experienced personnel. Such machines could obviously not be attended by laymen.

It is difficult to-day to establish who was the first to hit upon the solution to the problem. Although it was long maintained in the Firm that the credit was due to Ehrhardt, evidence would now seem to indicate that the Americans were quicker. It probably happened as often before: the solution was "in the air" and was found in several places more or less simultaneously.

About the time of the outbreak of the war, the Morkrum-Kleinschmidt Corporation brought out a new telegraph under the name of "Teletype." In this machine the synchronization problem was solved by allowing the revolving parts to depart from the same fixed starting position for each fresh letter and to return again to rest after one complete revolution. This had the advantage that the synchronization was always perfect at the commencement of each movement and that any slight difference in the speed of rotation of the transmitter and receiver, which were adjusted to approximately the same speed of rotation by simple regulators, could not have an adverse effect on the operation of the receiver in the course of one revolution—the difficulties only occur when the shafts are continuously revolving, thus causing these small discrepancies to add up. The machine started afresh for each separate letter, completed one full revolution, and then stopped. The receiver was switched on and off by special pulses from the transmitter, so that all in all, with the five pulses needed for the alphabet, seven pulses were required. The Americans referred to this method of operation as "Start-stop." The Reich Post Office later introduced the term "Springschreiber" for machines operating on this principle.

Described in this manner, the matter seems simple enough. However, much laborious testing and modification was needed before the first prototype of the teletype, the receiver of which still incorporated a decoding device on the Baudot principle and a type wheel, could be made available for the American business world.

Their rivals, engaged in Berlin on the same problem, were held up to some extent by the war events. In 1916, they produced the pendulum telegraph, but this could not be tested until the war was over. It operated in the same manner as the start-stop machine and acquired its name from the provision of a strong spiral spring in the main shaft of the transmitter and receiver which, swinging freely, absorbed the harsh shocks arising from the jerky operation of the machine. It proved to be a failure; in 1921, after a trial period of several years, the Reich Post Office refused to have anything to do with it and a great deal of trouble followed with the Swedish Telegraph Administration, which had bought a number of the machines as soon as they appeared. Ehrhardt then set to work on a new design which was intended to improve on its unsuccessful predecessor and was submitted to the Reich Post Office for trial in the middle of the 'twenties. It was called the "Keyboard High-Speed Telegraph," whereby the latter part of the designation was intended to indicate that several of the important components, especially the decoding device, had been taken over from the first machine of this name, as was also the case with the previous unsuccessful model. The Post Office had in the meantime acquired other systems for trial purposes, amongst them a start-stop telegraph made by Creed and the new, improved Morkrum-Kleinschmidt Teletype, in which the type wheel had meanwhile been replaced by a type basket of the kind used in typewriters. The machine now looked like a rather bulky typewriter. These foreign machines, especially the Morkrum-Kleinschmidt model, appealed to the Reich Post Office more than did the Siemens & Halske telegraph. In a lengthy letter they attributed this to the fact that in the other models, the decoding of the position of the five reception relays in the printing stroke took place by mechanical means, whereas the Siemens & Halske model, as successor to the high-speed telegraph, still kept to the electrical decoding principle used in this system. The Post Office took the view that faults were less liable to occur in a mechanical decoder than in an electrical one. That this criticism also included the sentence: "The workmanship displayed therein is above all praise....." showed clearly that it was not the workshop with which they were dissatisfied, but the Development and Design Departments.

Considering the friendly and fruitful cooperation that had existed for many years between the Reich Post Office and Siemens & Halske and the fact that both partners had contributed to the development of the automatic telephone system and the long-distance cable network in an exemplary spirit almost amounting to partnership, there was every reason for disquietude among the Directors of the Firm concerning the trend of matters in the telegraph field. But with Siemens & Halske the development of telegraphy had never proceeded in a fashion such as would have been expected by tradition of a firm of telegraph engineers, and all the praise of the high-speed telegraph, frequently emphasized though it was, could not create the illusion of well-founded and solid achievement. The root of the evil, as Francke now had to admit to himself, lay in the fact that the Development and Sales Departments had not even had the remotest contact with one another for over a generation. In every other field the Firm maintained a Sales Department which was also responsible for the development of the products in which it dealt, notwithstanding the fact that other laboratories and departments outside their own might also be engaged in the development, whereas the so-called Telegraph Department had no influence whatsoever on the design of the telegraphs and merely sold off the auxiliary equipment of the telegraph industry. It was impossible to lay all the blame on Georg Schmidt, who had been Head of the department for many years and had just died in harness, as it was no fault of his if the Head of the House felt the irresistible urge to invent telegraph machines in his private laboratory, together with a handful of assistants. From this time onwards the situation had got completely out of hand—inventors and designers were no longer in touch with reality. Statistics presented by Francke showed that the Central Laboratory had run through a quarter of a million Marks in the last three years for the development of telegraph equipment alone—the results of which were drastically illustrated by the letter from the Central Office of the Reich Post Office. Things just could not continue in this fashion.

Paul Storch, the new Head of the department, commenced his reign by instigating the development of a mechanical telegraph alongside the electrical one already under construction and pressed the matter forward with great urgency. He would hear nothing of objections that practically all ways were barred by patents held by Creed or Morkrum and ordered his assistants to start by finding the best solution to the problem, regardless of the patents. He was of the opinion that it would somehow be possible to reach an agreement with the C. Lorenz A.G., the German licencees of the Morkrum patents, who had just introduced the teletype into Germany, as some of the patents in question were not so impregnable as they might at first have seemed. If the worst came to the worst, they might have to pay licence fees. In view of the fact that Siemens & Halske, having completed the task in hand, were in a position to submit two models, the one electrical and the other mechanical, both protected by all manner of rights, Lorenz concurred to an agreement regarding patents and quotas. From the first moment, the new mechanical teleprinter won over the experts, even those of the Reich Post Office, by virtue of its pleasing lines and appearance—and as usual, the workmanship was "beyond all praise."

The new spirit in the Telegraph Department, which had meanwhile infected many of the younger members, spurred the designers on to exploit their success without delay. Not only was it their intention to sell telegraphs to the Reich Post Office, they were also determined to give them the benefit of their own conception of modern telegraphy. The teleprinter, they maintained, just like the telephone, should have its place not only in the Post Office but also in every private office. Completely automatic exchanges on the lines of those used for the telephone, to which anyone interested could be connected, would have to be designed for the teleprinter. It would then be possible to look up the number of the desired party in the subscriber list and dial it by means of a number plate on the machine. The called party would answer automatically by name—even if the machine was unattended at the time—and a letter sent which could be read straight off the sheet. And in order to show that such a system was possible, and to demonstrate the fact without more ado, a trial plant, using lines rented from the Post Office, was installed in the manner described between Siemensstadt and several of the external offices and functioned well, rapidly becoming popular in the House. The new system was demonstrated to business friends, a few large concerns also installed a private network on the same lines and much use was made of the daily Press to publicize the achievement.

The Post Office Authorities now became somewhat disquieted, especially as the ensuing agitation did not stop short of criticizing sharply the clumsy procedure then in use for the acceptance and despatch of telegrams. They felt sure that these young people, in their blind enthusiasm, had completely overlooked the consequences which would arise for the Post Office from the general introduction of the new means of communication, involving as it would an enormous capital expenditure for the authorities and devaluating a portion of the capital already invested in the telephone services. Lively arguments ensued between the Reich Post Office and Siemens & Halske, as a result of which the Ministerial Director involved finally forbade Siemens & Halske to give any further publicity to the idea of a teleprinter subscriber scheme.

Shortly afterwards, with the advent of National Socialism, other people succeeded to the leading positions in the Reich Post Office who in financial matters were rather more generous than their predecessors had been. Siemens & Halske found a hearing for their proposal to be allowed to install and operate, at their own expense, teleprinter exchanges in Berlin and Hamburg which would enable direct communication to take place between the two cities. After sufficient subscribers had been won over and the system had proved to be reliable, the two exchanges were taken over by the Postal Authorities. This network was soon extended and the neighbouring countries—particularly Holland—were encouraged to install similar systems, in order to build up an international teleprinter network. Above all the various State departments in the new Germany installed their own networks for internal traffic. The Army, engaged in a process of rapid expansion, installed a teleprinter network which connected all important centres of operations with their central command, and placed orders for large quantities of mobile equipment. The Air Force, for which no luxury was too extravagant, followed suit on a much grander scale, and the Navy did not lag behind either. The SA and the SS, the Workers Front, the railways and, among other responsible authorities, the Reich Ministry for Public Enlightenment and Propaganda, whose numerous branch offices throughout the country served to keep check on public opinion and to steer it in the required direction, were soon equipped with the new communication systems, the latter customer making by far the most use of the service. One of the largest of these networks belonged to the Police. It will suffice to mention that the police stations of one single German city were equipped with a total of nearly one hundred teleprinters. In this way the Totalitarian State spread its tentacles out over the entire country like some fabulous millipede, equipped as it was with a communications system that only a few years earlier would have been decried as the product of wildest phantasy. The teleprinter was particularly suitable as far as one special characteristic of National Socialism was concerned: all orders had to be promptly carried out but at the same time laid down in writing, even the most secret matters, on dictation from the highest command. It was now possible to connect up all these networks in such a way that all machines connected would simultaneously receive the text dictated by a central command. The ideal type of "yes-man" was furthered by the teleprinter in a way hitherto undreamt of. Over the telephone it was still possible to register doubt or protest, but not on the teleprinter. The message closed with the words: "Report compliance."

How were the assistants engaged on the design and development of the modern telegraph to know that their perseverance and ingenuity would one day be instrumental in suppressing human freedom?

XXVIII

PRECISION MECHANICS

The constant endeavour to decrease the size, weight and production costs of a new technical creation in relation to the effect achieved, a tendency readily noticeable in all technical development, was also evident in the large variety of measuring instruments produced by the "Wernerwerk für Messtechnik". It was the peculiar ambition of Georg Keinath, the inventive Head of the development laboratory of this, the world's largest manufacturer of measuring instruments, to surprise the public occasionally with startling new products. Keinath was one of those intuitively creative artists who frequently appear in the annals of the House. It was due to his initiative that measuring instruments, whether portable or switchboard-mounted, finally received a natural and suitable form, both with regard to the material used and to their application. When these new forms appeared, it was difficult to understand why the old ones had remained for so long.

Incorporated in the "Wernerwerk für Messtechnik" was a certain production department which had been in existance for over seventy years and had already been regarded as an outsider in the days of the Telegraph Works. This opinion was shared by all who were accustomed to think in rational terms, the more so since the House expanded to cover all branches of electrotechnical production. This department, the Water Meter Dept., had started off with a limited circle of customers, namely the various water works, which installed the water meters for their consumers in order to measure the amount of water consumed. As the consumers during the first few decades were only private households and a few small firms, it was sufficient to produce meters for pipes of small diameter. All of them were built on the vane water meter principle—a cup-shaped vessel, in which a light screw propellor revolved on a vertical shaft, was enclosed in a valve-shaped housing. The stream of water entered the vessel through tangentially-arranged openings, so that its eddying movement caused the screw propellor to revolve. The revolutions of the propellor were transmitted to a metering device. As the consumer firms increased in size and the water consumption steadily rose, it became necessary, in view of the large pipe diameters now coming into use, to resort to a method demonstrated by Woltmann many years earlier, in which a kind of propellor was introduced axially into the water pipe and driven by the flow of the water. This meter showed a lower pressure loss in comparison with other types.

When it came to dealing with very large quantities of water, such as in hydraulic power stations, where it was essential to check the water consumption of the turbines, the methods used up to that time were useless. In such cases, an observation made by Venturi in Bologna towards the end of the 18th century served to provide a solution. If a pipe carrying a liquid is narrowed down and then regains its normal diameter, so that the whole appears to assume the form of two blunt hollow cones placed end to end, the difference in the pressures occurring on both sides of the neck is governed by the rate of flow and can therefore be used for metering. To this end, the pipe is pierced on both sides of the neck and the pressures are led along narrow pipes to a manometer, which can be appropriately gauged to indicate the flow. This method can not only be used for liquids but also for gases, including steam and air. The longstanding problem of steam metering, which had come to the foreground with the advent of steam turbines and modern steam engineering, was thus solved in a simple and elegant manner.

It finally became necessary in all large boiler plants to determine the amount of water fed to the boiler as accurately as possible. This was the simplest way to determine the capacity of the boiler and its steam-raising coefficient, i.e., the amount of steam produced per unit of the fuel consumption. The pre-heated feed water was hot, however, and was therefore liable to damage the light vanes of the meters in use at that time. Siemens & Halske thereupon developed a design in which the water flowed through a measuring chamber rather like a hollow sphere with the top and bottom pressed in. Inside it was divided into two halves by a movable disc. Under the pressure of the water streaming into the chamber, the disc performed a peculiar tumbling movement, by which, in the course of a full revolution, a certain amount of water was led through the chamber from the intake to the outlet and metered by the disc. These "Disc Meters" were rapidly accepted—by 1925, over 12,000 boilers were equipped with them. Soon they were used for other purposes, particularly for metering liquid fuel, and thanks to their reliability they soon enjoyed great popularity in this field too.

In this way the range of the Water Meter Department had greatly increased in comparison with the pre-war days, both with regard to the scope of the production programme and the circle of customers, in particular the latter. This was accentuated by the great scarcity of coal in all European countries directly after the war, which gave rise to a new movement.

It was quickly realized in Germany that the best way to save coal was to utilize it to the full, i.e., to stop up the escape gaps in all heat-consuming plant. As the largest consumer of coal was the iron industry, which had been none too economical with coal during the years prior to the war, it was here that the idea first occurred to set up special control offices to keep track of the wasted calories. First of all this was the task of a few engineers, but in the large firms they soon extended their offices to positive "Heat Departments" and achieved noteworthy results. The Works Managements soon noticed that not only coal but also money could be saved in this way, and in many places the "Heat Departments" were extended, even after the acute shortage of fuel had eased off, to form supervisory organs whose influence on plant management and production organization was not inconsiderable. The idea of rational husbandry gradually spread from the iron industry to the rest of the heat-consuming industries.

The heat carriers, whether in perceptible or potential form, are mostly found in a fluid or gaseous state of aggregate; with water, steam, gases and air it is therefore usually necessary to determine the volume and temperature in order to measure the heat content. Frequently it is sufficient to measure just one of these two basic values, according to the nature of the task in hand. At all events, the measurement of volume and temperature are closely connected in heat economy.

In addition to these two basic values, it is frequently of interest to know the pressure and chemical composition of a gas. The latter in particular is of importance in the control of furnaces, such as with boilers. Analysis of the flue gas to determine its carbon dioxide content gives an indication of the efficiency of the combustion, and for this reason it was quite early the practice to take samples of flue gas from the exhaust flue and to analyse them, in order to keep check on the efficiency of boiler furnaces. Tests using rubber tubin, test tubes and solutions had to be restricted to the odd occasion. What the heat engineer wanted, however, was a built-in measuring instrument that would constantly register the carbon dioxide content of the flue gas and, if possible, record it too. He was accustomed to electrical instruments and was accordingly not easy to satisfy.

Gerdien, the Head of the research laboratory at Siemens, reasoned as follows: Gases vary with regard to their thermal conductivity, that of carbon dioxide being about 60% of that of nitrogen, which accounts for the greater part of the flue gas. If a gas is allowed to flow past an electrically heated wire, the latter is cooled, the rate of cooling increasing in proportion to the thermal conductivity of the gas, all other conditions remaining constant. The resistance of the wire, which varies according to its temperature, changes when the wire cools down and resistance can be measured electrically. By way of resistance, temperature, and thermal conductivity it should eventually be possible to measure the proportion of carbon dioxide in the flue gas, if the possible sources of error could be sufficiently eliminated from this complicated chain of interrelated factors to ensure a reasonable degree of accuracy. The proportion of carbon dioxide in the flue gas only amounts to between 8% and 16%, and every ½% is important. The engineer thus has to work with very small fluctuations in the measuring current, for the indication of which a very sensitive galvanometer would be required. This would have to be hung up beside the boiler, would be subject to contamination by coal dust, and the stoker would occasionally wash it down with the hose pipe so as to be able to read the scale. This was roughly the task that Gerdien set his assistant Dr. Max Moeller, an ambitious young engineer in his group who had just recently joined the Firm.

A year later, Moeller had made such progress that he was able to demonstrate in his laboratory a device that would function with a high degree of accuracy, and after another year had passed, the sensitive parts were ready for production, and were housed in handy but sturdy casings so that they were capable of being exposed to the heat, the coal dust and the stoker's drive for cleanliness without fear of damage. The flue gas test meter business flourished, for this was the sort of instrument that was required, and it was soon followed by a second instrument that indicated the content of carbon monoxide and hydrogen, the combustible constituents of the flue gas which had escaped combustion. Further designs for the analysis of other gases soon followed, chiefly to meet the requirements of the chemical industry. Von Buol, the Head of the "Wernerwerk für Messtechnik", in which all these instruments had to be manufactured, soon considered it a disadvantage that all these metering devices, electrical thermometers and pyrometers, gas analysers and all other accessories created for the sake of heat economy should be developed in various departments of the Measuring Instrument Works. He therefore withdrew the newly created metering device from the scope of the Water Meter Department, and the temperature measuring instruments from the Measuring Instruments Department and restricted both of these departments to their former production programme, the former to the supply of meters to the water works and the latter to the production of purely electrical measuring instruments. The recent additions were grouped together under the "Calorimetric Instrument Department," known briefly in the Firm as the "Cal. Dept." which was placed under the management of Moeller, who soon gave impetus to the new department.

This new impetus was favoured, apart from the quality of the products, by subtle advertising which under the slogan "Measuring is Saving" spread the underlying principle of heat economy in all heat-consuming industries. The idea had arisen, as was mentioned earlier, in the iron industry, but it was from the blast furnaces, the Thomas and Siemens-Martin furnaces, the casting houses and rolling mills that the idea caught on and, carefully fostered by the Siemens & Halske advertising, rapidly became popular with the other consumers. The collieries, whose own consumption of coal had previously been negligible because they had mostly used the low-grade products which could only be sold with difficulty, if at all, soon learned that careful supervision of their heat-consuming plant uncovered a number of other deficiencies which had hitherto escaped unnoticed. The furnaces used in industries concerned with the processing of earths and stones were redesigned as a result of the knowledge gained. Volume and temperature measuring instruments were found everywhere in the iron, metal-working and machine industries where casting, forging, rolling and tempering processes were carried out. It was obvious that the textile, cellulose and paper industries, which had a large heat consumption, could not do without them. An enormous new market was created when the chemical industry proceeded to erect on the site of the bituminous and brown coal deposits huge plants for the synthetic production of nitrogenous fertilizer and liquid fuels. The high pressures and temperatures which occurred during these processes caused the I.G. Farben industry to start developing in their own laboratories new designs of quantity measuring instruments for these special purposes, but here again a fruitful exchange of ideas and experience followed with Siemens & Halske, as a result of which the Wernerwerk continually received large orders. Long-distance gas supply systems, including the suppliers, the colliery coke-oven plants and large gas plants, could not possibly exist without a well-organized and efficient system of heat economy, which was based for the most part on quantity measuring instruments. This branch of industry was therefore the first to call for concentration of the measuring instruments at one point by means of long-range transmission, so that the entire process could be supervised and controlled from one point. Thermal control switchboards, on the lines of the large control switchboards used in electricity works, thus came into being and were quickly adopted by the other plants. From the thermal control switchboard of a blast furnace plant it was possible to check the proceedings at and inside every furnace, and the supervisor was also able to operate valves and dampers. Large boiler plants were equipped with thermal control switchboards containing hundreds of instruments, which reflected for the engineer in charge the processes in operation throughout the entire works. Even large heating plants, such as those in hospitals, were equipped in such a way that the stoker in the cellar knew exactly how high the temperature was in the operating room or the isolation ward.

Automatic regulation of certain values, such as the temperature of a room, had been introduced at quite an early stage. It was not difficult to equip an incubator with a temperature feeler, for instance a metal rod, the length of which changed according to the temperature, or a strip consisting of two pieces of metal with different coefficients of expansion soldered onto one another, which bent according to the temperature. These could be used to switch the heating current on and off and so to ensure that the temperature remained constant. In this way it was possible to control annealing furnaces, even the gas-heated variety, drying rooms could be kept at constant temperature and even whole factory halls, such as spinning rooms, could be kept at constant humidity. In the United States, where climatic conditions are in part very unfavourable, these "air conditioning" plants were developed to a high degree of perfection.

Regulation procedure is not always so simple as it may appear from the following. For one, every regulation tends to create a pendulum motion, in so far as the impulse which is caused by "too little" may easily cause "too much," which in turn must be corrected by an impulse in the opposite direction. This may well be too strong and so it goes on, whilst the whole procedure becomes terribly complicated when several different regulating factors are brought into play. This was particularly evident when Siemens & Halske started to tackle a problem which several others had already tried to solve, with varying degrees of success. This was the question of automatic boiler regulation.

In the early days of boilers, no one would have thought of trying to operate them without a stoker: the fathers of boiler legislation in Prussia would certainly have proclaimed him to be mad. But the boiler plant of an electric power station, for example, in comparison with the early days, now consisted of only a few large boilers, perhaps four in all, which could better be called steam generation machines and which, in the case of the forced-through-flow boilers, were no longer boilers in the true sense of the word but huge snake-like pipes hundreds of yards long. There was practically no more water in them and they were required to adjust themselves immediately to fluctuations in the steam requirements, and for this reason it was often extremely difficult to control and service them by hand. Automatic control in this case was no longer the hobby of ambitious factory owners or shop managers, but bitter necessity.

The first step in automatic boiler control consists in determining the steam requirements at a given time, which can be achieved at constant pressure by registering the fluctuations with the aid of a very sensitive manometer.

Then the fuel and water supply must be adjusted to the steam requirements, likewise the air supply to the fuel consumption, whilst the former must also be adjusted to the low pressure in the furnace which has to be kept within certain limits. A constant check must be kept on these interrelated factors by measuring the temperature at certain points along the water-steam circuit, in the furnace and in the exhaust flues. That the analysis of flue gases plays an important part in the whole process is obvious enough from the preceding discourse on flue gas analysers. All in all, a very complicated scheme of relationships, rather different from those involved in automatic machines, for which the imagination and patience of a clockmaker is usually sufficient. Here, however, complicated physical laws were involved and it required a great deal of schooled scientific thinking to master them. The Siemens boiler regulator, which was introduced in 1930 and heralded in a new era of power station design, was therefore rightly regarded by the "Calorimetric Instrument Department" as a milestone in the short period of their existence.

Whereas in most branches of communications engineering and measuring technique the first decades of the 20th century, in particular the third, were marked by a frequently irrepressible urge to forge ahead to new discoveries, this can hardly be said of the Railway Safety Department during the same period. Admittedly, the electric signalling and points control device invented at the beginning of the century asserted itself slowly but surely, but the section safety mechanism retained more or less the form it received in the Siemens & Halske workshops under Frischen. No revolutionary changes were made.

The position in the United States was quite a different one. It is obvious that the length of the individual block sections must be decreased, the greater the frequency of traffic, i.e., the closer the trains follow one upon the other, for if the blocks have an average length of 10 kilometres, the train halted by a signal must wait until the train ahead has cleared the whole section, i.e., is 10 kilometres ahead, which is ridiculous from the point of view of safety. The American railways therefore worked towards a block length of not more than 1 mile on sections where the traffic was heavy. On long lines, however, the result was a large number of block stations which it would have been impossible to keep manned day and night. On the other hand there were stretches with very little traffic which passed through desert-like and uninhabited country, so that it was impossible, by reason of the nature of the landscape, to install manned block stations. In both cases there were also stretches with bad vision, such as curved cross sections, which called for special safety precautions. The answer to these and similar technical problems in America was always the same: Automatic operation.

The automatic section block in America was given its basic form by the Westinghouse Electric and Manufacturing Co. The idea on which it was based was quite simple, although the actual design of the equipment in some respects occasioned much deliberation. The two rails of a track were insulated at the beginning and end of each block section from the neighbouring blocks by means of insulating intermediate spacers. At one end of the block a transformer feeds a low a.c. voltage to the rails, about 4—12 volts being sufficient for the purpose. A sensitive relay is connected to the rails at the other end and actuates the signal via a motor. It is of course essential for the two rails to be laid on wooden sleepers if they are to carry the current from one end to the other, as metal sleepers would earth it and thus make transmission impossible. As long as the block current is flowing and the relay is excited, the signal shows "Go," which is its normal position in this system, in contrast to the hand block, in which the normal position is "Halt." As soon as a train enters the block section, it short-circuits the two rails with its axles, and the signal behind it, which covers the entrance to the block section, moves to "Halt," thus protecting it from the train following behind. Not until the last axle of the train has left the block section is the short-circuit broken, whereupon the signal returns to "Go" and the section is clear for the next train. Electric railways, in which the rails are needed for returning the driving current, also require special throttle sections for bridging over the insulating spacers, which allow the driving current to pass, but not the block current. At the beginning of 1924, after 20 years' development, about 40% of the 170,000 kilometres of track, which were equipped with signals at all in the U.S.A., were already provided with automatic blocks.

When the success of the new system in America became known in Germany between 1905 and 1910, there was much opposition to the adoption of this system on the German railways, on the grounds that the operating conditions of the American railways could not be compared with those in Germany, which was indeed the case. However, opposition to the introduction of the system for the municipal railways, to replace the old manually-operated block system, soon proved to be unjustified. The block sections on the Berlin City and Underground Railway had to be kept so short that a large staff of pointsmen were required for their operation, and in spite of this, they were still unable to keep up with the speed of operation when the trains followed one upon the other at short intervals. A delay of a few seconds in the operation of the blocks was sufficient to cause considerable confusion in the timing of the trains.

An independent expert of the city of Berlin, the Geheimer Baurat Dr. Kemmann, managed, in spite of bitter resistance from the experts, who were also to be found in the Block Works of Siemens & Halske, to force through the introduction of automatic section blocks with daylight signals in the City Railway shortly before the outbreak of the war. As Siemens & Halske were under contract to supply the equipment for the railway, they had to tackle the problem now whether they liked it or not, and after the ice was finally broken they applied themselves to the task with much understanding and enthusiasm, developing a system that was adjusted to the German requirements and which then became the standard for all later German models.

The system could also be introduced in stations and combined with the existing safety devices in numerous ways. The fact that every train could be followed on its way as a result of the operation of the block relays could now be used for the development of an illuminated track diagram, which was situated just above the signalling equipment. It gave a schematic representation of the tracks, points, crossings and signals and was constructed in the form of a luminous-circuit diagram. The occupied tracks were lit up, the unoccupied remained dark, and the position of points and signals was indicated by coloured lamps. The official in charge of the signal box no longer had to try and survey the situation in the station from his window, a task not infrequently complicated by the irrational layout of the stations of those days—a glance at the diagram showed him everything, particularly when it was dark or foggy.

That these and other revolutionary changes in railway safety precautions, a more detailed account of which at this point would take us too far, encountered more openmindedness for technical innovations among the staff of the recently created Deutsche Reichsbahngesellschaft, was mainly due to the President of the Administrative Council of this company. As in his own firm, he made sure that sound ideas were not stifled by the arbitrary judgement of the administrative machinery. About 1930, it became evident that the Deutsche Reichsbahn was no longer an administrative authority but an active transport undertaking.

Admittedly, they had every reason to be, since the motor traffic in Germany had meanwhile attained such proportions that one could no longer speak of a monopoly of the railways in respect of the transportation of passengers and goods over long distances, as was formerly the case. The volume of traffic rose from year to year and assumed proportions in the towns, and particularly the large cities, which made traffic control a problem of the first magnitude for the police. Attempts had been made at first to unravel the chaos in the city streets by posting policemen everywhere, whose task it was to direct the traffic. This may have been sufficient at simple street crossings, but large squares in the heart of the city, where numerous main roads converged, required a whole host of policemen who found it very difficult to communicate with one another and were moreover not available for other more urgent tasks. Thus mechanical signals were used, which later gave way to coloured daylight signals of the type recently introduced by the Municipal City Railways. The same colours were chosen as for the latter, namely red, green and yellow, the last serving as a transition between the two main colours.

Siemens & Halske began with the development of suitable signal equipment for street traffic around the year 1925, and it was the Telegraph Department, not the Block Department that took the matter up and played an active part in the development. The first solution arrived at, whereby the lights were changed by a policeman whose task it was to keep an eye on the traffic, was not the best and did not represent a great improvement. The man was needed as before, although more suitably positioned and, above all, less exposed to danger. In addition, it frequently occurred in Berlin and other large cities that a long main street with dense through-traffic was intersected by numerous side streets with less dense but by no means negligible traffic. One crossing followed another and all of them had to be controlled. Automatic signals were therefore developed in which the lights were regularly changed by means of motor-driven shafts with cam disks. All these signals were connected by means of cables to a common network, which was controlled from a central switchboard. In order to prevent a vehicle travelling in the direction of the main stream of through-traffic from having to stop at every crossing to wait for the green light, the sequence in time of the change-over at the various crossings was so arranged that a green wave would move down the main street at approximately the same speed as a car. However, city traffic does not remain constant. It is different in the morning and evening to what it is at midday, weekdays differ from Sundays, and special occasions, such as celebrations and sporting events, can create abnormal traffic conditions. An extensive signal scheme with automatic control must be readily adaptable to meet all such requirements.

This was achieved in the Siemens & Halske models by providing a combination of different switching mechanisms by which the central control point could be adjusted to the traffic conditions prevailing. An automatic correction link was added: the ground beam. At the approaches to the main crossings, water-tight cases with an elastic top were let into the road, each about as wide as a car and containing the necessary contact equipment. These contacts closed under the pressure of the car, and special components taken from various branches of communications engineering, among them automatic telephony, added the pulses received from each contact, combined them with those from the ground bar of another stream of traffic and weighed up the claims of the various streams of traffic to the right of way. Scientific studies on road traffic, combined with constructive phantasy, yielded in various cases solutions which were almost uncanny in their operation. Thus Siemens & Halske installed one such system in Amsterdam, operated from a central control point but not always directly controlled, which covered a total of 30 crossings, one of which alone had 21 lights to operate. This system regulated the whirling traffic on a large square without the aid of a single human brain. The advantages of the method were most clearly illustrated by an experiment in Trafalgar Square in London, which in those days was regarded by experts as the square with the densest traffic in the world. The system installed there on the lines described above was compared by careful metering with the traffic regulation carried out by a large number of specially trained policemen. It transpired that in the peak traffic hour the system cleared 10% more vehicles through the maze than the most experienced Bobbies!

During those years the Telegraph Department was the collecting basket for everything that did not seem to have a proper place elsewhere. Among these was the photo-electric cell, which suddenly roused general interest in the public, although the physical principles of the phenomenon had been known for a long while. Elster and Geitel, who have already been mentioned in connection with the "Triergon" efforts to construct a sound film, brought out a photo-electric cell of the following design: An alkali metal cathode was enclosed in an evacuated glass vessel—potassium or sodium were used for the long waves of the visible spectrum, or cesium for the short ones. The anode, which was situated opposite the cathode, was formed in the shape of a ring so that the light ray could fall through it onto the cathode. If a direct current voltage is applied between anode and cathode, a weak current is generated by the emerging electrons on exposing the cathode to light rays. This current operates a relay via an amplifier.

These photo-electric cells, as they are now known, were used during the 1930's for a large variety of purposes, and Siemens & Halske contributed considerably to their introduction by constantly producing new designs. First of all, twilight switches were developed, which, depending on the amount of daylight present, operated lighting circuits. A light transmitter, which could also be equipped for infra-red light, i.e., invisible light, and was directed from a certain distance towards a photoelectric cell acting as receiver, formed a light barrier. In this way it was possible to guard the entrance to safes or—in museums—to valuable art treasures; escalators and lifts could be automatically set in motion by the user, doors opened on being approached, people passing through an entrance were counted, and above all it was possible in assembly-line production and transport to make any number of counts. In certain production processes these devices were refined to such an extent that no fault in a product continually flowing past the cell and no deviation in the dimensions of components passing by, not even a cigarette out of place in the packet, escaped the notice of the electric eye. It could be used to measure the height of the contents of tanks, silos and bunkers, or to control the indication in water gauges, so that the filling process could be stopped in time, even the centering of a balance indicator could be followed. Above all, the photo-electric cell proved to be an indispensable regulator in all manner of production processes, as it could detect conditions which could not be registered by mechanical means, such as the evenness of a surface or the degree of polish, and could direct the further processing as required. A whole series of production processes have been perfected to a high degree by the use of photo-electric cells.

The development of the photo-electric cell has meanwhile resulted in the final fruition of another project, one on which inventors had tried their skill for years with varying degrees of success: telegraphic image transmission. It was possible at quite an early stage to telegraph writing or simple sketches. The sheet of paper with the writing was laid over a drum, after making the writing conductive and the remaining surface insulating by means of a chemical process, and the drum allowed to revolve evenly, whereby it was slowly displaced axially. A fixed metal pin described a spiral line on the paper, with the individual threads close to one another. When the pin touched the conducting surface, a circuit was closed to which the receiver was also connected. This was equipped with a drum of the same diameter, revolving synchronously with that of the transmitter, and with an identical metal pin. The drum was covered with a sheet of paper which had been dipped with a solution of litmus tincture in sodium sulphate. When the current flowed, the pin of the receiver produced a coloured point on the paper by means of electrolysis, and the picture was composed of these separate points. The process was only suited for transmitting a rough outline and took rather a long time. However, the way was open in principle for a solution of the problem and all subsequent attempts took place along the lines of a revolving drum.

When the Kerr cell, improved by Karolus, was introduced into sound film and the photo-electric cell had also been sufficiently developed to be capable of utilization, the two elements required to transform image telegraphy into a system of telegraphy capable of fulfilling all requirements had been found. The pin was replaced by a photo-electric cell which was placed right in front of the revolving picture, so that a light ray reflected from the latter transformed the differences in the brightness of the picture into current fluctuations. In order not to have an uneven direct current, which would be difficult to transmit over long distances, the light ray was broken up by a quickly revolving perforated disk to obtain a series of short light flashes, and corresponding current pulses were thus obtained which could be used to modulate a carrier frequency. These pulses were transmitted to the receiver in this case by wireless telegraphy or long-distance cables. After demodulation on the receiving side, the pulses again produced light fluctuations in the Kerr cell which were projected, in the form of a sharp beam of rays of varying strength, onto the light-sensitive paper covering the drum of the receiver, which revolved synchronously with that of the transmitter and thus gave a true reproduction of the original.

This system had been developed by the central laboratory of Siemens & Halske together with Telefunken, as it was originally thought that it would mainly be used for long-distance telegraph traffic. It soon transpired, however, that it was the newspapers which were mainly interested in the new system, for whom even the high cost involved in transmission from overseas was of no importance. The large newspapers with huge editions, whose readers were less interested in serious news or articles than in sensations—scandals, sport and crime—wanted to be able to provide one or more of their provincial editions with pictures from a central office, usually in the Capital. Picture telegraph systems were therefore first installed for the Press-strangely enough—in Japan, followed by England, France and then Germany. As they were operated by way of long-distance cable they came under the sales organization of Siemens & Halske, and as Siemens & Halske also manufactured the equipment as well, the Telegraph Department did good business with them.

It is indicative of the reputation that Siemens & Halske had already acquired throughout the world that a company of international financiers founded in London in 1927 approached the Firm with the query as to whether they would be interested in producing a large number of machines known as photomatons. These were designed for completely automatic production of portrait photographs of the size of a passport photograph. The customer inserted a coin and entered a cabin, where, sitting brightly illuminated in front of the objective, he was photographed six times in rapid succession. Eight minutes later, the machine was supposed to eject the finished pictures. A number of patents protecting the process had already been granted.

The order could be completed in two years and no further orders would ensue. During this time the workshops involved would be assured of regular employment and no risks were involved as to the sales market, and no sales organization required. The offer was therefore accepted, only to find that a lot more work would have to be put into development and design than was originally thought.

Finally the order was completed and two years later most of the machines had already been withdrawn from use, as the pictures were not of a good quality—female vanity, in particular, would have nothing to do with them. This was in no wise due to the design and construction of the machine but to the idea. Two eyes and a human brain are needed for a portrait, as the robot can take over the purely mechanical functions to a great extent but cannot supply a substitute for good taste. And so a number of designers and production engineers sat brooding over plans, models and tools in the firm and said "Pity, it was such a good time." It certainly had been interesting.

After the war, as has already been mentioned during the account of the radio business, the branch offices of Siemens & Halske had become partners of their elder brothers, the branch offices of Siemens-Schuckert, and now enjoyed the same rights. Just as the latter had done so before them, they organized a special group to deal with the sale to the retailers of certain mass-produced articles. Now the sale of radio sets and the necessary accessories was a business with a very pronounced seasonal curve. It began in Autumn, reached its climax about Christmas time and had practically come to a standstill by Spring. Something was needed to fill in the gap in Summer, and as the so-called sub-standard film had been introduced into the film industry in 1923, the words 'sub-standard film' was often used by the branch offices as a slogan in the debates that followed and was readily taken up by the photographers, who had acquired a foothold in the Telegraph Department since the photomaton affair.

If the width of a film is decreased from 32 mm to 16 mm, 132 pictures of 10.4 by 7.7 mm can be accommodated on a metre of film. With such small pictures it is, of course, impossible to cover the whole of the screen of a cinema, which often has a width of six metres, but it is sufficient for a screen of about 1 by 1.4 metres and fulfils a multitude of purposes. It can be used in the home, in small lecture halls and in schools. The advantages are that the photographic and projection equipment is smaller, lighter and cheaper, that 100 m of sub-standard film will run for 13.2 minutes, as against 5.3 minutes with the normal size, and—a very important advantage—the sub-standard film can be mounted on acetylene cellulose, which is non-inflammable and is therefore not subject to numerous restrictions governing the use of normal film. Thus in the short period which had elapsed since the birth of the idea, a lively trend could be observed in the photographic industry which aimed at equipping the amateur photographer with a sub-standard film camera, coupled with the additional idea of copying suitable films, above all cultural and instructional ones, on sub-standard film and using them with the corresponding projectors for instructional purposes in schools and elsewhere. And so it came about that the Telegraph Department one day proposed a motion at a meeting of the Directors that the Firm should take up this promising branch of business.

Opinions differed on the subject. Some of the Directors were directly opposed to the idea on the grounds that it had nothing at all to do with electrotechnics. They had to agree that the projector, with its motor, rheostat, projector lamp and measuring instrument, could sooner be considered an electrical machine than an optical one, and that later on, as would surely happen, when the silent sub-standard film learned to speak as its big brother had before it, the electrical equipment would constitute the main part of the apparatus. Admittedly, the camera itself was an optical instrument, but this was a very essential requisite in photography and quite indispensable. Finally the Head of the House cast the decisive vote in favour of the motion. He considered that the new branch was so closely connected with the production methods of communications and measuring engineering, not only from the electro-technical point of view but from the standpoint of precision mechanics, that it could be integrated into production without causing any disruption in the workshops, and could probably be very useful to them as a sideline in time of need.

Sub-standard film proved to be a good business for Siemens & Halske. The design and workmanship of the equipment impressed the purchaser—as usual the workshops had excelled and were responsible for the fact that complicated parts of the mechanism, such as the film transport in the projector or the speed change device in the camera, functioned perfectly even in the most inexperienced hands.

In addition, the fact that sub-standard films were introduced in all German schools for instructional purposes was a boon to the business. A special "Reich Office for Instructional Films" performed first-class work in the production of cultural and educational films. After careful examination of the equipment available, they placed orders for the delivery of equipment with a number of large firms, whose designs seemed most likely to guarantee faultless operation. Siemens & Halske participated in this scheme with one of the largest orders.

Naturally the Directors had intended right from the start not to manufacture the objectives for the cameras and projectors themselves, but to obtain them from the optical industry. But the suppliers were to experience numerous surprises in this business with Siemens & Halske.

The camera objectives were subjected to various test procedures which were new to the optical industry. As the objective had a very small focal length, due to the size of the picture, the slightest inexactitude in the setting of the distance between objective and film caused a noticeable blurring, and if, in the course of mass production, this distance is fixed by suitable means, all objectives should have exactly the same focal length. No deviation whatever could be tolerated. The objectives, which were delivered in large numbers, therefore had to be subjected to a test procedure which was as rapid as it was exacting, with the result that optical laboratories attached to the central laboratory were set up for the purpose, commencing in the days of the photomaton with a staff of two, and employing 90 people ten years later. This rapid expansion was occasioned to a great extent by a branch of film development which had for years occupied the attention of some of the best brains in the industry: the coloured film.

The production of coloured projection pictures can be based on the fact that each shade can be mixed from the three basic colours red, green and blue by correspondingly graduating the proportions of these three colours, as had already long been common practice in so-called three-colour printing. In the case of the projection picture it would therefore be necessary to make three separate pictures using three coloured filters and to project the three black and white positives thus obtained exactly on top of one another with the aid of the same three coloured filters. It is quite clear that a procedure that requires three cameras and three projectors for a live picture is impossible from a practical point of view. As early as 1908, Rodolphe Berthon hit upon the idea of using just one camera, one film and one projector, basing his idea on an earlier idea of Liesegang's. He installed three coloured filters on top of one another in the same plane in the objectives of the camera and projector. The filters then had the same effect as three diaphragms on top of one another. The light-sensitive coating was on the back of the film, and on the front, diagonal to the direction of transport, fine ridges were made which had the same effect as narrow cylindrical lenses running parallel to one another. When the picture was taken, these ridges directed the three parcels of light rays which emanated from each part of the picture and passed through the filters next to one another, onto the emulsion, whereas in projection they served to guide the light ray parcels through the three filters, so that they were reunited to a compound colour on the projection surface.

A French group with American capital tried to put this idea into practice but ran into what appeared to be insuperable difficulties. At length the firm of Perutz, which as film manufacturers were interested in the process, approached Siemens & Halske with the suggestion that the two firms should cooperate, and in 1930 the latter declared themselves willing to develop the necessary camera and projection equipment.

In order to appreciate the technical difficulties involved in the problem it should be mentioned that the parallel cylindrical lenses on the front of the film must have a radius of curvature of 32/1000 mm, a depth of 0,004 mm, and be spaced at a distance approximately equal to the diameter of a woman's hair. These lenses were impressed on the celluloid by means of embossing rollers, for which a special material had first to be developed as their surface had to take a polish, the like of which had never hitherto been achieved, and the profile of the cylindrical lenses was then impressed on the surface of the rollers with diamond tools. The entire project proceeded in this style. The optical section of the equipment, the mechanical drive, the control of the light effect, everything demanded the utmost precision. It was, of course, inevitable that there were setbacks too, which occasioned far-reaching changes and fresh starts, and altough C.F. von Siemens was always impressed by the enthusiasm of his assistants on his numerous visits to the laboratories, he proclaimed energetically one day that this was to be the last million that he was prepared to put into the venture.

On the occasion of the Olympic Games in 1936, a short film with a Rococo motive was shown in Berlin which had been made with the new system. The soft pastell shades of those days were reproduced so faithfully that all those present were most surprised, and the creators of the coloured film had every reason to be proud of their success. However, the success was but short lived. Almost at the same time the Agfa brought out their new colour film, in which the formation of the colour effect was transferred to the emulsion itself. Whereas with the Siemens-Berthon process, as it was now called, the projection equipment needed certain supplementary devices, including a new projection screen, which the cinemas would have to purchase for themselves, the Agfa film necessitated practically no modification of the apparatus at all. This swung the tide in their favour, and with heavy hearts the Siemens directors decided to give up any idea of following the matter further, after a number of their best experts had been working on the project for many years, for the development of which a great deal of money had been expended. But a large undertaking must reckon with such setbacks, if it sees a justification of its existence in opening up new paths in science.

Around the turn of the century, Ferdinand Braun, the Strassburg man of science whose name was frequently mentioned in connection with the development of radio telegraphy, had used a cathode ray tube for indicating changes in current or voltage. For if the electrons, which are emitted from the cathode in a straight line, are parcelled by appropriate devices so that a sharply defined pencil ray is formed and this allowed to pass through a magnetic or electric field created by an electromagnet or two parallel metal plates, the ray is deflected on exciting the field and thus shows every change in the field, and accordingly in the exciting current or voltage, with the same accuracy as the needle of a measuring instrument, differing from this only in so far as the ray has no mass and follows every change in the measured value without delay due to inertia.

After Dufour had done some of the spade work, Rogowski succeeded in Aachen in developing a cathode ray oscillograph from Braun's cathode ray tube. In this, a photographic plate was displaced vertically to the swing of the ray. In this way a curve was described which showed the course in time of the quantity under measurement. The movement of the plate was later replaced by a second deflection of the ray, which was proportional to the time and vertical to the direction of its first deflection. In this way the same effect was gained in a much simpler way than with the plate. If periodic occurrences were being observed, as was often the case in electrotechnical experiments, the deflection of the ray proportional to the time could be so arranged that the description of the curve always started afresh from the same position whence it had started on completion of the period. The curve seemed to stand still. The Braun tube was now made of glass with a flat bottom, on which the end of the ray described the curve, and the inside of the bottom covered with a phosphorescent layer of zinc sulphide. The curve could now be comfortably watched, measured and photographed from outside.

One of the first models of these simplified, yet very efficient cathode ray oscillographs was produced by the AEG, and others quickly followed suit. However, Siemens & Halske had left themselves plenty of time in the development of the new instrument and it was not until several years later that they brought out a new model, which however, was well able to take its place beside the old bifilar oscillograph as far as the construction was concerned.

While work was being carried out in the High Tension Institute of the Technical High School in Berlin in 1928 on the cathode ray oscillograph, a student who was engaged in the research work, Ernst Ruska, was given the task of calculating the course of the electrons which were deflected by electric or magnetic fields of a certain form. If such fields were symmetrically extended with respect to rotation, their effect on the path of the electrons was similar to that of lenses on light rays. This was shown for the first time by H. Busch in 1926. One spoke therefore of electric and magnetic lenses and proceeded to develop electron optics. Ruska followed the idea further, and at the beginning of June 1931, M. Knoll, as representative of the Institute, gave a lecture before experts in Berlin on Ruska's idea of an electron microscope with magnetic lenses. Five days earlier, quite independent of all this, Rüdenberg had induced the Siemens-Schuckertwerke to apply for a patent to cover an idea which was basically the same as that put forward by Ruska. The AEG now protested against this application, stating that their Research Institute, founded in the year 1928, had been engaged for some time on similar studies, which had already been referred to in the bibliography. It can be seen that here again a problem was solved by three persons almost at the same time, so that in addition to the quarrel over the patent rights there was a bitter argument among the inventors as to who should be recognized as the first. Whereas the Rüdenberg patent was never granted in Germany due to the counter-claim, it was granted in America. Assisted by the Notgemeinschaft der deutschen Wissenschaft, Ruska built the first electron microscope in 1933, together with his old student comrade Bodo von Borries, with which the resolving power of the light microscope was reached and soon far outstripped. It should be remembered that the resolving power of a microscope is the distance between two points which in the corresponding enlargement can still be distinguished with certainty as distinct parts. This distance cannot exceed a third of the wavelength of the radiation. As the visible light spectrum has an average wavelength (green) of 5.5/10,000 mm, the resolving power of the most perfect microscope conceivable is restricted to 2/10,000 mm. This was demonstrated by Abbe.

Electrons can be considered as wave packets of a phenomenon known as "material waves," according to the views held by modern physicists, and not only as corpuscles, as was earlier the case. The wavelength of these material waves as a function of the speed of the particle in question is exceedingly small and can be taken to be about the 100,000th part of the length of the light wave in this case. The resolving power of an electron microscope is accordingly far greater than that of a light microscope and thus it was soon possible to construct instruments for electron rays which had 100 times the resolving power of the best optical instruments, i.e., were still able to detect distances of 1—2 millionths of a millimeter.

After negotiations with various authorities and firms for the acceptance of Ruska's invention had broken down, an agreement was successfully concluded with the House of Siemens, and Ruska and Borries were granted a special laboratory with a large workshop, attached to the central laboratory, in order to perfect their electron microscope for serial production, as far as one can speak of serial production in the case of such a complicated instrument.

The war, which broke out soon afterwards, was a great obstacle in the path of further development, but about 40 such microscopes were delivered by the end of the war. These instruments, standing about 2 metres high, were exceedingly well constructed, their complicated operation had been simplified by appropriate combination and the workmanship was in the best Siemens tradition. In order to facilitate the introduction of the microscope, special guest laboratories equipped with these microscopes were attached to the development laboratories and well-known research workers, particularly doctors and biologists, were permitted to use them for varying periods of time. Here they were able to see a virus for the first time in their lives.

The years between the two wars were on the whole very fruitful as regards developments in the field of physics, which frequently started as purely theoretical research of little or no practical use, only to experience a sudden change and yield results of far-reaching consequence to human life. The theory of relativity set up by Einstein finally asserted itself as a new source of knowledge after bitter struggles among the experts and, together with the development of quantum mechanics, created a new picture of the physical structure of the world which saw one of its main functions in propounding new theories on the structure of the smallest particles of matter and, with the aid of these, taking a more active part and even bringing about changes in the microcosm. One of the most important accessories in this venture was the generation of rays, which consist of rapidly moving particles of the smallest size.

Such small particles can only be brought up to high speed if they carry an electric charge, for only in this state can they be accelerated in an electric or magnetic field. Carriers of a positive charge are atomic nuclei or remnants of the same, such as helium nuclei, which have long been in use as so-called α-rays, or hydrogen nuclei (protons) and the nuclei of heavy hydrogen (deuterons), whereas the carriers of a negative charge are the electrons. The former have the advantage over the electrons that the mass of their unit, of the proton, is more than 1,800 times greater than the mass of the electron, i.e., that when used for bombardment, they have nearly 2,000 times the amount of energy at the same speed. First of all, attempts were made with arrangements designed to bring positive ions up to high speed. To start with, it seemed easiest to send them through a constant electric field with a very high difference of potential. But all methods developed to this end had the disavantage that the generators for the very high voltages took up a great deal of space and were very difficult to protect against leakage.

In 1930 a method suggested in the United States by Lawrence became known, by which ions are accelerated on a circular track by making them run round the inside of a round flat shallow tin, which is cut through its diameter into two symmetric halves. The two metallic halves of the tin are charged with opposite charges, and each time the particle passes the separating cut and is accelerated by the electric field in this section, the polarity of the charges is changed and the particle, on passing the cut, this time in the other direction, is accelerated again. It is kept on its circular track by a strong constant magnetic field which cuts the arrangement vertical to the track. In this way the acceleration increases constantly from revolution to revolution, until, after reaching the maximum speed, it is hurled out of the chamber. This arrangement was known in America as a cyclotron.

About the same time, other inventive scientists, the American engineer Slepian and the Norwegian Wideröe, who was studying in Germany, were at work trying to accelerate electrons on a similar track, without any tangible results. It was not until 1933 that M. Steenbeck, a member of the Siemens Röhrenwerk, managed to formulate the stability conditions mathematically and was thus able to develop the first practical instrument for this purpose, which the Americans called the betatron, whereas in Siemens the much more expressive term "electron gun" was coined. The electron actually behaves like a stone in a circular sling. It is brought from a heated cathode into a circular evacuated chamber, in which the track is crossed in a vertical direction by the field of a strong alternating current electromagnet. If the magnet is excited with a frequency of 50 c/s, for example, the magnetic field which commences to grow at a certain moment generates in the circular electron chamber an electric field running on a circular track, and the electron is accelerated in this field. The gyrating electron then forms the secondary current of the transformer, which is short-circuited in itself, the primary winding of the transformer being represented by the energizing coil of the magnet. When the field reaches its maximum value, the electron attains its maximum speed and leaves the track. The whole procedure takes place in the first quarter of a period; at the frequency given, then, in 1/200th of a second. In one certain experiment the electron made 280,000 revolutions in the ring-shaped chamber in this short time, covering a distance of 870 km and reaching a final velocity of 285,000 km per second, almost reaching the speed of light. In the next quarter of the period, the procedure is repeated with freshly imported electrons.

Steenbecks experiments were wound up in 1939 as the feasibility of the development described was proved, but the yield of fast electrons in comparison with the power consumption, i.e., the degree of efficiency, was too low to be of any practical use. In the United States, however, the General Electric Co. took up the Steenbeck patent and entered into negotiations with Siemens-Schuckert in 1941 on the question of its transfer. The entry of America into the war shortly afterwards put an end to all such agreements and the Americans now proceeded to develop the betatron on their own with great success. The importance of the betatron is based chiefly on the fact that with these rapid electrons, Röntgen rays of a hardness, i.e., short wave-length, can be generated which was inconceivable with the previous Röntgen apparatus and which could even surpass that of the hardest radium rays. As a result, the further development of the electron gun was later transferred to the Siemens-Reiniger works, so that Röntgen apparatus could be developed from it for purposes of deep therapy, particularly the treatment of deep-seated tumours.

When, in the year 1865, Werner Siemens had to quit the field with his high-speed telegraph in face of the Hughes machine, whilst the experts continued to occupy themselves with the question of accelerating telegraph traffic, commercial circles in Berlin which were particularly interested in the matter pressed for the introduction of a rapid means of communication between the Stock Exchange, as the most important centre of business, and the telegraph office for the dispatch of incoming and outgoing telegrams. Thus the first pneumatic-tube system in Germany was installed, which was constructed by the Firm at the instigation of Werner Siemens. The good results obtained with the new form of communication induced the Reichspost ten years later to install a whole pneumatic-tube network between the various post offices in Berlin, which was also available to the public for quick communication. These plants, which were also installed in other cities throughout the world, were called long-distance pneumatic-tube plants in contrast to the house tubes, which were introduced at a later date and mainly served multi-storeyed buildings or groups of buildings, their range being restricted to 400 metres. In comparison with the long-distance pneumatic-tubes, which had to be restricted to large cities, the house tubes rapidly gained importance. Banks, savings banks, insurance companies, in fact all types of large office buildings in which documents, notes and cards had to be sent quickly from one place to another, required far fewer errand boys with this plant. They were always somewhere else when you wanted them, anyway. Extensive networks with a number of posting and receiving stations incorporating various principles common in communications engineering were installed after the war, so that it was possible at every posting station to select the corresponding pushbutton for the station to which the message was to be sent from a row of pushbuttons, which, on being depressed, caused the tube points to change. Even simpler was the system in which the carrier found its own way. For this purpose the head was fitted with a screw ring which could be set for each different station like the time fuse of a shell. The carrier itself looked rather like a shell and electric feelers in the tubes recorded the setting of the ring and made the necessary point adjustments.

One of the institutions most interested in this type of house tube system was the Post Office itself, which required them for trunk offices where manual operation still prevailed. In order to avoid mistakes and complaints, everything had to be carried out in writing; the booking of the call from the acceptance point to the switchboard, the information service, alterations in the bookings, the charging of fees, faulty operation and other notices. The notes passed between the various offices of a large post office like swarms of bees. It would have been too awkward to put each one in a container and send it via the house tube. It was therefore decided to install tubes of a square cross section—about 10 mm by 70 mm—in which the folded notes could be placed and simply blown along by air (pneumatic ticket carrier). On certain stretches, mostly short ones, the notes were also transported by revolving belts, being either stood up on the belt or wedged between two of them.

It was mentioned earlier on that the firm of Zwietusch & Co. had passed into the hands of Siemens & Halske during the first World War and continued to function under the old name as a department of the Wernerwerk. They were engaged in the construction of exchanges and were thus obliged to devote some attention to the pneumatic tube systems, which had meanwhile become part of the basic equipment of the Post Office.

The idea of the pneumatic tube system soon spread and "small conveyor plants" appeared. Conveyor belts and belt distributors were installed to supplement the long-distance and house tubes in large mail and parcel offices and file transport systems. Pneumatic tubes were even used in steel works to convey hot samples of metal to the laboratory, in order to test the quality of the batch before pouring the block. As the few German firms engaged in the business of constructing and installing small conveyor systems hardly met with any competition from foreign firms, the business was of some importance for the nation's export economy.

The period between 1925 and 1928, which had witnessed a certain clearing up process in several fields with the foundation of the Siemens-Reinigerwerke, Siemens-Planiawerke and the Klangfilm GmbH., finally led to another such process in the field of railway safety devices. The nature of developments had forced the Block Works quite early on to integrate purely mechanical designs, the signals themselves in particular, in their production range. Right from the beginning of the railways in Germany a large number of firms, mostly small ones, had been engaged in the production of these mechanical designs, particularly the points, and also made gates for the level crossings and similar things. Of these firms, the Signal Construction Works of Zimmermann & Buchloh and Schnabel & Henning, both situated in Bruchsal, and Stahmer of Georgsmarienhütte near Osnabruck, had already amalgamated in 1909. In 1917, when the railway safety business was down on its knees as a result of the war, various other firms joined them, thus forming the Deutsche Eisenbahnsignalwerk A.G. In 1926 the Max Jüdel A.G. in Braunschweig, the strongest of the partners of the old signal works, acquired the majority of the shares of the Deutsche Eisenbahnsignalwerke and formed with them a new combination, the Eisenbahnsignalanstalten vorm. Jüdel, Stahmer, Bruchsal A.G. But the joint enterprise could not hold its own in this form either, as little or no attention was given to electrotechnical equipment. This, however, was the decisive factor now and the Block Works was able to draw on the various systems developed by the House of Siemens, such as remote signalling and control with the aid of the automatic telephone equipment described earlier on, relay technique, high frequency technique and the production of electric motors, whilst the optical laboratories assisted them with daylight signals and many other things. This support from the great House in technical matters gave the Block Works such an advantage over its competitors that the latter leaned upon it for support. It was therefore not difficult for Siemens & Halske to gain a majority holding in the Braunschweig firm, and together with the AEG they founded the "Vereinigte Eisenbahnsignalwerk A.G.," of which one third belonged to the AEG, one third to Jüdel, Stahmer, Bruchsal and one third to Siemens & Halske, whereby it should be noted that the third partner also controlled the second. The management of the enterprise, from which the AEG finally withdrew, was taken over by the Block Works.

Now the Block Works also produced benzine motors, which were chiefly supplied to the Automobile Works, as well as small numbers of other types of motors for special purposes, and they were later to develop the rotary-cooled aircraft engines, which had proved their worth in the war, for civil aviation, which was to be built up again in Germany. Another home had to be found for this line of production, as the Vereinigte Eisenbahnsignalwerke wanted nothing more to do with it.

Carl Friedrich von Siemens had long considered the benzine motor and everything to do with it as foreign to the Firm. On every possible occasion he stressed, in speeches, private letters and conversation, that it was the Firm's task to develop the various branches of electrotechnics, all of them admittedly, but that they should take care not to take up matters which did not lie within their field. Naturally it often occurred that a foreign body of this sort obtained access to the organism due to special circumstances and remained there for a longer or shorter period of time. One just had to wait for a suitable occasion to remove it. This opportunity had now come as far as the Automobile Works were concerned, which had always reminded Carl Friedrich of a serious blunder anyway. Another factor was the recent opening of the German frontiers for the import of cars from the United States, and if it were to be possible to enter into competition with the American production, which was based on the highly rationalized construction of enormous numbers of vehicles, it would be useless to continue on the basis on which cars were manufactured in Siemensstadt. The Protoswagen was admittedly exceptionally well constructed from a technical point of view, as was everything which came from Siemensstadt, an elegant car for people with a discerning eye, but much too expensive. There was no point in losing any more money on it. The operation was not exactly painless, as the Head of the Works, an active man who lived only for his work, together with his staff resisted the disbandment of their factory with all the means at their disposal, but Carl Friedrich remained firm. The "Protos Automobile G.m.b.H." was sold to the "Nationale Automobilgesellschaft A.G." which also took over a large part of the technical personnel. It was not difficult to find other use for the workshops which thus became free in Siemensstadt.

The Block Works had rented workshops outside Siemensstadt in Spandau for the production of motors before the foundation of the Vereinigte

Eisenbahnsignalwerke, and after the manufacture of cars was discontinued, they chiefly produced aircraft engines, besides other internal combustion engines. However, it was clear that the first-named line of production, although not the more important of the two, was nevertheless the more interesting, so the works, which belonged to Siemens & Halske, were named the Aircraft Engine Works. In this manner a strange assortment of different branches of production had come into existence, and although Carl Friedrich was often tempted to close down this "Benzine dump", as he angrily termed it, he was always restrained by the various arguments put forward to him, namely, that this was a large experimental workshop, which must be maintained for a while because of the idealistic and national values it embodied.

Looking back on the account of developments given in this chapter and considering that it can only touch on a small proportion of the numerous large and small enterprises which combined in the course of the years to swell the original production programme of the Wernerwerk, it is not difficult to imagine why the previous conception of a factory had long since been revised. In 1905 the Wernerwerk was a large factory, but it was not even extended to the limit. During the war the Wernerwerk M had been added, whereupon the old factory was named Wernerwerk F for the sake of clarity, and later on, Zwietusch, on the Charlottenburger Salzufer, and the workshops of the "Gesellschaft für elektrische Apparate" (Gelap) were taken under the direction of the Wernerwerk by Hettler. Workshops in North and South Spandau as well as in Haselhorst were also rented and extended in order to house the production of the Telegraph, Fire Alarm and Amplifier Departments. A large new building arose in front of the Cable Works in Gartenfeld for the carpenters workshops, and south of the Siemensdamm, the broad highway to Siemensstadt, the first wing of a large building, which was designed with a view to later extension, was constructed for the production of radios. Hettler ceased trying to give all his various factories, workshops and warehouses separate names: he simply numbered them. Wernerwerk 1 was the old building, which had provided the name for all the rest. Wernerwerk 2 was the Measuring Instrument Works and so on.

In 1930 he had reached Wernerwerk 16 in this way, this being a factory for dry elements, also situated in Spandau. In the same year, about 29,000 people were employed in this group, among them about 7,000 technical and office staff. Approximately 60,000 people were employed in Siemensstadt at that time.

One of these buildings, the Wernerwerk X, later known as Wernerwerk Hochbau, was not a factory but basically the new administrative centre of Siemens & Halske. The Chairman of the Board of Directors, together with his staff, had his offices here, together with the sales departments for communications engineering, which were originally seated in the old Wernerwerk F, and part of their most important laboratories, the design offices, the commercial administration, a restaurant for the employees in the basement, which also served the neighbouring works, and a large lecture hall in the top storey. Although the interior was fitted and decorated in a very severe style, there were a number of guest and conference rooms in which the architect—in excellent taste—had made it clear to visitors that the owners had placed liberal funds at his disposal. Of course the technical fittings, such as the water supply, fire precautions, heating, air-conditioning, lighting, lifts, telegraphs and telephones, pneumatic tubes, kitchen equipment and lecture rooms, were all of the latest design, and on studying these details the observer cannot help noticing that in contrast to the great monuments of the past, the princely palaces and the town halls, a large part of the material and mental effort is nowadays spent on the technical fittings of the interior.

The exterior of the building was markedly simple in style, completely lacking in ornament and shadow effects on the broad surfaces of the walls, and only the formation and arrangement of the masses gave an impression of purposeful design. Four tracts of unequal length and height surrounded the courtyard. A truncated tower rose up from one of the inside corners, at the top of which the machines for the main lift were installed. The dimensions of the building were naturally well proportioned, being exactly derived from the dimensions of the neighbouring street and buildings with due regard to sunlight and the artistic effect, but the building gave the impartial observer the impression of a cyclops castle, irregularly constructed from cubic blocks piled up by giant hands on top of one another to a height of eleven storeys, stern and severe in appearance, forbidding and sober. "An expression of the spirit of the times," the papers wrote, and the phrase went from mouth to mouth.

Was this era really so sober and objective? Oh, if only it had been!

XXIX.

ECONOMICS AS A MISSION

The Reich Decrees of the 28th December, 1923 and 28th March, 1924 concerning gold balances, made it necessary for Siemens & Halske to emerge from the financial chaos of the inflation period as well, and to bring the share capital into line. It will be remembered that the capital had been fixed at the time of the foundation of the Siemens-Rheinelbe-Schuckert-Union at 130 million Marks in ordinary shares, and the same amount in preference shares. The latter still lay in the safes of the other firms which belonged to the combine. As all this dated from the pre-inflation period, the nominal value of the shares was now written down—the preference by 95% and the ordinary by 30%. The ordinary share capital therefore amounted to 91 million Marks and the preference share capital to 6.5 million Marks, making a total capital of 97,5 million Marks.

The outstanding debenture debt of Siemens & Halske and Siemens-Schuckert had been reduced, in spite of the higher valuation decreed by law, to a total of approx. 21 million Marks, and thus no longer represented a burden of any size for the Firm. On the other hand, the need for investment capital had increased enormously as a result of the rebuilding undertaken during the post-war period, but money was hardly to be obtained at all in the first months of the Reichsmark in Germany. Instead, it was sought from America. Haller got in touch with the New York bankers Dillon Read & Co., who, in contrast to the other large banking houses associated with the Allies during the war, intended to devote themselves to business with Germany, and obtained from them early in 1925 a loan of 5 mill. Dollars for three years and a second loan to the same amount for ten years for Siemens & Halske and Siemens-Schuckert. Interest at the rate of 7% was to be paid on the two loans and certain stocks had to be pledged. By all standards common hitherto, that was a lot to pay for money.

More of it was soon needed, not only for the extension of the factories at home, but also for the big international deals. Sums running into several millions had to be advanced for the electrification of Ireland, and the appearance of Behn in the telephone business and the growing struggle for the foreign concessions called for the accumulation of considerable sums. In the meantime the Deutsche Bank had also entered the international credit business again and had entered into an obligation with Dillon, Read & Co., on behalf of the House of Siemens, which in the autumn of 1926 led to the granting of a further debenture loan to Siemens & Halske and Siemens-Schuckert. This consisted of a sum of 24 mill. Dollars in American currency and another of 25 mill. Reichsmarks in German currency, both over a period of 25 years and with interest payable at 6½%. Haller had made the deal palatable for the financiers by means of a special additional interest—a total of 130 mill. Marks was involved, which the Reich would certainly never have obtained on the free market. According to the terms of the agreement, the creditor received, in addition to the fixed interest of 6½%, an interest bonus of ⅓% for each percent of the dividends of the two debtor companies above 7%. In the business year 1926/7, then, the dividends of Siemens & Halske amounted to 12% and those of Siemens-Schuckert to 9%, averaging 10½%, so that the debenture creditor received a bonus of over 1%. The idea was original and tempted the speculative Americans. They saw a security with a fixed rate attached to the shares as long as they rose. If the cart started slipping backwards, the trailer was detached at a certain point. The money was dear for the debtor, but only as long as he earned well—incidentally, one paid 10% and more for bank credits in Germany at that time, depending on the nature of the case. With the money thus obtained, the original loan of 5 mill. Dollars taken up in 1925 for three years was paid back to start with.

The new loan necessitated a change in the organization of Siemens-Schuckert, although only an external one. The Firm had been registered since its foundation in 1903 as a G.m.b.H. (Limited liability Company). This form had been chosen at the time because the company only consisted of two partners—the Siemens & Halske A.G. and the Elektrizitäts A.G. vorm. Schuckert & Co., and a number of formalities laid down in the Companies Act could be avoided in this way. However, in order to make use of the American credit market, the style would have to be changed, as this form of company was unknown in America and did not comply with the strict regulations either. The Siemens-Schuckertwerke were therefore re-registered as a Joint Stock Company in 1926, with a capital of 120 mill. Reichsmarks, consisting of 90 mill. bearer shares and 30 mill. registered shares. The shares were all held by the two partner firms, i.e., were not traded on the Stock Exchange.

At the Annual General Meeting of Siemens & Halske on 26. 1. 1929, the

Board of Directors surprised the share holders with the proposal to raise the capital of the company by 14 mill. Reichsmarks. The entire sum was not to be issued at once, as it was intended to use the new shares initially to participate in two companies to which it was desirable to have more close connections, and the Board of Directors and the Board of Managers were accordingly empowered, on their proposal, to issue only such portion of the total sum as was necessary for the purpose. The first of these firms was the Elektrische Licht und Kraftanlagen A.G. which has already figured in this work as a joint foundation of Siemens & Halske and the Deutsche Bank, a trust company of the old style from the year 1897 with which connections had become rather loose over the years. In order to draw the ties closer again, Siemens & Halske acquired from Light and Power, as it was known on the Stock Exchange, shares to the value of 7,500,000 Reichsmarks in exchange for shares of their own to the value of 5,000,000 Reichsmarks. To the same end 4,589,900 Reichsmarks of shares were exchanged for £ 450,000 of ordinary shares of Siemens Bros. London, thus gaining an interest on a mutual basis in the one-time sister firm, which had been lost to the House as a result of the war. It was now a purely British concern and played a not unimportant role in the home market and in international telegraph and telephone business, and Siemens & Halske therefore believed that by the simultaneous conclusion of an agreement concerning the exchange of patents and details of production methods, they would find in her an ally in the struggle against the American firms. Dr. H. Wright, the Managing Director of Siemens Brothers, then took his seat on the Board of Directors of Siemens & Halske.

New shares to the total value of 9,590,000 Reichsmarks were needed for these two transactions, and in raising the capital anew it was agreed that the share capital should now stand at 100,590,000 Reichsmarks ordinary shares and 6,500,000 Reichsmarks preference shares, totalling 107,090,000 Reichsmarks in all.

The further development of the principle of "Participation debentures", tried out for the first time in 1926, which also marked the end of the financial reorganization in the House of Siemens, was represented by a further loan, likewise from Dillon, Read & Co. in conjunction with the Deutsche Bank, but this time only for Siemens & Halske, to the value of 14 million Dollars and 10 million Reichsmarks, the conditions of which can be considered unique in the history of German finance. The loan ran until the year 2930—it is ludicrous to speak of a business connection lasting a thousand years, but this was occasioned by an American regulation which dictates that all such agreements must have a final date of expiry—and could not be terminated by the creditors before the year 2005, in other words, to all intents and purposes it was interminable. Interest was payable to the value of the dividend of the original shares, 6% being the minimum. The resemblance of these debentures to the shares was made even clearer by the condition that the owners of the fractional bonds should be granted the same privileges as the share holders, should the latter obtain subscription rights or bonus shares on the occasion of an increase of the capital. In other words, these debentures differed from the shares only inasmuch as the minimum interest rate was fixed, and they were safer than the other shares in the event of the undertaking suffering any serious financial setback. Only one thing was lacking—the right to vote.

A large part of the participation debentures were sold by Dillon, Read & Co. to the General Electric Co. in accordance with an agreement made beforehand, which was perfectly in order as far as Siemens & Halske was concerned. As long as they were in such powerful hands, they could not float around on the Stock Exchange and be misused by speculative elements to create fluctuations in the price, which might have unpleasant results. The General Electric Co. could only be considered as a competitor in a very restricted sense and there was no harm in their being interested in the prosperity of Siemens & Halske. The remainder of the debentures were offered on the New York and Amsterdam Stock Exchanges at the rates of 233.5 and 236% of the nominal value.

It was due to the chaos prevailing at that time that the thousand year loan did not live up to expectations. Although Siemens & Halske still paid out a dividend of 14% for the business year 1929/30, "Having regard for the new loan creditors," as it was formulated in the Annual Report, the rate fell rapidly under the pressure of the world slump, which had now supervened, and when a moratorium was issued in Germany for the transfer of interest abroad in foreign currency, the prospects for the creditors became gloomy in the extreme. Further developments will be described at a later stage.

In view of the fact that Germany, seen as a national economy, was the strongest nation competing with America in the struggle for the electrotechnical market, it is peculiar in many respects that the largest German electrotechnical undertaking should receive such financial assistance from America. For if one expresses the electrotechnical world in figures, the United States took the first place and Germany the second, whilst all other countries belonged to the "also rans . . ." The total production of electrotechnical goods amounted, according to estimates, to a value of 7.1 milliard Reichsmarks in the United States, and 2.7 milliard

Reichsmarks in Germany. On the other hand, Germany's export of electrotechnical products amounted to 536 mill. Reichsmarks, or approx. 20% of the production, (compared with 331 mill. in 1913) whereas the American figure was 448,4 mill. Reichsmarks, or 6.8% of the production. The enormous home market, protected against the outside world by the high protective tariffs, absorbed practically the entire production. Thus it came about that Germany led all other countries in the export of electrotechnical products.

According to the annual report for the year 1928/9, the turnover of Siemens & Halske was 300 mill. Reichsmarks and that of Siemens-Schuckert 550 mill. Reichsmarks, whereby in both cases the daughter companies completely under the control of the parent companies were included in these figures. That makes a total of 850 mill. Reichsmarks. The American prospectus for the thousand year loan, on the other hand, quoted the figure for the turnover as 935 mill. Reichsmarks, or 225 mill. Dollars. No doubt this figure was meant to include the undertakings which were controlled by virtue of possessing a majority of their shares. Reckoning with only 900 mill. Reichsmarks, this shows that one third of the German electrotechnical production came from the House of Siemens. Over 100 large, medium and small firms accounted together for the other two thirds. About 30% of the production of the House of Siemens went abroad.

A total of 355,000 persons were employed in the German electrotechnical industry; 131,000 wer engaged in the House of Siemens alone, 108,000 of them in Germany. This meant that the share of the production, over the average of the Reich, amounted to 7,500 Reichsmarks per head, with a figure for Siemens of 6,900 marks. This shows how strongly the staff was permeated with workers whose work was non-productive, i.e., research, development, and integration of new production methods. One has only to think of the work described in the preceding chapter to realize the amount of personnel required for all these projects. Many other firms, large ones too, restricted themselves to running production, which they modified from time to time after others had broken the ice for them.

The ratio of the number of technical and office staff to the number of workmen in this respect was characteristic of the situation in the House of Siemens. There were 26,569 workmen as against 10,789 office staff in the German departments of Siemens & Halske, or a ratio of 2.5 to 1. The corresponding figures for Siemens-Schuckert were 42,798 and 16,401 or 2.6 to 1.

If an undertaking of this size has such a large number of white-collar employees, it clearly plays a different rôle in the community from the firm employing the same number of staff, most of whom are engaged on manual labour, as is the case with most undertakings in the mining industry. It has therefore been said in fun that the professors employed with Siemens could start up a Technical High School on their own.

In addition to the research workers, inventors and designers who gained the House this reputation, there was another group of people at Siemens who had devoted their lives to the workshop and, although they had no high academic titles, had raised the level of the work on which they were employed to that of a science, although they may not have been aware of it at the time. The first signs of this development became evident before the outbreak of the war, but the forces of the conservative-minded opposition did not allow the developments to mature until the war broke out, when it became absolutely essential to manufacture identical parts in large quantities in a number of different works, using for the most part unskilled labour. At the end of 1917, the "Standards Committee of the German Industry" was formed and set itself the task of restoring order in the vast variety of basic components used in the German industry, from shaft diameters to screw lengths and the size of the various sheets of paper, by standardizing sizes after careful consultation with all concerned. This was the first condition for economic production. After the war, when similar efforts were observed in other countries and it was seen, in the course of numerous journeys to the United States for the purpose of studying such matters, how successful the drive for scientific management had already been, a powerful trend developed in the German industry, inasmuch as it lay within the power of the engineers to initiate such developments, the aims of which can best be characterized by the slogan "rationalization." Characteristic of the impression obtained by German engineers in the course of their numerous study travels in the United States, the land of unlimited economic possibilities, was Köttgen's book "Economic America," which appeared in 1925 and has frequently been quoted. Rationalization has to commence in the design stage, and this can only be achieved if the designers endeavour to exploit to the full the improved quality of the production materials and try to produce a large variety of different models from a relatively small number of standardized components. Finally, design has to adapt itself to the production, and not vice versa, as was frequently the case earlier on. If all these principles are carefully observed, it is possible to continually decrease the cost of material needed for a particular product. In a lecture held before the Association of German Electrotechnicians in 1937, Köttgen illustrated to the experts in a drastic manner the achievements that had been made in this field in the course of the years. The weight of a three-phase-current oil transformer for 100 kva was 3,400 kgs in 1900, whereas it had dropped by 1937 to 800 kgs, and its price only totalled 22% of the original price. A three-phase-current cable for 10,000 v weighed 16 kgs per metre in the year 1910, but only half as much in 1937. Motors, meters, measuring instruments, telephones, but also large machines too, everything had not only become better but also much lighter, smaller and thus for the most part cheaper. "Mind overcomes matter," cried Benkert in his enthusiastic manner during a lecture on the subject.

In production, on the other hand, rationalization generally means economizing with human labour. The production process is steadily broken down into an ever increasing number of partial processes, and these are simplified by the invention of suitable tools and equipment to such an extent that the components involved can be mass-produced by unskilled workers in the shortest possible time and without any adverse effect on the quality. Where this results in an ever-recurring series of quite simple manipulations, the question arises as to whether this work could not be carried out by machines too. The decision here depends on the cost of investing in such machinery, and this cost must be weighed up against the volume of production and the probable duration of the applicability of the process. The first thing to be mechanized is generally transport.

The length of each individual process is naturally of fundamental importance in all such deliberations. This now had to be measured with the stop watch. The "Reich Trusteeship for Rationalization in Industry and Handicraft," founded shortly after the war, therefore created a "Committee for Economic Production" which in turn set up the "Reich Committee for Work Time Research" (Refa). Here was an enthusiastic and successful attempt to set the very controversial question of time studies on a sound basis, and the factories were recommended to carry out their time studies only along the lines indicated by the Refa.

The time study must be supplemented by the study of labour. This proceeds from the observation that a machine has a beat, whereas a human being has a rhythm, and that beat and rhythm are fundamentally different. The human rhythm is a very complicated biological process, which it is very difficult to follow with measuring instruments and which can only be described qualitatively, especially in view of the fact that every individual has a different rhythm. However, these individuals can be classified under different types and certain rules set up for their behaviour, in order to find out the probable labour requirements for a particular piece of work on the basis of the valid time studies.

These deliberations already lead us into the borderline territory between the physiology and psychology of work. The exploration of this territory is of fundamental importance for the atmosphere in the factory and interested the open-minded and lively Benkert to a high degree. After 6 years of fruitful work in Sörnewitz, he became Director of the "Kleinbauwerk" and 4 years later took over the management of the Electromotor Works, which was situated nearby and was a branch bordering on his own. Here he devoted himself, together with his pupils—every true master has pupils—to all those problems outlined above concerning rationalization and leadership with the whole force of his personality.

Thus Benkert, as the real initiator of the new spirit, introduced new conceptions into the factories, for which the rising National Socialist movement coined slogans such as "factory community," "staff loyalty," and "work ethics." The fact that Benkert later used this National Socialist phraseology more often than was actually necessary does not alter the fact that he was an idealist of the purest die who, in spite of the successful progress made by rationalization, staunchly resisted the subjugation of the human being by the machine.

His counterpart in Siemens & Halske was of quite a different stamp. After the Wernerwerk, originally a compact unit, had been divided up into a large number of more or less independent works by constant redistribution of the various processes and the addition of new factory buildings, Siemens & Halske finally instituted a sort of central factory administration on the style of the Siemens-Schuckert administration and termed it "Factory Management of Wernerwerk F." The Wernerwerk M continued to maintain an independent position as far as production was concerned for a number of years, until it was finally drawn into the "General Factory Management of the Wernerwerk." Successor to Alfred Hettler, the meritorious creator of rational production in the Firm of Siemens & Halske, in this Management was Gustav Leifer.

In contrast to Benkert and Hettler, who were both engineers by profession, Leifer rose from the workshop, where he had started as one of the most industrious representatives of the Berlin metal workers, to finally become a member of the Board of Directors of his Firm. He considered it wrong to supplant the schooled specialized worker by unskilled labour, simply by making the former redundant through over-emphasis on mechanization, especially as they were needed to instruct the rising generation. For this reason he took a particular interest in the training of apprentices and the "Specialist School for Precision Mechanics" founded on the initiative of Francke in 1922. This association, in conjunction with the city of Berlin, had founded the Gauss School, a technical secondary school with a marked preference for precision mechanics and electrotechnics, in the

Supervisory Board of which Siemens & Halske, represented by Franke and later by Leifer, had a predominating influence. The Firm assisted the school in every way and sent a number of their best apprentices there every year for further training, the cost of which was covered by scholarships. In contrast to the idealistic enthusiasm of Benkert, Leifer displayed a sober, often tedious nature and his subordinates had a hard time to satisfy him, especially as there was nothing they could teach him about factory methods and the like, as he was well versed in all such matters. One day a foreman showed his neighbour an innovation in production methods which he had thought out himself and of which he was especially proud, asking at the same time for the latter's opinion. After thinking for a moment the latter said, "Watch out that old Gustav doesn't see it!" The idea of rationalizing the industrial process had originated among the engineers, it is true, but when it began to spread throughout Germany in the years after the first World War, inspired by the American example, it was also taken up by those sections of the staff who, under the name of commercial employees, a term which was now no longer quite fitting, had so far been looked on as more than modest helpers in the whole process, particularly in the House of Siemens, but who now acquired fresh importance with the development of scientific industrial management.

Earlier on, in describing how the so-called Traffic Depts. of Siemens-Schuckert were built up before the war, it was mentioned that this division according to fields of activity—Central Offices Dept., Industry Dept. and so on—and the further sub-division of these departments was carried out so as to obtain a better overall picture of the financial results of the individual links in the chain. For this reason they were originally termed Balancing Depts., and the Works were also made quite independent in the same manner for purpose of accounting. This enabled the Management to assess the scale of importance to the House of each individual unit, and further, to set it a new target to be reached if possible during the coming year. In a corresponding manner, a series of further performance figures could be obtained, the final aim being to establish a reliable relationship between the costs and results.

That was where the difficulties began. These can best be understood if one has some idea of the method of accounting used in small machine factories towards the end of the last century.

In order to calculate the prime costs of a product in those days, either in the preliminary calculation made before production started as basis for the offer, or in the subsequent calculation made to determine the actual cost of production, the value of the materials required was first set down, then the productive wages for the processing of the same, and to this were added the overhead expenses in the form of a fixed factor. These comprised, or were supposed to comprise, all other costs which had proportionally accrued during the production process, starting with the interest and depreciation sums for the production means, and passing by way of the power costs, heating and light to the Director's, bookkeeper's and nightwatchman's salaries, not to mention travelling allowances, postages, paper and so on. As it was believed to be impossible to calculate this factor for each separate unit, they simply calculated the ratio of the total expenses to the total wages; if the total expenses were approx. 1.2 times as high as the wage sum, the expenses surcharge was 120%.

This method of calculating became more misleading, the more the production process was broken down and distributed over the factory. For if certain products occasioned particular expenditure over and above the production costs in the limited sense of the term, such as development, long tests, storage, special advertising measures and so forth, whereas this was not necessary at all or only to a limited extent in other cases, this would naturally contribute more than other factors to the expenses in general. The overhead therefore favoured these products at the expense of others, which it burdened unduly. Thus, when the factories increased in size and number, the number of development projects in the laboratories and design offices rose and the welfare expenditure was extended, in short, all expenditure over and above the actual production costs increased, a complete overhaul of the methods of accounting in the House of Siemens became increasingly urgent.

It was a lucky coincidence that in those times, filled as they were with a strong desire to create a new order of things, a group of young assistants were employed at Siemens in the post war years to whom the expression "commercial employee" formerly used could no longer be applied, as their training had not been restricted to an apprenticeship in the usual sense of that time; they had been imbued at the universities and commercial colleges with new ideas. After they had learned, in the course of several years of practical work, how industrial management really functioned and what shortcomings were inherent in the accounting methods of those days, they started on their own initiative to press on into new territory and develop new methods.

The root of the problem was evidently the distribution of those costs which did not fall to any one definite expenditure account but were left suspended in mid-air, as it were, as "expenses." They were re-christened "general expenses" at first, thus avoiding the unpleasant flavour attached to this word which tended to act as a psychological barrier to their distribution. Then they were classified according to two points of view. On the one hand, accounts were opened for productive and non-productive departments, the one to cover certain fields of work, the other being concerned with the various offices and their staffs. On the other hand, the different types of expenses were broken down increasingly until finally there were hundreds of types of expenses and likewise hundreds of accounts. The task then became one of debiting the right type of expense to the right account and of calculating with the aid of an individually determined performance key the expenses for the respective department and debiting them either to another department or to the various expense accounts.

If one had tried to make these calculations in the manner customary up to that time, such a large number of persons would have been required that the additional expense would have far outweighed the desired improvements, apart from the fact that the results would not have become apparent until it was much too late. But in the meantime, office machines had been perfected to a very high degree. The time-honoured calculating machines had now given way to the accounting machine, and the punched card machines developed in the United States had finally been introduced into Germany, where they were sold or rented out by the German Hollerith Machine Co. and the German Remington-Powers Punched Card Co. The Siemens Works concluded an agreement with the latter, in order to be able to introduce the machines into their own factories on a broad basis and to adapt them if necessary to their own special requirements. As is well known, cards are used in these machines for recording certain data expressed in the form of figures, whereby the details are registered by means of combinations of holes punched in the card. When the card is passed through the machine, feelers scan the holes and control all further procedure. In this manner, the cards can be sorted according to certain requirements, the details summarized and the results listed accordingly. The machines can also be connected up with the usual office machines, so that on writing out an invoice, details of statistical importance may be simultaneously registered by a punched card.

With the aid of these machines it was now possible to compile production and performance statistics covering all important operations and procedures and to produce any information required immediately. It was particularly important that this should be available whenever required, for what is the use of a check if the results are not available until months later? An accurate calculation of the prime costs is the most important factor. If a factory had been operating uneconomically in the past, everyone began to look for the squander-bug, and the departments "passed the buck" to one another with great dexterity. The culprit was now quickly found, and the Works Management had plenty of time to decide what was to be done about it. Of course it is possible, for example, if the market dictates a price which is below the prime costs, to decide to continue production in spite of this—there may well be very good reasons for such a decision. But at least one knows right from the very beginning that one is losing on the deal and to what extent, and it only remains to decide how long this policy is to be followed. The new systems of accounting therefore gave the Works Management a reliable insight into certain matters, without which the increasingly complicated nature of the procedure would no longer have been surveyable.

The improvements in the accounting methods were of particular importance for the works outside Berlin and the offices at home and abroad. For although these had been made independent to a great extent, they were still so closely connected with the parent House—a characteristic of the House of Siemens—that they had to be run along the same lines. It is therefore necessary to go into their development more closely, particularly that of the offices in their role as sales organizations.

Robert Maass, the meritorious creator of this organization, retired in 1918. The younger members of the sales departments of Siemens-Schuckert considered the methods in use to be out of date and clamoured for reforms, whereupon Dr. Ludwig von Winterfeld was appointed as successor to Maass. Connected with the Siemens family by ties of relationship, he had already seen service in the Firm before the outbreak of the war. First of all, only the branch offices of Siemens-Schuckert in Germany were placed under his jurisdiction, whereas the European offices were to remain under the management of Hermann Reyss, the Head of the technical section of the Overseas Department, who had held this position since 1910. As it was not yet possible at the end of the war to determine how much of the foreign organization would have to be built up again, it was considered better to leave the reins in one hand to start with. However, after affairs abroad had settled down somewhat it was possible in Berlin to gain some idea of the possibilities, the larger part of the European offices were detached from the Overseas Department and placed under the management of von Winterfeld.

The reorganization and reconstruction of the overseas trade of Siemens-Schuckert proceeded at a quicker pace than one had dared to hope. Five years after the end of the war, the volume of orders equalled that of the year 1913, although the British Dominions and Colonies had only just been made accessible for German trade again. Central and South America and Eastern Asia now formed the centres of trade. The rapid flow of capital from the United States made itself especially noticeable in Latin America, which was not solely to the advantage of the industry of the country of its origin, although this was of course the main aim. The competition of North America on the overseas markets presented the House of Siemens with a great number of difficulties, not so much as a matter of price but of delivery dates, which in many cases amounted to half or a third of the German delivery times. In Eastern Asia, in Japan, Korea, Manchuria and China, the rapid expansion of Japanese industry was the mainspring of that country's economic progress, behind which lay the political ambitions of the Empire. Thus it was that, long before the first World War, the Siemens-Schuckert Denki Kabushiki Kaisha was founded in Tokio and became one of the most important representatives of the House overseas.

After the war, the General Electric Co., the Westinghouse Electric and Manufacturing Co. and the Western Electric Co. had established relations with large Japanese firms, and it was clear that if the House of Siemens was to maintain its position in Japan, it would have to ally itself to one of the large industrial concerns there too. Such an ally was found in the Furakawa Denki Kogyo K. K., which also owned copper mines and manufactured cable and wire of all kinds in vast quantities. Siemens-Schuckert concluded an agreement with this firm in Autumn 1923, which led to the foundation of the Fusi Denki Seizo K. K. The House of Siemens participated in this with 30% of the shares, the Furakawa with 45% and the remaining 25% were held by foreign share holders, mostly Japanese. Under the management and direction of the Siemens-Schuckertwerke, the Fusi built a fine factory in Kawasaki, between Tokyo and Yokohama, the managing personnel of which consisted for the most part of Germans, and which manufactured machines, transformers, switching equipment and measuring instruments. From now onwards only special designs were to be supplied from Germany. The factory for telephone equipment, which was built by the Fusi in a similar manner two years later, has already been described.

In the year 1913, Germany led the world in the export of electrotechnical goods. From 1925 to the beginning of the second World War it maintained this place again, admittedly with the difference that the United States had almost drawn level. In 1936, Germany with 26.6%, the United States with 25.3%, Great Britain with 19.8% and Holland with 7.5% together accounted for 79.2% of the export of electrotechnical products in the world. All the other countries together made up the other fifth. The United States' share had been smaller before the war—they had held third place behind Great Britain—but from then onwards her powerful electrotechnical industry had paid ever increasing attention to the export trade and it thus became increasingly difficult for the other countries to make any headway against such competition.

In the Siemens-Schuckert Works it was realized very strongly that Germany was completely separated from the rest of the world during the war. This feeling of being cut off from technical developments in other parts of the world was the main reason for the numerous trips made by German engineers and industrialists to the United States after the war. Here they frequently encountered the wish of American firms to cooperate more closely with the Germans, and so it came about that when Reyss visited the United States in 1922, feelers were put out to the Westinghouse Electric and Manufacturing Co. by the Siemens-Schuckertwerke, which resulted two years later in an agreement concerning the regular exchange of patents and details of production methods.

After this, each of the partners kept an "ambassador" in the other firm, whose task it was to maintain the personal contact between the two and act as medium for the exchange of information. Westinghouse was, admittedly, only the second largest enterprise in the American electrotechnical industry—the largest was the General Electric Co.—but the firm enjoyed the reputation of being a particularly enterprising pionier and Siemens-Schuckert have never regretted the connection, which lasted until the outbreak of the second World War.

The reorganization of the German offices of Siemens-Schuckert demanded by the Traffic Depts. started with the calculation of prime costs. In contrast to the factories, they could not afford to let any part of the expenses go unheeded and the tracing of errors in the accounts, which had previously taken up so much time, was now no longer necessary. Stock-keeping and book-keeping were reorganized, the current account was transferred from the enormous ledgers of grandfather's day to the "Definitive" method of accountancy, as in the parent firm, on paper account sheets with carbon copies, labour-saving accounting machines were installed and the entire procedure so carefully summarized in regulations that positive instruction manuals came into existence, which have since become models for many other German firms. This reorganization of the accounting and invoicing system was of particular importance in such a wide-spread business because there was a grave risk that material or ideal values might become lost in any of the almost 100 more or less independent offices.

Hand in hand with all this, the technical personnel were trained to be more systematic in their advertising work, assisted as they were in many different ways, in particular by a very efficient filing system; to plan their journeys intelligently; and to carefully supervise all installation work, which in itself is very difficult to rationalize. In addition, there was the training and systematic employment of the travelling salesmen, whose task it was to sell the numerous articles for daily use, which was the field of the Small Accessories Dept. Special exhibition rooms were equipped for these products in the larger offices, in which the equipment was demonstrated to the public.

As the personnel employed in the large offices were counted by the hundred, and warehouses, car parks, exhibition rooms and repair workshops alone accounted for quite a considerable amount of space, it soon came about that premises had to be specially bought or built where hitherto accommodations had had to be rented. Many of these buildings belonged to the most representative office buildings of the city which they were situated, both at home and overseas.

In contrast to the rejuvenation and reorganization of the branch offices of Siemens-Schuckert, those of the sister firm Siemens & Halske had somewhat fallen behind the general development as regards organization, although the volume of trade rose rapidly from year to year. The Telegraph Dept. had brought all manner of new products onto the market, the private branch exchanges in telephony had rapidly become popular, electrical measuring instruments had been supplemented by those designed for use in the conservation of heat, the radio business had been added, the entire clientele had increased enormously in size. But the Central Branches Office was very careful to ward off the approaches of von Winterfeld and guarded their independence jealously. Whatever might be allright for Siemens-Schuckert was not necessarily allright for their business. Now for Carl Friedrich von Siemens there was only one House, and he therefore considered it an important duty to put an end to the bickering between these opposing parties and to induce his employees to work together in harmony. Wherever it was possible for the business of the branches involved to be settled by one common department, he chose this solution in spite of the opposition of those who felt themselves placed at a disadvantage. He was therefore of one mind with von Winterfeld in wishing to coordinate the branch offices of the two sister firms as far as possible, though it was not in his nature to accomplish this by force.

One day—about the end of 1924—an official of the criminal police in Berlin brought the attention of the Firm to the fact that the cashier of their branch office in Berlin was a regular attendant at race courses and other places where large sums of money changed hands. A thorough check of the books carried out immediately disclosed nothing to compromise him in any way. It was not until some time later that he was finally indicted and it transpired that 135,000 Reichsmarks had been embezzled. The judge at the trial agreed wholly with the speech for the defence, which claimed that the completely inadequate cash system and accounting methods of the Firm of Siemens & Halske had made it all too easy for the cashier to embezzle such large sums of money.

Carl Friedrich von Siemens, who was always careful to spare other people's feelings, first instructed the Central Branches Office, which had been shown up so badly, to put their house in order as quickly as possible, but after the responsible people had been running round in circles for a year and a half, he had to admit that they were unequal to the task and called in von Winterfeld, who had meanwhile been appointed a member of the Board of Directors of Siemens-Schuckert, to reorganize the Central Office and its branch offices. Soon after he appointed him to the Board of Directors of Siemens & Halske so as to create a closer bond between the two firms, a method which he had already used with great success in questions involving finance and personnel. The branches of Siemens & Halske were then completely harmonized with those of their sister firm as regards organization and in most cases—there were only three exceptions, namely the three largest branch offices—the commercial administration of the two firms was combined. Formally, two separate agencies had to remain, as legally they were acting for two separate persons. In order not to let the people in Siemens & Halske feel that they had come under the control of the younger partner in the course of this reorganization, the new office was situated in the Wernerwerk under the leadership of von Winterfeld.

The training of the young technical and commercial employees likewise fell within the scope of von Winterfeld's office. It was mentioned earlier that young graduate engineers as well as those who had passed out of the technical secondary schools, were first put through several departments, so as to prevent them from specializing too soon and in order to see whether they had any particular capabilities. Nevertheless it still proved difficult to watch and train the gifted ones so that they derived the maximum benefit from the training.

If professional training is to be given in a large firm, there is really only one way of setting about it—by starting a school. School in this case means that the trainees taken on in the course of the year formed a group or class, which was always called together for instruction, so that the instructors could keep an eye on their development, although they may for a while have been scattered throughout the various works to gain experience. This method had already been used in Siemens & Halske for the training of apprentices, as has already been mentioned earlier on, and the same policy was now followed in training the new commercial employees. Young people, mostly just after passing the matriculation exam, were trained in all branches of commercial management in a two year course, which covered instruction and practical experience in the offices. Later on, the first six months of the course had to be spent in actual manual work in the factory together with the apprentices, so that they could acquire a "handicraft sense". The results of this commercial training course were just as convincing as those of the apprentice training scheme had been.

An educational and organizational problem of a special kind arose after the war, when numerous professional officers were no longer able to follow their calling and were obliged to find a profession in civilian life. The larger part of the officers, whose number had risen enormously during the war, could not be accommodated in the army of 100,000 men which the Republic was permitted to retain after the war, and many of the young and adaptable ones amongst them accordingly sought positions in commercial life, whereby they showed a preference for large undertaking, which were naturally in a better position than the small ones to bear the expense of their employment. Thus a large number applied to Siemens & Halske with the request for employment in administrative and commercial posts, and C. F. von Siemens considered it a nobile officium of his Firm to provide them with the possibility of starting afresh after they had lost their former positions through no fault of their own.

Naturally there was opposition to be overcome, most of which arose from a feeling of resentment fanned by politically radical circles, and numerous other hurdles to be taken. The opponents spoke of militarists who were best employed on earthworks, so that they should learn the meaning of work.

Now there is a difference between being a soldier and being a militarist, for if militarism is considered to be a certain outlook which strives to achieve its own ends by force, regardless of right or wrong, then there are a number of militarists who have never seen a uniform in their lives. Admittedly, the soldier is more exposed to the temptations of militarism, but there are professions in which the temptations of conceit are no less dangerous, such as in the case of famous scholars and celebrated artists, and it would be most unjust to condemn them all from the start as conceited. It depends on the character of the individual as to whether he succumbs to the particular malady to which his profession is prone. The same is true of the soldier.

Siemens did not give the former soldiers an easy time. They were set to work at the bottom of the ladder and kept busy. They were treated in the same way as any one else in the Firm, as had always been the case. Those who were efficient and intelligent were advanced, although at times slowly, and the others remained where they were. Many of them soon noticed that their expectations of rapid promotion would not be fulfilled here and went on their way. The real militarists among them were soon swept away by the dark eddies of the post-war period to a society where the gospel of force was preached. Those who stayed and worked hard rose, either slowly or rapidly according to their capabilities, to responsible positions, some of them even to the highest levels, especially if they displayed noble sentiment, an open mind and a sound character.

Numerous sociological problems cropped up on all sides after the war: wage and salary claims, collective bargaining, social insurance, representation of the employees, occupations for war invalids, welfare organization and numerous other problems, and C. F. von Siemens was therefore of the opinion that these matters, which had hitherto been handled together with other economic problems by the Economics Dept., should henceforth be dealt with by a special group. He therefore detached them from the Economics Dept. and formed the Sociological Dept. to cope with them. In addition to this, the Personnel Office had been founded in 1919, the difference between the two offices being that the first of them dealt with general questions arising from the production factor "human labour" whilst the second was concerned with the individual case. Naturally each Works had its own Personnel Dept. in which all the administrative work concerning the personnel was handled, but it was necessary to have a central office to ensure equality of treatment, in addition to which it was essential to have a higher centre of appeal, especially as every worker had the right by unwritten law to appeal to the Head of the House if he felt that he was being treated unfairly. The Personnel Office also kept the files on the leading officials. This office was under the leadership of Hermann Görz, who had previously been Head of the Siemens Works in Russia and who, after the end of the war and the expropriation of the Firm's Russian property, found a position which was predestined for his distinguished and righteous nature. When Görz died in 1930, Carl Friedrich combined the Sociological Dept. and the Personnel Dept. under the management of a member of the Boards of Directors of both Siemens & Halske and Siemens-Schuckert, thus putting the responsibility for the administration and care of the entire human labour force of the House —far exceeding 100,000 men—into one hand. For this post he chose one of the previously mentioned former professional soldiers, Dr. Wolf Dietrich von Witzleben, who had been employed since the war in the Sociological Dept.

The second half of the '20's, which have been described here in some detail, thus brought a host of new technical problems, an expansion of business that was at times almost tempestuous, the building of further factories, as well as reorganization and amalgamations. The number of people working in Siemensstadt rose from year to year by thousands, the residential quarters spread out almost from day to day and a building policy, whereby the firm supplied land or mortgages from its own resources, was put into practice. A closed settlement of urban character with bright and well ventilated blocks of flats, built in the unpretentious style of the time and heated in winter by a remote heating plant, spread to the North of the main highway into the Jungfernheide, and to the North-West one and two-family houses surrounded by gardens bordered on to this settlement and extended to the Hohenzollern Canal. Scattered between them were parks with public buildings, among them two churches—all in all they had broken with the large gloomy tenement houses of the old style. In 1930, 15,000 people already lived in Siemensstadt.

This and the steady increase in the number of workers and employees, gave rise to traffic problems between the city and Siemensstadt that were almost frightening. From the point of view of traffic, the suburban station of Jungfernheide was the city boundary of Berlin. From this point a highway led to Siemensstadt and Gartenfeld, which was situated further away, along which the only means of transport were trams and omnibuses. Although the working hours in the various factories in Siemensstadt were for the most part staggered and the transport companies put on every available vehicle at the main traffic hours, they could not cope with the enormous crowds of people during the rush hours and many of the female employees gave up their jobs with Siemens due to the risk of ruining their clothes on the way to or from work. After long negotiations the Directors of the City Railway declared their readiness to build a branch line, starting from Jungfernheide and running through Siemensstadt to Gartenfeld, and to put on trains of 12 carriages running at two minute intervals in order to take away the masses of people during the rush hours, on the condition, however, that the Firm should take over the larger part of the costs of constructing this branch line. These were not slight, as the first part of the railway ran along the marshy banks of the Spree, which had to be crossed in two places. But finally the Firm agreed to this condition, which called for considerable financial sacrifice, in order to find a solution to the impossible traffic situation. The casual observer, who saw the long red trains, filled to overflowing with their human freight, rolling out of the spruce stations "Wernerwerk" and "Siemensstadt" at such short intervals that they never lost sight of one another, and was told of the conditions prevailing earlier before the railway came into existence, realized that without the railway it would have been impossible to carry out the last new factory construction or extension projects.

It was not only in Germany that the years between 1924 and 1929 had been a period of economic recovery, although the upward trend was particularly noticeable here after the stabilization of the currency, the temporary settlement of the reparations question by the Dawes Plan and the enormous influx of foreign credits. As we have seen, the cup was full to the brim of the fruits of technical and economic progress for the House of Siemens during these five short years. This tendency was no less marked in the United States. The need to make up for lost time after the years of destruction and privation had created such requirements throughout the whole world, mainly for consumer goods, followed by capital goods, that it seemed almost impossible to satisfy them. This in turn had created a wave of speculation on the New York Stock Exchange which rose higher and higher; favourable economic developments foreseeable from the general trend of business were continually being discounted in advance, and thus there arose in Wall Street a boom which rapidly assumed unhealthy characteristics—it needed only a little push to send the card house toppling over. On October 29, 1929, the "Black Tuesday," the event long predicted by the initiated, occured and the crash of the skyscraper shook the whole world. The world crisis, the great slump, one of the most disastrous events of the first half of the century, dates from that day.

The cyclic economic crisis is a phenomenon well-known to economists. In a free market, production always adapts itself to the expected requirements and it is only too natural that as the volume of production steadily rises, as had been the case in broad outlines since the beginning of recent historic times and the development of modern engineering, the forces of expansion overestimate the degree of natural increase and overproduction follows. The crisis then commences, and starts by reducing the growth of the production machinery until the more slowly increasing requirements have caught up again, whereupon the process starts all over again. The great slump was therefore by nature and by virtue of the impulse which released it a true cyclic crisis, which only differed from previous ones by its scope and severity, as it brought out all the effects of the first World War: the irregular distribution of gold throughout the world, the enormous national debts, the unreal stabilization of currency in the world, the senseless economic nationalism of the nations and the coupling of economics and politics, which resulted in the war being carried on later in the field of economics, as was best seen by the German reparations.

All these calamitous influences were set free by the outbreak of this economic crisis—the people who boasted that they had rooted out the worst war in history were presented with the bill. The common people had to pay, of course, with the result that certain figures arose out of the seething masses in the defeated country, in comparison with whose incompetence and wickedness the peacemakers of Versailles were true statesmen.

XXX.

THE THIRD REICH

The crisis which commenced in the autumn of 1929 with the crash on the Stock Exchange in the United States spread out over the whole world with the speed of an epidemic. In the United States the production index sank, taking 100 as the value for 1929, to 80.3 in 1930, 64.4 in 1931 and 48.4 in 1932, in other words, it fell to less than half of the value before the crisis. The corresponding figures for Germany were 100, 89.5, 73.4 and 60.8, or rather better, due to the fact that the German economy still achieved a considerable export, even in the worst days of the depression. In spite of this, Germany was the country among the big industrial producers that suffered the most under the effects of the crisis, and this for economic as well as psychological reasons. A particularly characteristic symptom of the crisis was unemployment.

An industrial reserve, as Marx called it, already existed in the early days of Capitalism, and it is not difficult to believe that it increased in times of crisis, although no figures can be given to support the theory as no statistics exist on the subject. This situation did not change in Germany until 1925, when unemployment was added as the fourth risk to the three existing branches of insurance, namely accident, illness and old age, and the National Institution for Employment Service and Unemployment Insurance was created as the pillar of unemployment insurance. These legislative measures now enabled a clear definition of unemployment to be made and permitted it to be determined by statistics. Further, if a man were unemployed, he did not have to pay Old Age Pension contributions without prejudicing his pension rights. Consequently, many persons hitherto outside the Pension Scheme, and who would never have thought of it otherwise, hastened to take up some form of employment, perhaps even temporarily, so that, even though they should lose their employment subsequently, they would still remain eligible for a pension, but without having to pay any further contributions. In this way the number of unemployed was always higher than it would otherwise have been, and as the crisis grew worse from month to month, the official barometer, the regular statistical publications on "persons receiving relief" had a similar calamitous psychological effect to that of the dollar rate during the galloping inflation, increasing the confusion and driving numerous people to panic acts which only served to deepen the disaster. Experience has shown that the seasonally occasioned peak of unemployment regularly occurs about the middle of February. In February 1929, before the outbreak of the crisis, the figure amounted to approx. 2 mill. and rose to 3.4 mill. in 1930, 5 mill. in 1931 and reached a peak in Feb. 1931 with 6.1 mill.

In the House of Siemens, the crisis first made itself apparent in the power current business, which confirmed the statement made earlier on that the boom waves in communications engineering, compared with those in power current engineering, have a phase displacement of approx. one year. When the accounts had been prepared for the business year 1929/30 at Siemens-Schuckert, it was clear that only a 7½% dividend could be declared, whereas 10% had been distributed for the two previous years. In the next year 1930/31 no dividends were paid out at all by Siemens-Schuckert and the accounts for the following year were so serious that only by falling back to a great extent on the floating and sleeping reserves could the accounts be made to balance at all. For four years in succession, Siemens-Schuckert were unable to distribute any dividends at all to their two partners—from 1930/31 to 1933/34—which was particularly unpleasant for the firm of Schuckert, which as a pure holding company was mainly dependent on the income from the production of the daughter company; Siemens & Halske were in a better position than Siemens-Schuckert, due to their extensive production, but they had to pay tribute too. For three years, from 1927/28 to 1929/30, they had paid out the regal dividend of 14%, in 1930/31 it fell to 9% and for the next three years amounted to only 7%, and that only in order not to let the market value of the thousand year loan sink too low. On the whole both partners were particularly badly off for inland business—power consumption in the power stations dropped from month to month and with it the courage to purchase new equipment, the private purchasers went on strike, the Reichspost only had a fraction of its previous requirements and industrial undertakings did not invest any more at all. In spite of the fall in the total turnover, the proportion of goods exported rose increasingly and reached nearly 54% of the total production of Siemens-Schuckert in 1931/32—it amounted to 45% in the case of Siemens & Halske—and the expression "hunger export" was frequently heard. The total turnover of the House, i. e., of the two firms and the daughter firms belonging entirely to them, which in the business year 1928/29 had reached the admirable figure of

850 mill. Reichsmarks, dropped in 1929/30 to 797 mills. and fell year by year from then onwards: 631, 410 and finally 329 mill. in 1932/33, the lowest point, which represented about 39% of the peak figure before the outbreak of the crisis. Even for an enterprise of the size of the House of Siemens, with its solid foundations, the situation gradually assumed a very dangerous form, especially as no one could say how long it was going to last.

The only way to keep the ship afloat was to cut the wages and salaries account drastically, as this is the largest factor in the prime costs. The Firm therefore began to lay off workers, first of all the young ones who had not been employed for long and were still single, later the older ones and married men. Among the employees, the laying-off process started both at the top and the bottom of the age scale simultaneously; the young were given notice, and the old were pensioned off before their time. Pensioning was decided on as it was still much better to send elderly employees away with a sufficient pension salary than to keep them on in the offices and factories without any work or just the occasional odd job. In addition, short time was introduced and the income of those affected correspondingly reduced. For C. F. von Siemens and his assistants, these years were, as he frequently said later, very tragic indeed. The choice of victims to be sent off into the wilderness was about the worst task that could fall to any employer. However carefully he proceeded and however sparingly, and with whatever regard for social considerations, embitterment was unavoidable.

It was quite understandable that the workers, being more easy to replace, were thinned out more than the employees. Between 1929 and 1932, Siemens-Schuckert reduced its staff in Germany from 16,800 to 10,200 among the technical and office employees or by 39% and from 38,900 to 18,600 or by 52% among the workers. The ratio office staff: workers therefore changed from 1:2.3 to 1:1.8. During the same period of time Siemens & Halske reduced their staff in Germany from 10,830 to 7,260 or by 33% among the white-collar employees and from 25,580 to 12,590 or by 51% among the workers, whereby the ratio office staff: workers was reduced from 1:2.4 to 1:1.7. On the whole, the staff of the House, at home and abroad, was reduced from 137,000 to 75,000 between Sept. 30, 1929 and Sept. 30, 1932, which means that it fell to 55% of its previous figure, compared with a drop in the turnover to 39%.

It was not everywhere the case in the German industry that the same scruples were exercised in laying off reduntant workers as in the House of Siemens. In many places, with regard to the state of emergency, which may have been more severe locally, little heed was paid and few scruples exercised. And beside the workers who had been laid off, were the pupils and students of the secondary schools and universities, waiting before the locked gates of their chosen profession.

After the Österreichische Kreditanstalt had closed its doors in May 1931 and had only been saved from complete collapse by the Bank of England, the Darmstädter und Nationalbank became insecure, whereby the German credit system, which up to that time had been kept going by dint of much effort, threatened to collapse as well. To prevent this, the Government declared a moratorium at home and abroad. Whereas the inland moratorium could soon be ameliorated, the foreign one was converted into a respite from claims by mutual agreement after negotiations with the various groups of creditors, and the introduction of State control of currency followed as a logical conclusion. The Reichsmark had thus ceased to be an autonomous currency which was negotiable everywhere. It had become an inland currency—the very thing that the Dawes Plan, which now no longer existed, had tried to prevent, had come about. A further consequence was that only one year after being granted, the thousand year dollar loan of Siemens & Halske could no longer be freely negotiated. Any international credit system, however well planned by business men, will break down as soon as the State starts juggling with the currency.

C. F. von Siemens considered the position which had arisen shameful. He was very sensitive where money was concerned, even more so when he was in the position of debtor than when he was the creditor. Thus he did not rest until the House of Siemens succeeded, as the only German loan debtor, in wresting from the Reichsbank their authorization for the issue of a conversion offer for the 6½% loan of 1926 and the thousand year loan of 1930. In this offer the debtor declared his willingness to pay half of the interest for the 1926 loan and 4½% interest on the thousand year loan, on condition that the total interest claim was thereby considered as fulfilled. The interest offered was paid in dollars which the Firm had earned itself, for the transfer of which the Reichsbank had finally declared its willingness. Most of the loan creditors agreed to this offer and received their interest right up to the beginning of the second World War. In this way they only received half of the interest agreed to on concluding the loan, but at least they received free dollars, whereas creditors of the other German loans only received blocked Marks, with which they could not do very much.

On the outbreak of the economic crisis, the political crisis in Germany, which had so far been more of the nature of a lingering disease, entered into an acute phase. It had not been entirely brought about by the economic position, but had certainly been aggravated by it to a great extent. Finally, at the end of January 1933, the President was obliged to appoint Hitler Reich Chancellor, and by the Law of Authority of March 24, 1933 the political struggle in Germany was decided in favour of the sole supremacy of the National Socialist party, whereby the German Reich became subject to the practically unlimited sway of one man, a solution which, from the point of view of constitutional law, would have been completely unthinkable during the previous generation.

Twelve years later, after Germany and the rest of the world had had some experience of this form of Government and its representatives, a trial was held of all those who were responsible for its coming into power, and representatives of industry were dragged before the court because they had helped Hitler and his party with liberal funds during the years of the struggle preceding their accession to power, i.e., in the 2½ years from 1930 to 1933. The accusation in this form is unjust, apart from the fact that it attaches an importance to money which the latter could never have for such a mass movement. If one could change the political face of a country with a few hundred thousand or million Marks, then it would most probably have happened after the first World War. It would be an inadmissible and primitive simplification of the facts, bordering on falsification of the historical truth, to attribute in the main to contributions from industry the complicated influences and events, some of which had their roots a long way back, in which on the whole all German parties, movements, classes, professions and groups—not to mention foreign countries—were involved in some form or other, although to very varying degrees. With regard to these contributions, it was an unpleasant but common habit in Germany, as in other countries, for the political parties, especially before elections were held, to go round begging funds from every possible contributor, particularly from industry. One gave something to each of them, "just to have peace and quiet," as one industrialist drastically put it at the Nuremberg trials. In the course of time it had become common practice to contribute roughly in accordance with the number of seats previously held by the party, and this assistance was also given to parties of which one should have thought that they would not have accepted anything from industry at all. But they all accepted it. That one or the other industrialist—but no one from the House of Siemens—gave special contributions to the National Socialist party from his private purse in addition to the other contributions, merely goes to prove his stupidity in political matters, but did not have any noticeable influence on the course of things.

Later, admittedly, when Nazism was well and truly in the saddle, industry as a whole "voluntarily contributed" large sums. As soon as Adolf Hitler had become Chancellor, a swarm of collectors of all sorts pounced upon commercial undertakings everywhere with lists and collecting boxes and tried to fleece them for the various requirements of the Party, whereby methods were used which in many cases were little different from those of the blackmailer. In order to establish some form of legal basis for the whole affair and to protect themselves from these unbearable conditions, it was agreed to found the "Adolf-Hitler-Spende der deutschen Wirtschaft", a neutral account which cashed in sums fixed according to a particular key from the associated firms and handed them over to the Party. The whole thing represented a special kind of Trade Tax which cost the House of Siemens millions every year.

After 36 years' service in the Firm of Siemens & Halske, Francke laid down his office as Chairman of the Board of Directors in order to join the Council of "Elder Statesmen" as had become the custom with people who had rendered meritorious service, and everyone considered it perfectly natural that von Buol should take his place, as had long been intended by C. F. von Siemens—no other candidature had been put forward. Von Buol's successor in the management of Wernerwerk M was Richard Schwenn, who up to that time had successfully led the Measuring Instruments Dept. and had grown up into his new position. In the House of Siemens a natural order of succession had crystallized in the upper levels of the hierarchy, and it can be considered characteristic of a healthy large enterprise that the successor for every important man matures and fits himself for his coming post while it is still occupied by his predecessor.

The leaders of the House were now faced with the task of coming to terms with the new powers in Germany, for it was clear to everybody that in this case, one could not leave politics to the politicians with a shrug of the shoulders, as had formerly been the case, and let them get on with it. These people demanded of every individual that he should declare loyalty to them, and the rising totalitarian State intervened unscrupulously in every walk of life, but particularly in the nation's economy, which it intended to bring completely under its own power.

On the whole, the leading persons of the House had very much the same opinion of the new regime, although the interpretation varied in various cases according to nature and temperament. The ideas expressed by the National Socialists before their rise to power as their aims in economic affairs, which were of course of interest then, such as the motion moved by the Reichstagsfraktion for "expropriation of the Bank and Stock Exchange Princes" were so childish that any discussion on the matter was impossible

The autarky they preached, together with the attacks launched on the international export trade, had led to sharp retorts from the House, one third of whose products were sent abroad, and the agitation stirred up against the large undertakings by the very influential small industry wing of the Party was not exactly designed to invoke the sympathy of the House of Siemens. The antisemitism of Hitler and his party got on the nerves of C. F. von Siemens. Not only had he a number of assistants in his own House who were of Jewish origin and whom he valued very highly—Rüdenberg and Laufer were very talented men and have already been mentioned earlier—he also had among his business acquaintances and other friends a number of Jews with whom he was just as friendly as with other people—he had no racial prejudices whatsoever. As a broad-minded business man of no mean ability he could not sympathize with Hitler's narrow-minded nationalism, and the slandering and maligning of political opponents which had become a daily exercise of the demagogue disgusted him. And most members of the Board of Directors thought just the same as he did, no doubt influenced to some extent by his definite and outspoken attitude. But most of these men committed the error which nearly all Germans who would have nothing to do with the Party made at the beginning—they did not take it seriously enough. Admittedly, the leaders of the Party made such an impression that one could not help thinking that a nation with such a great cultural tradition as the Germans would not put up with this form of Government for long, and it was quite natural for the economists to assume that this system would break down financially in about half a year. They therefore thought that they could just wait until it died a natural death. Both assumptions proved to be false.

Siemens received a foretaste of the National Socialist methods of government in the early summer of 1933 when they took action against the Jews. A coup d'état was made within the large and small technical associations and societies, some of which have already been mentioned, and the previous Boards replaced by party members—this was termed "political coordination." At the same time, the new boards were given far-reaching powers which were in direct contradiction to the previous statutes (Führerprinzip or authoritarian principle). Now, the gatherings and conferences of these societies and the journals published by them formed an important stage on which technical and scientific life took place; Jews were forthwith forbidden to set foot on this stage and were later shut out of the associations altogether. At the same time they were removed from all official posts in the State and in public bodies, it was made impossible for them to carry on professions such as medicine and law, and they were excluded from any activity in the press, radio, theatre and musical life. Under these circumstances many of them decided quite early to emigrate, and the earlier they decided to take this step, the better it was for them. The chances of being able to rescue a part of their property grew smaller with every month they waited. The position for the Jews got really bad after the Nuremberg Laws had defined the rather vague term "Jews" and those affected lost their rights of citizenship in every form. Thus the exodus started in the Firm at an early date.

The emigrants from the Firm had the advantage over many of their fellow sufferers that the far-flung administration and branches of the Firm were in a position to help them. C. F. von Siemens managed to get new positions for many of them abroad by using his personal connections, others were sent abroad on business trips in order to look for new employment and yet others received recommendations to foreign branches and offices of the Firm and were assisted further by these. But as the Jews in private undertakings were relatively little molested during the first few years of the Reich, so long as they did not make themselves conspicuous in any way, many of them thought that it was only a passing storm and that they could afford to wait in Germany until it had blown over. Those living in mixed marriages were particularly prone to this illusion, and if they had children, they were supposed to be protected.

In the meanwhile, the party was bringing increasing pressure to bear on the Managers of the Firm in order to make them remove the last of the Jews employed in the Firm, and as all the Jews in Vienna and elsewhere were thrown out of employment without notice and without pension rights after the Anschluss, and when the Siemens Directors in Berlin found out from a confidential source that corresponding measures were to be expected for the Reich, they commenced in the summer of 1938 to pension off the remaining Jewish employees, in order to ensure that they would at least have some means. To a head clerk of the Siemens Bauunion departing from the Firm as a result of these measures, C. F. von Siemens said on taking leave, "It hurts me very much to have to dismiss employees who have given my House many years of faithful service, merely because of their racial origin. I am the employer of over a hundred thousand men, but Germany is governed to-day by a horde of political adventurers who do not even allow me to make my own decisions in my own House. It has got so bad that if I oppose the will of the Government for the sake of a few, I should be setting the very existence of the House of Siemens at stake."

As early as the beginning of May 1933, all the administration offices of the Trade Unions in Germany were forcibly seized by the National Socialists, the officials thrown out and imprisoned and the funds declared forfeit to the State. The State transferred these funds to the Workers Front, the organization for all employees and workers, to which everyone engaged in Commerce or Industry had to belong if he did not want to be regarded as "beyond the pale of the community," with all the consequences that this entailed. The Workers Front was divided up regionally on much the same lines as the Party, and was under the leadership of Robert Ley, the Reich Organization Leader, one of those people who in spite of their not exactly irreproachable way of life, had somehow managed to create a kind of small dictatorship out of the position entrusted to them. By virtue of the enormous administrative and economic machinery of the Workers Front, he enjoyed power such as had never been entrusted to an official of the State before in Germany. No minister would ever before have dared to undertake even a fraction of the interference in the factories and the economic life of the country, which was now a daily part of the activities of the Workers Front.

It can hardly be supposed that any of the leaders, least of all Ley, had a clear idea of the purpose of the Workers Front from the very beginning. It was probably developed from case to case. As a whole, their activities were restricted to two fields: one of them was that of the German worker, who was to be politically schooled, professionally trained and kept in good humour in his spare time, and the other was that of the employer, who was also to be brought up in the true political belief, to be educated to be socially minded and otherwise to be constantly screened.

Measures had been taken at quite an early date in the House of Siemens for the welfare of the workers and employers, measures which were later summed up under the term "voluntary social benefits." These early beginnings have already been described earlier on when speaking of the foundation of the "Old Age and Invalids Pension Scheme" in 1872. Although the thread never broke off after that, the progress made in Berlin for sundry reasons was not so fast to start with as elsewhere in the industrial West, as can be seen from the social building schemes of other large works. In addition to this, the Trade Unions did not eye these social actions of the employers very favourably. They generally suspected that they were bonds with which to chain the worker to the factory, thus curtailing his freedom, and spoke scornfully of the social sport of rich old ladies and of welfare halfpennies, instead of which it would be better to pay better wages. These opinions did not change until after the war, when the term "Betrieb" (factory or works), which had been unknown until then in the German industry, first came into existence. When the people started to speak of "our works" it was no longer a matter of indifference which advantages were coupled with "our works." National Socialism, which, in contrast to the old Trade Unions burocracy, had appropriate apparatus for detecting such vibrations in the soul of the masses, plunged into this atmosphere with the slogans "factory community," "consciousness of social responsibility," "ethics of work" etc.

They found everything that an exacting social reformer could wish for in a large factory already in operation in the House of Siemens, a fact of which few firms could boast at that time. In the course of the years, one stone had been set on another to form an imposing structure; canteens, and shopping centres, which Siemens had initiated, were now to be found in every large undertaking. The Sick Insurance Fund of the House provided far more than the minimum demanded by law; the Pension Scheme, which was well provided with funds, took care of the workers and employees who were no longer able to work and who had already served the Firm for a certain period of time; a welfare bequest foundation, which was run on a footing of complete equality, could be called on in special cases of need and a management fund was available for cases for which no provision had been made in the statutes of the other schemes. Factory doctors and welfare workers took care to see that the health of the workers and employees was protected as much as possible, and approximately half the beds in a large hospital and a T.B. sanatorium were reserved for members of the staff of the House. Two rest homes were available to members of the Sick Insurance Scheme free of charge; a children's home, like the rest homes situated on the Baltic, was available at a very moderate charge, as was also the case in the holiday home for employees built on the site of the Werner von Siemens home near Harzburg. In Siemensstadt there was also a daily rest home for working men and another for female workers, and sport grounds, gymnasiums, boat houses and other sports club facilities were created for the youth and those who still felt young. It was a matter of honour that one of the largest factory libraries in Germany was situated in Siemensstadt, with more than 30,000 books, and that the House issued its own journal and took care to see that the contents were of a high standard.

Shortly after the institution of the Workers Front, when two high officials of this movement appeared in Siemensstadt and explained that it was the duty of the Workers Front to instruct all factories in the sociological aims of National Socialism, they received the laconic reply, "No instruction is necessary here, at the most you might learn a thing or two yourselves." Thus began the war between the House of Siemens, in this case represented by von Witzleben, and the Workers Front which lasted with increasing vehemence until the downfall of National Socialism.

It was in fact the case that the Workers Front, if they were truly interested in improving the degree of social welfare work in the factories, could not help learning from Siemens, but of course they could not possibly admit it. When they circulated a supposedly new idea concerning social aspects of the nation's economy, after expending much money, time and energy on bombastic speeches, they usually heard from the House of Siemens that this idea had long since been put into practice. The differences began to take a more unpleasant form when the Workers Front started to bring the entire training schemes of the various works under their control. The training managers, teachers, apprentice masters and commercial instructors grumbled that schools had been established and methods devised over the course of many years, only for these presumtuous people to come along and stamp everything with the swastika and claim it as a product of their philosophy. Even the factory journal was supposed to bear the swastika of the Workers Front, but the grotesque miniature war, which went on for about ten years and was caused as much by this unwillingness as by the contents of the journal, ended in the eddies of the general collapse and the Workers Front thus never was able to impose its will.

The differences between the Workers Front and the House of Siemens finally centred around the question of participation in the so-called production competitions. All totalitarian systems have the common characteristic of constantly driving the people, who in their opinion are only there to serve the State, to greater efforts in production. This is one of the main advantages of such an aggressive totalitarian system and accounts to a considerable extent for its superiority over peaceful countries. This sort of system can drive on the individual or the group with its whip, and the National Socialists preferred, to start with, to devote their attention to the groups, in this case the factories. This all took place at the expense of the employers, who had to organize their works so that those employed there felt at home and worked willingly—the latter had to pay the bill later on, particularly during the war. Thus production competitions were introduced with yearly prizes and the scheme was later extended further. It was frequently very funny for the critical observer to see how quickly many people caught on to the new idea. Siemens held their distance from all such competitions, and the Directors of the Firm actually managed, by adroitly taking advantage of differences on merely formal questions, to keep out of all such competitions until the end of the Third

Reich and thus to forego all tokens of distinction from the hands of Herr Ley.

In view of all this it is not difficult to appreciate that a personality like C. F. von Siemens was quite impossible from the point of view of National Socialism as President of the Deutsche Reichsbahn-Gesellschaft. During the years of the world crisis he had found it increasingly difficult and unpleasant to combat the various powers that tried to force him and the Administrative Council to change their policy. The Reichsbahn was for him a business enterprise like his own: admittedly, as a large undertaking it stood—like the House of Siemens—in the centre of the field of public interest, but it remained for all that a business undertaking, whose first task it was to stand on its own two feet. To place large orders with the industry for equipment which was not really needed, in order to create work; to lower tariffs in order to increase industrial capacity and to employ fresh personnel to overcome the unemployment, all this at one and the same time: this was approximately the task of the Reichsbahn in the eyes of numerous politicians.

When, after a further year of increasing difficulties, National Socialism had finally gained the upper hand, it soon began to decimate the Administrative Council by removing the two representatives of the Trade Unions, followed soon afterwards by the members of Jewish origin, and replacing them by people of their own kind. C. F. von Siemens now placed his office at their disposal. To Paul Silverberg, one of his Jewish colleagues, he wrote: "My time was up and I am glad that I have not made the mistake—made by so many—of not realizing the fact."

The transformation of the Reichsbahn into a purely State-controlled enterprise, as the former President witnessed with resignation, was only the first step to far-reaching interference on the part of the totalitarian State in private enterprise. The State relied on the combines already in existence, grouped them forcibly into cartels and then compelled them to carry out the orders given by the State in their own field.

If one makes a schematic representation of this State apparatus for the organization of industry: the Reich groups, the main groups, economic groups, trade groups and sub-groups, in the form of squares of different sizes with connecting lines, the entire structure commencing from a central point and developing ever finer branches, many sceptical people would be inclined to consider the whole thing as a game played by organizers to relieve their boredom and therefore not to be taken seriously. But here again they made the mistake of not taking National Socialism seriously enough. For the squares of the scheme were really switchboards and the lines between them were in reality lines, and when a number with a certain combination of digits was dialled in the highest command post, 35% cellulose wool was mixed into the cloth in the German cloth factories. If another number was dialled, the executive organs in the corresponding trade groups and sub-groups began to economize on copper in all their projects, and yet another order from the highest command post informed all consumers of iron how high their allocation of iron would be for the next three months. This was the most efficiently systematized economy that had ever been created up to that point and the very fact that the institution was named "Self-administration of the German economy" showed that National Socialism did not entirely lack a sense of humour, as has often been maintained.

In this way the Third Reich had not exactly expropriated the firms in a formal manner but had thrown them into chains, by means of a system of compulsory organization from without and the Workers Front from within, to such an extent that there could no longer be any mention of independent competitive trade. This method has of course the advantage that it is much cheaper than expropriation, which cannot be carried out without some measure of compensation. It was only to be expected that the State claimed a certain portion of the proceeds for itself. The House of Siemens is a good example for the situation during the Third Reich, as the following figures will show.

This account is based on the year 1934/35, because it stands midway between the years of the depression and those of the rearmament boom and thus shows balanced and healthy average values. In addition to Siemens & Halske, the E.A.G. vorm. Schuckert & Co. must also be reckoned as a financial pillar of the House. Schuckert held 50% of the shares of the Firm of Siemens-Schuckert, so that half of the dividends appeared in the accounts of Schuckert & Co. One must therefore calculate as if a single firm (which was actually the case years later) with a total share capital of 153.5 mill. Reichsmarks and with a total loan debt of 159.8 mill. Reichsmarks was involved, which paid 10.1 millions in dividends and 6.7 mill. in loan interest, according to the balance sheets.

The turnover, the "social product," that is the money which flowed into the accounts of the Firm as equivalent for its production, amounted to a round 550 Mill. At this point, turnover and total income are equal: this is not strictly correct as the companies have other sources of income apart from those resulting from the production, such as income from investments. But these, in contrast, to the pionier days described earlier on, are so insignificant in comparison with the income arising from the production, that they can be ignored in this survey without influencing the result.

The social product is divided up as follows:

1. Raw materials and accessory materials, depreciation, replacements, expenses	217.4	mill. RM	39.5 %
2. Salaries and wages	250.0	„ „	45.5 %
3. Compulsory and voluntary social expenditure	31.8	„ „	5.8 %
4. Dividends	10.1	„ „	1.8 %
5. Loan interest	6.7	„ „	1.2 %
6. Tax	34.0	„ „	6.2 %
	550.0	mill. RM	100.0 %

Whereas the workers received 51.3% of the social product, including the social expenditure made on their behalf, the share holders received 1.8% and the debenture creditors 1.2%—the proportion accounted for by the capital was 3% in all. If the dividends of 10.1 mill. had been divided up among the workers in proportion to their income, each one would have received an increase of 4%.

But the State took 6.2 % of the social product alone in direct taxation, and in addition to this it took 10 % of the wage figure in income tax deducted at the source, i.e., 25 mill. and together with the other taxes this made a tribute of 59 mill. Marks to the State. In this way the State was participating in the Firm as a sleeping partner with a dividend of 38 ½ % of the share capital, whereby it must be added for the sake of completeness that the Company Tax amounted in that year to 30 % of the income but was raised to 40 % in the following year. With this income of nearly 60 mill. Marks the State did nothing directly for the good of the Firm or its workers. The expenditure for all four branches of social insurance had to be borne by the enterprise and the staff. The two fifths of the share capital, which the giant drew every year from the Firm, were used for entirely different purposes.

In this way the National Socialist reign in Germany contributed considerably to the advance of collective thinking by showing that much that had previously been considered impossible of execution can be achieved in a rigidly planned and regimented economy, but at the same time showing the deeper thinker how closely this is connected with political enslavement. And the worst of it is that such developments can only be reversed again, even after a change of Government, with the greatest of difficulty, as the heraldic eagle is unwilling to loosen its grip on the prey in his talons. It is possible to remove the swastika, but the taxes are lost for ever.

XXXI.

REARMAMENT

The free convertibility of the Reichsmark had already been blocked in 1931 when the acute financial crisis broke out in Germany, but the Govt. in power at that time had only intended this step and the respite agreement with the foreign creditors as a temporary measure, to be released step by step as soon as the crisis eased off. This was the aim of their deflation policy, which has been much criticized. During the Third Reich, however, it not only proved impossible as a result of the economic policy followed, to return to normal conditions with regard to the currency situation, but total State control of currency had to be gradually introduced in a form hitherto unknown anywhere in the world.

Anyone who knows how carefully the annual reports of the House of Siemens were formulated, how every sentence, every word was carefully weighed before being laid down in writing, and considers with what mistrust the public announcements of such great firms were read by official circles, will appreciate the force of the following extract taken from the annual report for the business year 1934/35:

"The dollar loan taken up together with Siemens-Schuckertwerke AG. in 1925, with interest payable at the rate of 7 %, is due for repayment on Jan. 1, 1935. Our endeavours at an early date to obtain authorization from the relevant departments for repayment of the loan on the due date from the foreign currency arising from our own exports, have proved unsuccessful. We had to bow down to the principle that even the currency accruing from own export activity has primarily to be made available to the national economy, and we were thus only able to propose to our foreign creditors, apart from an extension of the loan, repayment of the same in blocked Marks, whereas we could suggest to our creditors at home that the loans due should be converted into 4½% RM bonds. Little advantage has so far been taken of this offer by our foreign creditors. We are therefore unable to fulfil our contractual obligations. The maintenance and future development of our export trade depends to a great degree in maintaining inviolate our reputation for the most scrupulous fulfilment of our obligations, financial and otherwise. We shall do everything in our power to catch up on the arrears in the fulfilment of our obligations."

The efforts thus announced were finally successful to a certain extent, especially as the effects of the rearmament boom resulted in an increase in the liquidity of the undertaking. It was possible during the course of the following years to redeem the outstanding loans with increasing rapidity and it is worthy of special mention that in 1941, shortly before the entry of the U.S.A. into the war, the larger part of the 1000 year loan had been redeemed at a rate corresponding to the rate of issue. At the end of World War II, therefore, the debts of the House of Siemens resulting from American loans were negligible.

In the years immediately following on the outbreak of the world crisis, there were numerous branches of technical development which registered a strong upward trend, quite independently of any external stimulus. It was as if a number of seeds had been sown during the quiet of the depression which now thrust upwards towards the sun, as after a warm shower of rain. Amongst these was the further development of the mercury vapour rectifier which has already been dealt with in Chapter V.

When Cooper Hewitt attempted experimentally to surround the anode of his apparatus with a screen as well, after the style of the high-vacuum electron gun, he soon had to admit that it was not possible to influence the strength of the anode current by means of the voltage at the grid, as in the case of the electron gun. Admittedly, a negative voltage of a certain value, which is applied to the grid round "cold" anode—which has not yet got an arc—prevents the formation of an arc to begin with; this voltage must be decreased sufficiently so that the discharge can set in, or "kindle." However, when this has taken place, it is no use raising the grid voltage to the original value again—once the door is open, it cannot be closed again against the current. The arc only extinguishes when the voltage between anode and cathode disappears, which is of course the case in every change of current, and its reformation can be prevented at will. In this sense, therefore, one speaks of kindling and blocking voltages.

Now in the case of the three-phase rectifier, for example, one end of the arc, the other end of which is firmly connected to the electron supply of the cathode, jumps in cadence with the change of the current from one of the three anodes to the other; it constantly tends towards the anode with the highest voltage, and then changes to another when the voltage of the first one has dropped to such an extent that it is exceeded by the rising voltage of the next one. If the anode is first blocked by placing a control grid around it, the arc is forced to remain on the previous one for a while (the time for such processes is reckoned in milliseconds) while the current drops, until it is able to pass on to the next anode when the kindling voltage is applied to the control grid—in this manner, the average voltage of the d.c. produced is lowered. By arbitrarily displacing the time of kindling with the aid of suitable devices, the d.c. voltage produced can be regulated—so far, the rectifier had only been able to produce one fixed d.c. voltage. Now it became a suitable substitute for the d.c. machine and like this, it could be used in Leonard circuits for drives with an adaptable number of revolutions.

Special circuits made it further possible to work in the opposite direction, i.e., to change an applied d.c. charge into a.c. or three-phase current (a.c./d.c. converter) and finally to convert three-phase current with the usual frequency or 50 c/s into a.c. of a different frequency, such as the railway frequency of 16 2/3 c/s. Round about the year 1930, the leading elecrotechnical firms in Germany and the U.S.A. began to exploit this discovery in various forms—the tube-type grid-controlled converters, as they were called, became an important field of electrotechnical development.

Grid control enabled the original mercury vapour rectifier, now tube-type grid-controlled converter, to catch up with the electron tube, the development of which had started about the same time as that of the mercury vapour rectifier. It appeared to many careful observers of these events that the time had come to abandon the differentiation between power current and signal current introduced approx. 60 years ago with the discovery of the electro-dynamic principle in favour of a uniform approach to electrotechnical problems—at least, this applied to further research into all problems concerned with the passage of current through a gas. Whether this involved the passage of current through high vacuums, whereby the electrons emanating from a heated cathode alone formed the stream of current, or the passage through tubes filled with a low-pressure gas, whereby the ions were also used for the passage of current; whether currents of a fraction of a milliwatt were amplified or others of thousand of kilowatts were converted; whether glass tubes or large steel vessels were used to enclose the discharge path—basically all these processes obeyed the same laws regarding the passage of current through gases, laws into which further research would call for a great deal of hard work. C. F. von Siemens was particularly aware during the course of these years that the various directions of development constantly tended to spread further apart as a result of ever-increasing specialization, and that they should be brought together again wherever possible, and he therefore approved whole-heartedly of the proposal, made in 1933, to combine all the groups engaged in research on the subject to form a Siemens Tube Works. There was no need to erect new buildings for the works, as it could be housed in the rooms originally built for the Automobile Works and later used for the Dynamo Works.

The liability of damage to constructional elements used in the transmission of energy had naturally increased as a result of ever increasing transmission voltages. The danger arose from the fact that sudden changes of current in a h.t. circuit, especially in switching operations, can be brought about by the occurrence of rapidly rising additional voltages; they can also be caused by atmospheric discharges, which are of a vastly different order in the long lines suspended between high masts than in the early days of electric energy transmission. Thus, soon after the war there was a marked desire to reproduce these load surges, in order to be able to use them to test the components involved—chain insulators and other types of insulators and the windings of transformers.

Erwin Marx, an engineer at the Hermsdorf-Schomburg Isolatoren G.m.b.H. at the time, had developed and patented a process in 1924, whereby the storage capacity of the condenser for electric charges was utilized for this purpose. He connected a number of condensers in parallel and charged them from a source of d.c. current. When the charging voltage had been reached, which due to the size of the series-connected resistances, only took a fraction of a second, the voltage jumped across at carefully adjusted spark gaps, thus causing the condensers to be connected in series and their voltages to be added. In this way, momentary voltages of several million volts could be produced; in addition to this, the discharge current of a condenser in the first milliseconds of the process is of considerable strength—the entire energy stored up in the condensers is discharged in a powerful impulse of very short duration (surge tests).

As a result of the great advantages over the previous testing processes, which consisted of increasing the usual a.c. voltage up to the disruptive voltage, surge testing rapidly became accepted for examining insulators, switching equipment and transformers, and contributed considerably to raising the degree of reliability of various types of equipment. It called for a considerable amount of apparatus, however, as became particularly evident when the Siemens-Schuckertwerke decided in 1933 to set up a surge testing plant for 3 million volts and 42 kw/secs on the site of their Transformer Works in Nuremberg. The test generator stood in the open, a 12 metre high framework of 6 porcelain columns which kept the condensers, protective resistances and spark gaps at a respectful distance from the ground. In the large hall of a buildings standing nearby was housed a smaller test generator for a million volts, while the observation and measuring instruments were installed in several other rooms. The surge generator in the open was surrounded by earth walls 5 m high which separated it from the immediate surroundings in order to screen the houses situated further away from "the noise which arises during testing," as it was euphemistically formulated in a description. This "noise" was identical with that produced by a powerful discharge of lightning on striking a house or tree.

In the following year, the Switchgear Works also set up a similar impulse testing plants in its h.t. test field, which, however, could only generate 800,000 volts. The switch testing field was extended by replacing the short-circuit current generator by another of 62,000 kva at 3,000 revolutions, which allowed exceedingly accurate control of the consecutive switching processes during testing. The Dynamo Works, on the other hand, set up a centrifugal pit in one of their largest shops, in which the machines to be tested were installed in special bearings with their shaft in a vertical position—with many hydro-electric generators this was the normal working position anyway, whilst the others just had to put up with it for the duration of testing. If one considers that the number of revolutions performed when racing the machines can amount under certain circumstances to three times the number during normal operation, and that the machine has got to stand up to this number of revolutions during testing, one can appreciate the precaution of carrying out such experiments in a 9 m deep, reinforced concrete pit of 12 m interior diameter, which, due to the shifting sand, cost proportionally as much to build as an office or administration building would for a smaller firm. The building—and operation, too—of such testing and experimental shops swallowed up enormous sums, but for such purposes C. F. von Siemens did not spare the costs—the Works Managers knew that when they made their proposals.

The Four Years Plan, which was intended to make the country independent of the importation from abroad of certain raw materials, played an important part in the rearmament of the Third Reich, which officially began in 1935. Amongst other things, the construction of numerous plants for the synthetic production of ammonia, liquid fuels and rubber was included in this programme, most of them being situated in the coal-mining regions of the country.

These plants, which were mostly very large and were constructed in quick succession, represented a rich source of orders for the electrotechnical industry. In addition to the extensive distributor, switching and regulating plant, it was the driving motors, especially those of the large compressors, that appealed to the ambitious-minded engineer. In order to be able to compress the hydrogen to the enormous pressure required for the contact furnaces, piston compressors of a hitherto unknown size and capacity were required, and large slow-running motors were needed to drive them. As these motors ran for months at a time at constant speed once they were started, there was no need to install expensive starting equipment, and thus either asynchronous starting motors with short-circuit rotors were selected or, for larger plants—because of their greater efficiency and power factor—synchronous starting motors, the rotors of which had an additional starting winding. With the aid of this, the motor was started like an asynchronous motor with a short-circuit rotor—as soon as it had nearly reached the synchronous number of revolutions, the excitation winding of the poles was cut in automatically, so that the motor fell into synchronism. These compressor machines stood in a long row in machine halls of a hundred metres and more in length. The enormous pole wheels of the driving motors turned with hardly a sound, and as the quality of the finished product required that the whole process should take place evenly and without any interruption, these machines had to work constantly day and night for about six months at a time until they were relieved by a nearby reserve motor in order to allow routine checking to be carried out. All in all, the Siemens-Schuckertwerke delivered about 300 of these slow-running asynchronous starting machines with an average capacity of 830 kw, in addition to about 100 synchronous starting motors with an average capacity of 2,630 kw; the largest of these was rated at 6,200 kw at 94 revolutions per minute and weighed about 145 tons. In addition, an equally large number of high-speed engines for driving turbo-compressors were constructed, the largest of which actually had a capacity of 8,800 kw. As a rule, the numerous visitors to the Dynamo Works in Siemensstadt were proudly shown a whole series of these enormous machines for the synthetic production of ammonia and petrol in various stages of completion.

A quite unusual electrotechnical performance was demanded of the Siemens-Schuckertwerke by the I. G. Farben Industrie for the synthetic production of ammonia. The gas circulates continuously between the contact furnace, in which the ammonia gas is developed, and the absorption vessel in which it liquifies, and an electrically driven bellows was to be installed in the circulation pipe-line between the two in order to maintain the flow of ammonia gas. The gas leaves the furnace with a pressure of 300 atmospheres, which is raised by approx. 25 atmospheres by means of the bellows so as to be able to overcome the friction resistance, and is exceedingly corrosive where copper and the usual insulation materials are concerned. Under these conditions, the "mole motor," as it was jokingly called, a three-phase asynchronous starting motor with a short-circuit rotor for 375 kw and 3,000 revolutions per minute, was housed in a thick-walled steel pipe of 600 mm diameter which was freely suspended from a supporting bridge 6 or 8 m above the ground in the open. It ran constantly for 4 or 5 months at a time and could not be seen at all, even the bearings were not accessible. This last feature alone is sufficient to make an engineer's hair stand on end. But it worked—the Siemens-Schuckertwerke, who designed the motor in collaboration with the client, delivered 46 of these moles up to 1943.

The continued electrification of the railways can also be indirectly attributed to the rearmament programme of the Third Reich.

After the first World War, two large networks had developed in Germany, not including the Leipzig-Magdeburg section mentioned earlier: one in Southern Bavaria, the other comprising the Silesian mountain railways. Of these, the Bavarian network commenced to expand after the world economic crisis and extended its branches to Württemberg too. The railways accordingly needed more locomotives and as numerous suggestions were put forward for the solution of the driving problem, the result was a number of different types. The engineers wanted to avoid the high-mounted motor with its precarious shank drive, and thus all kinds of ingenious but complicated designs were created at home and abroad, in which the engine torque of the chassis-mounted motors was to be transmitted to the carrying axle by means of elastic connecting links. On the other hand, Reichel put forward the theory that the principle of the axle-mounted motor, which had proved successful in trams, should be reintroduced; although half of the weight of the motor in this design was borne by the carrying axle, there was no reason to fear any adverse effects on the track, even at high speeds. And in order to prove the correctness of his opinion, he arranged for a goods train locomotive equipped with four axle-mounted motors and an all-welded lightweight chassis to be built by the Siemens-Schuckertwerke at their own risk and placed at the disposal of the Reichsbahn for trial purposes. The result was the general introduction of this type and the application of the same principle to the passenger train locomotives. On the whole, the Siemens-Schuckertwerke supplied the Reichsbahn with the equipment for 365 locomotives between the two wars; the two largest developed 8,000 h. p. and drew the heaviest express trains up the steep slopes of the Thuringian forest with their 25 per mil gradients at a speed of 60 kilometres per hour—no steam locomotive was able to compete with them here!

In those days, the Dynamo Works was busy with the construction of a large number of machines of unusual proportions, and about the most interesting of these were those intended for the propulsion of ships by electrical means. Originally, the propellor was connected to a piston steam engine installed in the centre of the ship by means of a long shaft—machine and propellor performed the same number of revolutions. When the steam turbine was introduced in shipbuilding, various difficulties were encountered at the outset; the turbine had to run much slower than it was accustomed to because of the propellor, and special reversible turbines were required in order to be able to manoeuvre the ship. The first of these difficulties was later overcome by installing gear-wheel transmission between the turbine and screw shaft, a technique which was developed to a high degree of perfection. Electrotechnicians had, however, attempted at quite an early date to make use of electrical transmission between turbine and propellor, whereby the turbine, running at its usual number of revolutions, drove a three-phase current generator which fed the propellor motor situated in the stern of the ship—the turbine thus became lighter and more economical and in addition, the propellor shaft was no longer required. This idea did not meet with a favourable reception at first in the somewhat conservative circles of the ship-builders and ship-owners and only the United States Navy introduced it into their battleships so as to make them as manoeuverable as possible, thus giving the American firms an opportunity to gather experience with this type of motor. Not until the year 1933 did the Siemens-Schuckertwerke, due to Bingel's persistence, receive an opportunity for large scale trials, for which Bleiken, the contracting engineer of the Hamburg-America Line, offered his assistance. The fast steamship "Potsdam" with a displacement of 18,000 tons, which was just being laid down for the Eastern Asia route and was designed to make 21 knots with its twin screw drive, was to be equipped with two turbo-generators for 10,000 kw and 3,200 r.p.m. each. These fed two synchronous motors with asynchronous starting, developing 13,000 h.p. and 160 r.p.m. each, which were to drive the propellor. As there were four possibilities for the combination of the two sets of turbo-generators and propellors, at low speeds one turbine operating economically and at full load could feed both propellor motors. The steam was generated in Benson boilers with 80 atmospheres pressure—the first case of high pressure in shipbuilding. The ship was a complete success and brought in seven further orders for the Siemens-Schuckertwerke in the course of the next few years, one of them for driving "the largest diesel-electric ship in the world," a pleasure steamer of 25,300 tons ordered by the Workers Front and named after Ley. Its two propellor motors of 4,350 h.p. were fed by 6 diesel generators.

Apart from these new projects, the normal line of business of the Siemens-Schuckertwerke continued to expand at an ever increasing rate.

An order for the drive of a rolling mill in Dortmund-Hörde for the production of armour plating for tanks attracted particular attention due to its size: a converter, the two parallel-connected d.c. generators of which each developed 11,000 kw, fed the reversing rolling mill motor, which developed 19,000 ka at 53 r.p.m. or 25,800 h.p., by way of a Leonard circuit—it was the largest motor of its size built up to then in the world. A similar task arose in connection with the broad band mill train which was installed by the Vereinigte Stahlwerke in their hoop iron rolling mill in Dinslaken. This expression was used to denote a special process first used in the United States, whereby thin sheets of one or two metres breadth were milled in as long a strip as possible. The broad steel band had to pass through a number of rolling stands and it is obvious that the rollers of the individual stands must all be adjusted to exactly the same speed in this method, otherwise the band would develop loops or tear. In this case, the Siemens-Schuckertwerke supplied 6 d.c. motors of 2,200 kw each which were fed by a grid-controlled rectifier and automatically adjustable as regards speed—it was the largest and most impressive plant of its kind in Europe. The same can well be said of other equipment supplied—in 1938 the Siemens-Schuckertwerke received through the mediation of "Fusi" an order for machinery for the large hydro-electric plant near Supung, on the Yalu river, which marks the border between Korea and Manchuria, at that time under Japanese control.

This order covered four of the total of seven generators for 150 r.p.m. and 100,000 kva each, which had a diameter of more than 10 m and weighed more than 1,000 tons. They could thus be called the largest current generators ever made in Europe. The same applies to 7 so-called mobile transformers (which were suspended between two special trucks for purposes of transport) for 120,000 kva at 220,000 volts high tension—peak performance was the rule everywhere. The Dynamo Works in particular was working to the limit of its capacity.

Among the cranes constructed by the Siemens-Schuckertwerke for particularly heavy duty were a number of floating cranes, four of which, ordered shortly before the war by the Navy for use in the construction of large warships, were conspicuous by reason of their huge dimensions and very high performance. The derrick-type crane was erected on a floating pontoon of 5,000 tons displacement which was able to move under its own power by means of three electrically driven propellors of a particular type, one at the front and two laterally arranged astern. Inside was an electric plant with three generators driven by diesel motors and developing a total of 2,500 kva. The heavy mast of the crane with its adjustable derrick was erected on the deck of the pontoon and rose up

114 m above the surface of the water when the derrick was completely vertical. At a radius of travel of 18 m, measured from the outer edge of the pontoon, the crane could lift and swing 350 tons, and at 48 m radius of travel it could still manage 50 tons. Siemens-Schuckertwerke found in this difficult task a welcome opportunity to prove their capabilities. One of the cranes was sold on completion to the Soviet Union by the Reich Government, and arrived safely in Leningrad on June 21, 1941.

It was stated earlier on that by reason of the restrictions made by the Treaty of Versailles, the "Nedalo" was founded in Hengelo for the development of large searchlights. A patent applied for by Heinrich Beck in 1910 to cover a new arc lamp design had in the meantime acquired great importance for searchlight development. The important feature of the Beck Lamp was that the positive carbon, which was completely saturated with metal salts, had a smaller diameter than the crater which formed in the positive carbon of the earlier searchlights, so that the starting point of the arc was greatly over-heated and thus resulted in a light of great intensity. The advance made was similar to that from the carbon to the metal filament lamp. Thus it was that the largest searchlight built up to the end of the war, which had a reflector diameter of 2 m and was equipped with solid carbons, had a light intensity of 350 mill. candlepower, whereas a searchlight of the same size with a Beck Lamp gave a beam of 2 milliard candlepower. It was therefore possible to raise the intensity without increasing the diameter of the reflector by constantly raising the current in the arc, until in 1944 the searchlight had a beam of 4.4 milliard candlepower, or 12½ times the intensity of the searchlights of 1918.

After 1933, the most important part of the development and production work was transferred back to Nuremberg from Hengelo, but the rapidly increasing requirements ensured the Hengelo factory of sufficient work in spite of this. Whereas in the first World War it was the Navy that was mainly interested in the searchlight, the Air Force now came into the foreground, in addition to the Army. It called for range and direction finders in order to be able to detect enemy aircraft, and for the combination of these with searchlights by means of remote control, together with transport facilities for the searchlights and generating plant. An enormous and increasingly specialized field of development opened up, in which the satisfaction with the products of the human intellect was merely damped by the thought that they were so closely connected with the work of destruction.

The "Gesellschaft für elektrische Apparate" which, as reported earlier, was engaged in the manufacture of electric signalling apparatus for the Navy and Merchant Navy, and had originally commenced operation in a very modest works in Marienfelde, near Berlin, increased more rapidly in size and importance than could have been foreseen at the outset. For the rebuilding of the Fleet was started as early as 1922, although it was severely restricted by the Peace Treaty. But within these limits, the Navy intended to achieve the highest degree of technical perfection and if the size of the warships was restricted, then the aim was to increase their firepower as much as possible within the permissible limits. With this in view, the Navy found in the firm of Siemens & Halske an ambitious physicist, Dr. Rellstab, who had been with the Firm for some time, and both parties were fully aware that one of the most important ways to achieve these aims was to perfect the fire-control systems.

The development of these has been followed right up to the end of the first World War. The idea put forward by Raps, namely, to keep the target in the sights by means of a telescope known as "direction finder" coupled with other apparatus, whereby all guns were directed onto the target and delivered a salvo simultaneously, which in contrast to spasmodic fire from the individual guns has a considerably greater material and psychological effect, could not be put into practice during the war, and when the matter of fire-control at sea was taken up again in 1924, it was clear that certain aspects of the task would require further development before the entire problem could be mastered. One of these concerned the remote control of the heavy guns, another involved the consideration of certain correction values. With regard to the first of these problems, the elevation setting of the heavy guns by manual means had been abandoned, due to the enormous weight to be moved, and hydraulic drive introduced, whereas the swivelling of the turrets in the horizontal plane was carried out electrically. Both movements were to be controlled electrically from the bridge. The second task, the consideration of the so-called correction values, consisted chiefly of compensating the movements of the ship caused by the sea. For this purpose an artificial system of coordinates had to be created with the aid of rapidly rotating gyroscopes, by which the separate movements of the ship caused by the sea, such as yawing, rolling and pitching, could be measured. The values obtained by means of instruments created for the purpose by a firm of specialists had to be translated into electrical values and then taken together with other values to make the necessary calculations. Furthermore, the distance measured had to be constantly corrected, as it changes according to one's own speed and course and those of the enemy—these values from the direction finder were also used in the calculation. But as the shells took one to two minutes to reach their target at ranges which had meanwhile increased to 20—30 kilometres, the distance had meanwhile changed again.

This change, together with the influences of "external ballistics"—wind direction and strength, air density, powder temperature and other influences on the flight of the shell—were calculated by means of a correction instrument and likewise translated into electrical values. Finally, there is also a certain delay between the closing of the fire contact and the departure of the shell from the muzzle—this influence of "internal ballistics" may seem immeasurably small to the layman, but it is sufficient in a heavy sea to produce an error in the required position of the gun—and this was compensated by means of an advanced fuse device, which brought the "advanced fuse angle" into the calculation.

Naturally, this development did not proceed as smoothly as it may appear from this account. On the one hand, other firms applied for and received delivery contracts, some of them firms which had been founded with the aid of the Navy, particularly in the case of those manufacturing gyroscopes and calculating machines, and on the other hand, the Firm did not get away from the mark at the first try. Thus the Siemens engineers spent years over unsuccessful attempts to construct a large liquid pendulum to be used instead of the gyroscope for determining the coordination, endeavours to carry out certain calculations by photographic means were also in vain and a calculation table, which was actually very ingenious and was tried out for a whole year, together with the relevant drawing table, on the ship of the line "Schlesien," failed to find favour in the eyes of the Naval commanders either.

Things went this way on numerous other occasions—years of difficult and expensive work which yielded no results, trouble with the Navy over the resulting high prices, quarrels with other firms over patents and priorities and doubts in the House concerning the ever-increasing organization which had been called into existence merely to meet the demands of one single customer, who in addition had become very difficult to work for. But by 1936 matters had progressed so far that a new fire-control system had been elaborated in spite of all difficulties—the Gelap had gained the lead by fusing all these complicated calculations in one composite solution. A few ingenious combinations of mechanical and electrical components formed an instrument with a bewildering number of different parts; they measured, calculated and corrected all the required values and then moved the long barrels, so that a slight pressure on the pushbutton sufficed to release a salvo, and even when, during the course of a heated bombardment, several salvos were on their way simultaneously, the flight of each of them was governed by a different set of values. Ships like the "Bismarck" could be regarded as exceptional achievements from a technical point of view, not least of all by reason of their fire-control systems, and were consequently respected by their opponents—not without good reason, as it later proved. But the course of the war showed that the days of such large battleships were over.

The remote-controlled target ship is naturally not unconnected with fire-control systems. Target practice with mobile targets at sea had so far only been possible by towing large target boards. As the tow rope could not exceed a certain length, the exercise was not without a certain measure of danger for the ship engaged in towing, apart from the fact that the most important aspects of a battle cannot be reconstructed with a simple target board moving across the line of fire, in addition to which target practice is necessarily restricted to a more or less calm sea. When the Fleet was in the process of rebuilding, much attention was given to the possible use of the remote-controlled ships developed during the war. The idea occurred that electromagnetic waves, which had been used in these remote-controlled boats, could be employed for the control of large unmanned ships, which could serve as practice targets. For this purpose, an old ship of the line, the "Zähringen," was converted by the Navy and equipped with remote control apparatus by the Gelap. It was fitted out with automatic furnaces and motors for the steam valves and rudder, so that it could follow any course at any speed required. The orders were telegraphed to the ship in the form of impulse trains similar to those transmitted by the dial plate of a telephone. In this way, switches were operated on the target ship which closed the corresponding circuit, such as "full speed ahead." Thus a large number of orders could be sent to the ship and their receipt acknowledged. When the necessary order was given, it could even be made to simulate gunfire!

The success of this first attempt induced the Navy to have the former ship of the line "Hessen," which was larger and more modern than the "Zähringen," fitted out as a target ship by the Gelap in 1935. It could carry out as many as 200 different orders. The Italian Navy also had the former armoured cruiser "San Marco" converted into a target ship. The work was carried out according to the Berlin plans by the Officine Lombarde Apparecchi di Precisione (Olap), which was founded in Milan in 1931 and was under the control of Siemens & Halske, although Italian capital was invested in it too. The Olap developed very well and did good business with the Italian shipbuilding industry, which was very active, in addition to other activities.

In the Gelap, work had finally been started at the end of the 20's on a problem which had interested inventors before the first World War—the problem of reducing the rolling of the ship caused by the sea. Schlick had suggested the use of a large gyroscope, an idea which was followed up in the United States by Sperry. But these gyroscopes were large and expensive plants with constant and heavy power consumption, and another solution was accordingly sought. Frahm suggested one of sparkling simplicity—on both sides of the ship he arranged large chambers filled with water, so-called stabilizer tanks, which were connected with one another by means of a pipeline of large cross section. In later models, the pipeline was replaced by the sea itself, by providing large openings at the lower end of the tanks through which the seawater could flow in and out. The idea was that the water should flow to the lower end when the ship listed, thus delaying the upright movement and reducing the rolling. In this arrangement the water should reach its greatest speed of flow when the ship reaches one of the two final positions in rolling—the speed of rolling and the speed of the water flow had a phase difference of a quarter of a period.

This idea is only really practicable if the ship rolls regularly like a pendulum. However, this is not the case—the movement of the sea is irregular, its effect on the ship depends on the course taken by the latter, natural and induced oscillations of the vessel in the water combine to form a complicated movement, the wind and other influences can cause continuous heeling—in short, the simple stabilizer tank was still imperfect. It was necessary, so they said at Gelap, to control the movement of water in the tank in accordance with the rolling and this would first have to be measured—this was the "Leitmotiv" of the House, which can be followed throughout its entire course: measuring, measuring, measuring...

Now in the development of fire-control systems it had been learnt how to measure the movements of a ship against a fixed system of coordinates, and a gyroscope was again employed, the values determined being used for the control of the liquid in the tank, for which the bunker oil reserve can also be used. In order to move this liquid, the tanks would have to be connected at the top and bottom by means of pipes—the liquid flows through the lower one and the upper one is needed for the regulation of the air cushion, which is set under pressure by means of bellows. A damper in the upper pipe, controlled by the regulator, enables the pressure to be distributed on either side in accordance with the movements of the ship and thus to force the liquid to follow certain movement phases. The results showed that the rolling of the ship could be considerably smoothed out in this way—of course, it could not be abolished altogether.

So far, the name of Gelap has only been mentioned in connection with the Navy, but as the Army needed electrical communications equipment as well, it approached Siemens & Halske with its requests, and as part of the apparatus, such as telephones and their exchanges, were frequently similar in design in both cases, it was quite natural that the Gelap with its extensive factory in Marienfelde should also assist in production for the Army. However, the Navy considered this factory its own domain, and grotesque quarrels frequently arose between the two customers as to who had prior rights, until Siemens & Halske decided to set up a special works for the Gelap in Lichtenberg with which to carry on production for the Army. Apart from special designs, the Army needed enormous quantities of the standard products of the House, especially when re-armament was in full swing, varying from power cables to sub-standard film cameras, and frequently special stipulations were attached concerning the design which it was not always possible to refuse, as the political leaders and their deputies were quick to respond with accusations of sabotaging the nation's defence. Now the Army was not satisfied with the handling of its orders by the House of Siemens and would no longer tolerate being passed from one department to another, in the process of which it was impossible to guarantee that the secrecy regulations could be observed—in the Third Reich every screw delivered to a military depot was a secret—in short, they demanded that a special department should be set up to deal with their requirements.

Under such pressure, Siemens & Halske decided in 1933 to found the "Siemens Apparate & Maschinen G.m.b.H." (SAM). The new company took over the "Gesellschaft für elektrische Apparate," with its two works in Marienfelde and Lichtenberg, and also the Aircraft Engine Works in Spandau, and was chosen to be the central office for all business with the Forces. The Technical Director was Dr. Max Moeller, so far Head of the Calorimetric Instrument Department.

The Aircraft Engine Works did not remain in the new formation for long, as the Air Force, now in process of rebuilding, proved to be the most exacting customer of all. Under pressure from this quarter, it was amalgamated with the newly founded "Brandenburgische Motorenwerke G.m.b.H." in which the Air Force reigned even more supremely than the Navy had in the Gelap earlier on. They soon demanded that the Works be extended to such an extent that C. F. von Siemens could not see his way to complying, especially as he had always considered the construction of internal combustion engines to be foreign to the nature of the House of Siemens. After long negotiations with the Air Ministry he succeeded in selling the whole of Siemens & Halske's share in the business and was thus finally rid of this branch of production.

But he was not rid of the Air Force, whose other demands had so far been handled by the SAM. Even before the Air Force started to rebuild, the Gelap engineers had been engaged on the problem of automatic pilots, which ensure that during blind flying, i.e., on flying through zones where visibility is very bad, the required altitude and course are maintained quite independent of external influences—gyroscopes enable deviations from these settings to be measured, and these measurements are transmitted to regulating devices, which readjust the elevator, side rudder and ailerons by way of regulating motors. Relieved in this way, the pilot can devote himself to navigation. These automatic pilots had no direct military importance, nor had the blind landing device developed from it later, but they served as a basis for remote control problems of all kinds which cropped up in fighter aircraft during the course of the war. The Air Force demanded that the machine guns should be capable of being loaded, sighted and fired from one position. For this and other purposes, electric energy was required in no small quantities; the necessary generators, lines, switching, measuring and safety equipment had to be developed to meet the requirements of aviation, as the designs used in electrotechnics up to that time could not be used in aircraft—above all they were far too heavy. The "constructional units," as they were named, had to be adapted to the requirements of aviation and this was one of the most important tasks of the Aviation Dept. which developed within the SAM. It was soon heard that the department would need a works on its own. C. F. von Siemens, for whom working for the Air Force was becoming more of a torture every day, resisted the idea strongly at first but finally had to give in to the pressure from inside and outside the Firm. The Air Ministry built quite a large works from its own means in Hakenfelde, near Spandau, and allotted it to Siemens & Halske as lessees. The department was detached from the SAM and made independent under the name of "Luftfahrtgerätewerk Hakenfelde G.m.b.H." After a short interim period, Capt. Altvater, an able man, was chosen as Head of the new Works, as he had originally worked with the chief of the Naval Dept. engaged on the development of the fire-control system and later with the SAM, and now saw the fulfilment of his ambitions in the rebuilding of the new Air Force.

But for all this emphasis on various departments in which the rearmament drive of the Third Reich made itself noticeable, it should not be overlooked that by far the greater part of production continued to serve peaceful purposes. This was also true of the laboratories. The scope of this laboratory work can be seen from the fact that every sixth engineer employed by Siemens & Halske in Siemensstadt worked in a laboratory, and the following account will give some idea of the work carried out.

The Research Laboratory under the leadership of Gerdien was designed for research of a general nature, and was at the disposal of the entire House, jumping in at the initiative of its leader wherever specialized problems arose in the course of development, the importance of which called for the assistance of his personnel and special equipment. This department carried out research on the physics of electrical discharges and the transmission of electricity, and carried out very extensive and valuable studies on the nature of electrical contacts. Its acoustic research and the invention of apparatus for the analysis of gases has already been mentioned. The physical-chemical research carried out in this laboratory was of great importance for studies on raw materials; in this connection, purest iron and purest nickel were produced as the basis for new materials, and new hard metals for machine tool steel (Akrit) as well as a new insulating material (sintered corundum) for sparking plugs created. Grondahl discovered in the U.S.A. that when a copper plate is annealed in the presence of oxygen and a layer of cuprous oxide burnt onto it, a sort of rectifier effect is achieved between the two substances, whereby the current is conducted readily from the cuprous oxide to the copper, but hardly at all in the opposite direction. Twelve years' cooperation between the Small Accessories Works and the Research Laboratory were necessary before the cuprous oxide dry rectifier could be factory-produced in uniform quality and it soon developed into a very good business.

Around the year 1935, Siemens-Schuckertwerke engineers began to follow up the phenomenon, already known for some time, that the element selenium, a semi-conductor, acts as a rectifier at the point of contact with a metal, i.e., will let the current through in one direction but blocks it in the other. Here again, systematic research over a period of many years was required to develop the selenium rectifier to the production stage. Later it not only restricted the application of the cuprous oxide rectifier to certain fields, but also largely superseded the mercury vapour rectifier for low voltages and large currents.

As the Cable Works and the Siemens Valve Works were the common property of the two main Firms which comprised the House, their extensive development departments and the research laboratory could be considered as the expression of their cooperation. But these and the almost unsurveyable host of specialized laboratories in the various works were exceeded in scope by the positively enormous expansion of the Central Laboratory for Communications Engineering during the course of the years.

One can debate for hours on whether it is advantageous to allow a group of laboratories to expand beyond a certain point, thus restricting their Heads in the main to administrative work, but as the problems of long-distance transmission in telegraphy and telephony, including picture telegraphy and television, as well as the nowadays almost unavoidable transition in most cases from metal conductors to radio waves and vice versa, has occasioned such a mass of closely interrelated fields of development, it was right to let things develop as they did. The only comparable undertaking of this size at the time, the Bell Laboratories, have also grown up into a gigantic structure. In addition, the Central Laboratory, starting with its initiator Lüschen, always had the good luck to be under the command of men, who, in spite of all their administrative work, still found time to guide research in the right direction and contribute creative thought themselves.

The phenomena which are normally grouped together under the term magnetism, in particular the behaviour of ferro-magnetic materials, had been a matter of interest for research even before the science of electrotechnics came into existence, and in the course of time a whole mountain of observation material and reports had been accumulated, but a systematic classification and comprehensive explanation of these phenomena continued to create the greatest difficulty. It was believed that the so-called internal or mechanical tensions were the main cause of the particular characteristics of the materials in question, and that these were generally caused by the inevitable changes in temperature resulting during their production, but could also be increased by subsequent cold-working, and resulted in disturbances in the regular structure of the crystal lattice. Recently it has also been recognized that even very small, scarcely measureable additions of non-ferro-magnetic materials have a certain influence on the magnetic behaviour of ferro-magnetic substances. This is not the result of what certain practical researchers would consider "idle" speculation, but of research of far-reaching importance in practical science. On the one hand, it leads the way to magnetically soft materials, in which the adjustment of the magnetic effect to the magnetizing cause was very far advanced, and on the other hand to types of steel for permanent magnets, the fields of which, in proportion to the amount of material used, are scarcely to be believed.

As the electrotechnician, whatever he may be doing, is always surrounded by magnetic fields, it was no wonder that in view of the many laboratories at Siemens, numerous departments were simultaneously engaged on problems concerning magnetism and that much research work was carried out in the limited sense of the word. More than 50 publications on an advanced scientific level had been brought out on the subject during the period 1930—1945. After the war had broken out it was decided to concentrate the actual research work under M. Kersten, in order to avoid further dissipation of effort, and to name the department "Development Dept. for Magnetic Materials." The advantages of such a concentration are quite clear, but one in particular is worthy of note—a department grew up here in which the scientists of the House who were interested in the problem, and most of them were, frequently met in discussion which resulted in many a fruitful exchange of ideas.

It was much to the advantage of this and other research work that Siemens & Halske had since 1933 held a large number of shares in the Vakuumschmelze AG in Hanau, which had developed from the longstanding firm of Heraeus chiefly known for the production of Quarz lamps. The smelting of metals in a vacuum, first used at Siemens by Bolton for the production of tantalum, had meanwhile achieved great importance for the production of magnetic materials and for resistant materials of special quality, but also for metals which have to be smelted into glass in the production of valves of all types. It is clear that in such cases a particularly close connection exists between scientific research, production of raw materials and design and production of the final product; on the other hand, the amounts produced are not large; just think what a coil of high-grade resistance material, which is connected to the input side of a sensitive measuring instrument, may weigh. In this form of production, a group of laboratories are involved which have to produce quite a large number of different types of materials, all of them used in very small quantities. If such a department is to function economically, it must dimension its production in such a way that other consumers can take advantage of it—on the other hand, it must first serve its own masters. This form of cooperation proved to be so fruitful that Siemens & Halske followed it up more closely still by the further purchase of shares in 1937 and by increasing the capital.

Since the foundation of the Siemens-Schuckertwerke in 1903, the Elektrizitäts-AG, vorm. Schuckert & Co., Nuremberg, had only been a holding company. It administered the undertakings it had founded at home and abroad, in addition to its shares in the Siemens-Schuckertwerke, which accounted for practically half of the capital of this firm. From year to year, the importance of these other undertakings dwindled; new concessions were not granted in Germany and the old ones gradually passed into the hands of the large State, municipal and mixed undertakings as the latter steadily expanded. For Schuckert too, the first World War had meant the loss of his undertakings abroad, and almost the main function of the administration in Nuremberg after the war was to receive the half of the dividends paid by the Siemens-Schuckertwerke and to pass them on to the shareholders as Schuckert dividends. Of the remaining interests, those in the power stations, tramways and funicular railways of the Bergische Land were the chief ones of any importance, apart from their interest in the Franken Power Station, and the Municipal Authorities, particularly in the recently developed city of Wuppertal, were already clamouring for the former.

From the Siemens point of view, this state of affairs could have continued for a long while, had it not been that another factor had become increasingly unpleasant during the course of the years. On the amalgamation of the firms in 1903, Schuckert agreed to discontinue production, and everything he had produced up to that time was transferred to the Siemens-Schuckertwerke—in addition to this, Siemens & Halske had its own production. Now it could not be a matter of indifference to the Schuckert shareholders which of the firms was engaged in the various lines of production, for they had a share in the profits of the one and not of the other. For this reason, the fields of development and production had been laid down in the contract between the Siemens-Schuckertwerke and Siemens & Halske, the border running between power current and signal current. In 1903, these terms had been quite clear, but not 20 years later, and the more time marched on, the more the two fields merged into one. In the end the position was such that development in the border regions between these two main fields was seriously restricted, as quarrels soon arose on the question of competence and rights, behind which were the financial interests of a group of shareholders. It was thus clear to C. F. von Siemens at the beginning of the 30's that the only way out of the constant bickering was the complete liquidation of Schuckert.

But it was a number of years before he finally achieved his aim, as a number of human factors were involved in the further existence of Schuckert. It was not until the Annual General Meeting of the Siemens & Halske AG on June 13, 1939 that it was decided to increase the capital of the undertaking by 50,000,000 Reichsmarks by issuing new preference shares without voting rights, and on the following day, the Annual General Meeting of the Elektrizitäts-AG vorm. Schuckert & Co. decided to reduce the original share capital of 56,500,000 Reichsmarks to 50,001,000 by cancelling some of their own shares, and to accept the offer extended by the Siemens & Halske AG to exchange these Schuckert shares at the rate of 1 : 1 for the new Siemens & Halske preference shares. The Schuckert shareholders now became Siemens & Halske shareholders without voting rights, the entire property of the company was transferred to Siemens & Halske and the firm of Schuckert was liquidated after lasting for 66 years.

Naturally, these years of rapid business expansion brought many changes in the Management and among the departmental Heads. The natural course of things occasions the retirement of older members and their replacement by younger ones. But details of these changes would overburden this account too much, and will be restricted to stating that Winter-Günter, the Head of the large and important group in Nuremberg, retired in 1933 after 20 years as Director of the group and was succeeded by Karl Knott. In 1939, the untiring Köttgen had to bow down to his 68 years. His place was taken by Rudolf Bingel, as had long been planned, who in turn suggested Scherowsky as his successor as Head of the "Industrial Department." "My time is nearly up," said C. F. von Siemens sadly to Köttgen as his faithful servant took leave, "for I am only one year younger than you." Although he was blessed by nature with a sound constitution, he was gradually beginning to suffer from certain unpleasant symptoms of old age, such as failing eyesight, which impressed upon him the necessity of thinking about a successor. For some time past he had been training his nephew Hermann, the eldest son of his brother Arnold, who had worked his way up in the Firm to become a member of the Board of Directors, to be his successor. What depressed him most of all was the feeling that he was no longer master in his own House. This is not meant in the same sense as it would have been around the turn of the century, when certain industrialists took the view with regard to their employees that they were "master in the House." He had early grown out of any such ideas, which due to his liberal turn of mind, he considered to be completely outdated. But he felt himself responsible for the undertaking as an industrial and economic body and he did not feel capable of carrying this responsibility much longer if decisions were forced upon him from outside which resulted in an extension of or addition to the already existing number of factories. As life in general, so that of the nation's economy was also threatened by the demon of the State, which is often called the Totalitarian State. It had the economic and commercial life of the nation in its hands and had made it a part of the State, and its fate was now insolubly connected with that of the State. This was the heavy burden which weighed upon C. F. von Siemens, for what should become of the House of Siemens if the all-powerful man at the head of the Totalitarian State should allow the rearmament to break out into an armed conflict?

XXXII

THE SECOND WORLD WAR

When Hitler, on concluding the Russo-German Pact of August 23, 1939, had achieved his aim of dividing up Poland for the fourth time, and the second World War broke out as a result of this blow, the position of the German economy was much different to that in 1914. On that occasion, the economy, in particular the industry, was completely unprepared, and this resulted in the faulty decisions, incomprehensible to later observers, which have been described here in the relevant chapters. This time, however, the leaders of the State had carefully planned everything in advance, which must have been clear enough to even the most simple-minded when strict State control of foodstuffs and other essential consumer goods was introduced. Rations cards were already printed and only needed to be distributed. The position was much the same for industry. As it was harnessed into a rigid system of regimented economy and divided up into groups, it was only necessary for the central command posts to give the required orders to make any essential changes without causing any rippels on the surface.

For the House of Siemens, the main difference from the first war was that the utmost exertion was necessary to fulfil the direct, but chiefly indirect, demands of the war leaders in electrotechnical matters, and it was thus impossible for the House to give any thought to other matters foreign to the nature of the Firm, as was the case during the first war. However, the State procurement offices did give some thought to the matter, and brought pressure to bear on the Siemens-Schuckertwerke, in particular, whereas they assumed that the enormous demands of the forces for communications equipment would keep the workshops of Siemens & Halske occupied. Its sister firm, on the other hand, had participated during the first war in the manufacture of artillery and other material directly needed for warfare, and could in their opinion do the same again this time. Bingel needed not only all the skill at his command, but also a great deal of personal courage at times to evade the pressure brought to bear upon the Firm or even to openly oppose it, and when an order for turning armoured shells for heavy naval artillery was finally forced through, after alluding to the mobilization regulations, Bingel managed soon after to show the unbidden guests the door.

The so-called "counter-espionage" measures represented an enormous burden for the industry. The dread of spies common to all totalitarian systems rose during the war to a paroxysm. In the Third Reich, the District Commanders had ordered the appointment of so-called counter-espionage agents in all factories during the last years of peace, who were made responsible for the execution of very strict secrecy regulations and were charged during the war with others tasks, among which sniffing out the opinions of their fellow-workers in order to counteract defeatism was the most unpleasant. As the various organs of the army proved to be unsuitable for the task, it was transferred to the police in 1940, and the counter-espionage agents, although employees of the Firm, now received their orders direct from the Secret Police.

The course of the first year and a half of the war brought Poland, Denmark, Norway, Holland, Belgium, Luxemburg, France, Jugoslavia, Greece, Hungary, Bulgaria and Romania under German rule, most of them by direct conquest, and the rest by way of indirect subjugation through the medium of a Government which was dependent on Germany. As Czechoslovakia had already been incorporated into the Greater German Reich beforehand, and Italy gradually became entirely dependent on Germany during the course of the war, Hitler thus controlled the greater part of Europe and its war potential as regards foodstuffs, raw materials and industrial capacity, the latter particularly in Czechoslovakia, France, Belgium and Luxemburg.

As a result of this, the blockade set up by Great Britain in the same manner as during the last war was not so effective as it had been on the first occasion, although of course Germany had no access to the overseas markets. The blockade ring was not closed either; in the East the vast Soviet empire delivered enormous quantities of raw materials and foodstuffs in accordance with the terms of the agreement concluded between the two countries. Under these circumstances it soon became clear that Germany would not be overcome by blockade alone. The population was kept rather short of foodstuffs, but they had sufficient to live on, and nobody doubted the intention, openly expressed by the Führer, of letting the others starve sooner than the Germans. There were a number of difficulties with raw materials, especially metals, but here again one soon learned to improvise and find a way out of the situation. Many of the old hands in Siemens, who had been in the Firm during the first World War and with this knowledge of wartime economy had made dark prophecies in their private circles concerning the outcome of events, had to admit that in respect of economic problems they had "completely misjudged the genius of the Führer."

In the course of 1940, C.F. von Siemens, now 68 years old, felt that he would not be able to carry on at this pace and sought medical advice. He was urgently advised to retire from business, and therefore transferred the current business matters to his nephew Hermann, whom he had chosen to be his successor, and frequently retired to his country seat near Baden-Baden for convalescence. But he just could not part with his work entirely and was always back again in Berlin when important matters were to be decided. Irrespective of the course of the war up to that point, he remained hostile to the National Socialist regime, and the more Hitler and his horde of followers, blinded by the rapid success, boasted of their exploits, the blacker the future of Germany appeared to him. In a letter to one of his assistants, written on May 25, 1941, he wrote "I can well understand your desire to retire. I have the very same desire, and my work no longer brings me satisfaction or joy. Those who were once proud that their work was devoted to the task of serving progress and humanity, can now only be sad that the results of their work merely serve the evil of destruction. Whenever I start to think 'why,' I should prefer to creep into a corner, so as not to see or hear any more..."

Fate spared him the pain of seeing or hearing much more of this madness. On July 9, 1941 a short illness put an end to his life. His mortal remains were taken to the Court of Honour of the administration building in Siemensstadt for a worthy farewell ceremony, for he was mourned by the entire staff of the House. On this occassion von Buol held the memorial speech on behalf of the House of Siemens, and after speaking of the personality of the deceased and of the role he played in the history of the Firm in unpretentious and simple terms, he closed with the sentence: "We admired C. F. von Siemens, but we did more: we loved him." The voice of this earnest and seemingly cold man broke as he spoke these words and a noticeable feeling of emotion went through the crowd assembled.

One of the last important tasks with which the Head of the House had been occupied, the completion of which he was not to see, was the settlement of the Telefunken case.

At the beginning of the 1930's, the extension of the agreement between the AEG, Siemens & Halske and their common daughter firm met with increasing difficulties. When the agreement was concluded between the two firms in 1903, the subject of the agreement, wireless telegraphy, was a strictly limited and easily definable term. It remained so for quite a while, until the appearance of radio after the first World War caused certain complications, which however, were overcome in the manner described. The more the boundary between cable communication and wireless communication was obscured by the multiple use of cables and overhead lines with modulated carrier frequencies—or, which actually amounted to the same in the end—the use of the high tension lines of power stations for the transmission of messages on the same principle, the more frequently did the quarrels occur. It was in the nature of communications engineering that a message was frequently sent over a cable or overhead wire to start with and then transmitted to a mobile station from a certain point, either to a ship, vehicle or plane, by wireless. It often happened that two or more different methods of transmission had to be used for other reasons too, as in the case of the Greek Concession Agreement for the connection of the islands with the mainland—it was impossible to have two partners quarrelling as to which was competent at the junction of the two systems. Siemens & Halske, as one of the leading firms in the world in the field of communications, was suffering increasingly under such difficulties, of which their main competitors knew nothing, and in the course of developments unavoidably came into a position where they were no longer able to respect the boundary line drawn thirty years earlier, and it was naturally on their side that the desire for a thorough revision of the Telefunken Agreement was stronger. In addition to this, the two partner firms, on founding Telefunken, had intended to restrict the daughter company to development and sales, and to keep the production for themselves, which proved to be increasingly impracticable. Test workshops developed from the laboratories of Telefunken and factories unavoidably grew up out of these. These grew up not only in Berlin, but also in other German towns. Finally Osram's valve factory came into the hands of Telefunken. Thus, in 1938, Siemens & Halske approached the AEG with the news that they could no longer tolerate the position with regard to Telefunken and would have to press for a complete revision of the agreement. The negotiations which took place lasted for three years, as the original proposals made by Siemens & Halske to divide up the entire substance of the Telefunken firm between the two partner firms proved to be impracticable. In the end, they agreed that the firm of Telefunken should become the property of the AEG, for which the Telefunken transferred half of its participation rights in certain wireless undertakings at home and abroad, the entire capital of the Deutsche Grammophon-Gesellschaft m.b.H. and their share in the Klangfilm G.m.b.H., to Siemens & Halske, whereas the AEG transferred their shares of the Vereinigte Signalwerke A.G. and of the Klangfilm business, together with the shares of the Bergmann Elektrizitätswerke in their possession to Siemens & Halske. The remainder of the purchasing price left uncovered was paid in cash. Thus Siemens & Halske now found itself faced with the task of building up a new works for radio production, for which, it is true, the technical and administrative foundations were already there.

The numerous types of electronic tubes were important components in radio technique and already during the preparations for the founding of the new Wernerwerk für Funkgeräte (wireless equipment) it was obvious that development and manufacture would be the most important tasks of the new works. A special Tube Works had been set up in Vienna for various reasons, chiefly to avoid the concentration of ever increasing masses of people in Siemensstadt. However, that would mean disbanding the old Siemens Tube Works, in which up to quite recent times the largest rectifier vessels and the smallest radio reception tubes had been manufactured together. "Together" should not be taken in the strict sense—the difference in the size of the vessels, in the material and the purposes for which they are used had occasioned a division into special departments at quite an early date. Now, after the foundation of the Radio Works, the time seemed ripe for a complete readjustment of the position, especially as there was every reason to believe that the original grouping of the entire valve business in one works had yielded the desired results and could now be given up without harm. Development and manufacture of valves for long-distance communication were therefore put in the hands of the new Wernerwerk for Radio Equipment, which was placed under the management of Hans Kerschbaum, and the rest of the former Siemens Valve Works were now re-named the Rectifier Works. Its manufacturing programme included mercury vapour glass rectifiers made with pyrex for up to 500 amps and iron rectifiers, mostly for the higher amperages. Originally air pumps had been necessary to maintain the vacuum, but later it had been learned how to introduce the anode through the top of the iron vessel so that the latter would be completely gas-tight. The anode of chromium steel, with a glass ring around it, was held in an iron tube, and the tube welded or soldered onto the vessel. The difficulty was to melt the glass on the inside and outside with the iron, and the necessary resistance to fracture was obtained by reason of the fact that the glass had to be kept under pressure in the manufacturing process. Metal vessels with heated cathodes, filled with the rare gas Xenon, served as thyratrons in the manner already described for the purpose of releasing a current at an exactly predetermined moment by charging the screen around the anode with a certain potential. They were switching devices of an unheard-of precision in time for those days. In addition to the cuprous oxide rectifiers, a contact converter was also being developed, in conjunction with the Switch Works, in which a metal sliding contact was to move over fixed contacts in place of the arc, which sprang from one anode to the other of the rectifier.

A particularly important task arose for the Rectifier Works when the idea of using high voltage direct current for the transmission of large quantities of energy over large distances, which had been recommended by Thury many years ago in Geneva and had frequently been put into practice, gained new importance under the rapidly changing circumstances. In accordance with these plans, which incidentally were being followed up about the same time in Switzerland, three-phase current was to be generated, changed into high voltage direct current by means of transformers and rectifiers and transmitted to the long-distance line in this form. At the receiving end it would then be reconverted into three-phase current by the reverse process. The advantage over the previous three-phase current transmission was that one of the three conductors of the three-phase current system could be dispensed with and that cable would probably be used, as this could be loaded with much higher voltages due to the absence of the dielectric displacement current, in addition to which there would no longer be any of the complications inherent in lines operated with three-phase current. Admittedly, the double conversion of the current system had to be taken into account.

A thorough reorganization of the works still running under the name of Wernerwerk F (Communications) revealed the necessity of building a special works for the production of radio equipment. It had, admittedly, as already described in Chapter IX, been divided up in the course of time into an ever-increasing number of workshops, which as such were put under the control of Gustav Leifer when Hettler departed in 1929, but the whole complex was still called Wernerwerk F, next to which was situated the much smaller and far more compact Wernerwerk M. The time now seemed ripe to change the departments, which up till then had differed according their functions, into works, whereby the difference between "works" and "factory" should be noted. The latter term covers only the manufacturing shops, whereas the former is a more comprehensive term, which also covers development and sales in addition to the production. The Wernerwerk F was therefore split up into works for telegraph equipment, telephone equipment, amplifiers, radios and components, wireless telegraphy equipment and electro-chemistry, to which was added the Wernerwerk for Measuring Instruments. Fritz Lüschen as Deputy Chairman of the Board of Directors of Siemens & Halske, who had been Head of Wernerwerk F since 1933, took over the management of this group of seven works. The Heads of the Works, always watchful to guard their independence, would probably not have been very pleased at this introduction of a further link between them and the Chairman of the Board—von Buol—if their respect for the capabilities of the world-famous Lüschen had not been supplemented by a good measure of genuine affection for his dashing personality.

Although the blockade of the European Continent by the British Fleet was incomplete, it nevertheless proved to be a big obstacle, not only for the German import from overseas of raw material but also for the shipment of finished products out of the country. Among other things, one of the four giant generators ordered in 1938 for the Yalu River power station was finished and was waiting in the Dynamo Works for shipment, and a second one was nearing completion. How were they to be brought to Korea?

Now after the Germans had occupied the Atlantic coast of France, occasional ships left the coast to try and break the blockade and it was a singular coincidence that the first of the two Yalu generators started on its journey one day on board the SS "Osorno," a motorship built by Blohm & Voss for the Hapag and equipped with electric propellor motors built in the same works as the generator being transported. The "Osorno" reached Japan safely with its cargo, whence the latter was brought by the "Fusi" to Korea and installed. On its second trip the "Osorno" carried a section of the stator of the second generator with it, but as it started its third journey with the other section, it suffered the same fate as so many merchant ships of the warring countries which sailed the worried seas. The rotor waited in vain in Bordeaux for the return of the "Osorno" and disappeared in the later confusion of the war.

The Dividend Payment Decree of 1941 and the regulations thereunder forced the German Joint-Stock Companies to re-adjust their capital, which as a result of the inflation of the balance sheet figures, bore no relationship to the large volume of business actually done. Siemens & Halske purchased in the open market 6,090,000 Reichsmark of the original bearer shares, the 6,500,000 Reichsmark preferences shares with voting rights mentioned earlier and 4,501,000 Reichsmarks of the preference shares without voting rights, a total of 17,091,000 Reichsmarks, and wrote them off at the expense of the special reserve, so that a share capital amounting to 94.5 mill. original shares still remained. Of this capital, the first 6,650,000 Reichsmarks were increased to 19 mill., with sixfold voting rights, the remaining 87,850,000 Reichsmarks with single voting rights to 251 mill. and the remaining 45.5 mill. without voting rights to

130 millions, so that the entire share capital amounted to 400 mill. Reichsmarks. As can be seen, a factor of 2.86 is used in all the calculations, the content of "water."

In the meanwhile, the war, which had so far run succesfully for Germany, had taken a decisive turn, for Hitler attacked Russia on June 22, 1941 with an enormous mass of troops, without a declaration of war and in direct violation of the agreement signed less than two years ago. Although the Russians resisted the advancing German troops tenaciously, the front line in the Southern Ukraine was approaching the Dnieper by the middle of August and coming ever closer to the large engineering works near Saporoshie, of the construction of which an account was given at the end of Chapter VI. It was clear to the Russian commanders that this must not be allowed to fall into enemy hands intact. They therefore had the generators short-circuited and run with the turbine regulators wide open, while the oil ran out of the bearings. At the same time they drove several lorries loaded with explosives into the 3½ metre high control tunnel in the lower part of the dam which runs approximately 20 meters below the level of the impounded water from one bank to the other, and exploded this on August 18, thereby tearing out the centre third of the dam wall. Along the crown of the dam, which had been laid down as a road 800 metres long, masses of retreating Russian troops were crowding back, together with a part of the civilian population, when the dam was blasted, and when one considers that the water, which had been kept back by the dam, rushed forward through the gap in a giant wave, one can picture the situation.

The German administration of the occupied Eastern territory, which was expanded considerably in the next year of the war, was naturally interested in bringing the extensive industrial plants in Dniepropetrovsk, Saporoshie and Woroshilograd, the ore basins of Kriwoi Rog and the Donez region, all of which drew energy from the large power plant, into service again for war production and therefore lost no time in tackling the problem of restoring the dam. Considering that it took 4½ years to build in the first place, one began to wonder whether there was any sense in making the attempt at all, especially as there were differences of opinion among the German experts called in as to the most appropriate way of restoring it. Finally Max Enzweiler, the Head of the Siemens-Bauunion, who had functioned as building adviser to the Soviet Government when the dam was constructed, managed to carry the day with his proposals. He considered it possible to have it finished by the end of October 1942. Under the leadership of the Siemens-Bauunion, an association of German building firms was created which actually managed to complete the dam in fourteen months, reckoned from the day of the destruction, in accordance with Erzweilers plans, an astonishing feat considering the enormous difficulties. The electric power plant of the dam was repaired by the AEG.

But the dam only remained in operation for one year before it was blown up a second time, this time by the Germans retreating before the Russians. Building—destruction—rebuilding: the union of war and technique proved to be sheer madness.

The prolongation of the war due to the Russian campaign made itself felt in the increasing shortage of manpower in the German industry. On the one hand, the army made increasingly heavy demands: whereas the losses in the previous campaigns had been insignificant in proportion to the results achieved, they had risen since the beginning of the Russian campaign to an alarming figure. A large number of new formations had to be set up, for on December 11, 1941, a few days after the attack by the Japanese on the American Pacific Fleet in Pearl Harbour, the war had become a World War when Germany declared war on America. On the other hand, German workers were constantly being called into the occupied Eastern territories in order to restore or increase the production there. In the East, this mainly consisted of the cultivation of large areas of very fertile soil but also of working large coal and ore desposits, whereas in the western regions there were factories of all kinds to be operated, and even if local labour was used for production, the management had in many cases to be left to German experts. If the German econnomy, including agriculture, was laid bare in this way and a steady rise in production demanded in spite of this, the acquisition of extra heads and hands would soon become a problem of the first magnitude.

As in the other warring nations, women had been conscripted for work in Germany as well, as had also been the case in the first World War. Labour service on a compulsory basis was introduced for them, in so far as they were not exempt by reason of old age or having to care for small children. At Siemens, most of these women worked in the factories, where they had already been employed for fifty years as a result of the increasing mechanization of production and assembly. A small number of them found employment in the offices, where they performed lower grade work of a commercial or administrative nature, so far as they were not employed as typists. There were no women employed on skilled engineering work.

As the rearmament created a shortage not only of material but also of manpower in the last few years before the war broke out, this soon became pronounced among the young engineering personnel in particular.

The youths consequently had positions assured to them before they had even finished their studies and the competition between firms for the young engineers showed peculiar and often unpleasant results. In Siemens, the question was brought up as to whether women could not be used for a number of technical jobs in the offices and laboratories.

As female technicians did not exist, Siemens decided to take the matter in hand themselves. Girls leaving the high schools, who were willing to take part in the experiment and who seemed suitable on account of their reports, were selected, paid on the same scale as salaried employees and sent to special schools, which were set up for the purpose in Siemensstadt and in certain of the branch offices. There they had to learn in a two year course, under the tuition of engineers of the House, about the same amount as the young engineers at the university in the first four terms up to the first examination. In order to achieve this, they had to work very hard. It was not handed to them on a silver plate. As the initial results were sufficiently satisfactory to encourage the Firm to make further attempts, the system was gradually extended. In 1943, approx. 250 girls were undergoing training in 10 different schools. In all, a total of about 500 electro-assistants, as they were called, passed through these schools, although the last batch did not complete their training, for after the autumn of 1944, war events made it practically impossible to carry on.

On the whole, the trial could be considered successful. As the name "assistant" suggests, these girls were intended to help out the engineering personnel and to relieve older engineers engaged on independent work in laboratories, testing rooms and design rooms of much of the tiresome routine work. The general opinion was that they acquitted themselves well in this capacity, and they made a special name for themselves by showing more patience and reliability in long serial tests and their evaluation and in complicated calculations—such as the computation and representation of the field of an electronic lens and similar games of patience—than the men.

But the gaps, which grew in size and number from day to day, were not to be filled by employing women alone, not by a long way, nor by employing the numerous prisoners of war who poured in from the East in large numbers from the middle of 1941 onwards. For this reason, the German Government started quite early to recruit "voluntary" workers in the occupied territories. The living conditions in the occupied countries, which were generally quite bad, may well have misled many of them to believe that conditions in Germany would be better. But as the number of volunteers was not sufficient either, pressure was brought to bear on the others, and the appointment of one of Hitler's veteran Gauleiters as Delegate General in charge of labour mobilization at the end of 1942 was the signal for the satraps in the occupied countries in the East to herd together all men and women suitable for the purpose in the most brutal manner and to deport them to Germany, where they were housed in special barrack camps in the vicinity of the large firms. Similar camps were set up in Siemensstadt for various nationalities, to which another for Italians was added later. In the Firm, every effort was made to ease the lot of these uninvited workers and everyone who had anything to do with them was told to remember that these foreigners, when they returned home, should only be able to speak well of the Firm. Thus it came about that quite tolerable relations sprang up between the German supervisory personnel and the foreign workers, and the foremen all spoke with appreciation of the willingness and handiness of the workers from the East. But if an objective observer had watched these grey masses of strange men and women stream back out of the gates of the factory to their barrack camps on the edge of the Jungfernheide after work was over, a strange, sad feeling must have come over him when he thought that these Works, once built as workshops for free Germans, were now filled with foreign slaves who longed to be back again in their homely peasant cottages, although they were certainly not used to a life of luxury there either.

In addition to the prisoners of war and foreigners there was a third group of people who were forced to work in the factories: the Jews. From November 1938 onwards, the Jews had no civil rights whatsoever. They were degraded and persecuted and from autumn 1941 onwards they were forced to wear a yellow star on their breast, which marked them as outlaws. Finally the deportation of the Jews to the East started, in so far as they were not willing to work in the large factories, which had to open up special Jewish sections. Thus there were several Jewish sections in Siemensstadt too, for the operation of which comprehensive official regulations covering every detail had been laid down, just as was the case with the foreigners and prisoners of war. In spite of this, the Firm tried their best to ease the lot of these unfortunate people wherever possible, and went so far in their violation of official regulations that the persons responsible more than once found themselves faced with serious consequences.

When, after the war was over, judgement was passed on the National Socialist regime and all who were even suspected of having abetted it in any form, and all leading officials were suspended from their posts and had to appear before Commissions of Enquiry and Denazification, a witness gave the following testimony before one of these courts:

"With regard to your question as to what I know of the personal attitude of Mr. X to the Jewish problem, I think I can cite the conversations I had with my cousin, Mrs. Käthe Zadeck, née Hirsch, with whom I was very friendly, as being of particular interest. She was employed as a worker in one of the Siemens factories. It was the usual thing in those days whenever one came into contact with Jews to talk chiefly about the way they were treated in the factories. In many of them they were treated abominably. I offered to put in a word for my cousin if she had any complaints. She declined the offer and said 'conditions could not be better than they are at Siemens. The payment is bad, but that is no fault of the firm.' She received specialized worker's pay but the tax and the special social contributions the Jews had to pay accounted for about half of it. In spite of the long journey from the Nicholassee, and she had to stand all the way, as the Jews with stars were not allowed to sit down in the trams, and in spite of the long working hours, she said that conditions could not possibly be better. To be employed at Siemens was the biggest stroke of luck that could come their way. She cannot testify to this herself, as she was deported and is still missing."

On the whole, about 2,000 Jews were employed at Siemens during the first years of the war, and the Firm as well as the Jews themselves believed that it would remain so until the end of the war. But at the end of January 1943, the Secret State Police started to remove all the Jews from the Berlin factories and to transport them elsewhere. The members of the Boards at Siemens were horrified at these measures, for they knew what it meant for the victims. A member of the Board of Directors went into the lion's den, in this case the office of a first squad leader of the S.S., and succeeded, by urgently remonstrating with him and painting a picture of the collapse of vital war production, in obtaining authorization for the Firm to keep the Jewish workers for the time being. They could breathe again, but not for long, as four weeks later, just after work had started in the morning, a column of lorries appeared in front of the factories, police brought the Jews out and loaded them on the lorries—before anyone had time to do anything to stop them, the lorries and their victims were gone. They were never seen again.

On October 25, 1942, the British 8th army opened the battle of El Alamein, on November 8, the American troops landed in Algeria and Morocco, and on November 19, the Russians broke through the German lines near Kletskaja on the Don, encircling the 6th army in Stalingrad. These three events in quick succession marked the turning point of the war. From now onwards, Germany's military position went from bad to worse.

At the same time it became obvious that it was no longer possible to properly defend the factories and installations vital for war production against attacks from the air. Size, load carrying capacity and defensive armament of the bombers increased with every new model brought out by leaps and bounds, and instead of selecting single objectives, a certain area was allotted to each formation and a carpet of bombs dropped which destroyed practically everything it covered. This new tactic was first used on German towns in the Spring of 1942 with devastating results, and the damage caused in the winter of 1942/3 was decisive for the further course of the war.

Each of the three Forces, Army, Navy and Air Force, had had its own administration offices as early as the commencement of rearmament, and these were responsible for the provision of arms and the necessary equipment, as well as development of the weapons, for their Commands. Now the Reich Air Ministry had always had a touch of megalomania, which must have attracted the notice of anyone who had anything to do with it, even in the Third Reich, and as a result of this and the initial success of the German Air Force, the responsible persons grew blind to the dangers which were bound to arise from the perseverance of the Allies in the improvement of their own Air Forces, coupled with the early assistance of American technique and production capacity. The development of defence, which can only be effectively carried on from the air by fighters, was therefore rather neglected and when the people in charge finally realized the magnitude of the threat, it was already too late.

In order to balance up the requirements of the Forces one against the other and to exploit the capacity of the available production centres to the full by appropriate distribution of the orders, a Reich Ministry for Armaments and Munition had been created at the beginning of the first winter of the war. When the first Head, Todt, died two years later as a result of an accident, he was succeeded by Speer, who was a decisive factor in the organization of the industrial capacity of the nation. Obliged to force up the production not only of the actual war material but also of all things even remotely connected with warfare, to which every electromotor and every trouser button belonged, Speer's Ministry tried to straighten out all the differences which had arisen between the various firms in the course of the years concerning patents, production secrets, designs and production methods.

For this purpose, the individual branches of industry formed Central Boards, under the direction of which circles and committees allotted the orders according to production groups or certain separate products. The Central Board for Electrotechnics covered, in general, the peace-time economic group of the electrotechnical industry and as Lüschen had been leader of this economic group since 1942, he expressed his willingness, under the pressure from the Ministry of Armaments, to take over the leadership of the Central Board for Electrotechnics.

Up to the outbreak of the war, Lüschen, like most of his colleagues, had taken a sceptical attitude towards National Socialism and up till then had avoided joining the party out of opportunism. At the very beginning of the war he had lost his only son, to whom he had been bound by a deep bond of affection, and his sorrow was mixed with the feeling that all these youths should not die in vain, i.e., that the war must be won first—there would be an opportunity to reckon up with Hitler and his gang later. With these feelings he threw himself into the new task and with his enormous vitality and zest for work he completely wore himself out in this office.

The damage done by the enemy Air Force to the German industrial capacity took on ever-increasing proportions in the course of 1943. First of all every effort was made to restore the plants as quickly as possible, regardless of the material or manpower required, but in spite of this the production of the works involved was interrupted for a longer or shorter period of time, in addition to which the repairs caused a considerable expenditure of material and manpower, which had to be withdrawn from other sorely needed work, and finally one had to reckon with the repaired plant being destroyed again. One often had the impression that the enemy spared the works they had attacked, say a petrol plant, until they estimated, with the aid of a good information service, that the repair work had been completed, and then returned to attack it again. Under these circumstances, the attempt to keep production going was like the task of Sisyphus in the old legend.

It was therefore decided to use evasive tactics and transfer important sections of endangered factories to areas outside of the large towns and traffic centres. One finally went so far as to build large underground plants in suitable districts, or even to take refuge in old mines, especially potassium mines. The insufficiency of these methods soon became clear—a well organized production drive calls for direct cooperation between all those concerned in the manufacture. If some parts are manufactured in Thuringia and others in Westfalia, and the whole unit assembled in Berlin, whereby the general dispersal of goods and passenger traffic and communications merely serves to increase the chaos, in addition to which the whole process can be completely upset by the increasing danger from the air, it is not hard to see where all this leads to. Long before an enemy soldier set foot on German soil the war production had been completely disorganized by the Allied Air Forces.

Up to the winter of 1943/44, Siemensstadt had been spared any heavy air raids, but from then onwards considerable damage was done, chiefly by a night attack in February 1944, in the Block Works, Dynamo Works, Electromotor Works, Small Accessories Works and in the long flat buildings of the Switch Works. During spring and early summer 1944, every effort was made to repair a large part of the damage, but in winter 1944/45 further damage was caused which put the Wernerwerk for Measuring Instruments almost completely out of service. The workshops of the Wernerwerk for Radio and Radio Components were hardly usable either. Nevertheless it was not so bad in Siemensstadt as had often been expected. The Nuremberg workshops of the Siemens-Schuckertwerke had suffered much worse by comparison. During an air raid on Nuremberg on January 2, 1945, they were so badly hit that it took several months of clearing up before production could recommence on a very modest scale. When, after the war, the Management tried to get some idea of the general state of the House, the destruction due to war events, by which is chiefly meant air raids, was calculated at about 700 mill. Reichsmarks.

Naturally, in keeping with the tendency of those days, Siemens, too, sought relief by resorting to dispersal. People were always coming and going, looking for empty textile factories in small towns, former foodstuff factories in country districts or lonely castles—which were very popular for laboratories. The number of these decentralized factories rose into the hundreds and if anyòne had asked one of the Directors at the time to list from memory the location of all his branches, it would have been impossible to get a complete answer. During the last few months of the war there was indeed no lack of occurrences which, in spite of the seriousness of the situation, bordered on the ridiculous. The construction of power current condensers, normally carried out in the Dynamo Works in Siemensstadt up till then, was transferred to Pirna in Saxony as it was no longer possible to manufacture them in Berlin after the heavy air raid on February 15, 1944. One year later, after much hard work, when the factory was ready to start production again, the Russians moved in. In the Aircraft Instrument Works in Hakenfelde, on the other hand, it had been decided to transfer the construction of the so-called fighter control systems to a salt mine near Helmstedt, which was extended to take the plant. As the waggons with the machine tools and equipment arrived in Helmstedt from Hakenfelde, American tanks crossed the Weser. They arrived in Helmstedt before the unpacking was finished.

Since the Allied landing in Normandy and the break-through of the Russians on the centre sector of the Eastern front, everything which happened in Germany on a military or economic basis became completely devoid of any purpose—it was like the twitching of a dying man. The Reich Air Ministry, subject to severe criticism on the part of the High Command, was relieved of the development of weapons and instruments for aircraft—this was taken over by Speer's Ministry. They tried to change horses in the middle of the stream. This sort of thing gave the Siemens people an idea of the state of things in the country. Under pressure from the various boards and circles, programmes were set up for the production of instruments for fighter planes which could only be fulfilled by neglecting other urgent matters. But the instruments thus manufactured could not be installed as the Aircraft Works, whose workshops were destroyed and who were seeking in vain for factories in the country or underground plants, could not supply a sufficient quantity of aeroplane cells. If a certain number of aeroplanes had been fitted out, then the engines were missing, and if a plane was finally completed, then there was no fuel.

This last phase of the war saw the use of a new weapon by the Germans, which those at the head of the nation hoped would bring about a decisive turn in the course of the war, and is mentioned here because the House of Siemens, by way of the SAM, participated in the design and production of its complicated mechanism. This was the rocket, developed under the type number A 4. Work on this weapon was commenced before the war, when the Military Armaments Office, on the initiative of circles interested in space travel, set up a rocket test station in Penemünde, on the island of Usedom, where work was pushed ahead during the war with all possible speed. The rocket which was finally produced was a 14½ m long torpedo-shaped body of nearly two metres diameter. It contained a warhead weighing about 1000 kg., and was driven by the combustion of superheated alcohol in pure oxygen, whereby the exhaust reached a temperature of nearly 2000° C and exerted a thrust of approx. 25,000 kg. On starting the rocket rose vertically, then automatic mechanism switched the rudder at the tail over until the rocket was set at an angle of 45° to the horizontal in the desired plane of flight. After reaching a certain speed, which depended on the range of the target, the combustion process was interrupted and the missile continued to fly in a parabolic curve. With the rocket used, the maximum height attained was 75 km and the range 200—300 km.

Complicated electrical mechanism for stabilizing the flight of the missile and correcting any deviation from the required course, for switching off the combustion process at the speed required, according to the range of the target, and controlling the trajectory and carrying out measurements, was partly installed in the rocket and partly at the rocket base, whence it communicated with the rocket over very short wavelengths. The accuracy of the rocket was satisfactory, considering the long range, provided, of course, that no faults occurred in the complicated mechanism. But the time was too short to test it thoroughly. The use of this weapon of destruction, which was designed to terrorize the civilian population in the enemy country, was nothing more than an act of desperation which could no longer influence the outcome of the war.

By the middle of February 1945, it was possible to estimate that the enemy forces closing in from the East and West would probably meet in Berlin. All over the world there was talk of the race to Berlin, as nothing was known of course of the Yalta Agreement, in which other provisions had been made. Hitler, during the last few months of his life, was in an advanced state of physical and mental degeneration, partly due to the misuse of drugs, and in this condition he decided not to withdraw to Berchtesgaden, as originally planned, but to remain in Berlin in order to let the German people, in this case represented by the population of Berlin, heroically meet their doom around his Headquarters in the bunker of the Reich Chancellory. This was no pleasant prospect for the responsible people in the House of Siemens, who had to think what was to become of the factories and personnel entrusted to them.

The Board of Directors and the Board of Management took counsel and decided that the Siemens-Schuckert factories and branches outside Berlin should be grouped together in three groups—Group West, chiefly the Works in Mülheim and the important offices in Western Germany, were placed under the command of Friedrich Bauer, the Head of the Central Department; "South and Central" and "South-East," with the main core of the Nuremberg works, were placed under the leadership of Scherowsky, who was also the primus inter pares for all areas outside Berlin. Only one outside group, with its seat in Munich, was set up for Siemens & Halske, for which Ernst von Siemens was appointed Director. "Director Ernst von Siemens is appointed to guard all the interests of the House including the daughter companies in trusteeship," was the formulation in the official circular of February 19, 1945 in which the changes were announced. The remaining members of the Board of Directors remained in Berlin, determined to share the fate of the Works and the personnel.

Later on, the opinion was frequently expressed that on this occasion, discretion might have been the better part of valour. But on the one hand, it was impossible to foresee how inhumanly the victors would treat defenceless people, and most of these men had the feeling that it was their duty to remain at the posts to which fate had appointed them, although sober deliberation may have recommended a different course of action.

As the danger from the air increased, so-called works air raid precautions had been forcibly introduced in the German industry, in which the entire personnel of the works was obliged to take part. The squads formed relieved each other in fire-watching by night and day, every day of the week. When it seemed likely that Berlin would be turned into a battlefield, the introduction of air raid emergency companies was decreed for all factories. For if fighting went on, in the vicinity of the Works, they would be particularly exposed to the risk of fire and as they could not continue production anyway, a sufficiently large emergency force was to remain there permanently, as if in barracks, so as to protect them as much as possible. As the Russian troops coming from the North and East had worked their way up to the outskirts of the town by the middle of April, the order went out to the emergency squads in Siemensstadt to take up positions on the day after the following, a Sunday. This Friday was the last working day of the war—salaries were paid and even advance payments, as far as the funds went.

On April 23, 1945 the Russians, approaching from Tegel and Reinickendorf, had advanced to the Berlin—Spandau Ship Canal which runs through the Jungfernheide north of Siemensstadt. On the South bank, weak formations of German troops were drawn up to oppose them, the position being characterized, as usual in the fighting in and around Berlin, by the hopeless inferiority of the defence. In Gartenfeld, at the West end of the canal, there was a severe clash between the Managing Director of the Cable Works and the German field commander, as the former tried to prevent the use of the Works as a defence base and was promptly arrested. In the course of the next few days, the Russians crossed the canal and attempts made by the Volkssturm (Home Guard) to hold them up at the railway line between Siemensstadt and Gartenfeld had to be abandoned. The factory buildings suffered much damage from artillery but the occasional fire was extinguished by the emergency squads. On the evening of April 25, after the Volkssturm had retreated, Russian tanks and infantry formations moved through the streets of Siemensstadt.

The emergency squads of the individual Works had expected that responsible officers would appear next day in the factory buildings in order to take charge of them. First of all, only a few Russians appeared, ostensibly to look for German soldiers in hiding and weapons, but really coming to plunder. A female worker of a medical squad in one of the works gave the following report on the first appearance of Russian troops in the administration building: "On Thursday, April 26, 1945, at about 4 a.m., we heard the first Russian shouts way down the corridor. At last the time had come. It was fortunate that we received instructions yesterday to put on grey overalls—the women and girls all had dark headscarves on. We all kept our white coats on over our grey overalls. The Russian voices came closer: the noise of heavy sliding steps, the banging of doors, made us very nervous. The door was thrown open, two young Russian soldiers came in, anxiously, cautiously. Their glances passed round the gloomily lit room, along the walls, into the corners. Then they came up to each one of us singly, pointed their machine guns at us and began to feel our arms for watches—Uri! Uri! As my watch was broken and there was a crack in the glass, I was set free with a gesture to go away—Uri kaputt..."

This was just a relatively harmless prelude. In many of the other Works they started off from the very beginning with terrible acts of violence. They plundered unscrupulously and if anyone did not stop immediately on command, he was shot on the spot, whereas the female members of the emergency squads had to be carefully hidden away to protect them from the worst. At various points in the Works there was still telephone communication with the outside world and while the squads waited for the arrival of the Russians, they heard with horror that their wives and daughters living in Siemensstadt were exposed without protection to the lust of the troops, for whom the simplest rules of behaviour towards women observed by all civilized peoples even in times of war meant absolutely nothing. Many of them, sensing the coming events, had brought their families into the works during the last two days, as they hoped that the company of their dependents would provide a certain protection. One of them shot his wife and child and himself in the Switchgear Works under the impact of the terrible scenes. Several cases of suicide occurred in the residential areas of Siemensstadt too—one woman poisoned her child and herself with veronal—a man jumped from the steeple of a church, at the foot of which lay the bodies of two young girls, raped and murdered by the Russians, others used their pistols. A few artillery shells still landed in the streets, as fighting was still in progress further to the West and South. Meanwhile the flats in whole streets had to be cleared in order to make way for the soldiers. The emergency squads were held responsible as hostages to see that there was no shooting from the houses in Siemensstadt, in addition, a number of them, in particular those of higher rank, were arrested, interrogated and some of them sent to Bernau, where a prison camp had been set up for such cases.

The street fighting, without equal in modern history, which lasted for over a week in the centre of a large city of millions of inhabitants, in which planes, tanks and artillery all took part, naturally claimed many victims among the civilian population, and the House of Siemens had many losses to mourn among its employees. One of the first of these was

Wilh. Rabanus, the Director of the Wernerwerk for Amplifier Equipment, who was killed by a shell on his way home before the Russians had actually entered Siemensstadt. His colleague Illig, the Head of the Electrotechnical Dept., suffered the same fate at approximately the same time during a bombing raid while on a journey to Southern Germany. When the Russians entered the south-western suburbs of Berlin, which were known to them as the residential quarters of people who they were not particularly fond of, they perpetrated the worst crimes of all. In many streets, one villa after another was burnt down and stark terror reigned. On this occasion, Max Moeller, Director of the Wernerwerk for Measuring Instruments since 1943, was murdered. He was found later in his garage with a bullet in his head.

Gustav Leifer, chief of the General Management of the Wernerwerk, has apparently foreseen all these things and those which were still to come. It was not in accordance with his temperament to expose himself to the deepest humiliation and he voluntarily departed from this life when the Russians entered Siemensstadt and he saw his life's work ruined. For Lüschen, on the other hand, the collapse meant the end of an emotional and spiritual crisis, which had already started around the turn of the year and which now convinced him that death was the atonement for the tragic mistakes of the last few years of his life. Six weeks had passed since the Russians had taken over Berlin, conditions seemed to be slowly returning to normal again, and a young assistant who was very much attached to him tried to save him. He had prepared a safe path of retreat to the West and implored Lüschen to make use of it, telling him "over there are the judges, here are the hangmen." But Lüschen declined. He wanted to die, and so he carried out his own plan.

The above-mentioned cases of suicide are only those which took place among the upper hierarchy; quite a number of others cannot be listed here by name. Most of them were office staff, a few chief clerks were among them and others in higher positions, but there were also workers among them, too. In some cases, those who had believed in National Socialism and its prophecies may well have seen the collapse of all that they had dreamt of and have taken their lives in a moment of despair, but in most cases it was probably the horror of all that was happening around them which drove them to depart from this life which now seemed to consist of nothing but terror.

Meanwhile the MWD had commenced its activities. It was impossible to judge according to which points of view the arrests were carried out and it probably depended initially on the arbitrary decisions of the executive authorities. Immediately after the occupation of Siemensstadt, the men who were apparently in charge of the emergency squads were arrested; in some cases, they returned sooner or later, in other cases nothing more was heard of them. Then the addresses of the leading officials were noted down in the Firm and they were duly collected from their homes. In these cases, too, arrest, interrogation (or not), release (or not), further arrest and so on, followed one upon the other at a confusing rate. Others were arrested in the street while certain residential quarters were being combed out, large groups of people being herded together in the process and then carefully sifted out. In this manner, high officials, judges, professors and other teachers, journalists, members of the free professions, industrial leaders and economists of all grades, right down to the shop stewards and finally officials of the National Socialist Party were arrested and imprisoned in camps, not only in Berlin but in the entire Russian zone of occupation. Towards the end of the Summer of 1945, a total of approx. 300,000 people were held in 18 camps. Ketschendorf, near Freienwalde, was usually the first camp for those from Berlin, later they were mostly spread over the other camps. One especially large camp was that in Landsberg a. d. Warthe.

The living conditions, the food and the treatment in all of these camps was such that a large proportion of the inmates perished from exhaustion or from the inevitable epidemics. From the regrettably large circle of Siemens members who fell victim to these conditions, Rudolf Bingel was the most illustrious representative. The men, mostly elderly men too, who were suddenly wrenched from an orderly way of life and flung into primitive living conditions barely fit for Tartars and Kalmucks, were just not physically able to withstand the shock. To this were added the great mental and spiritual dangers which an inactive life among a vast crowd of people living under inhuman conditions can present—a certain percentage of the inmates of such camps relapsed into a state of apathy, whereas the evil instincts were aroused in others and drove them to save themselves, regardless of the fate of others, like those who push others away from the lifeboats when the ship goes down. In such a situation as this, Bingel's conduct in the Ketschendorf camp was exemplary; even in spite of the most humiliating treatment he retained the dignity of the truly great and the principles of a Samaritan towards his fellow sufferers, and kept them going by his good example. On being sent to the camp in Landsberg, he was forced to march in the scorching summer heat and collapsed. He died shortly after he was brought into camp. Similar reports of praiseworthy conduct were heard about Robert von Siemens, the second son of Arnold, who had been Head of the Scientific and Technical Central Office of the Siemens-Schuckertwerke. He fell victim to a serious illness in the camp, from which he appeared to be recovering at first, until his weak and emaciated body finally succumbed—a doctor who was later set free gave glowing accounts of his courage and fine character. The "Siemens people," as they were commonly known, were on the whole the most active and spirited people in the camps and took a particularly active part in the secretly run university courses which were organized in order to combat the tendency to become dull and apathetic under the influence of camp life. A large proportion of them left their lives on this field of honour—a term which can well be used in this case.

A different fate to that of the others awaited von Buol. When work was discontinued in Siemensstadt on April 20, he was unable to return to his villa in Fronau as this suburb was already the scene of fighting, so he retired with another member of the Board of Directors to Heinenhof an der Havel, near Potsdam. This was a former residence of C. F. von Siemens and after his death it had been converted into a group of laboratories, with the exception of a few rooms which could still be used as living quarters. This section of the city was also occupied by the Russians towards the end of the month and it was not long before uniformed members of the MWD appeared, who had evidently been informed that a Siemens laboratory had been discovered where a number of important people were staying. Several interviews, partly held in a courteous and informal tone, probably resulted in a report being made to Moscow, with the result that von Buol was invited to an interview at the nearby Staff H.Q. and promptly arrested. He was taken next day by lorry to an airfield, where he and a group of other civilians were put aboard a transport plane which then set course towards the East.

It was not difficult for von Buol to see the reason for this move. If it was the intention of the Russians to execute him as a war criminal, they need not have gone to such trouble and Russia would scarcely be the most suitable place for a mock trial, for which he would have been a most unsuitable object anyway. No, the MWD had evidently been informed by the experts at home of the international reputation of this prisoner and it was not to be assumed that he would be mistreated—provided, of course, that he gave no occasion for it. If he carried out the wishes of his captors, he would probably lead an outwardly tolerable existence, admittedly in a golden cage. It was even possible that he would be sent back home again later, at a time when the Russians thought that he could no longer be of service to them.

Earlier on, a generation ago, strong feelings of repulsion would have taken hold of the average German when he found himself in such a position, feelings which would have been fed by the bitterness arising from the strong feelings of nationalism which formed a barrier between the peoples. Admittedly von Buol had never been able to appreciate these forms of nationalism even before Hitler had carried them to the extreme, and the war was already over anyway. But the atmosphere and the feelings of the population towards the Russians at that time were already different to those towards the other nations, and in addition he was also bound by duty to the House which he had served all his life. He could not tell whether it would survive or not, but he hoped so, and if it was to be possible to bring it to life again, it would need all the loyalty and devotion of the members of the staff. And he would have to serve as an example to them. At a time long before it was clear that a political and military collapse was impending, he had already become accustomed to the idea that this time, the industry in Germany, especially the large concerns, would be held responsible for a number of things which by rights were purely affairs of the State, and had, as if sensing the approach of such a situation, informed his immediate associates shortly before his arrest that they should defer all responsiblity to him in such cases. Whereas he considered it the duty of his staff to save themselves for the task ahead, he felt that it was his own duty to take the blame upon his own shoulders for actions in which scarcely anyone could have participated to a lesser degree than himself.

When the plane started to land, sunset was spreading its glow over the whole country and numerous lights lit up in the Capital. Moscow was celebrating May Day and was rejoicing over the final victory that was just round the corner. A police car collected the passengers and took them to the prison. Here they were searched for any objects which might have been used for a suicide attempt, as von Buol quickly realized. It was obvious that they would find the small phial which he had carried with him for some time past for all eventualities. If he was to use it at all, then he would have to do so at once, before it was too late. And so he too departed this life, preferring this solution to a life of slavery.

On May 7/8, the unconditional surrender of the German Forces was signed, thus concluding the war between Germany and her enemies, and the rubble and barriers were now removed from the streets of Berlin, the Russians forcing large sections of the population to take part in these operations. In Siemensstadt the first groups of workers reported back for work again, admittedly almost exclusively those who lived on the site, as all the bridges over the Spree and the Berlin-Spandau Shipping Canal had been blown up, so that this industrial quarter was almost like an island. Instead of the wild hordes of pillaging soldiery who had occasionally paid unwelcome attention to the Works, regular sections with a large percentage of officers appeared and informed the staff that they formed part of a technical commission which had been given the task of taking stock of the machines, equipment, raw materials, semi-finished and finished products, and to search for drawings, calculations, test reports and other technical documents and models. It soon transpired that nearly all of these officers were electrotechnical experts, among them specialists in machinery, rectifiers, switching equipment, communications engineering and measuring instruments. They gathered together the remaining emergency squads, the workers reporting back for duty and any other workers they could find on the streets and set them to work immediately on dismantling the workshop equipment.

Meanwhile, the remaining members of the Management—there was as yet no contact with those who had been detached to the western zones—met in Siemensstadt and endeavoured to restore order in the chaos. With the unanimous approval of his colleagues, von Witzleben was appointed Chairman of the Board of Directors of both Firms.

The task of greatest urgency was to obtain permission from the Russians to recommence work and above all, to bring an end to the dismantling. They succeeded in making contact with the City Commandant of Berlin, Col. General Bersarin, and in making it clear to him that if his orders concerning the quickest possible restoration of the Berlin traffic, supply and production facilities were to be realized at all, the cooperation of the Siemens Works would be absolutely indispensable, and that he should not make it impossible for them to recommence production by continued dismantling. Bersarin agreed to intervene on their behalf, but the technical commission seemed to have better connections in the higher quarters, as the dismantling of equipment continued apace. Another visit to Bersarin resulted in the latter asking for a memorandum giving a list of the equipment needed by the works in order to participate in the reconstruction. This voluminous memorandum—in Russian—was handed in at the shortest possible notice, but did nothing to relieve the situation; in fact, the speed of the dismantling increased, as the Russians knew that they would shortly be moving out of the western sections of the town, which would then be taken over by the other Allies.

To start with, the technical commission had selected about one third of the equipment for dismantling in some of the Works, so that it was hoped that it would be possible to save the other two-thirds, then another third was requisitioned and finally the rest was taken away too. This dismantling process was not restricted to the machine tools, of which the largest were taken away first, followed by the smaller ones, until in the end all machine tools and apparatus had disappeared. The cranes soon followed, lifting tackle and other transport equipment, the numerous furnaces for smelting, annealing and drying, the welding equipment, asphalting plant, soaking and impregnating equipment, die-casting machines, electrolytic baths, gas and oxygen generating plant, liquid pumps of all kinds, the compressor plant, bellows, vacuum pumps and piping, valves, dampers and containers, the entire testing and experimental rooms, whereby the loss of the whole of the frequently mentioned switch test room of the Switchgear Works was a very bitter pill to swallow. A complete block of buildings had been specially constructed for this equipment, and the enormous generators were now carried off on well waggons, together with all the laboratory equipment, including many thousands of very valuable instruments, typewriters, calculating and bookkeeping machines from the offices, the heliographic equipment, the photomats, copying equipment, the works printing press, the teleprinters and their exchanges, the time-electrical distribution system, all the telephones, complete with the exchange which was situated in a separate building, the lighting, draft boards, drawing pins, pencils, slide rules—absolutely everything, including, of course, any money they happened to find. All the cupboards and desks were broken open the contents scattered over the floor if they were not taken away, and the files were mostly thrown out of the windows. An eye-witness report states that every second room in the administration building had been used as a toilet, so that myriads of flies filled the rooms. When the British troops took over Siemensstadt early in July, they started by setting sanitary squads to work.

The value of this "expropriation," as it is called in the official jargon, has been estimated at about 450 mill. Reichsmarks, added to which were the requisitioned bank accounts and shares amounting to 350 mill. Marks, sequestrations to the value of 100 mills., the loss of all property abroad valued at 500 mills. and war damage to the amount of 700 mills., i.e., a total loss of 2,100 mill Reichsmarks, which reduced the property of the House of Siemens to about a quarter of its former value. Not included in this figure are the loss of the 25,000 foreign patents, the obligatory publication of details on all important new fields of research, development, design and production methods, the disruption of the clientele, built up in the course of many years with great patience both at home and abroad, and the loss of many invaluable members of the staff, from the two Chairmen of the Board of Directors down to the most modest worker.

Judging by the economic theories expounded and the opinions held in commercial circles at that time, this was indeed the end of the House of Siemens.

But this was not the end. After 5 years of seemingly interminable difficulties and hard work, the rubble was cleared away and the foundations of a new building laid, and after a further 5 years, this reconstruction was almost completed—the phoenix rose again from the ashes. A full account of this will be given in a later work.

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