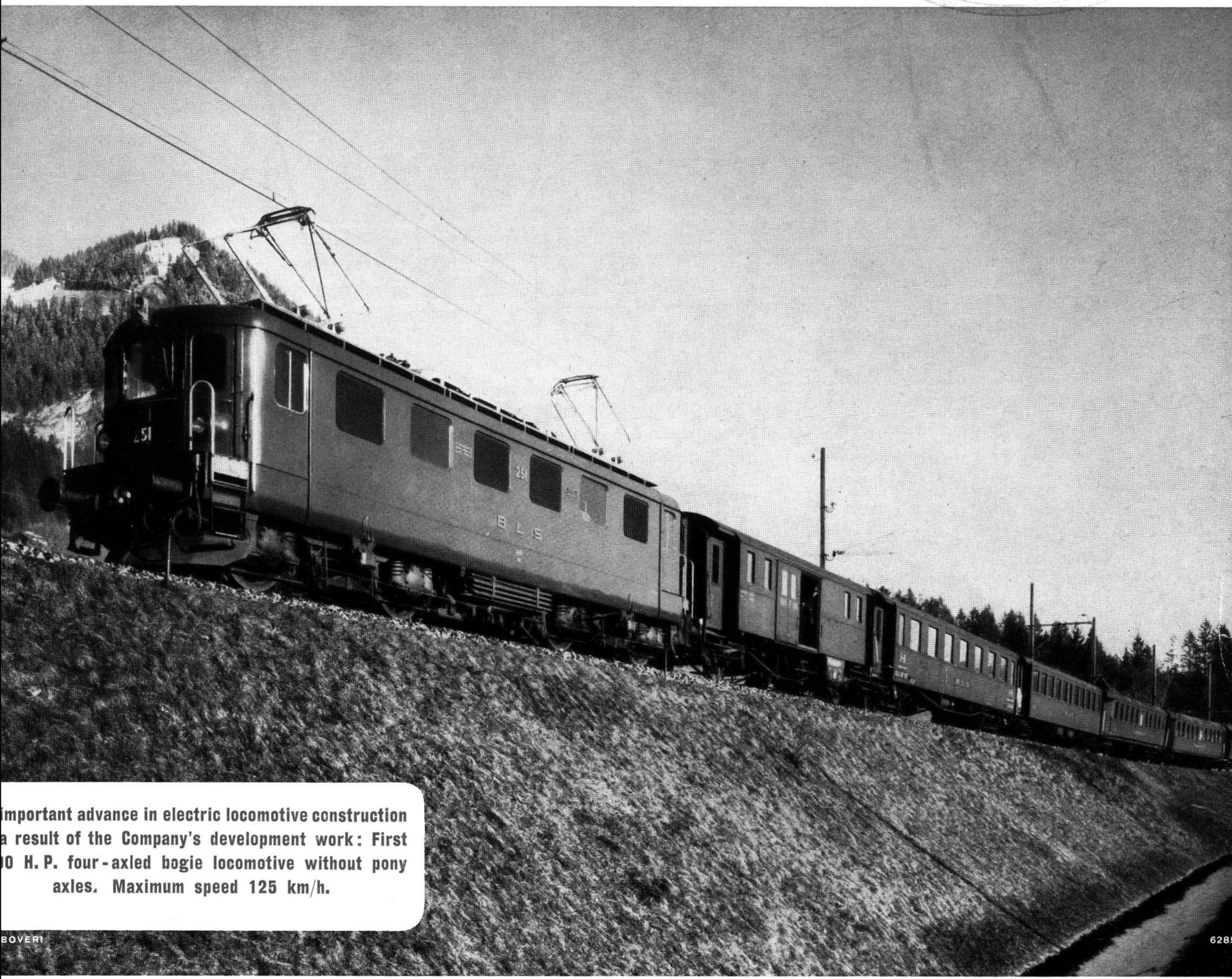
THE BROWN BOVERI REVIEW



No. 6031. BRB. 3. X. 1939

The new $B_0' B_0'$ locomotive, series 251, of the Berner Alpenbahn-Gesellschaft (Berne-Lötschberg-Simplon)

Compared with the one-hour rating of 4000 H. P. at a running speed of 75 km/h the weight of 80 t is extremely low. The locomotive hauls trains of 600—650 t and 360—400 t up gradients of 15 and 27 in 1000, respectively, at 75 km/h. Although this locomotive has no pony axles it runs very quietly and smoothly under all working conditions, not only at all speeds up to the maximum speed of 125 km/h, but even at the speed of 135 km/h attained during the trial runs.

Builders of mechanical part: Swiss Locomotive and Machine Works, Winterthur.

Progress and Work in 1944

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THE BROWN BOVERI REVIEW

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PROGRESS AND WORK IN 1944.

INTRODUCTION.

FOR the twentieth time the first number of a new volume of this journal is devoted to a Review of Progress and Work during the past year. It is gratifying to have been able, year after year, to keep the resolution to begin each new volume with a retrospect of the technical achievements of the previous twelve months.

Due to a kindly Providence the fifth year of the war saw the Company still working in peace — with the regular staff and completely intact manufacturing facilities — on the further development of the products marketed and on systematic research into the important problems of the future. The progress achieved, however, is by no means over-estimated, for it is realized that in other countries not enjoying the same privilege and having to work under strenuous war-time conditions, technical development has nevertheless not come to a standstill. In some countries it has doubtless taken a more or less one-sided form, due to the necessities of the war, but in view of the concentration of the whole resources of the country it has been pushed forward all the more intensively in certain fields.

The Company's developments and work in the past year, however, were uniformly distributed over all of the different lines of manufacture, although the fuel shortage and the temporary but repeated absence of certain sections of the staff on military service proved a hindrance. Special lines as well as standard manufactures, such as are chiefly required by electricity consumers, were both given attention, the latter perhaps more than the former. Particular care was likewise devoted to all manufactures requiring a large amount of high-skilled work, but relatively little material, a policy naturally dictated by the shortage of raw materials in Switzerland. A typical example is the work in the high-frequency field. Among the problems of the future that of the transmission of power with high-voltage direct current has been furthered.

It is known that the friends of the firm always look forward to the annual appearance of the retrospective number of this journal and read it with particular interest. Great pains have therefore again been taken this year to give as complete an idea as possible of the state of progress in all of the Company's fields of activity. It is therefore hoped that every reader will find something to keep up his interest in the firm.

E. Klingelfuss. (E. G. W.)

I. ENERGY GENERATION.

A. VELOX INSTALLATIONS.

During the past year, a Velox installation was put into service which deserves to be mentioned because the fuel is natural gas from which the higher hydrocarbon constituents have been removed to make motor spirit, so that the gas consists of pure methane only. This gas, because of the slowness with which it ignites, often causes difficulties in ordinary types of boilers which do not occur with the Velox steam generator. Fig. 1 shows this boiler on the test bed at our works.

The large Velox steam generators built for an Argentine power station have at last been put into service (Fig. 3). A customer who visited another Argentine plant in order to get first hand information as to the reliability of this type of boiler, reports that the boilers in this plant operate to the full satisfaction of the owners and that during the year preceding his visit, the astonishingly high operating factor of 97 % had been achieved. The service interruptions of only 3 % of the total time were due to the normal overhauls such as are in any case carried out in the entire plant.

Very satisfactory reports have also been received of Velox boilers operating with blast-furnace gas. The Velox steam generator can therefore now be considered as being able to compete with any other type of boiler as far as reliability is concerned. In regard to its special characteristics, namely, those inherent

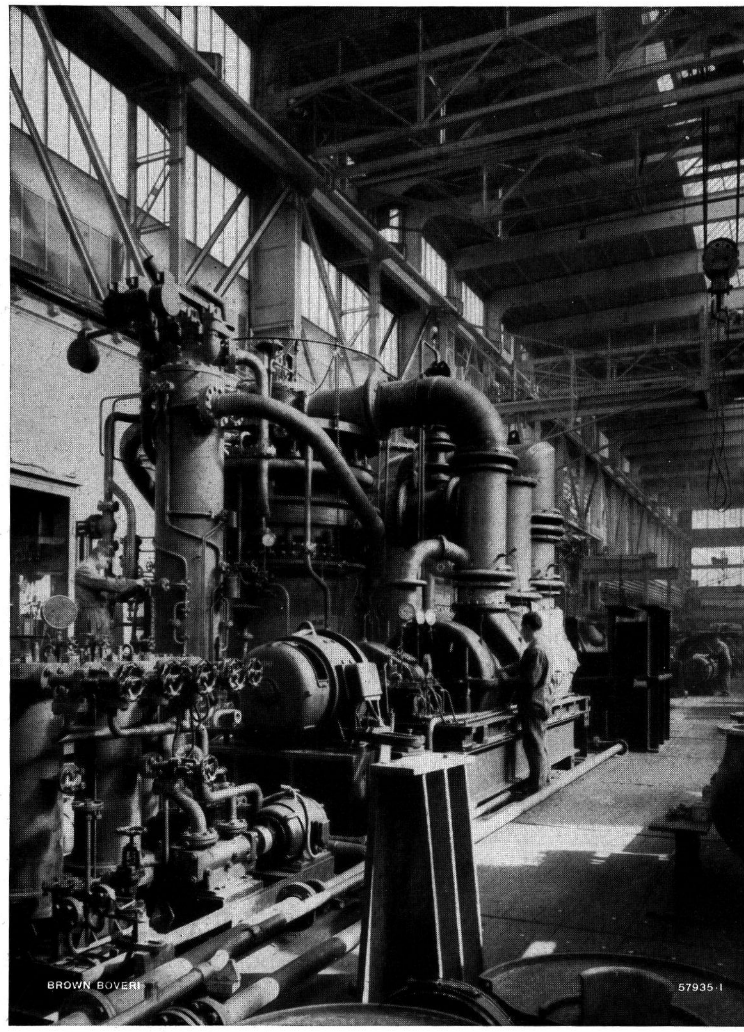


Fig. 1. — 32 t/h Velox boiler for a pressure of 40 kg/cm², 415° C on the test bed.

Even the largest Velox boilers are completely assembled at the works and tested before dispatch. The erection on site and the final putting into service can, therefore, be carried out in the shortest possible time.

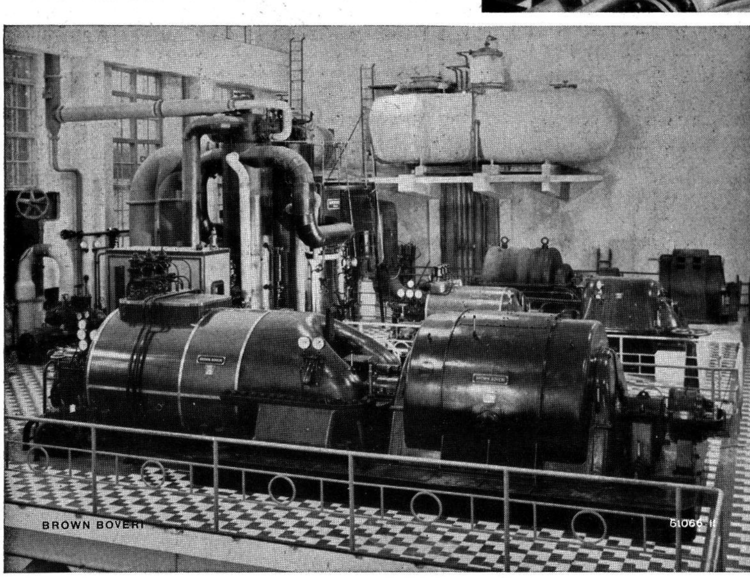


Fig. 2. — Machinery room of a steel works, containing: a Velox steam generator, a turbo-set and two blast blowers.

The Velox steam generator has an output of 27 t/h at 38 kg/cm² abs and 435° C. It is installed in the same room as the other machines.

in the Velox principle, it is unequalled by any other form of boiler. The quickness with which it can be started, its small space requirements, and its high efficiency are not attained by any other form of steam generator. In nearly all Velox installations, the boiler and the machines are placed in the same room (Fig. 2), which also results in a clearer arrangment and facilitates attendance.

The experiments with pulverized coal have now reached a stage where the results obtained enable a start to be made with the detailed design of Velox boiler for this fuel. It has been found that apart from the coal handling and pulverizing plant, the space and the material requirements of such a boiler are hardly greater than those of an oil-fired Velox steam generator; such a boiler will also possess most of the advantages of the latter.

B. STEAM TURBINES.

The steam turbines which were built or put into service during the past year are all of the Company's well-proved standard design and do not present any special characteristics. The 35,000 kW machine shown in Fig. 5 was supplied to a foreign electricity supply company which already has two 28,000 kW Brown Boveri sets[1], each of which has more than 100,000 hours of service to its credit since started up in 1928/30. Fig. 4 shows a further large steam turbine of about the same output.

The turbine shown in Fig. 6 was supplied to a paper mill. It is a two cylinder condensing machine rated at 4000 kW and is built to operate with steam at 41 kg/cm^2, 450 ^{0} C. Extraction points are provided at 12 and 4·5 kg/cm^2 abs. The numerous regulating devices illustrate the manifold requirements in regard to regulation of the power, speed, and extracted steam pressure and steam quantities, which thanks to the Company's new regulating system, can be fully satisfied.

The turbine shown in Fig. 7 is worthy of attention because of its regulating system which will be referred to in detail in the section on regulating devices (page 10).

As evidence that in certain countries the starting up of a Brown Boveri turbine sometimes gives rise to a state ceremony, a view is given in Fig. 8 showing the president of the Republic of Paraguay, General Higino Morinico and his suite, with the management of the electricity works of the city of Asunción just after the president had cut the ribbon holding the handwheel which controls the main stop valve.

Studies and projects on extra high pressure and high temperature plants[2] were also continued during the year. Unfortunately, the present conditions have made it impossible to go ahead with the projects on

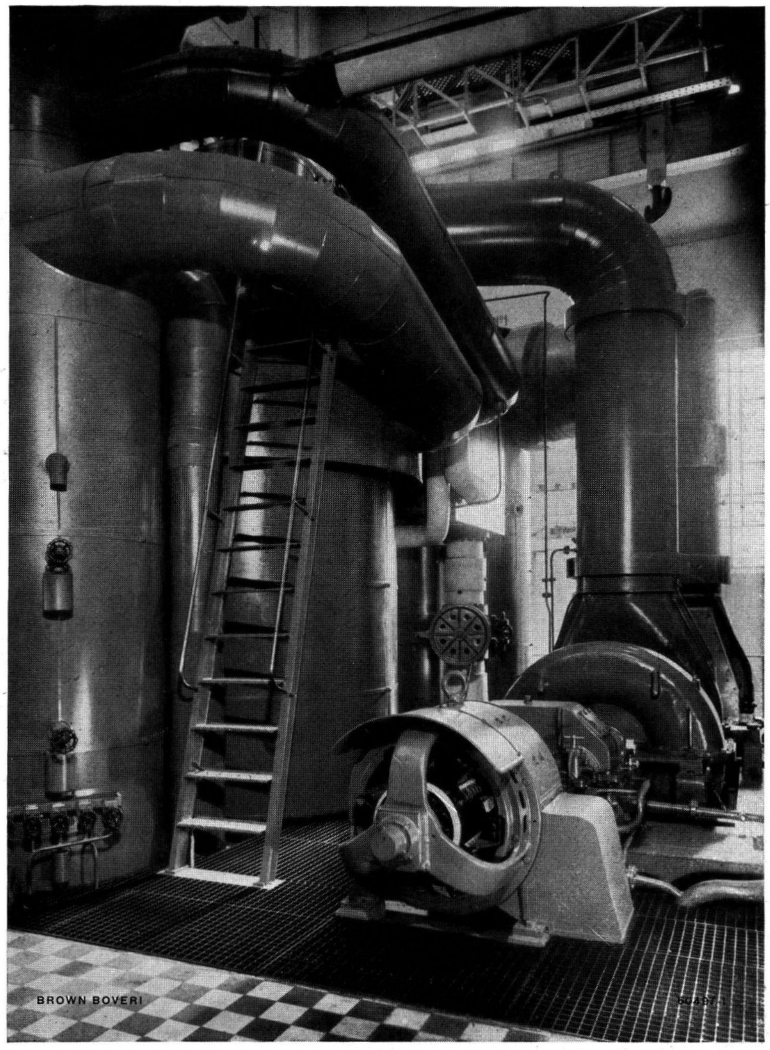


Fig. 3. — 80 t/h Velox boiler in an Argentine generating station.

Many generating stations have made use of this type of boiler not only for peak load purposes, but also because of its high efficiency and good service characteristics as a continuous service boiler. Where the Velox boiler is not installed directly next to the turbines in the machine room, it is often erected in the place of an old steam boiler. It then always generates several times the amount of steam of the boiler which it replaces.

[1] Brown Boveri Rev., 1943, Nos. 1/4, p. 8.

[2] Brown Boveri Rev., 1944, Nos. 1/2, p. 10 and 1943, Nos. 7/8, p. 131.

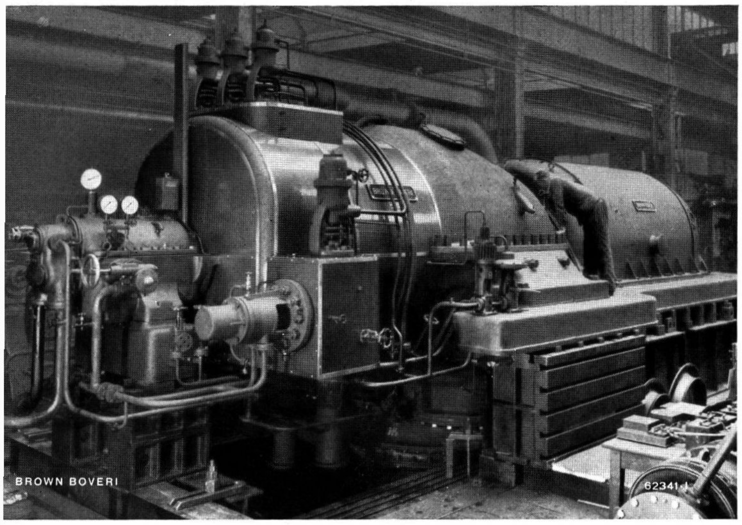


Fig. 4. — Modern 25,000 kW single-cylinder turbine on the test bed.

eam pressure 32 kg/cm² abs. Temperature 420° C, n = 3000 r. p. m. Note the compact rangement of the regulating valves on the turbine casing. This is made possible by our elded construction. As the main steam stop valve is also connected to the pressure oil stem of the regulating valves, a small hand wheel is sufficient to operate it. The devices sible on the turbine bedplate protect the turbine from excessive pressure rises, either in the impulse wheel chamber or in the condenser.

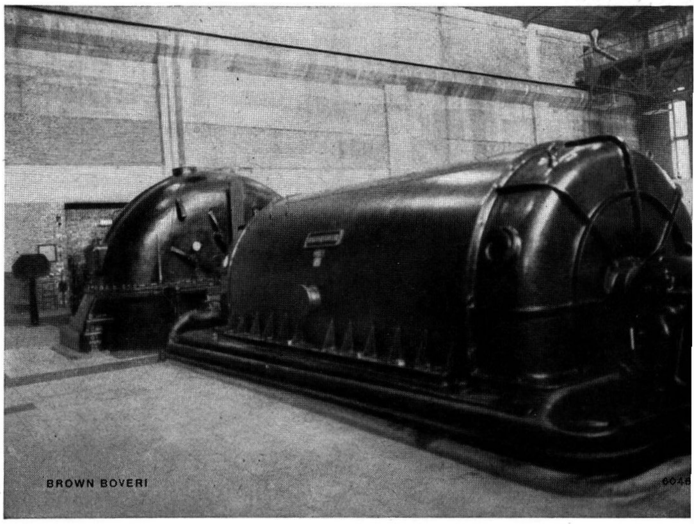
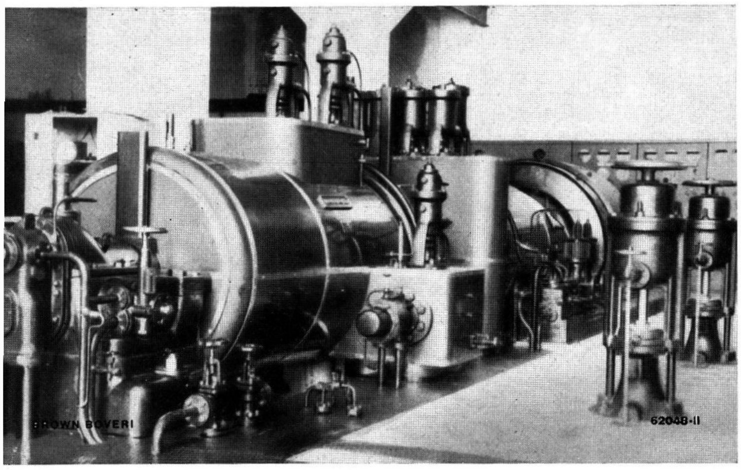


Fig. 5. — 35,000 kW turbo-set.

Two-cylinder arrangement with double-flow exhaust. 71 kg/cm² abs, 485° C, 3000 The generator is built for 50,000 kVA, 50 cycles, 10,500 V. The same power stati tains three further Brown Boveri turbines of the same output, one for the above liv conditions and the two others built in 1928 for a pressure of 26 kg/cm² and a ature of 400° C. The increase in the steam pressure and temperature, as well a improvements has enabled the heat consumption of the new turbine to be reduced l than 12 % compared with the old one.



g. 6. — 4000 kW double-extraction turbine for 41 kg/cm² and 450° C with regulated extraction points at 12 and 4.5 kg/cm² abs.

nis turbine is provided with a so-called "pressure transformer" regulator for meeting e requirements of the duties it has to perform. The pressure transformer is contained the box in front of the second turbine casing. The two regulating devices on the right erve to keep the over-flow valves open, when no heating steam is required and the turbine perates without extraction, i. e. as a pure condensing turbine. By keeping the over-flow valves open, it is possible to avoid throttling losses.

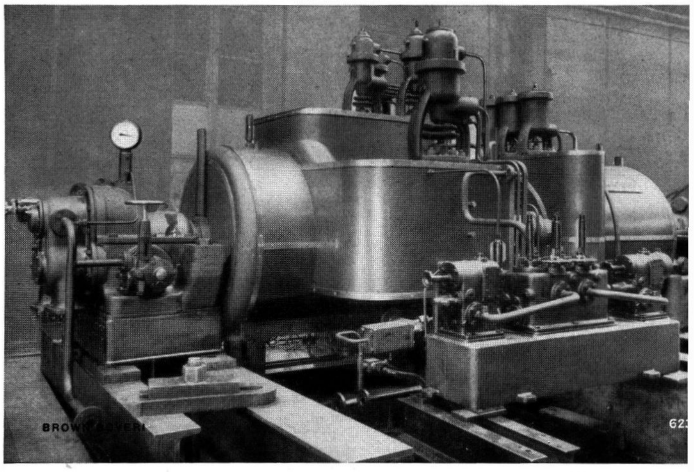


Fig. 7. — 4000 kW extraction back-pressure turbine.

The regulation of this turbine, which is described on page 10 is interesting. The is mounted on the test bed where all the Company's turbines are submitted to a car before dispatch.

Fig. 8. — Putting into service of a 5000 kW Brown Boveri condensing turbine at Asunción, Paraguay Republic.

The president of the republic, General Higimo Morinico has just cut the ribbon securing the control hand wheel and thus symbolically put the plant into service.

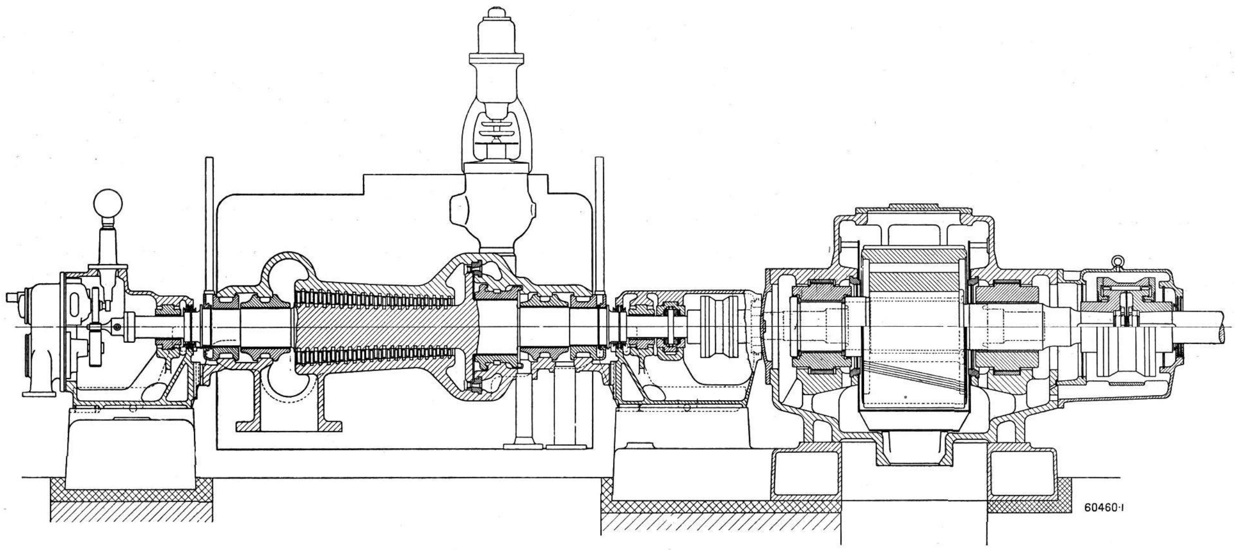


Fig. 9. — Section through a high-pressure primary turbine of 4150 kW with gearing, for 100 kg/cm² and 500° C.

Because of the relatively small steam quantity the speed had to be high, in order that the length of the blades should be sufficiently long to ensure a high efficiency. The speed is 9000 r. p. m. and is reduced to 3000 r. p. m. by means of gearing.

which work was to have been started. An occasion present itself, however, of supplying a primary turbine the design of which is very similar to that which it is proposed to employ for the high-pressure stage of the abovementioned projects. The turbine in question has an output of 4150 kW. The high pressure (100 kg/cm²) and the relatively small steam volume make it necessary to use a small diameter with a high speed in order to obtain reasonable blade heights. To ensure quiet running in spite of this high speed, great care is given to the bearings. Bearing shells and shaft journals are both subjected to a special finishing process which ensures perfectly smooth surfaces and exact dimensions. Fig. 9 shows a section through the turbine with its gear.

1. *Small Turbines.*

In the retrospective number for the year 1943, a small turbine design for an output of 500 kW was described and the simplicity of the governing system of this turbine referred to. During the past year, this range of turbines was extended by the creation of two further models. The standard sizes are rated at 35, 50, 100, 250 and 500 kW (Fig. 10), the smaller sizes being designed for a back-pressure of 2 kg/cm² abs and the larger ones for 5 kg/cm² abs. These turbines are so constructed, that they can operate with the highest steam pressures and temperatures. They can therefore be used for driving auxiliaries in the most modern power stations operating with the highest pressures, being particularly suitable for driving fans and pumps. They may, however, also be employed on ships and even on locomotives. Because of their simplicity and reliability, they are especially suitable for stand-by auxiliaries and where quick-starting is necessary, as well as for back-pressure installations in industrial plants, where in addition

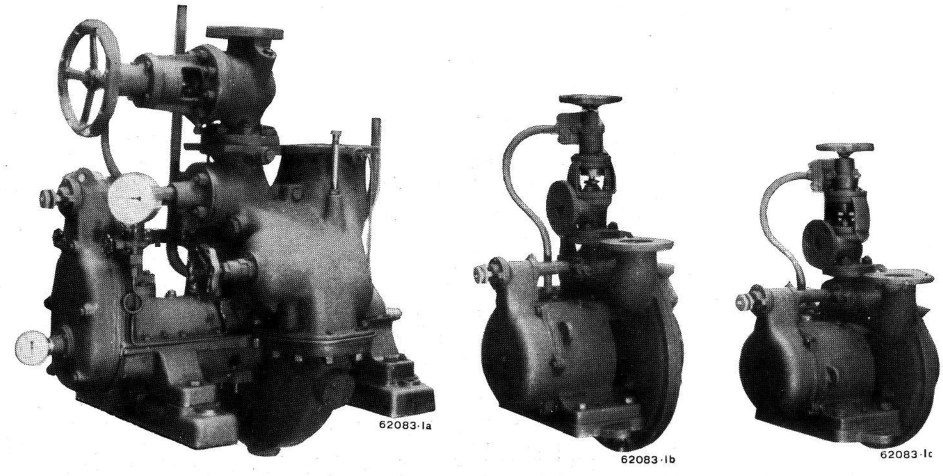


Fig. 10. — Small turbines.

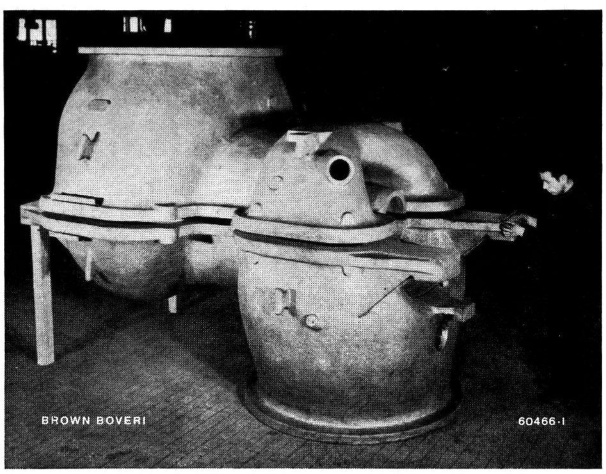
This view shows three sizes out of the series of small turbines now available for powers of 35, 50, 100, 250 and 500 kW. These small turbines are particularly robust and simple in construction and can also be employed for high pressures and high temperatures. Their simple regulating system consists only of an inlet valve, a speed governor and a rod, which transmits the movement of the governor to the inlet valve.

to generating power, they serve to expand the heating steam down to the required pressure.

2. *Steam Power Stations.*

As known, not only do the Company build the different machines, but also undertake to an increasing extent the construction of complete steam power stations. Where oil or gas is used as fuel, Velox boilers are employed; the plant can then consist entirely of Brown Boveri material.

If the fuel is coal, the boiler, the coal transporting plant, and the ash removing installation still has to be obtained from other manufacturers for the time being; the complete turbine and electrical equipment is, however, built by the Company who also undertake the planning of the complete installation, including the boilers.



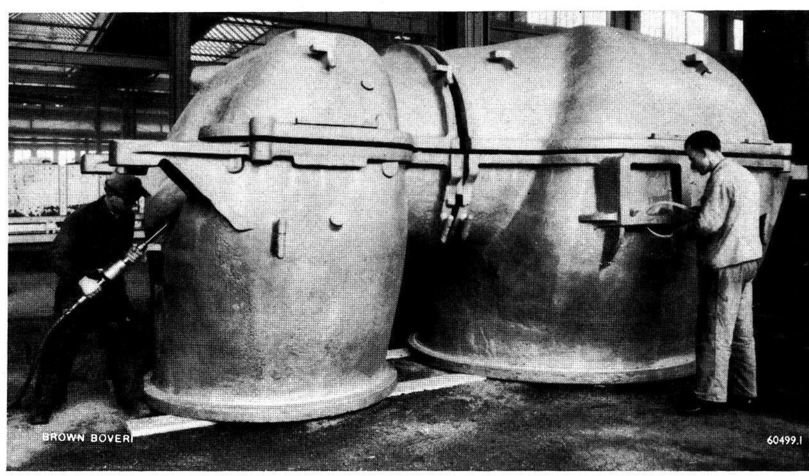


Fig. 11. — Castings for a 10,000 kW combustion turbine.

Left: high-pressure cylinder. Right: low-pressure cylinder.

The casing consists of molybdenum cast steel. Instead of the generally used welded construction, a cast design was chosen in the present case, as it enables better flow conditions to be ensured.

During the year under review, a number of interesting installations, among which are a plant for an output of 23,000 kVA for Spain and another smaller power station with two turbo-sets each rated at 800 kW for Portuguese East Africa, were in hand.

C. COMBUSTION TURBINES.

At the present time a combustion turbine plant intended for South-East Europe is under construction. This unit has an output of 10,000 kW and is the largest installation of this kind up to the present. It is intended for peak-load and stand-by service on an interconnected system comprising also water and steam power stations. The fuel consists of natural gas. Although this gas fuel is relatively cheap in the country concerned, and the service referred to above requires mainly a cheap and not an economical turbine, a two-stage unit was all the same chosen but without a recuperator. The efficiency which it is thus expected to obtain with an initial temperature of the gases of 600 °C, referred to the output at the generator terminals, is 21·5 %.

It would have been possible, with a recuperator of 0·4 m^2 of surface per kW of useful power, to obtain an efficiency of 30 %, but the increased cost of the plant would not have been justified in the case concerned.

The two-stage combustion turbine[1] consists of two gas turbine sets which are connected in series on the gas side. The high-pressure turbine drives the second stage of the compressor, the low-pressure turbine drives both the low-pressure compressor and the generator. The speed of this set therefore remains constant; the speed of the high-pressure compressor, however, varies with the load. There are two combustion chambers, the second one being placed between the high-pressure and the low-pressure turbines. In this second combustion chamber, the exhaust gases of the first turbine which contain a considerable amount of excess air, are again heated to the initial temperature by means of additional fuel. In order to reduce the power required to drive the compressor, the air is cooled between the two compressors.

About 300,000 kg of air are required per hour for a useful output of 10,000 kW. It is compressed in the first compressor to 3, and in the second to 12 kg/cm^2 abs, the power taken by the two compressors being 14,500 and 11,000 kW, respectively. The gas is supplied at a pressure of 5 kg/cm^2, and

[1] Brown Boveri Rev., 1944, No. 5, p. 177.

in the case of the first combustion chamber, it is raised to a pressure of 12 kg/cm^2 in a special compressor.

The amount of cooling water required is small. Altogether, about 300 m^3 per hour are circulated in the case of cooling tower installations. A small fraction of this is necessary to compensate for the evaporation losses. (A steam turbine plant for the same conditions would require about 2500 m^3/h or about 8 $^1/_2$ times as much.)

Both sets are provided with motors for starting. These are capable of bringing each set up to 20 % of its full-load speed, after which the turbines accelerate themselves to full speed. It is estimated that the time required from the moment of starting until the set reaches full speed will be about 10 minutes. The entire process takes place entirely automatically and can be controlled from the switchboard. Fig. 11 shows parts of the turbine before machining and Fig. 12 shows the layout of the installation.

Reference was already made in last year's retrospect[1] to the very great importance of the recuperator in gas turbine plants where high efficiencies are required. Studies on the question of the gas turbine recuperator have now been completed and have resulted in very advantageous solutions. In order to obtain the same efficiency as the best steam turbine plants, about 0·4 m^2 of heater surface are required in the case of two-stage gas turbines and about 1 m^2 in the case of single-stage sets. It must be possible readily to build these heat exchangers in spite of their great size, and their components must be accessible and replaceable; further, they must not take up too much space or be too heavy. It has now proved possible to reduce the total weight to 15 kg/m^2 of useful surface. These recuperators have been so designed that they may be installed out of doors, in which case, they form the lower part of the chimney, or they may be installed in a walled duct

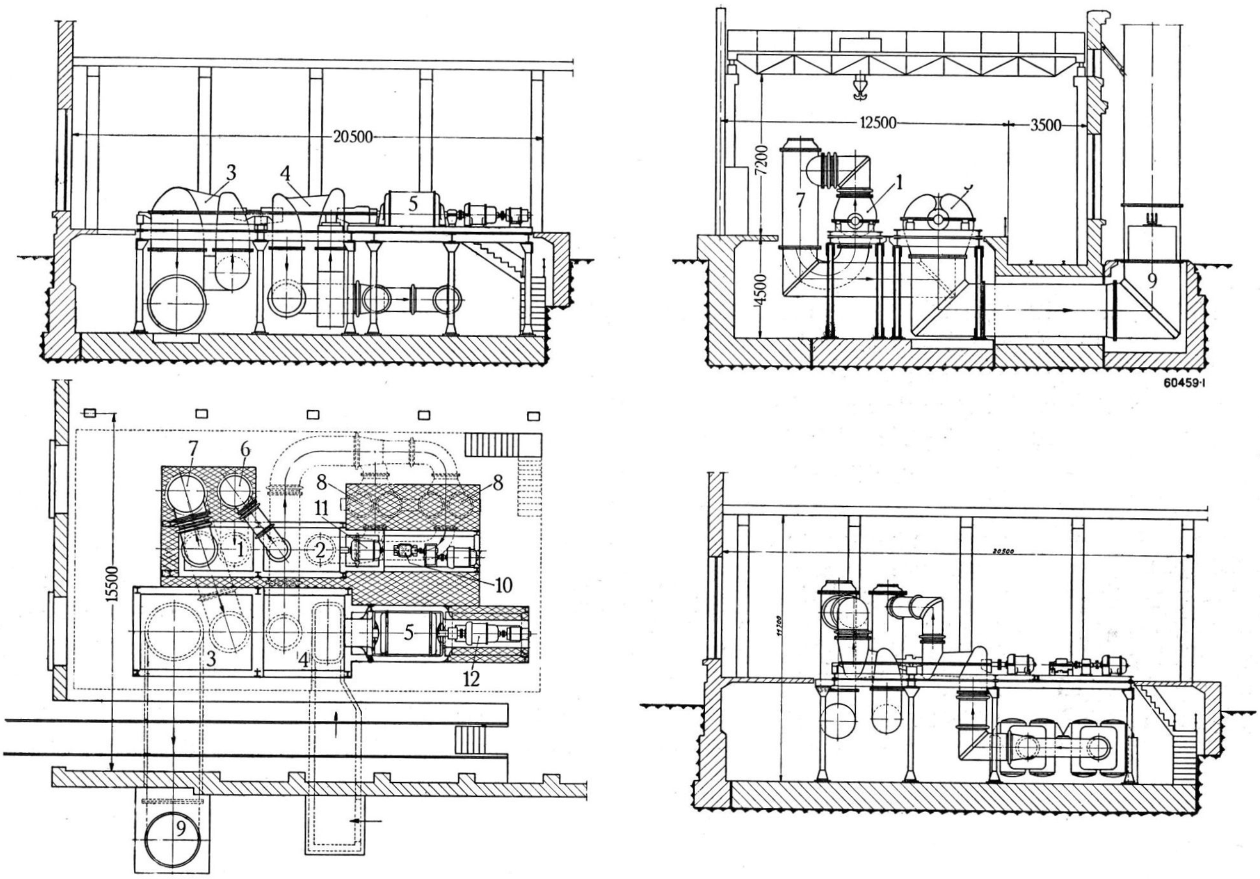


Fig. 12. — Arrangement of a 10,000 kW combustion turbine plant at present under construction.

The plant consists of two gas turbines, namely the high-pressure turbine 1 with the high-pressure compressor 2, and the low-pressure turbine 3 with the low-pressure compressor 4, as well as the generator 5 supplying the useful power. The driving gas is produced in the combustion chamber 6 and is reheated to the original temperature in the combustion chamber 7, which is placed between the high-pressure and low-pressure turbines. Between the high-pressure and low-pressure compressors there is a cooler 8 for cooling the compressed air. The plant has no recuperator. The exhaust gases of the low-pressure turbine, therefore, discharge directly to the atmosphere at 9. The fuel is natural gas which is compressed by the compressor 10 to the pressure in the first compressor chamber. The pressure at which the gas is supplied is sufficient for the second combustion chamber. The two sets are started by means of the starting motors 11 and 12.

[1] Brown Boveri Rev., 1944, Nos. 1/2, p. 12.

which serves at the same time as a passage for the gases, run below the turbine room floor.

Test results and experimental data were available from the gas turbine locomotive as well as from the 4000 kW plant at Neuchâtel. The gas turbine locomotive is referred to separately on page 72; it is, however, again stressed here that the operating experience obtained up to the present justifies the most sanguine hopes. No troublesome or fundamental difficulties have been met with nor has any wear of the blades or of the recuperator tubes been observed. This is attributed to the fact that gas oil or fuel oil of any quality can be burned equally well in the gas turbine and without any formation of coke particles.

Research in purely turbine questions has also benefited from the gas turbine. In order to elucidate problems of rotating blades, i. e. under actual operating conditions, a multi-stage air turbine having an output of 500 kW (Fig. 13) has been built to serve exclusively for experimental purposes; this has already given interesting results. Pure flow and blade problems are, however, investigated on models in the same manner as before in the Company's flow apparatus.

Fig. 13. — Experimental turbine (hot air turbine) for testing blading.

The turbine can deliver 500 kW. The view shows the rotor after blading of the first row. The blades are of aero-foil section.

D. REGULATING DEVICES.

Among the various regulating devices to which attention was paid last year may be mentioned the so-called pressure transformer regulators[1] which were already described in 1941, and are now being employed in four further plants.

When the manufacture of pressure transformer regulators was begun, it was not certain how this branch would develop. There was no experience or previous designs to base on. Some initial difficulties were therefore experienced which have, however, now been overcome. It has been found that the most difficult regulating problems can be solved in the most satisfactory manner with the aid of this regulating device.

One of these pressure transformer regulators was applied to a 4000 kW double-extraction turbine in a foreign paper mill (Fig. 6). The regulating arrangement consists of three regulators, namely the speed regulator for maintaining the speed, a pressure regulator for the first extraction point and a second pressure regulator for the second extraction point. The central control device of the regulating system is the pressure transformer, consisting of a casing provided with a number of regulating piston valves, in which the hydraulically transmitted impulses produced by the individual regulators act on corresponding stage surfaces of the regulating piston valves and are thus transformed and again hydraulically transmitted to the valve to be regulated, i. e. to the main steam inlet valve or to the first or second extraction control valves.

This regulating system fulfils all the requirements which can reasonably be demanded of such a device. It operates without hunting. The various regulating processes do not interfere with one another, even when the one or other of the regulating valves has reached its end position. Finally, it is possible to switch over from operation with extraction to operation without extraction and vice versa. The regulating piston valves operate practically without friction and the whole apparatus is the result of most careful research work and long experience with machines on the test bed.

Another pressure transformer equipment was used in connection with two extraction-back pressure turbines of 300 and 500 kW output. In this case, it was required that the extraction and back pressures should be accurately maintained within at least 2—3 %. At the same time, the old pressure regulators in this plant were replaced by new ones with adjustable static drop.[2]

[1] Brown Boveri Rev., 1941, Nos. 1/2, p. 9.

[2] Brown Boveri Rev., 1944, Nos. 1/2, p. 14.

In another extraction-back-pressure turbine installation of 4000 kW (Fig. 7) it was required as an alternative to be able to regulate the back-pressure to a constant value. At the same time, it was required that under both operating conditions the two regulated values should remain independent of each another. But speed-extraction pressure regulation and extraction pressure-back pressure regulation are two very different things. In order to fulfil these requirements two separate pressure transformers would normally be required, which could be changed over depending on the type of regulation required. Thanks, however, to a special characteristic of the pressure transformer it was possible to manage with one. This characteristic is that even limit conditions and to a certain extent also regulating devices even in their end positions are still so well controlled, that the remaining values to be regulated and their static drops are maintained unchanged under limiting operating conditions. An extraction-back-pressure turbine can, however, be regarded as a double extraction turbine operating under limiting conditions in which the second flow-over valve — which is actually not provided — is completely open. This pressure transformer therefore enables such a double extraction turbine operating under limit conditions to be regulated either according to the speed and the first extraction pressure, or, to regulate the first and the second extraction pressures in such a manner that these regulated quantities remain independant of one another. In this way, it was possible to solve this difficult regulating problem with relatively simple means.

The regulating equipment described above operated from the beginning in both speed-extraction pressure service and extraction back-pressure service without difficulties of any kind. Each type of operation under limit conditions in which even two of the regulating piston valves were in the end position was carried out satisfactorily. It should specially be mentioned that the permanent static drop of the two regulated pressures can be reduced to zero or less so that an increase of the extraction quantity may even be accompanied by a rise in pressure.

Later, the installation is to be extended by a condensing turbine for utilizing the superfluous back-

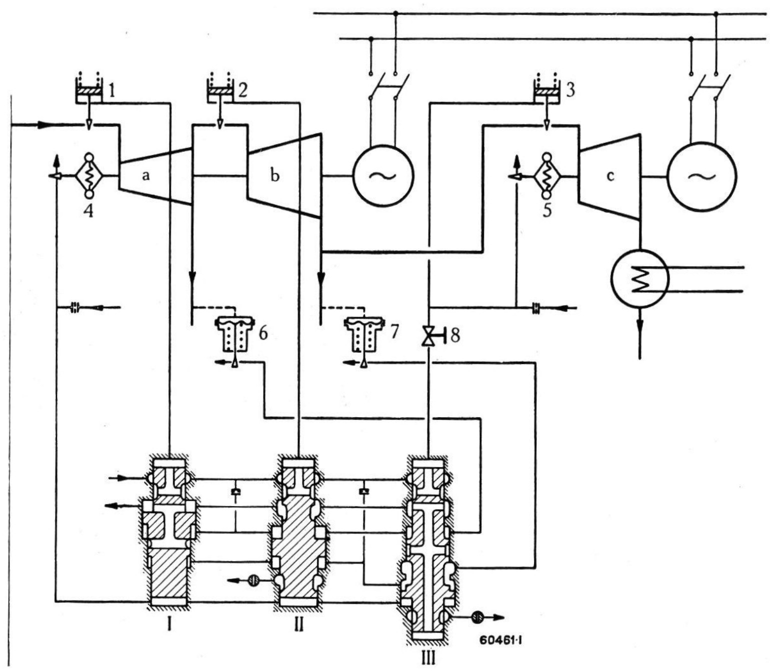


Fig. 14. — Regulation of an extraction back-pressure turbine by means of a pressure transformer which operates in parallel with a condensing turbine.

The pressure transformer is an additional device to the Company's oil pressure regulation for transmitting and converting regulating impulses. It consists in the present case of the three control valves I, II and III. The live steam quantity of the high-pressure part a of the extraction back-pressure turbine is regulated by the valve 1 flowing to the intermediate-pressure part b by means of the over-flow valve 2 and the steam quantity of the condensing turbine c by means of the over-flow valve 3. The speed is kept constant by means of the speed regulators 4 and 5, whilst the pressure regulators 6 and 7 regulate extraction pressures as required. All regulating devices are hydraulically connected to the pressure transformer. In this transformer the impulses sent out by the regulators are converted at the corresponding surface step of the control valve and transmitted to the valve to be regulated. The hand valve 8 enables the oil regulating system of the condensing turbine to be disconnected from the pressure transformer.

pressure steam. The extraction-back-pressure turbine then becomes from the regulating point of view a sort of double extraction turbine, especially as both turbines are electrically coupled together by being connected to the same network.

Fig. 14 shows the diagram of the regulating equipment of the complete plant, i. e. including the condensing turbine to be installed later. During the first period of operation, the control oil pipe to this turbine is therefore blanked off. The pressure transformer however retains its three regulating pistons, one of which remains continuously with one of its regulating edges in the end position.

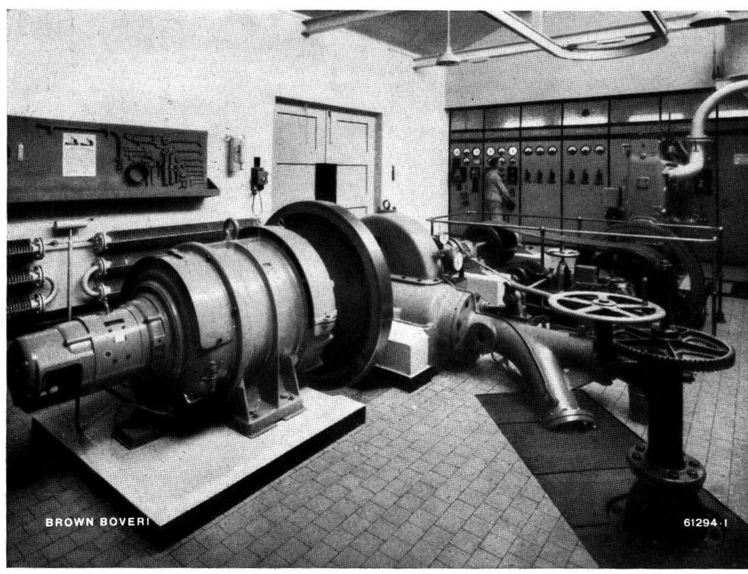


Fig. 15. — Example of a small, modern hydro-electric power station for a textile mill.

The plant comprises a single-bearing, three-phase generator with a rating of 205 kVA at 290 V and 750 r. p. m. and, as prime movers, a Pelton turbine and a Diesel engine, of which the latter can be coupled and decoupled during service by means of a clutch. This standby machine ensures maintenance of power supply under all conditions. Automatic regulators supervise voltage, power, and power factor according to operating conditions.

E. GENERATORS.

The increasing activity in the construction of power stations mentioned in the last retrospect has continued during the past year, with the result that, with due consideration to the wartime conditions, the Company was nevertheless able to complete the manufacture of quite a considerable number of generators, some of which were for large outputs. In view of the growing shortage of coal, generators for hydro-electric power stations naturally predominated, a state of affairs which will presumably prevail for some time after the war on account of a strong tendency to reserve coal for other purposes than combustion in power station boilers.

1. *Turbo-alternators.*

It was mentioned in the last retrospect that the Company is studying the design of two-pole alternators for an output of 100,000 kVA. The problem of dissipating the large quantities of heat due to the losses in alternators of this power demands the uninterrupted continuation of temperature-rise measurements on turbo-alternators. The object of these measurements is to gain an insight into the most suitable arrangement of the cooling-air passages and to find means of eliminating, or at least reducing, sources of losses which can still be tolerated in an alternator of about half the output, but which may lead to considerable local overheating in one with a rating of 100,000 kVA. The measurements deal with the whole problem of the conduction of heat in alternators, the investigation of the influence of air films on the temperature gradient between the conductors of stator and rotor, respectively, and conductors and iron, the associated problem of the heat transfer from surfaces to moving air, the question of the necessary quantity of cooling air and of the best kind of cooling system, the problem of unequal expansion due to temperature differences, etc. The Company's opinion on these questions, based on the results so far available, was expressed in detail in the December number of 1944 of this Review, and reference may be made to this article[1] for further information on the subject.

2. *Generators for Hydro-electric Power Stations.*

A number of design improvements were incorporated in generators, both horizontal and vertical, built during the past year. Of these design improvements, the use of self-lubricating journal bearings, even for comparatively

[1] J. Prevost, Brown Boveri Rev., 1944, No. 12, p. 383.

large units, deserves special mention, the advantage being the elimination of oil pumps, piping, and special devices for lubrication during starting. Air cooling can be employed in the case of low-speed machines to carry away the heat developed by the frictional losses of the bearings, thus eliminating the cooling-water piping to and from the bearings. The thrust bearing and the upper guide bearing of the larger units can be combined in one and countersunk in the bearing spider. This reduces the number of oil reservoirs and associated packings required and permits an appreciable saving of material, firstly because the central section of the bearing spider is used as oil reservoir for the thrust and guide bearing, and secondly because the overall height of the machine is smaller.

A number of generators, mostly with vertical shafts and quite considerable outputs, were built for export, principally for Spain and Portugal, and were equipped with the above-mentioned combined thrust and guide bearings, these being self-cooled for those machines running at moderate speeds.

Apart from those already discussed, a number of small and very small industrial power stations were renovated or newly built and set to work. Especially noteworthy among these is the power station of the *Zinggeler* Silk Doubling Mills at Richterswil (Switzerland), the operation of which has been made to a large extent automatic by the adoption of automatic synchronizing and power regulation to ensure the maintenance of the active and reactive power quotas drawn from or delivered to the public supply system without the necessity of continuous supervision (Fig. 15). The considerable advantages which can be obtained by modernizing industrial power stations of this kind are worthy of special mention. For the same quantity of water, the power produced can be considerably increased. The excess power can at first be supplied in many cases to the public electricity supply system, and later will enable the production capacity of the factory itself to be extended. In order to provide employment, such renovations are particularly desirable to-day in view of the general economic situation of Switzerland, since

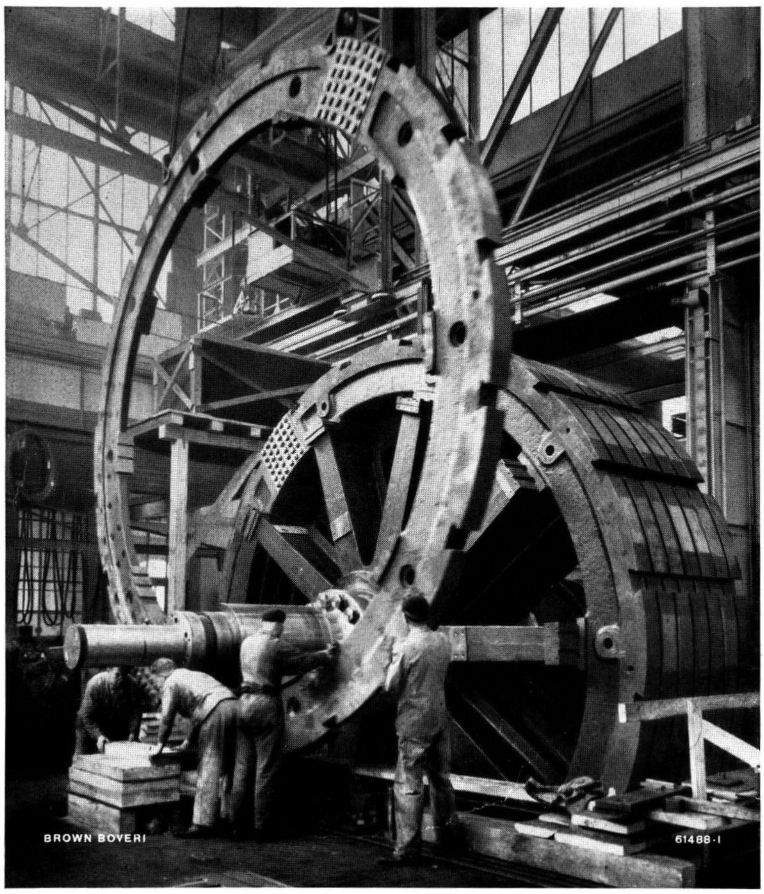


Fig. 16. — Mounting the last rim section on the rotor spider of the single-phase generator, with a rating of 25,000 kVA, 11,000 V, 100 r.p.m. and 16⅔ cycles, for the Rupperswil-Auenstein power station.

This photograph is a forcible reminder of the amount of work necessary to completely erect a large rotor at the maker's works for the overspeed test.

a large portion of the work is translated into wages and little new material is required.

The chief item of interest associated with the construction of generators was the completion of the *25,000 kVA single-phase generator* for the *Rupperswil-Auenstein* power station. It is well known that the construction of single-phase generators presents difficult problems both of a mechanical and an electrical nature. The mechanical difficulties are due to the power pulsations of twice the system frequency and the resulting danger of resonant oscillations of the whole machine which may be transmitted by way of the foundations to the whole building even up to the roof structures. The electrical difficulties arise in connection with the correct dimensioning of the damper winding which has to counteract the negative rotating field of half amplitude. On the occasion of the completion of this unit, the largest single-phase, low-frequency generator ever built insofar as output and dimensions are concerned, it may be emphasized that neither of the two problems has ever caused difficulties in spite of the considerable number of generators of this kind already built. The single-phase generators built by the Company, among which those for the power stations of the Swiss Federal Railways are outstanding, have proved entirely satisfactory from the very beginning and have never given rise to trouble. Fig. 16 shows the heavy rotor of the Rupperswil-Auenstein generator, which alone weighs 225 tons, during assembly. Fig. 17 shows work on the stator which has a bore of 7 metres. On the evening of August 31st last year, the rotor was subjected to the prescribed overspeed test in the Company's large erection bay. The test consisted of a run at 280 r.p.m. for two minutes, i. e. at 2·8 times the normal speed. On the basis of experience gained from overspeed tests on the rotors of generators for the Ryburg-Schwörstadt, Albbruck-Dogern, and Klingnau power stations, which by virtue of their dimensions are among the largest generators built in Europe, the rotor of the Rupperswil-Auenstein machine was also enclosed in a wooden casing for the overspeed test (Fig. 18); by this means the windage losses were reduced and consequently also the driving power necessary for the test diminished from about 3000 to about 400 kW. On the 6th September of the past year, the Administrative Board of the Swiss Federal Railways and a number of members of the General and District Managements also inspected the rotor of the Rupperswil generator on the occasion of a visit to Baden.

Fig. 17. — A crane driver's view of the stator and lower bearing spider of the 25,000 kVA single-phase generator for the Rupperswil-Auenstein power station during erection.

Seen in this perspective, the construction of heavy machinery resembles a kind of gigantic jigsaw puzzle. Great precision, however, is an indispensable proviso in this case also for the accurate fitting of the parts.

3. *Generator Protecting and Regulating Equipment.*

Great interest in all designs of *regulators* was everywhere in evidence, but unfortunately the Company was not in a position to satisfy all wants on account of difficulties caused by the war. So far as *high-power regulators* are concerned, the most important delivery, intended for two large hydro-electric stations with four units of 70,000 kVA and two of 60,000 kVA, went to France.

The high-power regulators for the Lucendro power station, now nearing completion, are fitted for the first time with a supplementary adjusting device to enable large high-voltage networks, involving reactive powers of the same order of magnitude as the total machine output, to be placed under voltage[1].

The development of *primary regulators* was carried on, the aim being to obtain simplification and to facilitate the assembly with the parts to be supplied by the turbine manufacturers. During the past year, the first statically adjusted primary regulator in the *Unter-Aa power station* was put into service for testing purposes. This new design provides a still more stable operation of the governing system which should prove of special advantage for turbines that are difficult to regulate at no-load, i. e. where the valve opening at no-load is extremely small in comparison with that at full load. The new regulator also allows the well-tried recall and stabilizing systems of the mechanical turbine governors to be retained. This new regulator will also be installed in its final form in the Aarau power station for which the Company supplied the first primary regulator in 1937 and which will now be equipped with the fifth regulator of this kind (Fig. 19).

In the previously mentioned Rupperswil-Auenstein power station, both the single-phase and three-phase machines — the latter supplied by another firm — will be fitted with electrical primary regulators manufactured by the Company. The primary regulators of both machines will be fed directly by the generator voltage, by which means it is possible to dispense with the pilot generators for the governor drive, an especially expensive item for such large, low-speed machines.

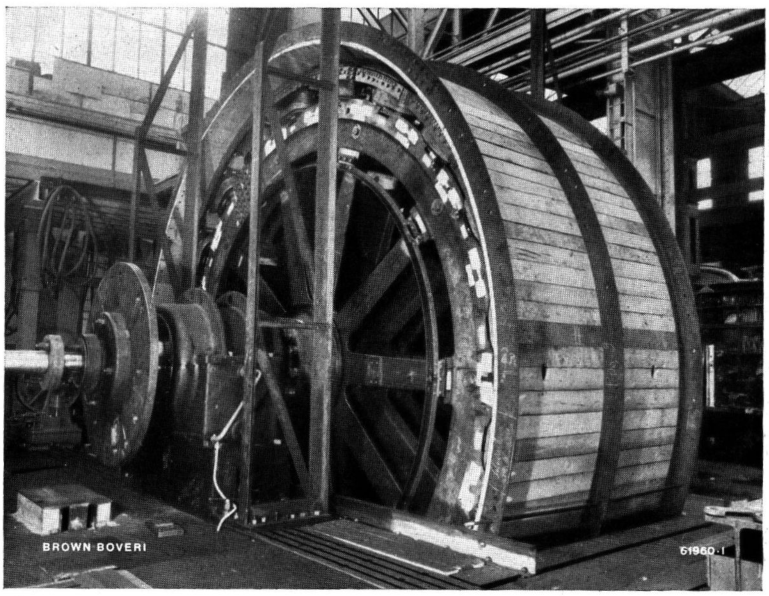


Fig. 18. — The rotor of the single-phase generator for the Rupperswil-Auenstein power station mounted over the pit for the overspeed test.

The rotor was surrounded by a strong wooden casing during the test in order to reduce the windage losses. Thanks to the casing, a driving power of only 400 kW sufficed even for the high overspeed of 280 r.p.m. (2·8 times normal speed).

The *frequency-dependent power regulating equipment* at the Dixence power station of the Energie de l'Ouest Suisse, mentioned in the retrospective number of the Brown Boveri Review, January to April 1943, was tested in practical service during the past year. It was demonstrated in detail during the early part of the year to a large number of experts of the Swiss power stations[2] (Figs. 20, 21, and 22).

[1] Brown Boveri Rev., 1944, Nos. 1/2, page 21 et seqq.

[2] D. Gaden and R. Keller, Bull. SEV, 1944, page 333.

This kind of network regulation is based on the fundamental principles laid down for the stable and economical regulation of active power in interconnected systems by Prof. Ossanna and Graner in Germany, and by G. Darrieus, I. Fallou and Ailleret in France.

Thanks to the keen interest and obliging cooperation of the "Energie de l'Ouest Suisse", it was possible to develop the frequency-dependent power regulation in practical service and to bring it to such a stage of perfection that is has become a valuable auxiliary for large interconnected systems. In contrast to previous regulating systems, this new design is distinguished by the fact that the internal load fluctuations of each individual network are taken over by a frequency controlling set and the transfer of power over the connecting feeder to other systems is stabilized with the help of frequency-dependent power regulators with a drooping characteristic. The drooping characteristic is obtained by making the recall of the speed or primary governor dependent on the power transfer and not on the opening of the turbine admission valve. The regulation system just described was developed in conjunction with the Charmilles, Geneva, acceleration governor. It is absolutely stable under all service conditions and, most important of all, during disturbances.

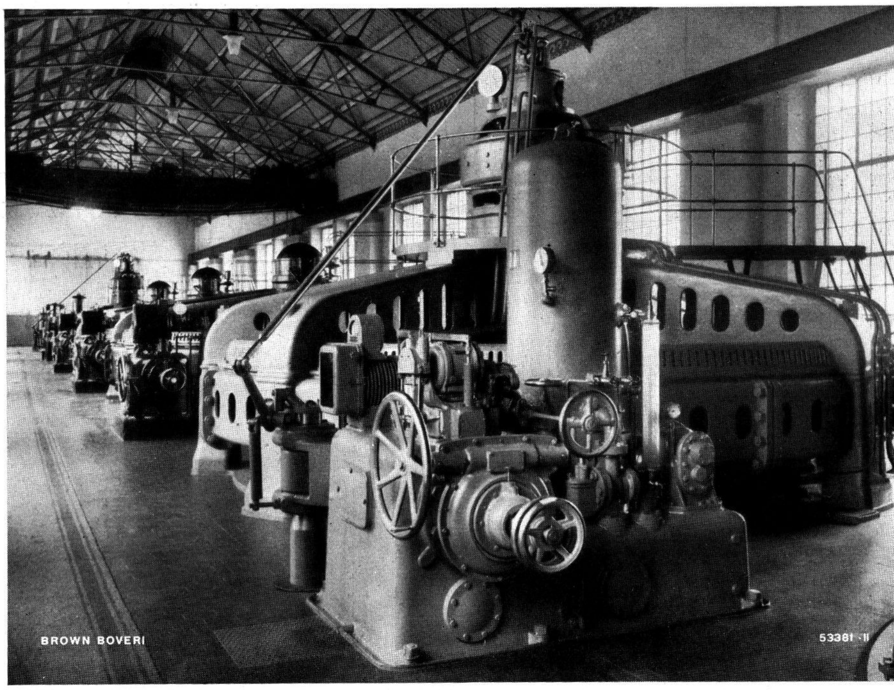


Fig. 19. — Brown Boveri electric primary regulator mounted on the governor of a Bell turbine in the municipal power station at Aarau, for which the fifth regulator of this type has already been ordered.

No belts or gear drives between turbine and governor, not even a pilot generator for the governor drive. The old mechanical governor has disappeared and been replaced by an electrical regulator in which there are no rotating parts at all.

Due to the direct control of the hydraulic servomotor of the turbine governor by the power exchanged, it has been possible to stabilize the power transferred at any desired value in a perfectly satisfactory manner. By choosing the slope of the characteristic controlling the power transfer, it is possible to determine in advance the measure of mutual assistance afforded by the individual networks in case of disturbances. Test and

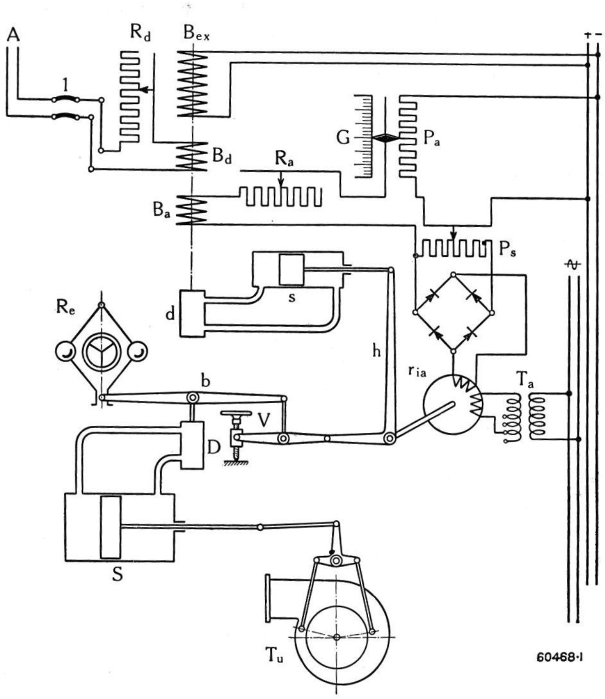


Fig. 20. — Diagram showing the principle of an automatic speed governor fitted with the Brown Boveri Charmilles frequency-dependent regulator illustrated in Fig. 21.

The set provided with this governor maintains the power exchange between two networks with adjustable dependency on the frequency and at the same time controls the frequency in its own network.

- B_a. Recall coil.
- B_d. Telemetering receiver coil.
- B_{ex}. Exciting coil.
- D. Pilot valve of the main servo-motor.
- G. Potentiometer scale.
- P_a, P_s. Potentiometers
- R_a. Variable resistance.
- R_e. Speed governor.
- S. Main servo-motor.
- T_a. Transformer for the induction regulator.
- V. Speed adjusting lever.
- b. Lever.
- d. Pilot valve of the auxiliary servo-motor.
- h. Lever.
- r_{ia}. Induction regulator.
- s. Auxiliary servo-motor.

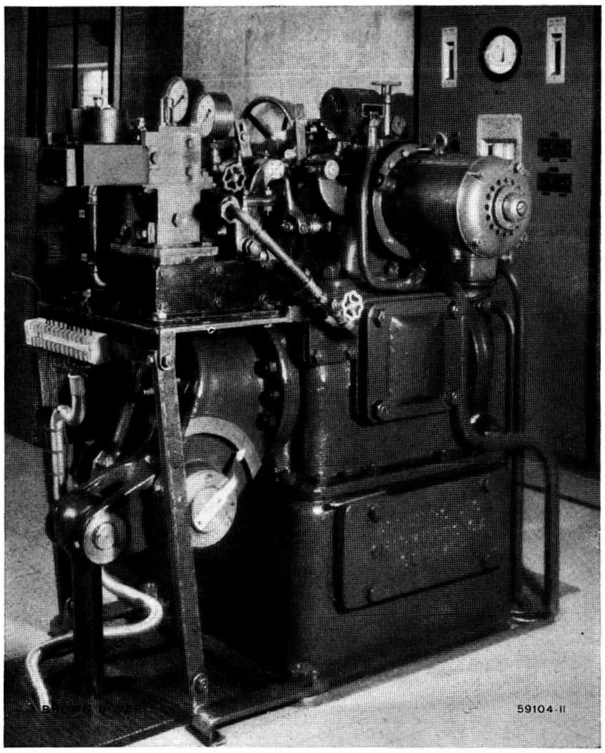


Fig. 21. — Direct-acting, frequency-dependent power regulator combined with the speed governor of a 40,000 H.P. Pelton turbine in the Dixence power station.

The power regulator does not act on the speed control but directly on the governing oil system. The recorder charts reproduced below show how the accuracy of governing has been improved by the installation of this equipment.

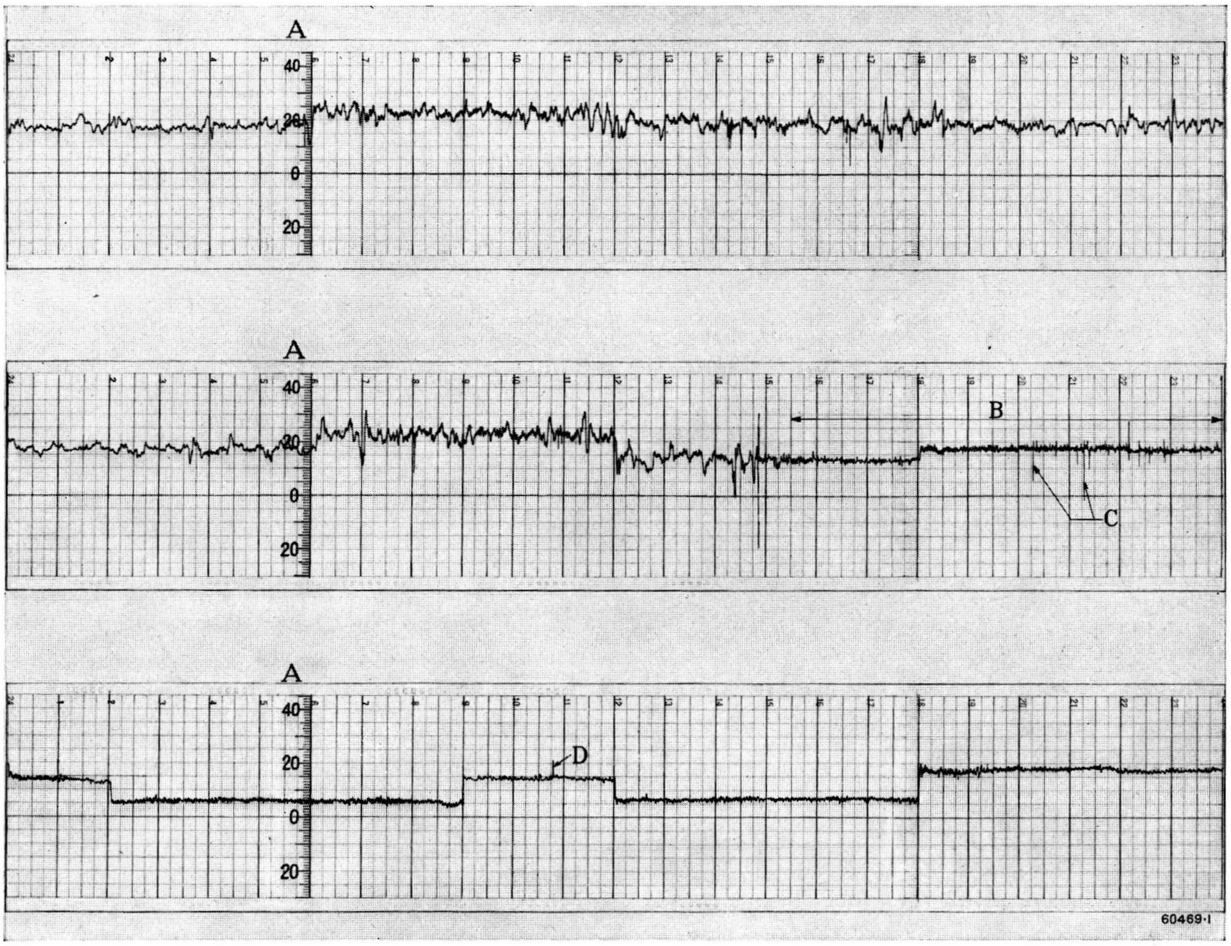


Fig. 22. — Charts of power transfer over the transmission line to Galmiz on the 28th (top) and 29th February (middle) and on 5th March, 1944 (below) recorded on the telemetering wattmeter of the Chandoline power station (telemetering receiver), in which a 40,000 H.P. turbine is equipped with Brown Boveri Charmilles frequency-dependent power regulation and controls the power transfer.

Top chart and left half of the middle one recorded before switching in the new governing equipment, right half of the middle chart (B) and lower one after setting it to work. The much more exact operation of the new equipment is obvious.

A. Telemetered value of the power transfer in 1000 kW.

B. Frequency-dependent power regulation set to work.

C. Trip out of important consumer.

D. Trip out of secondary tie-line.

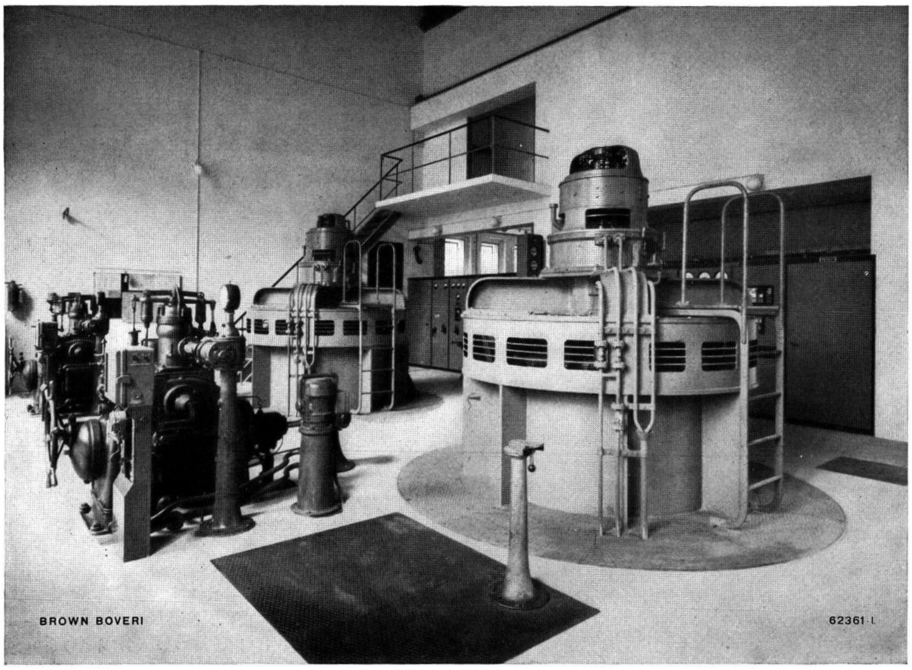


Fig. 23. — Interior view of the semi-automatic power station at Pintrun (Graubünden, Switzerland).
The whole power station is automatically supervised during operation. The two generators, each with a rating of 4400 kVA, 3300 V, 750 r.p.m. 50 cycles, are connected over a transformer of 8750 kVA to a 50 kV transmission line for the supply of power to the factory of the Holzverzuckerungs-A.G. at Ems. The 3 kV and 50 kV switchgear consists entirely of high-speed air-blast circuit breakers designed and manufactured by the Company.

service results showed remarkably stable behaviour despite the exceedingly unfavourable relationship between tie-line and system capacities, the former amounting to only a few percent of the latter. The one system consists of the whole complex of power stations in West Switzerland and the other of the Bernese and Oberhasli power stations, and of the power stations of the Nordostschweizerische Kraftwerke A.-G. (NOK). This suggests that it may be possible, in many cases, to apply this method of regulation to realize direct system interconnection instead of using either rotary or static converters to obtain an elastic coupling[1], as has been the practice up to the present.

An interesting type of regulation was used for the first time in the *Pintrun power station.* For the time being this power station is intended to supply all power generated to the Holzverzuckerungs A.-G. at Ems, where it is connected in parallel with the Albula network. In order to obtain the best operating conditions, the power generated at Pintrun is governed as a function of the water level. The plant is semi-automatic, i.e. unattended in normal service, while automatic equipment ensures that the circuit-breakers are switched out selectively in case of disturbance or that the complete station is closed down if necessary. If the supply from the Albula network is interrupted due to a disturbance, however, there is an automatic change-over from water-level to normal speed governing. The essential apparatus for accomplishing this change-over consists of two frequency relays which respond to the drop in the frequency caused by overloading of the Pintrun station when the supply from the Albula network is interrupted. The one relay in the power station switches over from water-level to normal speed governing, and the other in the substation interrupts supply to all parts of the factory not of vital importance. The power station is thus able to meet the reduced power requirements fully for some time; it acts in this case as a standby station. Starting up and paralleling are carried out manually just as in an attended station.

To complete the modern protection equipment, it is intended to extend and improve the selectivity in the near future by providing network protection with distance relays.

Due to the nature of the operating conditions, it was possible to build a relatively cheap plant with the simplest imaginable circuit arrangement by dispensing with comprehensive standby equipment. The plant is nevertheless fitted out with the most modern equipment.

The Pintrun power station, situated about 1 km above the Trins station, is a medium-head plant and, as such, utilizes the last stage of a tributary joining the "Vorderrhein" on the left side. The electrical equipment, consisting of two generators of 4400 kVA each (Fig. 23) embodying the new design of combined thrust and guide bearing already mentioned, a transformer with a rating of 8750 kVA, an 80 kVA house transformer and the complete switchgear, was supplied by Brown Boveri.

[1] Th. Boveri and R. Keller, Bull. SEV, 1945, page 25.

II. POWER TRANSMISSION, DISTRIBUTION, AND CONVERSION.

A. POWER TRANSMISSION OVER LONG DISTANCES.

In the last retrospective number the conviction was expressed that the question of transmitting power over long distances showed promise of becoming the most important of the future problems of power engineering and that it will presumably demand a comparatively quick solution after the end of the war. In order to be prepared for this moment, it seems necessary to clear up all questions in detail at once, if possible also by means of tests, so as to be able to reach an absolutely unbiassed decision on the relative merits of direct and alternating currents.

In the past year, the investigations were pursued. Of these, the questions of earth-leakage compensation of long lines and of the influence of corona received considerable attention. Some of the test results are communicated in the following paragraphs.

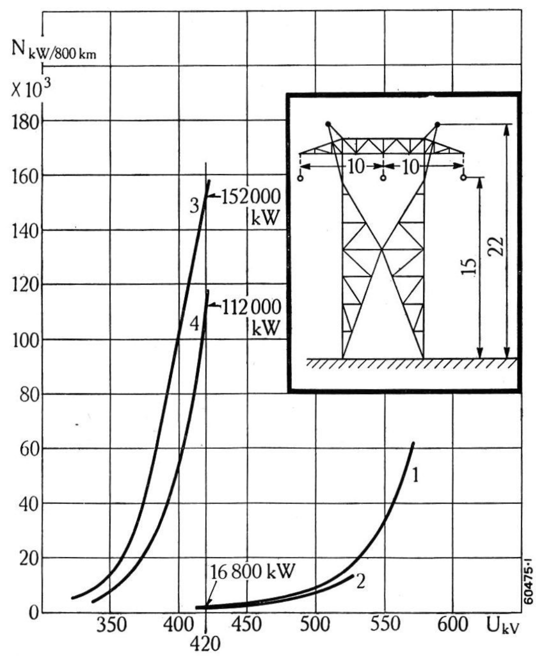


Fig. 24.

Conductors:— Three hollow aluminium conductors of 50 mm diameter in a horizontal plane.
1. Normal operation with two earth wires.
2. Normal operation without earth wires.
3. Earth fault with two earth wires.
4. Earth fault without earth wires.

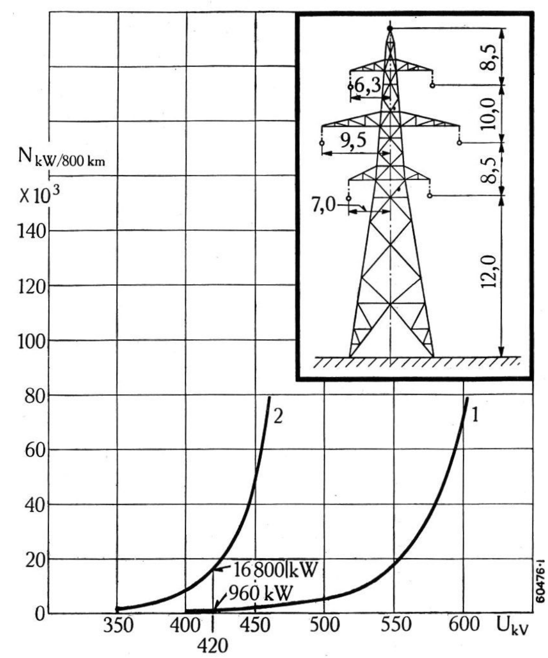


Fig. 25.

Conductors:— Six hollow aluminium conductors (two per phase) of 50 mm diameter arranged at the corners of a six-sided polygon, and one earth wire.
1. Normal operation.
2. Earth fault.

Figs. 24 and 25. — Corona losses of an 800 km long, 400 kV transmission line, which is provided with an arc suppression coil at each end, as a function of the voltage between phases in normal operation and in the presence of an earth fault.

On the occurrence of an earth fault, the losses rise to such a high value that suppression of the arc by the coil is no longer possible unless the conductor diameter is increased to meet this contingency. The consequent increase in the cost of the transmission line, however, precludes such a solution and recourse must be had to solid earthing of the neutral point.

On right in each diagram:— Arrangement of conductors on the masts.

Weather conditions:— Average weather, cloudy to hazy along the whole line.

For extra-high-voltage networks, e. g. from 100 to 400 kV, it is well known that widely divergent opinions are held on the question as to whether operation should be with solidly earthed neutral or with arc suppression coils, while a network with insulated neutral does not enter into consideration on account of obvious disadvantages. In studying these questions, the problem of insulation stressing during earth faults and, most important of all, the general question of network protection play a decisive part.

In the case of earthed and compensated networks, values of about 75 and 100 % of the voltage between phases must be taken into consideration for the voltages to earth of the sound phases at the earth fault after the steady state is reached. As the voltage peaks of unloaded transmission lines and the transient overvoltages due to earth faults are proportional to the steady state voltages (since intermittent earth faults occur neither in earthed nor in compensated networks) the ratio 75 : 100 for the overvoltages occurring under operating conditions is the real criterion for judging the relative merits of the two alternatives. It is clear from this fact that the earthed network is, indeed, subjected to smaller stresses than the compensated network, but that these stresses are nevertheless appreciably higher than would be the case if only the phase voltage were the deciding factor. A condition for this reduced stressing is, however, that all transformers with substantial outputs should be connected ⅄/△ (or ⅄) and should be as well earthed as possible at the neutral point, and further that the transmission lines should be provided with earth wires (reduction of the zero phase sequence reactance). On the other hand, it is assumed in the case of the compensated network that, if large sections of the network (more than 80 %) may have to be switched out on the occurrence of an earth fault, the arc suppression coil is always provided with a specially dimensioned arrestor and that the occurrence of excessively high overvoltages due to the interruption of the inductive circuit is thereby prevented.

Due to the high voltages necessary for power transmission over long distances, corona losses are of decisive importance when forming a judgement regarding the advisibility of solidly earthing the neutral point. The corona losses were therefore calculated for a single and double 400 kV transmission line with a length of 800 km and consisting of hollow aluminium conductors with a diameter of 50 mm, each line being provided at both ends with arc suppression coils. The investigations, of which the results are collected in Figs. 24 and 25, show that inadmissibly high losses arise in the presence of an earth fault, which are most probably accompanied by a considerable drop in the voltage. Due to the residual earth-leakage current, there is also a danger that the arc will not be extinguished. Operation with arc suppression coils would therefore only be possible by increasing the diameter of the conductors, i. e. only by considerably increasing the capital cost, which could hardly be tolerated. This provides a definite proof, however, that future high-voltage, a.c. transmission lines must be operated without arc suppression coils and that solid earthing of the neutral point must be employed.[1]

In the last retrospective number, the construction of a test plant for *high-voltage, d. c. power transmission* was mentioned. This was preceded by the systematic development of a mutator for a d. c. voltage of 33 kV, which was taken in hand immediately after the successful operation of the d. c. power transmission line between Wettingen and Zurich during the Swiss National Exhibition in the summer of 1939. The plant erected at the Biaschina power station of the Aare-Tessin A. G., of which a photograph was published in the last retrospect and which was connected as shown in Fig. 26, was several months in test operation, and provided thereby the definite proof that the fundamental problems of high-voltage, d. c. transmission, with an a.c.-d.c. mutator at the input end and a d.c.-a.c. mutator at the output end, have been solved, so that a large scale test could be ventured to-day without further ceremony. Fig. 27 shows a section of one of the many load charts, the load being at the time about 400 amp. at 33,000 volts.

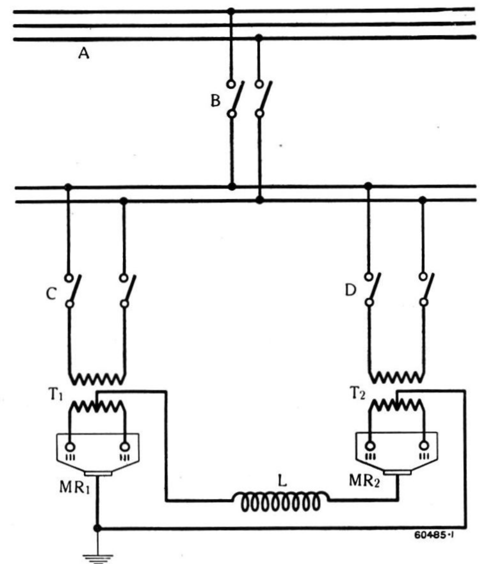


Fig. 26. — Fundamental diagram of connections of the test plant for high-voltage d. c. transmission in the Biaschina power station.

A. 50 kV busbars.
B. Main circuit breaker.
C. Set for outgoing power.
D. Set for incoming power.
L. Reactor.
MR_1. Mutator for outgoing power.
MR_2. Mutator for incoming power.
T_1, T_2. Transformers.

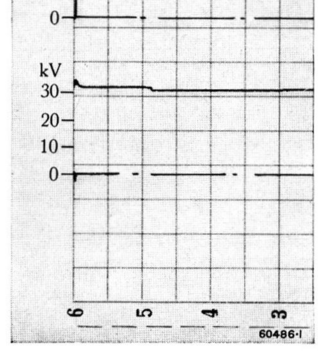


Fig. 27. — Load chart of the test plant for high-voltage d. c. transmission in the Biaschina power station.

The large-scale test, during which currents up to 400 amp. at 33 kV were transmitted, has proved that d. c. transmission of large blocks of power has now reached a stage of maturity for practical application.

[1] Th. Boveri, Bull. SEV, 1944, page 270.

B. TRANSFORMERS.

The last two retrospects mentioned developmental work on the construction of transformers, in part completed and in part in progress, which led to the adoption of fundamentally new transformer designs, namely designs for large outputs and high voltages and for special types such as traction transformers, variable reactors, etc. A certain reserve has been maintained in disclosing details up to the present, and published information confined, for the most part, to references to the progress achieved has been in the form of statistical comparisons. A meeting on the 13th July, 1944 at Zurich, organized by the Swiss Association of Electrical Engineers for purposes of discussion, presented the Company with the opportunity of abandoning this reserve and of disclosing more intimate details of research work and its results. As the subject matter treated by the Company's representative speaker[1] will also be published in this journal, only some fundamental questions will be dealt with in this article.

The comparatively large dimensions of transformers for relatively high voltages are due to the arrangement of windings and insulation which has been the fashion for decades. One result of this arrangement, in which there are a number of alternate layers of oil and bakelized paper in series along the voltage gradient, was that the oil layers had to be made disproportionately thick in order to avoid excessive dielectric stresses. A further result was a poor utilization of the high-quality dielectric properties of the bakelized paper layers. These difficulties have been overcome by the adoption of the so-called *splayed flange or multi-flanged former.* This consists of a relatively thin bakelized paper cylinder on which selected insulating paper is wound in the form of a band of the same width as the final length of the paper former. Inside diameter and wall thickness are so dimensioned that the space between primary and secondary windings is filled with the exception of a small amount of play. The collars are formed by splaying out the cylinder ends and spacing the paper layers by inserting distance pieces at intervals. The splaying obtained in this manner ensures that the end of the former offers the necessary resistance to surface discharges. The introduction of the splayed flange former enabled the designer to reduce the spacing between primary and secondary windings without more ado to less than half the previous value, which further resulted in a reduction of the ratio of iron to copper by weight from the former value of about 6 to a value between 2 and 3. The improvement obtained is still more apparent when a comparison is made between the external dimensions of the new 47,500 kVA transformers, supplied in 1942 for the Innertkirchen power station and erected in underground rock caverns, and the 26,000 kVA transformers supplied in 1928 for the open-air substation at Innertkirchen (Fig. 28). The weight of the new transformers, including oil, is only 75 % of that of the old ones, in spite of the fact that the output is 83 % greater. The direct connection of the 150 kV cable to the transformer, with built-in disconnectable links, is also noteworthy. Fig. 29 shows the new transformer with the four built-on cable end boxes, and Fig. 30 one of the many large transformers with the new type of windings manufactured during the last year.

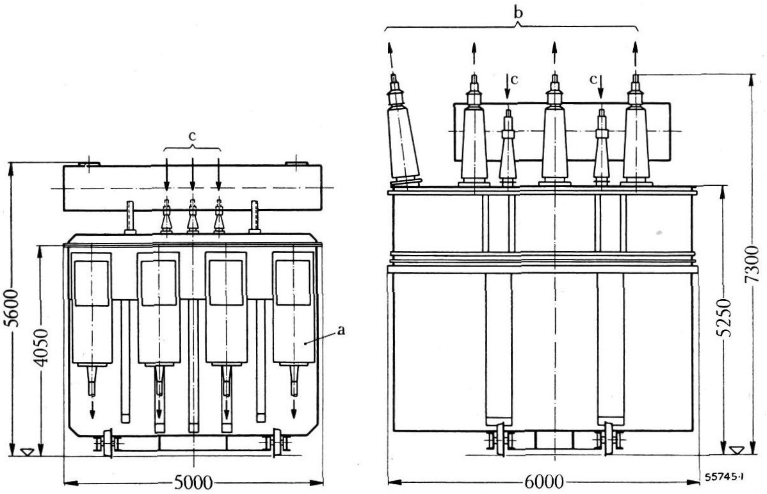


Fig. 28. — This comparison of the dimensions of a 47,000 kVA transformer of new design (left), with 150 kV cable end boxes, with those of a 26,000 kVA transformer of the year 1928 (right), with 150 kV outdoor bushings, shows more clearly than words can express the immense progress made in the construction of transformers during the last sixteen years.

The new design results in a considerable reduction of the dimensions, so that even transformers for the largest outputs usual to-day can be transported by rail.

[1] A. Meyerhans, "Neue Bauweisen bei Transformatoren und Drosselspulen", Bull. SEV, 1944, page 632. Also being published in Brown Boveri Rev., March, 1945.

For outputs up to 140 MVA and voltages up to 220 kV on the high-voltage side, it will certainly be possible to build three-phase core-type transformers in this manner which can still be transported by rail. For outputs greater than 150 MVA and for a voltage of 400 kV, however, as will be required for the high-power and high-voltage transmission lines of the future, the only practicable solution, if the requirement of transport by rail is to be fulfilled, consists in subdividing the three-phase transformer into three single-phase units. In order to introduce this solution in Europe — which has been applied for years in America but which is very expensive — the Company has developed a new design of single-phase, shell-type transformer, of which the central column has radial laminations and a circular section, and which has a comparatively large number of [-shaped return paths for the magnetic flux. This construction leads, on the one hand, to an appreciable shortening of the yokes and therefore of the overall height and yields, on the other hand, an extremely robust cylindrical arrangement with almost no dead spaces, which can thus be mounted in a cylindrical oil tank. The result is that this design of transformer requires very little oil. Exact calculations have shown that three single-phase units of this design for large outputs are only a very little more expensive than a corresponding three-phase transformer. The reason for this is that a bank of three single-phase units of this design only has three legs with windings instead of six as would be the case if single-phase core-type transformers were to be used. A bank of the new type of transformers offers special advantages if the extra-high-voltage network is operated with solidly earthed neutral point, so that each of the single-phase units needs only one large bushing. Fig. 31 shows the preliminary design for one unit of a 240 MVA bank for a 400 kV network together with truck for transport.

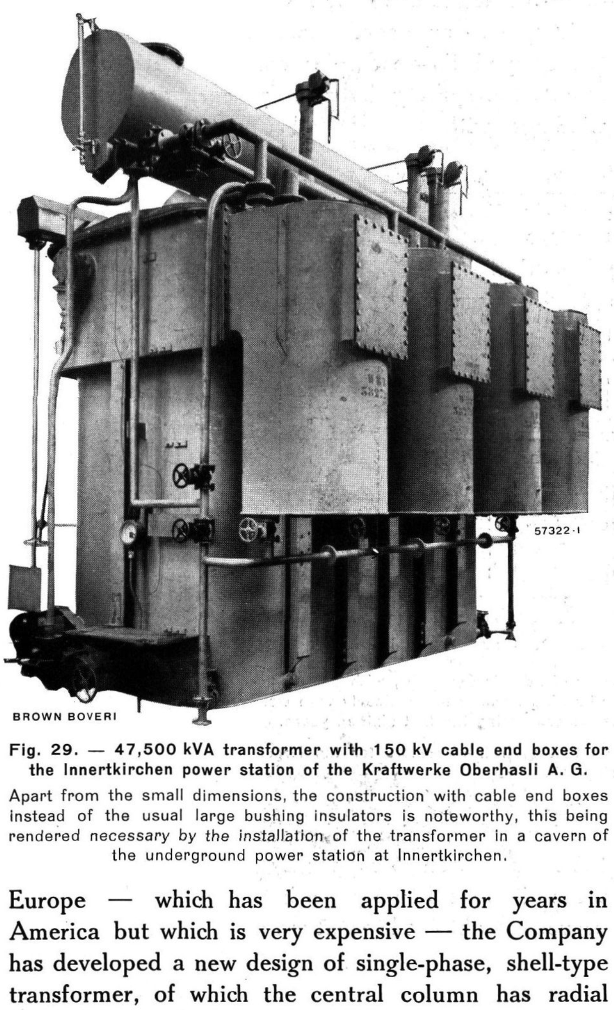


Fig. 29. — 47,500 kVA transformer with 150 kV cable end boxes for the Innertkirchen power station of the Kraftwerke Oberhasli A. G.

Apart from the small dimensions, the construction with cable end boxes instead of the usual large bushing insulators is noteworthy, this being rendered necessary by the installation of the transformer in a cavern of the underground power station at Innertkirchen.

In the course of the past year, an order was already obtained from an important Swiss electricity supply undertaking for a 42 MVA transformer bank built according to the design just described. It consists of three single-phase, tap-changing transformers for outdoor erection, 3×14 MVA, $141{,}000 : \sqrt{3}/47{,}000 + 23 \times 517$ V, with tap-changing switches for operation at high voltages in the windings on the low-voltage side, and with supplementary, forced-draught cooling.

Other especially important applications of the new design are for reactors and traction transformers. Fig. 32 shows a transformer for a motor-coach. In this case, the circular shape of the tank is partially concealed by the extension seen behind the transformer for leads to the tappings of the secondary winding, and by the radiators fitted to the sides and exposed to the wind produced when the coach is in motion. However, a smaller overall height can be obtained with the new design in spite of the vertical arrangement of the core, which is more advantageous for the winding, and a small overall height is always required for the most favourable installation of motor-coach transformers below the floor.

Fig. 33 shows a large locomotive transformer with built-on tap-changing switch for control on the high-voltage side. Regulating and main transformer are, in this case, combined to form a single unit, while, in the first designs for high-voltage control, the regulating and main transformers were, so to speak, merely placed together, this requiring a three-legged core of which one leg had no windings and served as return path for the resultant flux of main and regulating transformers. The new design of traction transformer has resulted in a considerable reduction of weight in comparison with the former construction, and this is all the more important in view of the fact that the transformer of single-phase locomotives or rail coaches represents the heaviest item of electrical equipment on account of the low frequency.

Work has also proceeded intensively on *small regulating transformers* without contacts for the continuous regulation of the voltage of low-voltage networks. The simple design of robust, contactless, dipping-coil transformers type TQ (Fig. 34) is manufactured normally for 380 volts and a regulating range of 74 volts. It is especially suitable for maintaining the voltage constant at the end of long distribution lines in sparsely populated areas, and also for all those cases where a consuming apparatus, which is highly sensitive to voltage fluctuations, requires automatic maintenance of the supply voltage at a constant value. In order to meet the requirements of clients as fully as possible, a complete range has been developed for rated currents (through-puts) of 10, 25, 50, 100, 200 and 400 amp. The TQ regulating transformers are manufactured as three-phase network regulators for all voltages between 190 and 500 volts, and as single-phase regulators for voltages from 110 to 500 volts, rated currents and regulating range remaining unchanged.

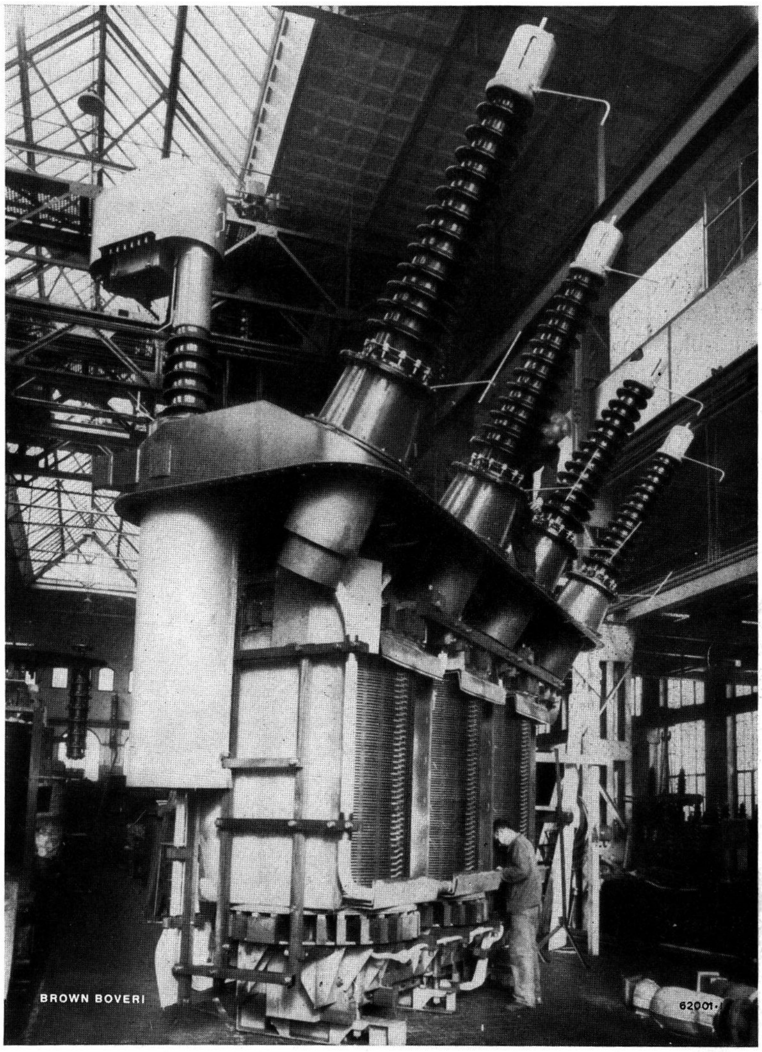


Fig. 30. — A further example of a large transformer with the new construction of windings and insulation. Three-phase, three-winding transformer for 35,000 kVA, 167 kV / 48 kV + 23 × 822 V / 9·3 kV for the Gösgen power station of the "Aare-Tessin A. G. für Elektrizität".

This unit transforms the voltage of the power flowing to the Gotthard transmission line from 150 kV to 50 kV and vice versa. The tertiary winding, necessary for operation of arc suppression coils, also serves for power output from the 8 kV busbars of the Gösgen station to the 50 kV or 150 kV network respectively of the Aare-Tessin A. G. für Elektrizität, and can be used as well for power factor improvement by controlling the excitation of the generators in Gösgen.

C. CIRCUIT-BREAKERS.

The last retrospective number contained information concerning the new series of air-blast circuit-breakers for indoor erection with rated voltages of 10, 20, and 30 kV, which at that time were in the final stages of development.[1] A few months later, this series was placed on the market and the opportunity was taken of describing the special advantages of these circuit-breakers and the internal coordination of their insulation in a comprehensive article,[2] so that there is no need to go into further details here.

To introduce these circuit-breakers, the Company invited a large number of interested persons to a

[1] Brown Boveri Rev., 1944, Nos. 1/2, p. 32.

[2] H. Thommen, Brown Boveri Rev., 1944, No. 4, p. 141.

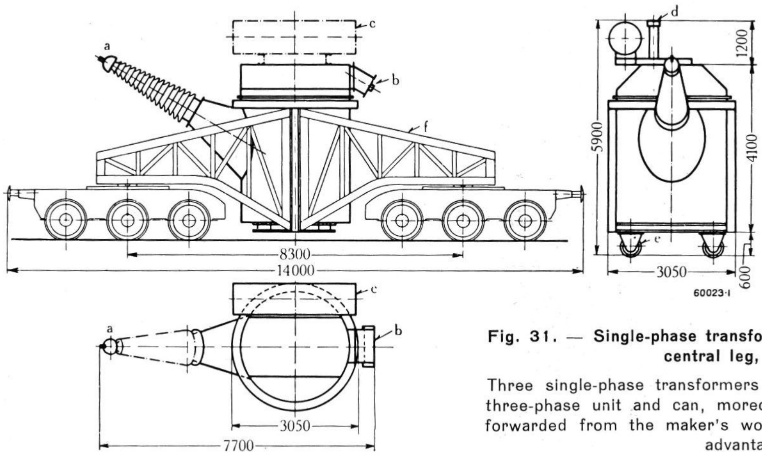


Fig. 31. — Single-phase transformer, of the new design with radial laminations for the central leg, for a three-phase 240 MVA group.

Three single-phase transformers of this design are only a little more expensive than a three-phase unit and can, moreover, be built for transport by rail, so that they may be forwarded from the maker's works complete with oil filling and ready for service, an advantage of considerable importance.

"Circuit-Breaker Day" in October of last year, at which a whole series of successful demonstrations and tests provided proof of the immense progress made in the construction of air-blast circuit-breakers during the last few years. This is best illustrated, from the point of view of economy, by the comparison of the former and new designs of air-blast circuit-breaker (Fig. 35). The ratings (voltage, current, and rupturing capacity) of the circuit-breakers shown are identical.

The demonstrations also provided an opportunity of showing again, in an impressive manner, the great advantages to be gained by the operating engineer from the installation of air-blast high-speed circuit-breakers, with special reference to the effective reduction of the influence of disturbances by the application of high-speed reclosing. With the aid of a loaded converter set (Fig. 36), of which the driving motor could be run both as asynchronous and synchronous motor, it was possible to follow the drop in speed, caused by a brief interruption of the current supply, by means of a stroboscopic disc. The speed drop is so small that the motor does not fall out of step even when operated as synchronous motor.

Amongst other characteristics, the excellent adaptability of the air-blast high-speed circuit-breaker for installation in existing plants was the subject of particular attention. The circuit-breakers can be mounted in practically any position. A really excellent solution

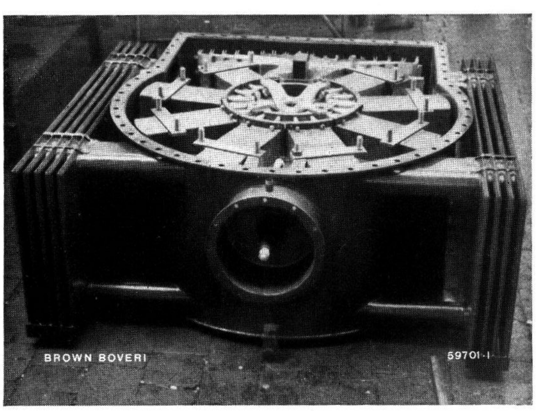


Fig. 32. — Motor-coach transformer of the new design for 410 kVA, 8000 V on the high-voltage side, and $16\frac{2}{3}$ cycles.

In spite of the vertical arrangement of the legs, a flat construction is obtained which allows of installation below the floor of the coach.

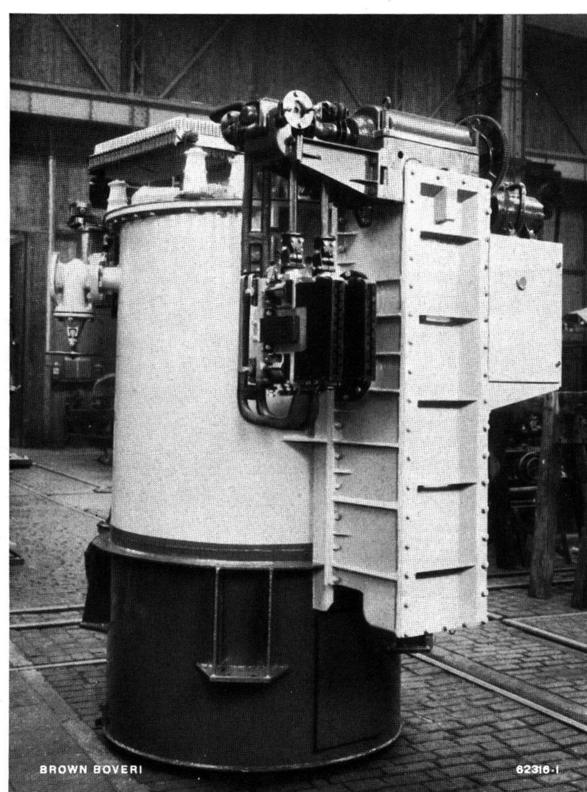


Fig. 33. — Power transformer of the new design with radial laminations for 15,000/25—450 V and a continuous rating of 2700 kVA for the new $B_0 B_0$ locomotives, series 251, of the Berner Alpenbahn-Gesellschaft (Lötschberg railway).

The tap-changing switch for control on the high-voltage side is mounted in a vertical housing and built directly on to the circular tank of the transformer. In spite of the large number of taps for the high-voltage control, 28 in all, only two contactors with arc chutes are necessary.

Fig. 34. — Small regulating transformers type TQ for the continuous regulation of the voltage in low-voltage networks.

This extremely simple, robust, and contactless transformer has been developed for rated currents of 10, 25, 50, 100, 200 and 400 amp.

is to install them in cells of which the side walls are only inserted during maintenance work to eliminate any danger to the workmen in the cell concerned. The immense superiority of the air-blast circuit-breaker over the oil circuit-breaker will be appreciated from a critical examination of Figs. 37, 38, and 39. In normal service, the ease of supervision of a plant with air-blast circuit-breakers is considerably enhanced by the clearly visible isolating links (Fig. 40).

In some circles, the compressed-air plant is considered by operating engineers to be a complication. These operating engineers have doubtless overlooked the fact that a single rotating compressor usually replaces a large number of power-storage or motor operating mechanisms which likewise contain rotating parts. The simplicity of a fully automatic compressed-air set was shown during the demonstrations by means of a plant installed as for normal service (Fig. 41). The experience gained with some hundreds of plants supplied has shown that no disturbances at all occur. The comparatively small Pintrun power station, already mentioned in this number, was also equipped to advantage with air-blast circuit-breakers, not only for reasons of security, since the station is unattended in normal service, but also for the sake of economy.

D. NETWORK PROTECTION.

Many engineers have expressed the wish for a simple instrument with which *to test secondary relays*. This long-felt want is filled by the testing unit illustrated in Fig. 42. On account of the wide regulating range for current and voltage, the testing unit is well suited for all kinds of small tests although its construction and circuit are the simplest imaginable. It should not be lacking in any electricity supply undertaking nor in any electrical installation firm of any importance.

The development of *high-speed distance-relay protection* may be regarded as concluded for the time being. The pick-up times obtained with this protective equipment in conjunction with the short rupturing times of high-speed air-blast circuit-breakers have now provided a solution for the problem of stability in interconnected networks. At the present time, there are 32 various designs of high-speed distance relay available, from which types may be selected to meet any conditions which can possibly prevail in a network. The results of operating experience are regularly placed at the Company's disposal by several large

Fig. 35. — Comparison between an earlier (right) and the latest design (left) of air-blast high-speed circuit-breaker for 10 kV and 400 MVA.

The considerably smaller dimensions of the new circuit-breaker, with which an appreciably lower air consumption is combined, are at once obvious.

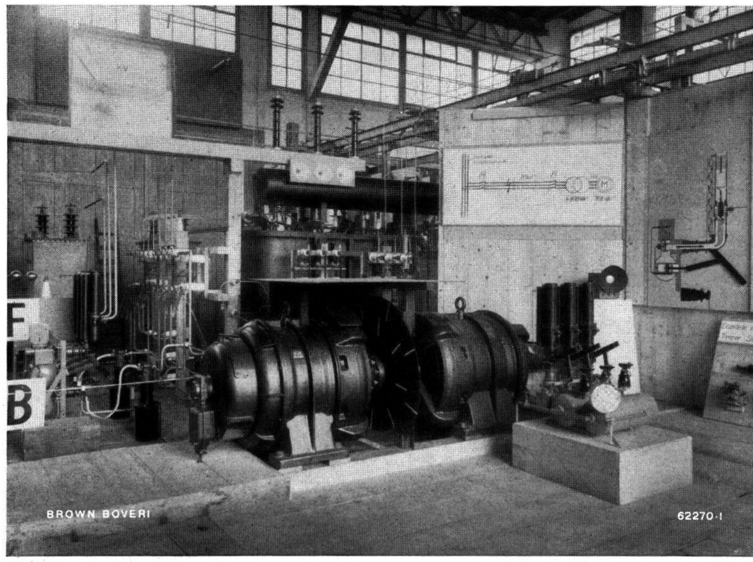
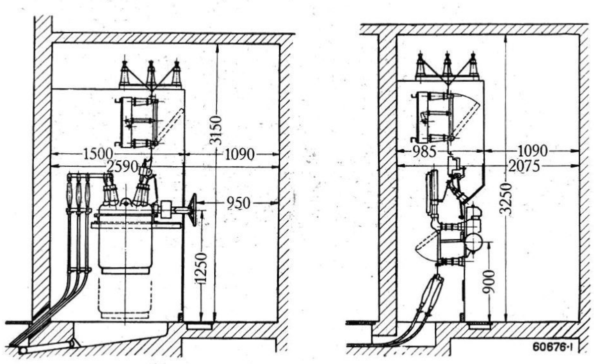


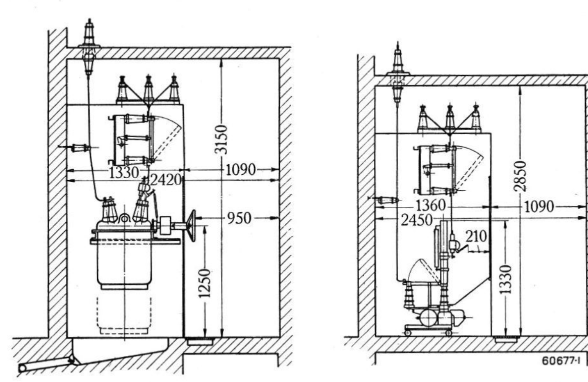
Fig. 36. — **Partial view of the motor-generator set with stroboscopic disc installed for demonstration purposes during the exhibition of the new air-blast high-speed circuit-breakers with high-speed reclosing in the Company's Works in October, 1944.**

This equipment provided the proof that the synchronous motor does not fall out of step, even at full load, during the short interval between the interruption of a short circuit and reclosing of the air-blast breaker.



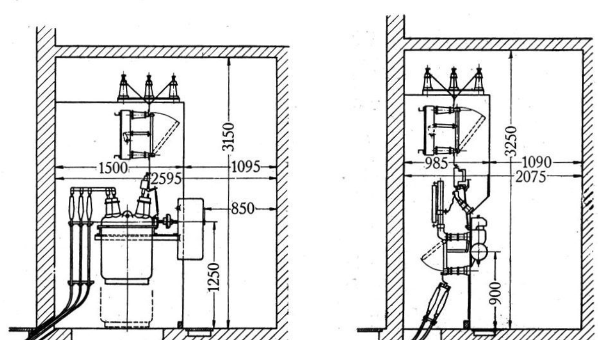
Oil circuit-breaker. **Air-blast high-speed circuit-breaker.**

Fig. 37.



Oil circuit breaker. **Air-blast high-speed circuit-breaker.**

Fig. 38.



Oil circuit-breaker. **Air-blast high-speed circuit-breaker.**

Fig. 39.

Fig. 37—39. — **Comparison between various methods of installation of oil circuit-breakers and air-blast high-speed circuit-breakers for indoor erection.**

In all cases, the appreciably greater ease of supervision and the small space requirements of the explosion-proof air-blast circuit-breaker are obvious.

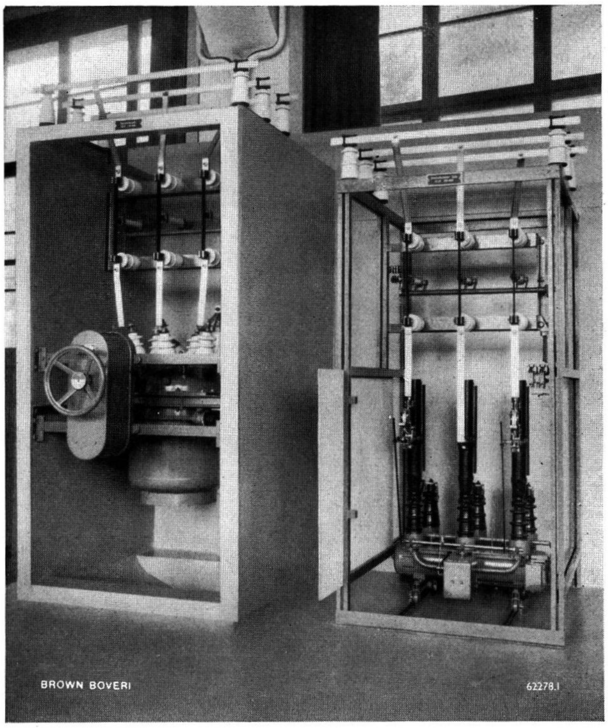


Fig. 40. — Comparison of the installation of an oil circuit-breaker (left) with that of a air-blast high-speed circuit-breaker (right) with the same rating (20 kV, 400 A, 200 MVA rupturing capacity).

The massive walls, necessary for the installation of an oil circuit-breaker on account of the danger of oil fires, are eliminated in the case of the air-blast breaker. An open installation providing ease of supervision and requiring little space is therefore possible. Before commencing maintenance work during service, eternite sheets are inserted on the left and right in the frame of the cell. These sheets, which act as isolating partitions, are visible in the photograph.

undertakings in Switzerland and other countries. This opportunity is taken of thanking the undertakings in question for the technical assistance they have provided, since many improvements and refinements are the result of this extremely valuable cooperation.

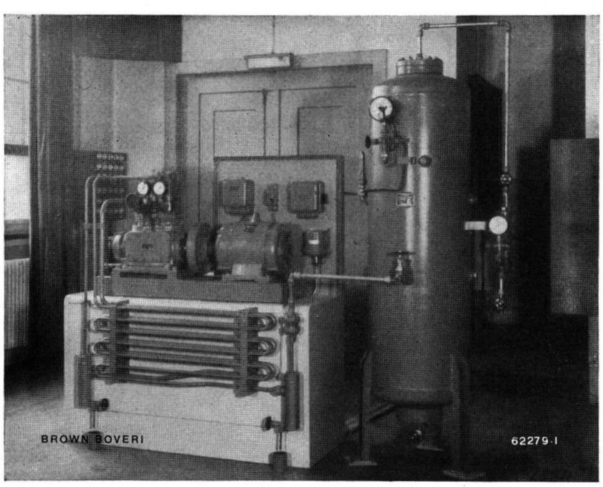


Fig. 41. — Automatic compressed-air plant with accessories for air-blast high-speed circuit-breakers.

Efforts aiming at standardization of relay constructional forms have also led to the manufacture of high-speed distance-relay equipments for flush mounting (Fig. 43). These equipments are so designed that good accessibility to the individual component relays is ensured. After opening the front cover, the frame on which all relays are mounted can be swung out and clamped in the open position. Maintenance work on the relays can then be carried out in exactly the same way as in the case of the semi-projecting pattern.

Another innovation, which appreciably simplifies the work of checking disturbances, is the inclusion of a

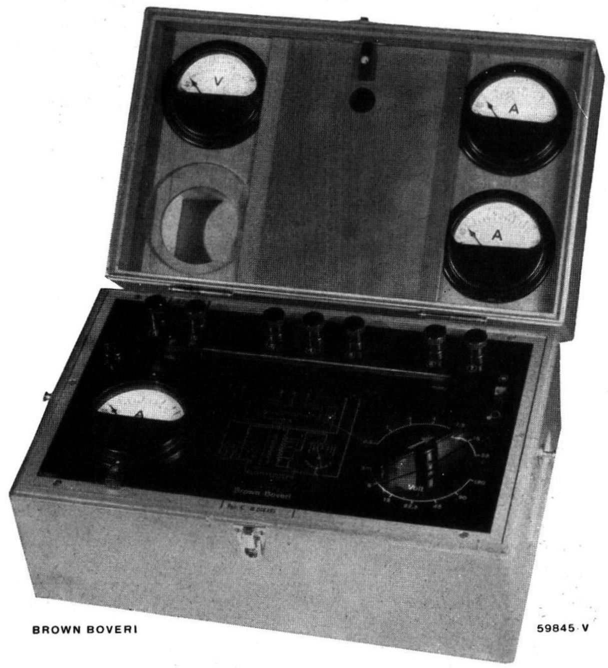


Fig. 42. — Test unit for checking secondary relays, a welcome instrument for maintenance engineers.

Primary voltage 220 V, secondary voltages 3—180 V, secondary currents 30—105 amp. The apparatus is ideally suited for small tests on account of the ease with which current and voltage can be regulated. The regulating resistance is protected from overloading by a built-in switch with thermal releases.

group of indicators in the distance-relay panel (Fig. 43). These indicators replace the signal flags of the auxiliary contactors. The concentration of the signals in one unit allows greater freedom in the choice of the site for the installation of the distance-relay equipment. If difficulties are encountered in mounting the equipment in the control room on account of the large space requirements of the distance-relay panel, it is quite sufficient to install the indicator unit there alone. It may be mentioned that the indicators are reset electrically.

In the case of electricity supply undertakings, the engineers responsible for power supply and distribu-

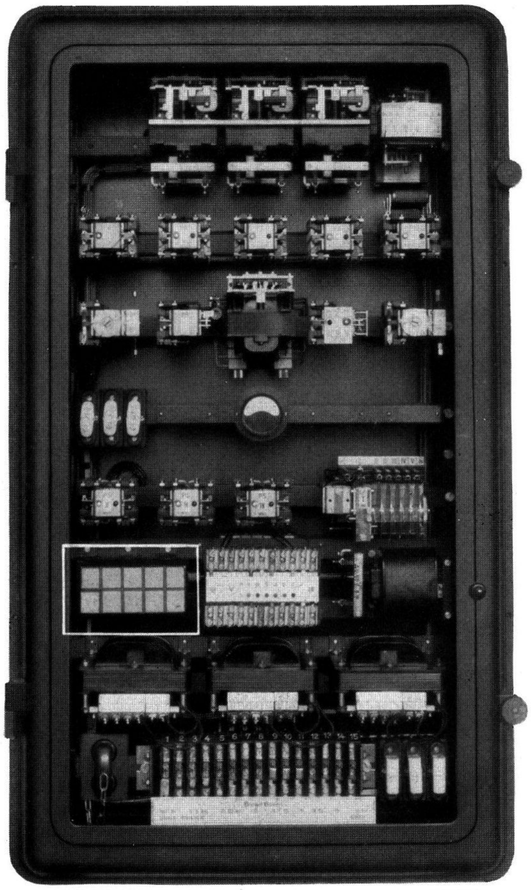


Fig. 43. — Distance-relay panel with built-in grouped indicators (in white rectangle) for 10 printed signals.

The grouping of the signals has the advantage that all fault indications are concentrated at one point, while all signals are reset electrically by depressing a single push-button. The signals can, however, be mounted individually or as a group in the panel or control desk in the control room.

tion often require to know exactly the magnitude and direction of any short circuits which may occur at any points in their networks. In the same way it is necessary for the Company's engineers to have a clear conception of the short-circuit conditions in a network if the correct protective equipment is to be provided. The predetermination of short-circuit currents and their distribution is generally difficult and, in the case of networks with a high degree of interconnection, means a long and tedious calculation. A *network analyser* (Fig. 44) has therefore been developed which is based on well-known principles and permits the conditions prevailing in any network to be reproduced in miniature, so to speak, by adjustment of its impedances, and the short-circuit currents to be ascertained.

Adjustable choke coils, as single-phase units for network protection, have naturally profited to a large extent from the new design of single-phase transformers. In the former design, consisting of a core with parallel laminations and fitted with a winding on each leg, the air-gap had always to be subdivided into a large number of small gaps. Due to the fringing effect, part of the flux enters the outside surface of the laminations transversely and produces eddy currents. The larger the gap the greater are the eddy currents produced, and the gap is generally made less than 10 mm. In view of the multitude of gaps, regulation could not be carried out by adjusting the length of the gap, but only by using a tap-changing switch to select varying numbers of turns and thus changing the flux. In order to reduce the current in the coil to $1/n$ of a given value, the number of turns had to be increased $\sqrt{n}$ times. This meant a considerable increase in size if a large regulating range had to be provided, apart from the other inconveniences associated with the large number of taps.

The application of the core with radial laminations has made it possible to build large choke coils with variable air-gap, thus eliminating taps on the windings. With this design, the stray flux enters at the fringes of the air-gap through the thin edges of the laminations, so that additional eddy-current losses are completely eliminated and the gap can be made as large as desired.

Numerous choke coils of this design for use as arc suppression coils, with ratings up to and exceeding 5000 kVA and regulating ranges up to 1 : 10, have been in service for a considerable time. Air-gaps of almost 1 metre have been employed without encountering any difficulties. In arranging the windings, however, careful attention must be paid to the appreci-

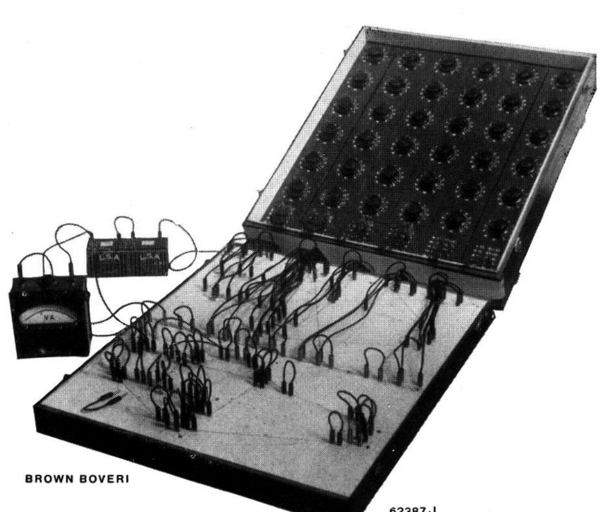


Fig. 44. — This d. c. network analyser is used for the rapid determination of the currents flowing at various points of networks under varying conditions.

able straying of the flux away from the central axis. It is just in such cases that the core with radial laminations shows up to advantage on account of its insensitiveness to stray fields and its valuable property of balancing out the magnetic forces. A mechanical position indicator fitted to the arc suppression coils with continuous regulation allows the adjustment of the coil current to be read directly.

gear plant for 8·2 (later 16·4) and 11 kV service voltage contains no oil whatever. Oil is used neither for insulating nor for rupturing purposes. All isolating switches are provided with pneumatic remote control-gear. In this plant there are five three-pole air-blast high-speed circuit-breakers of the new series, two of these having a rated rupturing capacity of 1000 MVA and the other three a rupturing capacity of 400 MVA.

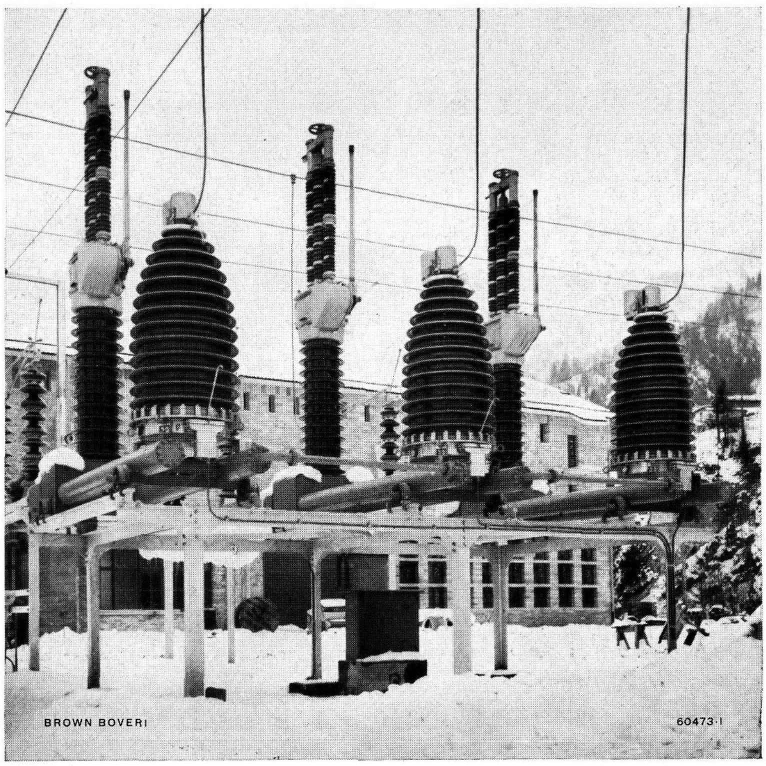


Fig. 45. — 150 kV air-blast high-speed circuit-breaker with built-on current transformers of the insulator type in the Lucendro power station of the Aare-Tessin A. G.

Due to the design with potential-controlled multiple-break, this circuit-breaker has the high rupturing capacity of 2500 MVA despite its light construction.

E. SWITCHGEAR.

The design and manufacture of a large number of air-blast high-speed circuit-breakers for indoor and outdoor erection acted as an inducement to make provision for a still better and more harmonious lay-out of switchgear plants. Reference has already been made to some essential points, such as the saving of space, in the section dealing with the new air-blast high-speed breakers for indoor erection.

Of the many switchgear plants supplied during the last year, the one for the almost completed *Lucendro power station* would in any case be worthy of special mention if only on account of the large quantity of material involved. The complete installation comprises an indoor and an open-air plant. The *indoor switch-*

There are also twenty-eight three-pole isolating switches, of which the eight for the generators have a rating of 2500 amp. while the other twenty are rated for 400 amp., as well as thirty-one current transformers of the bushing and loop types without oil. The *open-air plant,* designed for a rated voltage of 150 kV, comprises four three-pole air-blast high-speed breakers of the multiple-break type with built-on oil-filled insulator-type current transformers, as well as the associated separate supplementary compressed-air vessels and control pedestals, the latter containing the various pneumatic relays for control and supervision. The rated three-phase rupturing capacity of each complete circuit-breaker is 2500 MVA. There are also four three-pole 50 kV air-blast high-speed circuit-breakers, each with

Figs. 46—48.

The new Lucendro power station of the Aare-Tessin A.G.

(See also Fig. 45, page 29.)

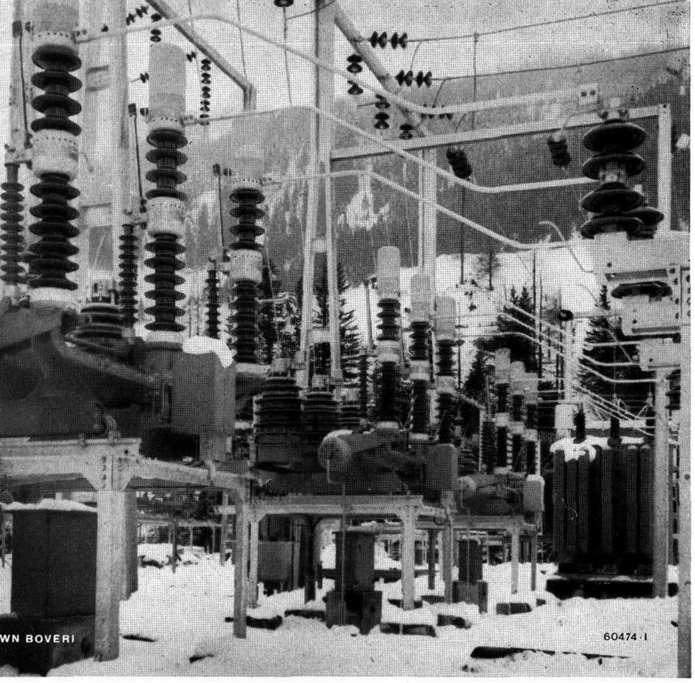


Fig. 46. — 50 kV air-blast high-speed circuit-breakers, each with a rupturing capacity of 800 MVA and built-on current transformers of the insulator type.

In the background can be seen the regulating transformer with a rating of 3000 kVA, 8/50 kV. To ensure reliability and efficiency, general use is made of compressed air for rupturing purposes and for the operation of breakers and isolating switches in this modern peak-load station.

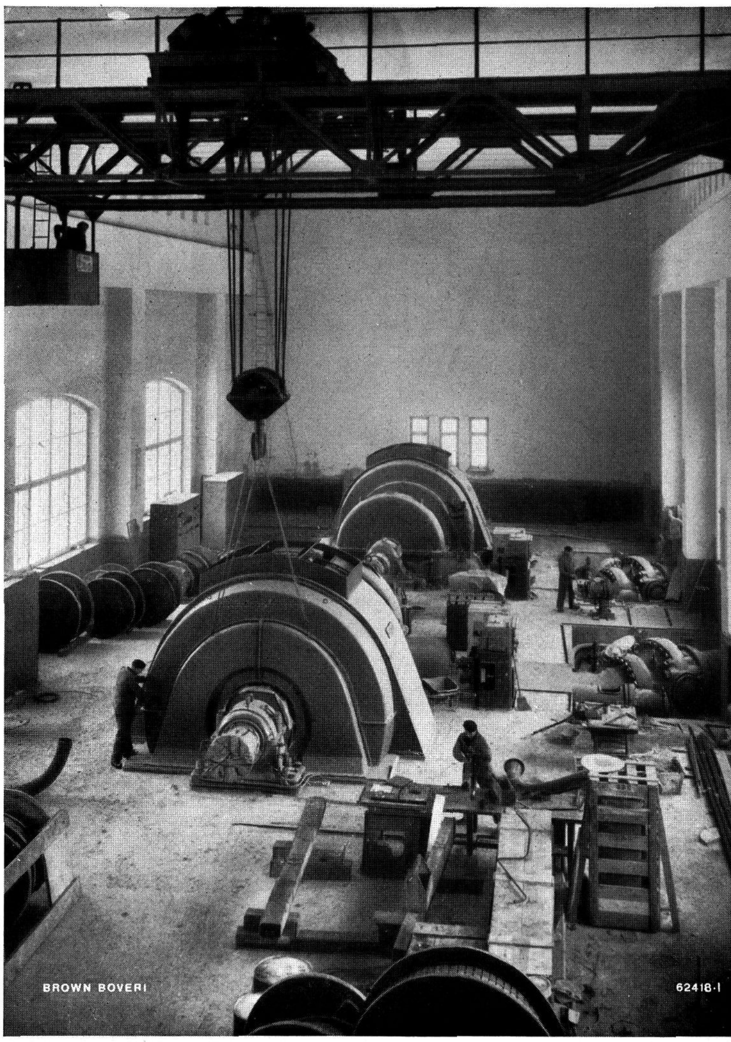


Fig. 47. — Part of the machine room of the Lucendro power station during erection.

The photograph shows the two three-phase generators, each with an output of 30,000 kVA at 11 kV and 500 r. p. m., supplied by Brown Boveri. Remote controlled shutters mounted in the openings visible on the top of the generators allow warm air from the ventilation system to be used for heating the machine room.

Fig. 48. — Open-air, high-voltage transformer plant of the Lucendro power station comprising two three-phase, three-winding units, each with a rating of 31 MVA, 11 kV/160—145 kV.

The new design developed by the Company (see page 21) allowed these transformers, complete with oil-filling, to be loaded on crocodile trucks without exceeding the rail loading gauge. Only external components, primary and secondary bushings and the wheel assembly, had to be removed.

a rated rupturing capacity of 800 MVA and of the single-break type, these likewise having built-on oil-filled insulator-type current transformers and separate supplementary compressed-air vessels. Apart from these, the plant contains eight three-pole 150 kV isolating switches, six three-pole 50 kV isolating switches and the instrument transformers. The switchboards, comprising eighty-seven panels, include all protective, metering, control and signalling equipment for the machines and other plant of the whole station.

Figs. 45—48 are some views taken shortly before the completion of this power station, the most modern and largest equipped by the Company during the past year.

F. MUTATORS.

Of the orders recently received for high-power mutators, two plants deserve special mention as representative of typical applications of heavy-current units. The first is for an aluminium works in Spain and the second for the current supply to electrolysis baths in a Portuguese works. The duty of the mutator plant in the aluminium works is to transform 50 cycle three-phase current at 6000 volts into direct current at 500 volts. The current is maintained constant at 25,000 amp., while the d. c. voltage can be regulated from 100 to 500 volts. The maximum output of the plant is therefore 12,500 kW, three double mutator sets being provided of which one serves as stand-by. The electrolysis plant is designed for a total output of 12,528 kW divided equally among three double mutator sets. Each double set supplies a separate series of electrolysis baths with a current of 7200 amp.

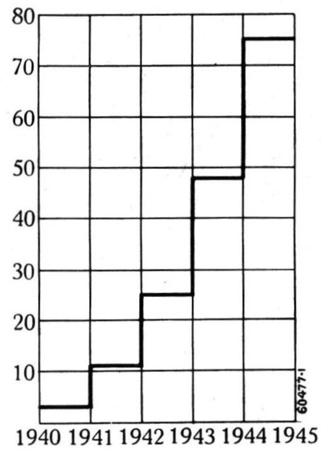


Fig. 49. — Sales of pumpless air-cooled mutators since manufacture of this type was commenced.

The various advantages of this type of mutator, such as low maintenance, automatic and noiseless operation, small space requirements and high efficiencies even at small outputs, ensure its steadily increasing employment in the most widely varying fields of application.

at a d. c. voltage adjustable between 480 and 580 volts. The primaries of the mutator transformers are connected to a 50 cycle, 60,000 volt three-phase system. Twelve-phase sets are employed for both plants.

The development of pumpless mutators was also carried a stage further. The Company took up the manufacture of this type of mutator rather late, but seventy-five such units have already been built for a total output of 18,000 kW, fifty-five of these being for substations of traction systems and twenty for other purposes. Up to the present time, eighteen

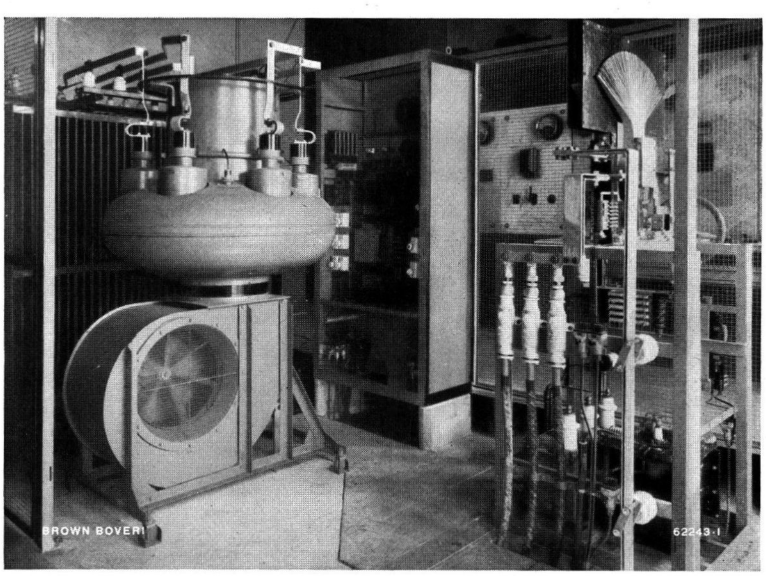


Fig. 50. — Pumpless air-cooled mutator for 390 kW at 650 volts in the Aigle substation of the Aigle-Leysin railway.

The mutator plant is designed for 100% overload for 30 minutes and 200% overload for 15 minutes.

Considerable numbers of the pumpless mutators already supplied are in operation in traction systems and have proved entirely satisfactory for this kind of service.

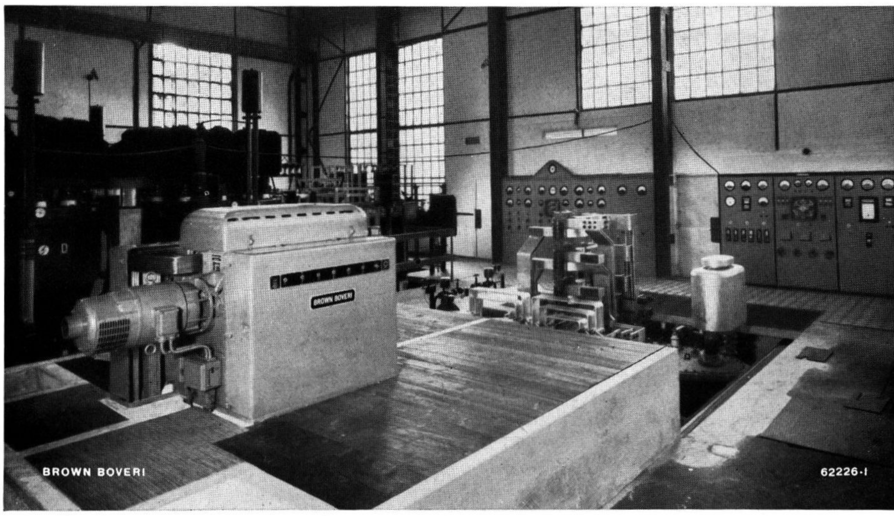


Fig. 51. — Mechanical rectifier rated for a d. c. output of 8500 amp. at 400 volts. Primary voltage 5500 volts at 50 cycles.

The mechanical rectifier has been developed in recent times parallel with the mutator and is especially suitable for low voltages and heavy currents, under which conditions it is distinguished by its high efficiency. The mechanical rectifier with its driving motor can be seen on the raised dais in the foreground.

pumpless mutators have been installed in Switzerland (Fig. 49).

The first test plant with the larger mutator tank for a rated current of 1500 amp. in the "Drahtzug" substation of the Zurich Municipal Electricity Supply, of which a load chart was published in the last retrospective number of the Brown Boveri Review, has been followed by two further plants, the "Les Chevalleyres" substation of the "Chemins de Fer Electriques Veveysans"[1] with a unit for 500 amp. at 850 volts, and the "Aigle" substation of the Aigle-Leysin Railway for 600 amp. at 650 volts, convertible to 1300 volts at a later date (Fig. 50). Both plants are designed for very heavy overloads.

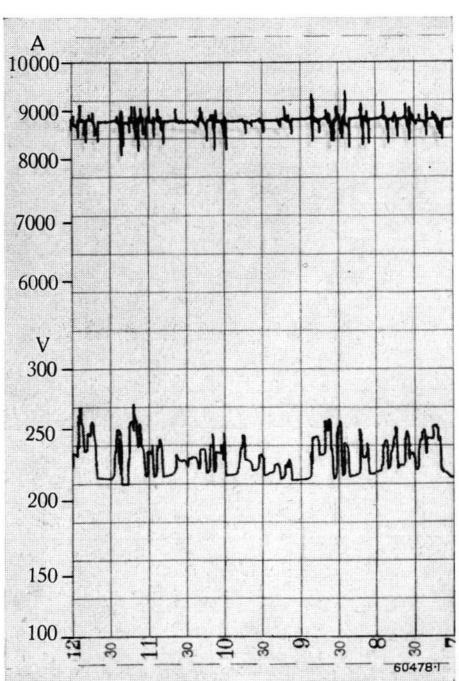


Fig. 52. — Recorder chart showing the loading conditions when the mechanical rectifier is supplying a bank of aluminium reducing furnaces.

In spite of the voltage fluctuations, the current is maintained constant by the automatic regulation.

It was mentioned in the last retrospective number that the Company had taken up the manufacture of mechanical rectifiers or what may be termed *"contact converters"*. These are employed as a. c.-d. c. converters for low voltages and very heavy currents, under which conditions mercury-arc rectifiers, on account of their constant voltage drop (arc loss), or the d. c. machines of motor-generator sets would have an efficiency that is much too low. The first contact converter built by the Company, the practical result of a long period devoted to developmental work, was completed just in time to be mentioned in the last retrospective number. This unit was delivered during the past year and has now been in continuous service for several weeks at the Chippis works of the Aluminium Industrie A. G. with a load of about 8500 amp. Measurement of the losses during test operation at 55 % of the rated maximum voltage showed that an overall efficiency of 92 % was reached. Fig. 52 shows a section of the load chart.

[1] A. Odermatt, Brown Boveri Rev., 1944, No. 8, page 273.

III. BROWN BOVERI MANUFACTURES IN INDUSTRY, TRADE, AND AGRICULTURE.

A. MOTOR DRIVES AND ASSOCIATED CONTROL GEAR.

Introduction.

Electrical energy is finding ever-increasing application for the production of power and heat in different industries and trades. In view of this trend it is the duty of the electrical industry not only to develop the equipment to meet the demand for the more and more intensive "electrification" of working processes, but also to show where and how it can be best applied to the greatest effect.

Industrial applications of electrical energy must be adapted to the technological working processes in question. Electrical engineering is therefore not autonomous in these fields, but is restricted by conditions imposed by the application. This applies both to motors, which only indirectly participate in the working process as the driving element of a machine, and to an increased extent to thermal applications with which, for instance, in the case of melting, welding, and steam generation, the process itself is carried out electrically. Close cooperation between the engineers specialized in the electrical equipment, the manufacturers of the mechanical part, and the users of the plant is therefore indispensable. It is only from the particulars of each individual case that

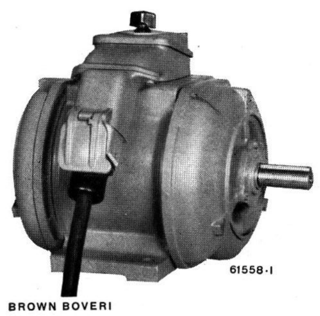


Fig. 53. — Three-phase motor with rotary switch (built into terminal box) and built-on plug socket.

Note the harmonious assembly of all of the parts.

Fig. 54. — 0·55 kW three-phase motor combined with six-stage change-over gearing for the drive of various tools through a flexible shaft.

A mobile electric tool for a hundred and one jobs.

Fig. 55. — 1·1 kW three-phase motor combined with flat grinding machine for parquet floors and the like.

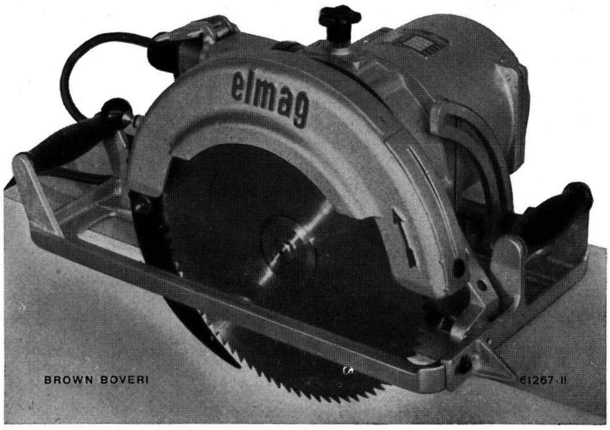


Fig. 56. — 1·1 kW three-phase motor combined with hand circular saw.

Motor and machine form a self-contained unit. All cast parts are of light metal, thus resulting in a low weight which greatly facilitates the work. The motor has a particularly high stalling torque so that it pulls well under all load conditions.

the electrical equipment can be made to meet the imposed requirements and the advantages of electrical operation be exploited to the full.

The innovations in the electric motor and electrothermal fields described hereafter show how the Company is constantly at work to adapt their equipment more and more closely to the requirements of industrial and trade applications.

In many cases it is a definite advantage when the motor and its operating or protecting switch are assembled together. The motor terminal boxes are so arranged that the industrial switchgear can be conveniently screwed on without any design modifications whatsoever, which naturally facilitates installation on site.

In the case of small motors a rotary switch can be flush-mounted in the standard terminal box and is thus protected against all extraneous influences. This design is depicted in Fig. 53 with a plug socket instead of a conduit gland or cable dividing box. The arrangement is intended for mobile motors. It will be seen from the illustration that the assembly is by no means an improvisation, but that all parts harmonize perfectly with one another.

The three-phase motors manufactured by the Company on mass production lines are designed from the standpoint of maximum adaptability. Only slight design modifications are necessary to enable them to be adapted to the very varied requirements imposed by assembly with machines of all types. Figs. 54—57 are examples of such designs.

In the interest of motor customers the Company is constantly endeavouring to widen the range of the simplest and most efficient of all motors, i. e. the three-phase squirrel-cage motor. The most important requirement is to keep the starting current low so that the motors will be more widely admitted for connection to public supply systems. In cases where an initial starting torque of 50—60 % of the rated torque suffices the restrictions imposed by public supply undertakings are readily fulfilled with the Company's type OS star-delta switch. When this has been closed it changes over automatically after the elapse of a certain time which can be adapted to the actual starting conditions. In this way the rush of current occurring at the change-over from the starting to the running position is limited to the lowest value possible theoretically, so that the current occurring during the whole starting process is even lower than in the case of motors with centrifugal starter.

In order, however, also to be able to employ squirrel-cage motors in cases where a considerably higher initial starting torque is required, but only a limited starting current is admitted a new reinforced star-delta starting process has been evolved (Fig. 58). In this manner, for a four-pole motor, for instance, an initial starting torque of approximately 90 %, corresponding to a mean starting torque of roughly 100 % of the rated value, with an initial starting current of only about 270 % of the current rating is attained. The already proved star-delta switch referred to above, but in a slightly modified form, is employed as starting and protecting switch. Reinforced star-delta starting forms a valuable alternative to the hitherto conventional methods of starting

Fig. 57. — 0·7 kW three-phase motor installed for assembly with domestic machines.

The smooth casing can be readily cleaned, while operation is simple with the directly built-in rotary switch.

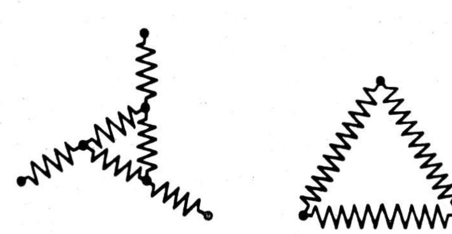


Fig. 58. — Diagram of a motor for reinforced star-delta starting.

This method of starting also enables the robust squirrel-cage motor to be employed where slip-ring motors or motors with centrifugal starter had to be resorted to hitherto.

a. Starting. b. Running.

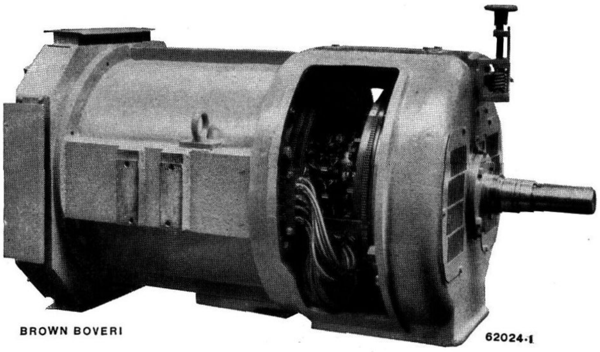


Fig. 59. — Three-phase shunt commutator motor variable from 73 to 30 kW and from 2000 to 800 r. p. m., with constant motor torque, designed as dynamometer motor for a pump test bay.

Casing removed. The excellent regulating properties of this motor are continually increasing its importance in driving applications.

squirrel-cage motors. As a result this type of motor can be employed in many cases where otherwise motors of the slip-ring or centrifugal-starter type would have to be resorted to, and what is more a reduction of about one-third on the cost of these drives is also realized.

By reason of its excellent regulating properties the shunt commutator motor is finding wider and wider application and as stated in last year's review of progress has been developed still further in two respects, viz., to enable speed ranges up to 1:50 and substantially higher speeds, i. e. much higher outputs per pole, to be obtained. By way of example Fig. 59 shows such a motor rated 73 kW at an upper speed limit of 2000 r. p. m. and variable down to 800 r. p. m. with constant torque, which was supplied as electrical dynamometer for a pump test bed. Fig. 60 is another view of the same motor complete with dynamometer accessories.

Following on the further development of the medium-size motors the principle of axial ventilation has been extended to the larger range. Figs. 61 and 62 are examples of high-voltage motors of this type. Axial ventilation has also proved to be of great advantage here. The motors are generally built with former-wound coil windings and open slots. Special care has been paid to the air system and the very effective ventilation obtained as a result has enabled the dimensions to be kept much smaller than usual. The brush gear can be readily inspected and, if necessary, replaced.

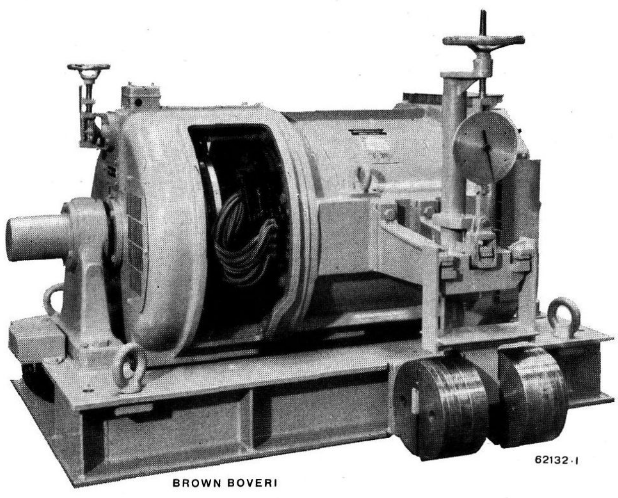


Fig. 60. — Motor in Fig. 59 with dynamometer equipment for a pump test bay.

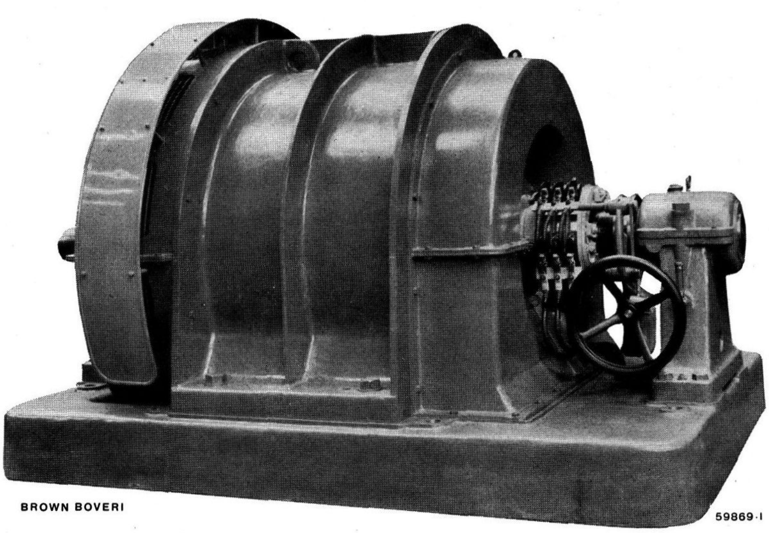


Fig. 61. — Three-phase slip-ring motor rated 755 kW, 735 r.p.m., 6000 V, 50 cycles, for the drive of a cement mill.

The motor has semi-pipe ventilation. The covers over the air outlets at the driving end can be dispensed with where conditions permit. The hand-wheel is for operation of the short-circuiting and brush raising gear.

The new low-voltage high-capacity automatic circuit-breakers which are now available with ratings up to 4000 A have already proved their worth in many installations. The numerous design alternatives and the possibility of providing the circuit-breakers with a wide variety of protective relays and the most appropriate operating mechanism enable equipment to be selected for each individual case which meets the imposed requirements in every respect.

The circuit-breakers are also suitable for inclusion in banks of switchgear (Fig. 63). In this case they are enclosed in a tightly-closing sheet-steel box which

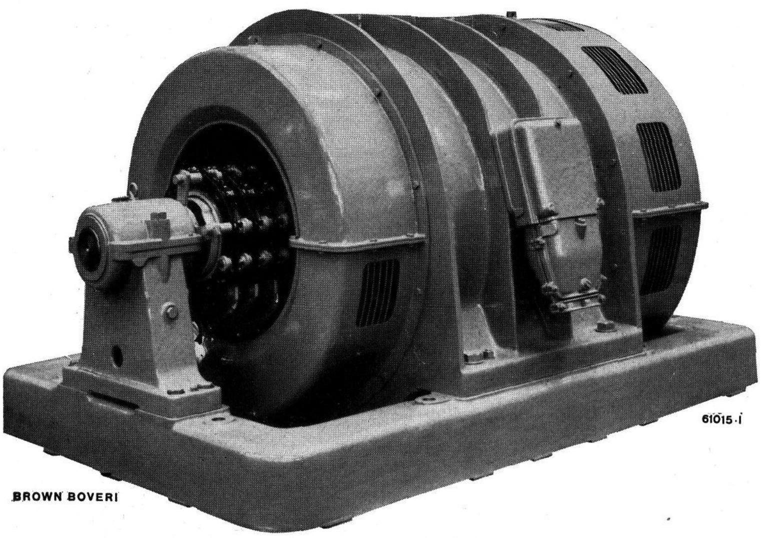


Fig. 62. — Three-phase slip-ring motor rated 1450 kW, 985 r. p. m., 3000 V, 50 cycles, for the drive of a blower.

The motor is of the open type with continuous contact brushes. Note the stable construction of the casing with the reinforcement ribs.

can be assembled into a bank with the other apparatus in the usual way.

1. *Drives in the Textile Industry.*

Particular care was again paid to this field during the year under review. Interesting *research results* will not be gone into here, but will be made the subject of separate articles later. Mention may, however, be made of two important problems which were investigated.

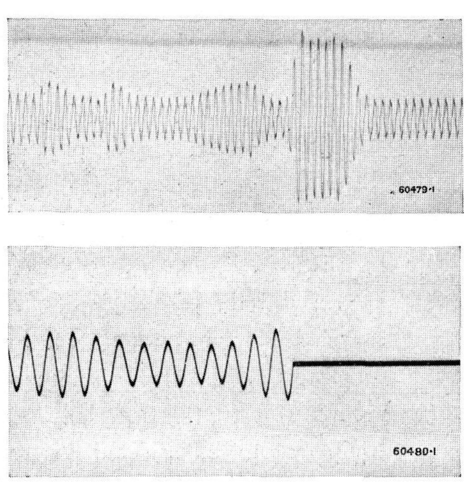


Fig. 64. — Current traces of a loom motor during braking by stop bracket without (top) and with (bottom) Brown Boveri high-speed release.

Top: The current rises suddenly to the starting value. The large additional stressing moment lasts for 8 periods of the 50-cycle alternating current.

Bottom: The motor current is interrupted before the braking process begins, so that there is no additional stressing and in consequence no current rise.

The spinning conditions on modern *ring spinning frames with a large ring rail lift* were investigated in collaboration with *Prof. E. Honegger* of the Textile Institute at the Swiss Federal Institute of Technology, Zurich. The large balloon which forms on such frames is inclined to strike on the separators arranged between the spindles, especially at high speeds and when the traveller is light. The purpose of the investigations was to see whether it is necessary to vary the speed by a special process. This only proved to be the case when a frame having a large ring rail lift has to produce a low quality yarn and the productivity of the frame is pushed up to the utmost. The

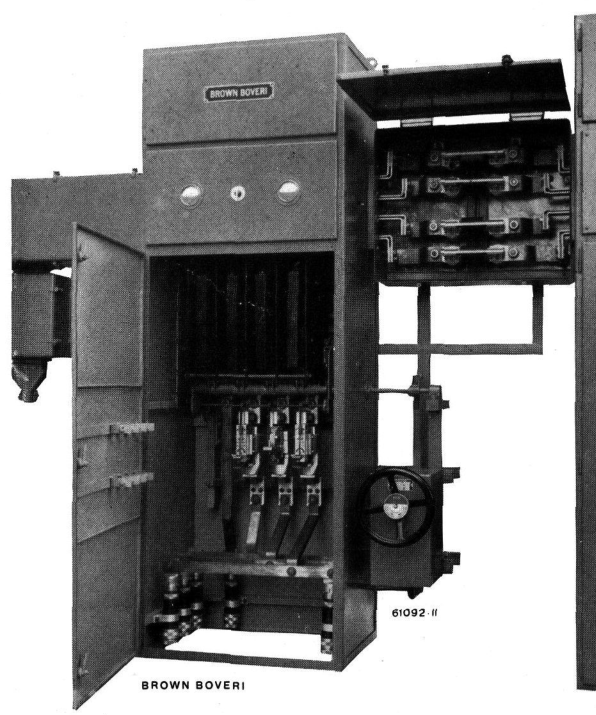


Fig. 63. — Automatic circuit-breaker type G (with relays types HT and HB) with motor operating mechanism, included in a bank of switchgear.

The new circuit-breaker can be assembled together with other apparatus in a simple manner into a bank of switchgear and is characterized by its many-sided applications.

majority of variable-speed spinning frame drives, however, can be based on the spinning diagram introduced by the Company as early as 1907/08 and which has been employed with great success ever since.

Exhaustive tests were also made to devise equipment for the *rapid disconnection of the loom motor* in the event of faults occurring on the loom. If the shuttle begins operating erratically the slay motion is blocked by the stop bracket on the majority of looms. Under these conditions both the slay and the driving gear are subjected to heavy retardation forces, especially as the motor torque continues acting against the braked slay until the coupling between the motor and the crankshaft is declutched. In order to eliminate this stressing occasioned by the motor torque a device has been evolved which disconnects the motor from the supply in 6—10 thousandths of a second immediately the buffer effect of the stop bracket sets in (Fig. 64).

The automatic control gear for *cotton spinning mills,* already referred to earlier, has aroused great interest and as a result has been further developed to obtain *cycle controls,* which have been installed in numerous bale braking and blowing rooms. In the case of the plants in question loose fibres are pneumatically conveyed from one machine to the other without human intervention whatsoever. A cycle control comprises the protective and control apparatus for all of the motors of the machines operating together, it being immaterial whether the latter comprise an opener-scutcher combination or whether an entire blowing room is concerned. All machines can be started and stopped one after the other in correct sequence with a couple of push-buttons. Selector switches permit the desired programme for dealing with cotton, staple or mixed fibres to be chosen with only a few manipulations. Apart from the big saving in labour for the transport of the material the simple operation and adaptability of the equipment to changing operating conditions are advantages which are particularly appreciated (Figs. 65 and 66).

Of the ever-increasing and many-sided applications of the *shunt commutator motor* the variable-speed drive of *high-capacity cone warping machines* is worthy of special mention (Fig. 67). The excellent regulating properties of this type of motor are utilized during the warping process to adapt the speed by hand to the most suitable thread speed for the material in question and in the case of beaming to keep the thread speed automatically constant with increasing beam diameter.

For *automatic wool carding sets* with which the sliver is transmitted from one machine to another electrical individual drive has the advantage that the cards can all be started up together, maintained in

Fig. 65. — Banks of switchgear for 86 individual drives in the blowing room of a cotton spinning mill.

The desired cycle for the processing of cotton, staple, or mixed fibres can be selected with only a few manipulations for each of the six opener-scutcher sets by means of a selector switch.

Fig. 66. — Part of blowing room in Fig. 65.

View over the eight feeder boxes of the double scutchers with drive of the feeder box regulating cylinder and suction box. Even in the dusty atmosphere of the blowing room the totally-enclosed surface-cooled motors require practically no attendance.

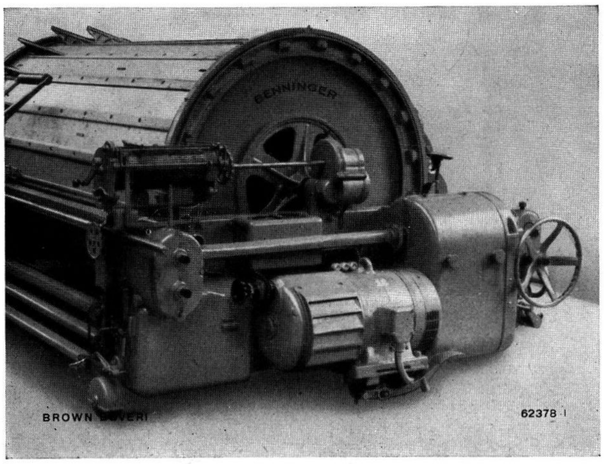


Fig. 67. — **Three-phase shunt commutator motor for the drive of a cone warping machine.**

When warping, the warp speed can be adjusted by hand in the ratio of 1:6; when beaming the warp speed is maintained constant with increasing beam diameter by automatic speed variation of the motor.

synchronism during operation, and shut down simultaneously. Accumulation or breakage of the sliver with the resultant loss of time and alteration in yarn number are thus avoided. The cards of each set can all be started with one single push-button and stopped with a second.

To meet a requirement occasionally specified the control has been modified to enable the working speed to be varied in several steps and thus adapt it to different materials. The desired working speed can be conveniently adjusted or varied before or during service by means of a selector switch (Figs. 68 and 69).

2. *Drives in the Paper Industry.*

In the *paper industry* the big advantages of the electrical sectional drive of paper-making machines are meeting with ever-increasing appreciation, so that not only are such drives being provided for new machines, but they are also being substituted for the lineshaft drive of existing machines.

In such cases it is not absolutely necessary to replace the whole equipment at one and the same time, but it can be done in two stages since two relatively short stoppages are frequently more convenient to arrange than one single, lengthy shutdown for the modernization of a machine. Figs. 70 and 71 illustrate the conversion of the wet end of a paper-making machine, the new individual drives operating in synchronism with the main lineshaft drive which is being retained for the time being. At a later date, after alteration of the dry end of the machine, the remainder of the lineshaft drive will be replaced by individual drives, for which the starting and regulating equipment has already been supplied.

The latest paper-making machines have a so-called double press instead of the usual two or more separate wet presses. This double press comprises three cylinders pressed one up against the other and between which a felt and the paper is taken. The most advantageous arrangement is to drive the two outside cylinders and

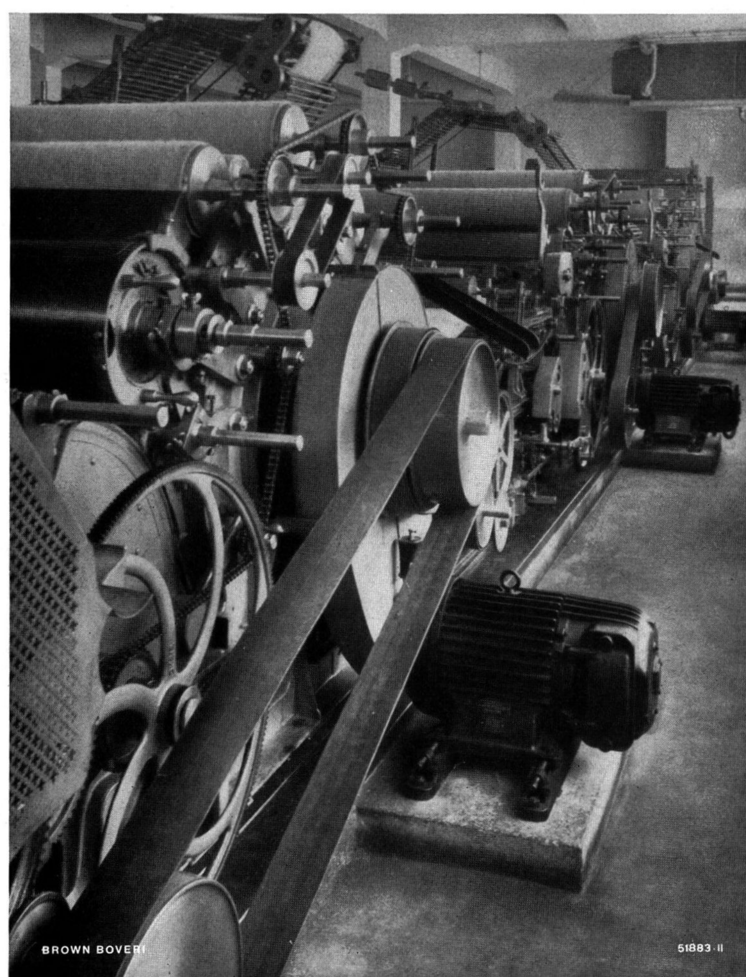
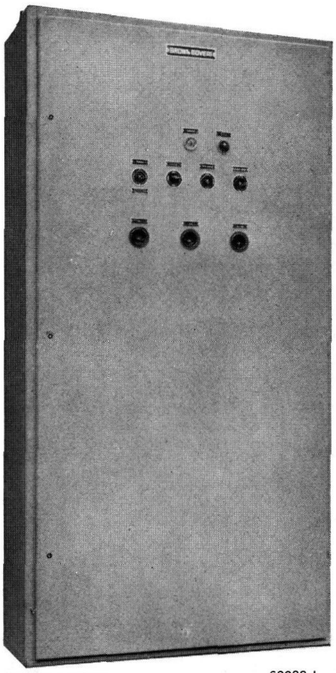


Fig. 68. — **Synchronized wool carding set drive.**

The chain or vee-belt drive gives a compact arrangement. No accumulation or breakage of the lap between the cards.



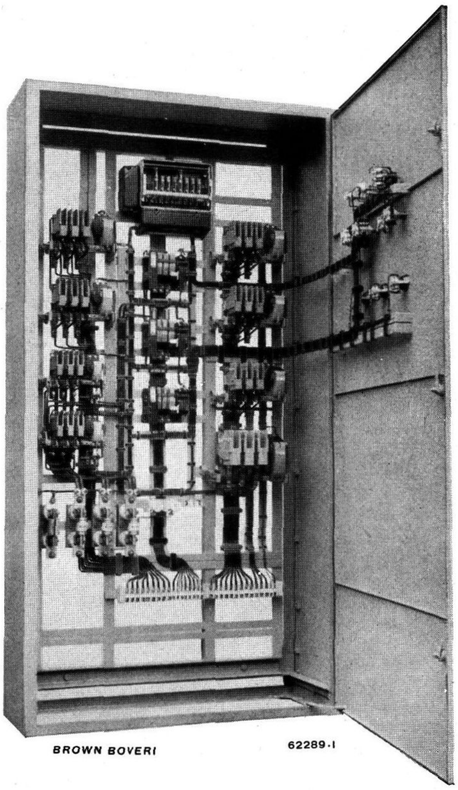


Fig. 69. — Switch cubicle of a synchronized wool carding set drive with speed regulation.

The drive can be operated by unskilled workpeople. The control and protective apparatus are combined into a clearly laid out, totally-enclosed, dust-tight bank of switchgear or supplied already fitted in a switch cubicle.

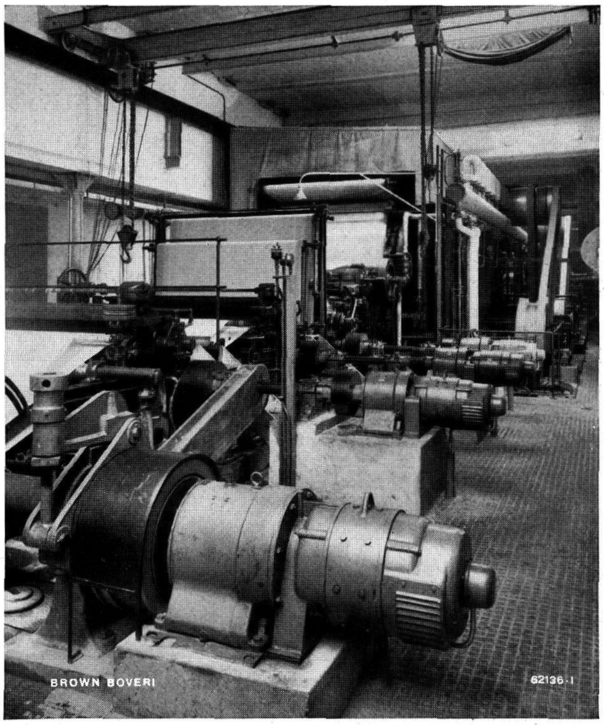


Fig. 70. — Wet end seen from suction cylinder side.

In the background lineshaft drive for the dry end (which is being retained for a certain time) and the calender. The winding apparatus is already equipped with a centre-driven reeler.

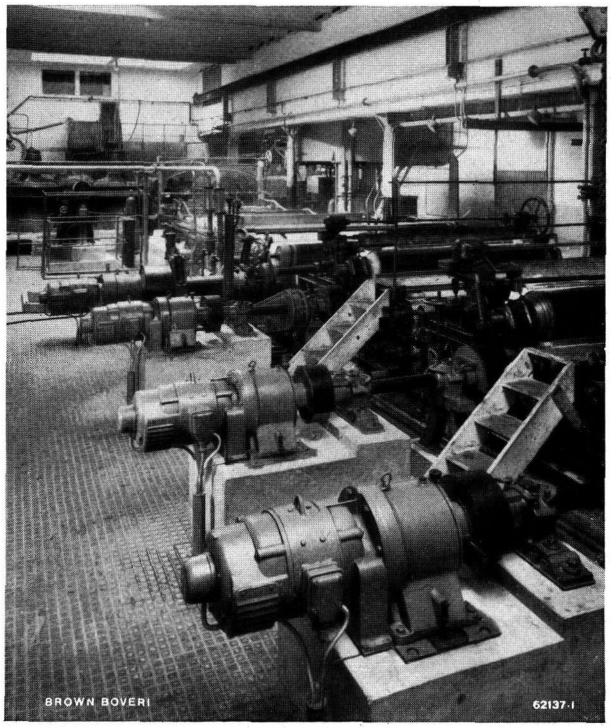


Fig. 71. — Wet end of a paper-making machine with which the heavy lineshaft drive has been replaced by individual drives.

As a result a large amount of space has been saved and the machine made readily accessible even at the driving end. All of the apparatus necessary for adjusting and maintaining constant the paper draws are outside the room in which the paper-making machine is installed and is thus well protected against dust and dirt. The very accurate regulation permits of better utilization of the machine, an increase in production, and improvement of the quality of the paper produced.

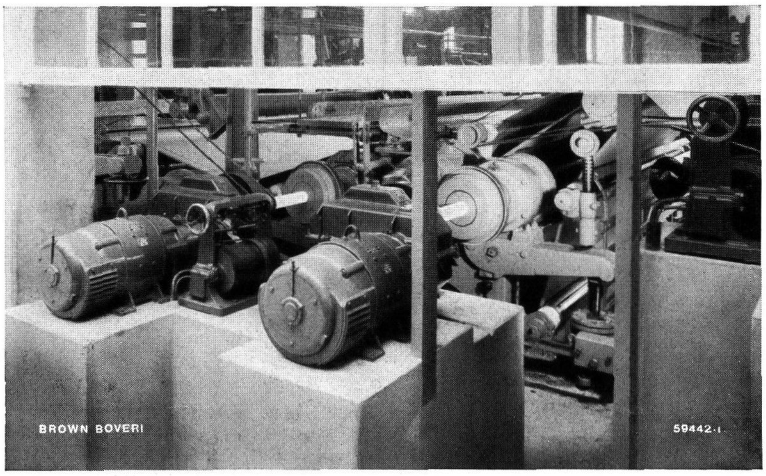


Fig. 72. — Part of the paper-making machine with the wire 3450 mm wide and a paper speed of 18—200 m/min, equipped with electric sectional drive.

Advantageous drive of double press, torque distribution to driven cylinders correct and capable of being checked, less wear and tear on felts and paper. The cylinders are coupled to the gearing through cardan shafts, so that they can be opened wide enough to change the felts.

allow the third to be entrained entirely by friction (Fig. 72).

Satisfactory operation of such equipment and in particular minimum stressing of the paper can only be achieved with electrical individual drive, since lineshaft drive causes difficulties for the following reasons:—

Due to their mutually pressing one against the other the three cylinders all have practically the same peripheral speed. If the two outer cylinders are belt driven over conical pulleys — which is necessary to adjust the paper draw in relation to the neighbouring sets or to take account of a reduction in the diameter of the cylinders due to wear — it is very difficult to adjust the belts so as to obtain the speeds exactly corresponding to the given peripheral speed. One of the belts or cylinders must cede and slip. The torque transmitted to the pulley may have a driving or retarding effect, which cannot readily be determined. In the case of electrical drive, however, the ammeter readings give an exact indication of the torques imparted by the two motors to the cylinders. A good idea of what is going on in the machine and how the total torque is distributed between the two motors is obtained. Moreover, this torque distribution can be accurately adjusted with a rheostat to meet manufacturing requirements. Only the one motor is given the correct speed by the paper draw adjustment and the associated regulator, whereas the other, due to its flexible speed characteristic, automatically adapts itself to this speed.

3. *Industrial and Agricultural Drives and Switchgear.*

The brake lining of ***high-capacity sugar centrifugals*** is subject to heavy wear and is very costly to replace. Moreover stoppages are frequently occasioned for its renewal, usually just when the centrifugals are most urgently required. It is due to this drawback that electric regenerative braking has largely been substituted for the mechanical brake and special centrifugal motors developed (Fig. 73). These motors are of the squirrel-cage type with all the inherent advantages of this class of machine, i. e. simple, robust design, no parts such as brushes and the like requiring constant renewal, high reliability, and little attendance. Notwithstanding the large amount of work of acceleration due to the frequent starts and long starting times they are economic on the score of power consumption and pay back electrical energy into the supply system during the braking operation. A fan arranged in the top of the centrifugal motor also cools the windings during shut-downs and thus increases the load capacity of the motor. During lengthy stoppages the cooling is automatically shut off.

Control is entirely automatic, pressure on a tiller-type handle (Fig. 74) being all that is required to start up the centrifugal. All other control operations necessary during a working cycle, including braking, take place automatically. The centrifugal switch located above the motor terminal box (Fig. 73) limits the filling speed, while the thermostat arranged above it protects

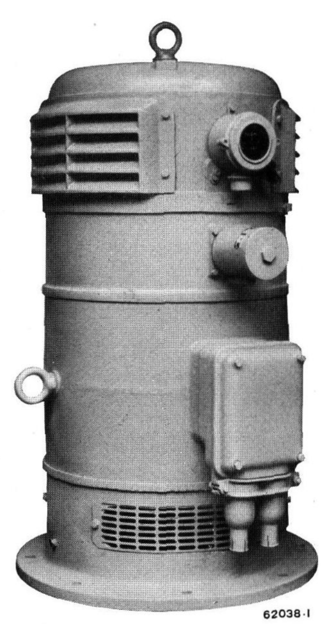


Fig. 73. — Vertical-shaft motor for the drive of high-capacity sugar centrifugals with drums up to 1200 mm in diameter and running at speeds up to 1500 r. p. m.

The motor has an economic energy consumption during the long starting period and pays back electrical energy into the supply system during braking. The motor is full-automatically controlled during the whole working cycle.

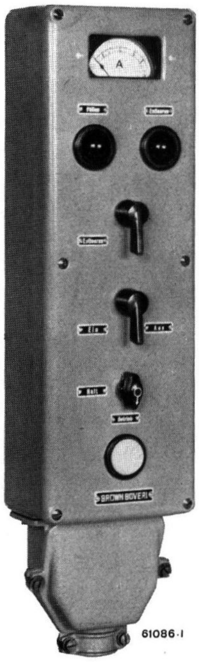


Fig. 74. — Control switch with tiller-type handles and pilot lamps for automatically controlled drives of sugar centrifugals.

With this switch unit control of the centrifugal is simple and clear. The pilot lamps show the attendant whether he has to fill or empty the centrifugal.

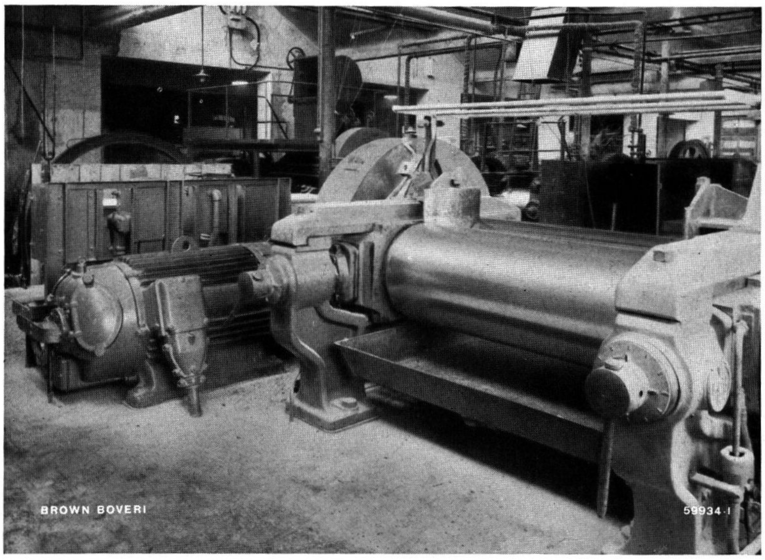


Fig. 75. — Individual drive of a rubber rolling mill by 80 kW slip-ring motor.

In case of emergency the motor is braked in about $^1/_4$ sec. This method of electrical braking is superior to all other systems.

the centrifugal motor against harmful overloads. Different coloured pilot lamps in the control switch (Fig. 74) fitted on the centrifugal indicate whether the centrifugal is to be filled or discharged.

Machines for *rubber manufacture,* such as, for instance, rubber rolling mills, calenders, etc., have to be stopped in the shortest possible time in case of emergency, to prevent accidents to the worker. The necessary sudden stopping of the machine is realized far more effectively by electrically braking the driving motors than with a mechanical brake. Figures illustrating the very strong braking effect obtained in this manner have already been given in earlier publications. Fig. 75 is a further example of a rubber rolling mill driven by a totally-enclosed slip-ring motor rated 80 kW, which can be stopped in case of emergency in about $^1/_4$ second, i. e. more or less instantaneously by reversal of the current. The braking operation is initiated simply by banging down the rodding running along the whole length of the machine. Very little electrical equipment is required for this feature. In the case in question the braking control is so arranged that the motor is switched out when at rest. By depressing a button, however, it can also be made to run in reverse.

Since it is at present very difficult to obtain certain *machine-tools* from abroad, the machinery in many Swiss trade and industrial undertakings has become more or less obsolete. Many works have therefore overhauled their machine-tools and replaced the drives. Particularly good experience has been made in the *modernization of planing machines* with the Brown Boveri rapid reversing drive to which allusion has already been made in the pages of this journal on numerous occasions.

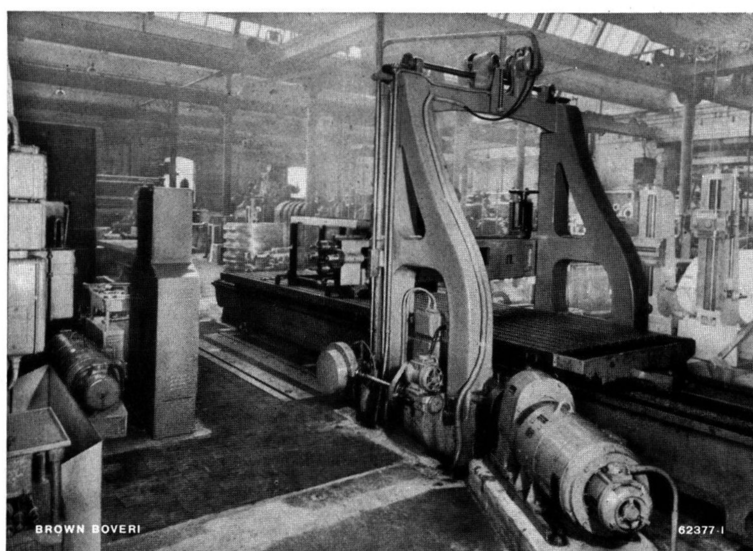


Fig. 76. — Modernized 52-year old double standard planing machine.

Brown Boveri rapid reversing planing machine drive and feed and transverse slide displacement drives. Cutting and return speed independent of each other in a ratio of more than 1:10, adjustable without steps, so that this "veteran" now operates like a modern machine. Readily understood and simple operation by means of suspended-type push-button station.

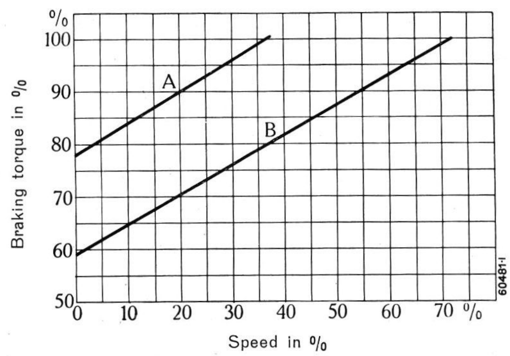


Fig. 77. — Braking torques in relation to speed with the new Brown Boveri braking connection with inversed and disconnected phase.

Note the high braking torques at low motor speeds and with the motor at a standstill. The load can be electrically braked rapidly and without shock down to the lowest speeds. The crane driver always has the load fully in hand; wear and tear on ships, wagons, goods, etc., is reduced.

A. Low rotor resistance. B. High rotor resistance.

Fig. 76 shows a planing machine modernized in this manner. It is fifty-two years old, but of such robust design that it was found possible to double the table speed with the same power on the tool. Notwithstanding the rapid reversal of the plane motor the table reverses without shock and runs absolutely quietly even at the highest speeds. Since the speeds of the cutting and reverse strokes can be adjusted without steps in a ratio of over 1 : 10, independently of each other, this "veteran" now operates like a modern machine.

The table is set in motion, braked to a standstill, or changed over to "Setting up", and the drive for displacing the cross-slide operated, from a suspended push-button station, so that any workman not conversant with the electrical equipment can be put on the planing machine.

4. *Drives for Materials-handling and Winding-engine Equipments.*

The *hoisting-appliance braking control* with inversed phase, which was described in detail in a previous issue of this journal (1943, Nos. 11/12) has been developed still further to obtain a braking control with inversed and disconnected phase. This new control develops high braking torques and permits the rated load to be electrically braked practically to a standstill in the shortest possible time without shock. Fig. 77 depicts the braking torques in relation to the speed for different controller positions.

The powerful braking torques which are achieved with this special hoisting appliance control are clearly evident from the foregoing figure. The mechanical brakes are not applied until the drive is practically at a standstill. As a result there is less wear and tear on the brake linings, which therefore have to be less frequently renewed. Moreover, the crane driver has always complete command of the load, so that wear and tear on both the goods and the ship or railway truck is greatly reduced. These are the reasons why the different large hoisting appliance equipments ordered during the year under review were exclusively

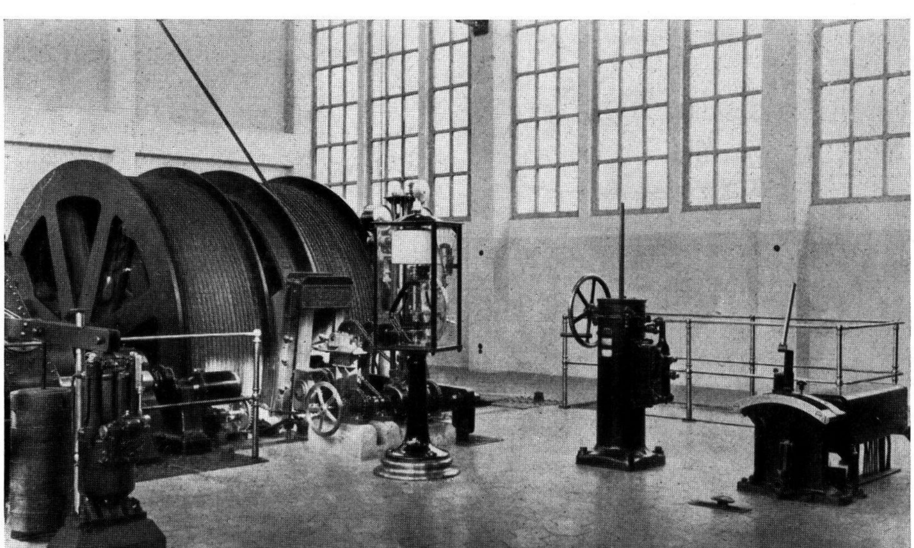


Fig. 78. — Mine hoist with cylindrical drums 3·5 m in diameter driven by three-phase motor rated 230 kW at 488 r. p. m., operated with a single-lever control stand in conjunction with a cam-operated controller and electrohydraulic thrustor.

Not only is wear and tear reduced on the mechanical parts of the winder, but also on the costly winding ropes through the smooth and rapid method of operation of the electrohydraulic thrustor.

provided with the braking control with inversed and disconnected phase.

Electrohydraulic thrustors are proving very popular as brake releasing device and it would seem as though they will ultimately completely supplant the fiercely operating brake releasing magnets. Numerous electrohydraulic thrustors with a work per stroke ranging between 250 and 2500 cm/kg were supplied during the period under review and give entire satisfaction under the most arduous working conditions. These hydraulic releasing devices operate quietly, rapidly, and reliably, no matter whether they have to make 600 operations per hour or work under extremes of climate (great heat, temperature below freezing). On the left of Fig. 78 a thrustor will be noticed which is designed for a work per stroke of 2500 cm/kg and applied as brake releasing device to a mine hoist.

The excellent experience made with *winders* equipped with *Brown Boveri single-lever control* also led to a number of contracts being placed with the Company during the year for the electrical equipment of winders, several being of the d. c. Ward-Leonard-controlled type. Two of these winders are of the Koepe sheave class each with a driving motor developing about 5000 kW (Fig. 79).

These equipments include a single-lever control stand with which the winder can be readily controlled and braked with only *one control lever*. Apart from a robust mechanical acceleration and retardation regulator an electrical travel regulator is provided to ensure positive command of the winder with the heavy loads and high speeds coming into consideration, as well as to permit of favourable travel diagrams being adhered to when working to full capacity. In order to stop the winder rapidly in case of emergency the high-speed free-fall safety brake, which has proved its worth over a period of several decades, is employed. This brake operates rapidly, without shock, and completely free from oscillations, so that even under the most unfavourable sheave winder conditions the rope cannot slip. As a result, overstressing of the winder, rope, and entire plant is avoided, while the men being conveyed are protected against accidents.

The more important components of the winder, such as the control stand, pressure regulator of the travel brake, depth indicator, and air valve of the safety brake are mounted on a common frame on the driver's stand, which simplifies erection and facilitates setting to work. The few interlocks render the layout clearer and enhance reliability.

B. ELECTRIC FURNACES.

The development work on the Elektrokemisk-type *electric furnace for reducing iron ores* chiefly of Swiss origin, was continued.

In order to elucidate a number of interesting phenomena occurring during the operation of such furnaces resistance measurement tests were carried out in the

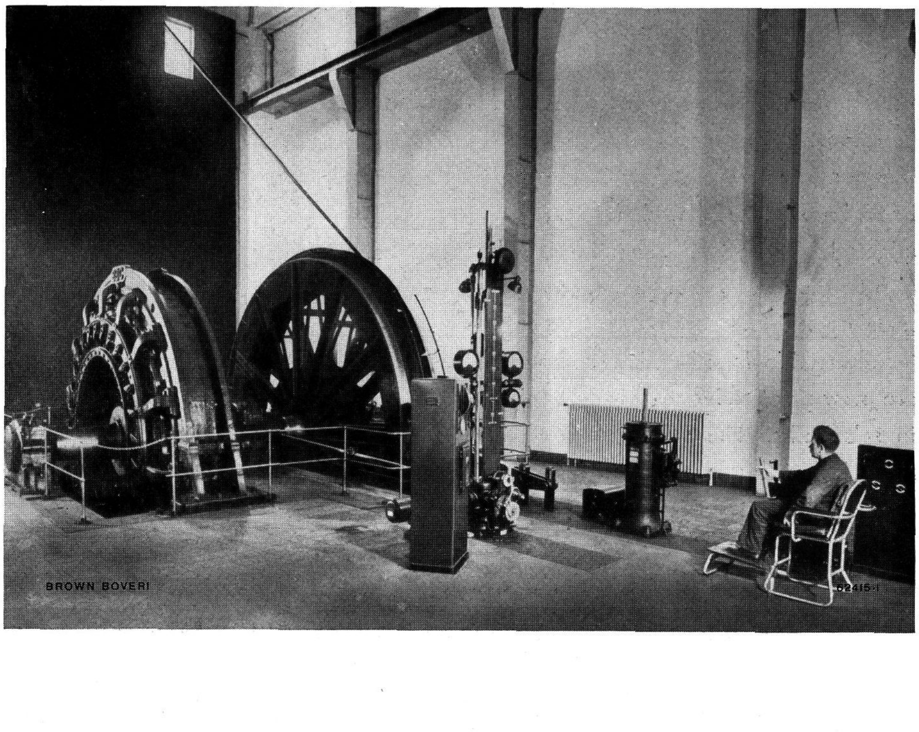


Fig. 79. — Winder with sheave 7 m in diameter.

Useful load 9300 kg, winding speed 18 m/s, depth 990 m. Drive by a d. c. motor rated 1860 kW at 49 r. p. m. controlled by the typical Brown Boveri control, braking, and safety gear in conjunction with a single-lever control stand. The clear and practical construction of the whole control gear, in conjunction with the single-lever control stand ensures easy and safe operation and maximum winding capacity.

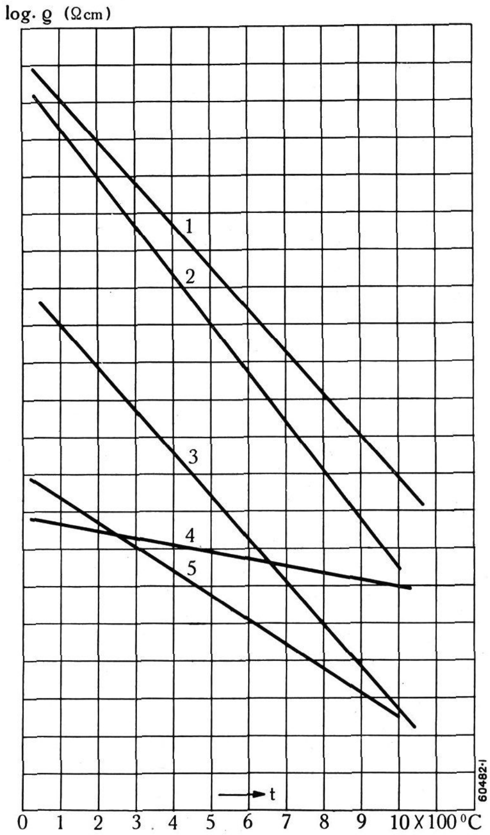


Fig. 80. — Specific resistance of Swiss iron ores in Ω/cm³ in relation to temperature.

1. Fricktal iron ore.
2. Delsberg ore.
3. Gonzen ore.
4. Mont Chemin ore (Valais).
5. Pyrite ash, sintered.

Company's laboratories on a number of the raw materials smelted. The electric resistance in relation to the temperature was determined for both solid and granulated materials with extremely interesting results, as will be seen from the curves in Fig. 80. These results, together with temperature measurements in the charge itself, have led to the burden mixture being adapted not only to the metallurgical, but also to the electrical requirements of furnace operation.

Industrial tools and machine components are now practically exclusively hardened in salt baths. The special wrought-iron crucibles with a heat-resisting "jacket" for external heating by means of wire coil elements are not only very expensive, but are now practically unobtainable, so that electric crucible furnaces have in many cases had to make way for electrode-type salt-bath furnaces with a bath of malleable wrought iron. Such furnaces are heated through the direct passage of the current between the electrodes immersed in the salt. This method of heating has been used for some years for salt-bath furnaces for hardening high-speed steel tools at temperatures up to 1350 °C. The advantages of the electrode-type salt-bath furnaces over the crucible type are greater productivity and longer life of the readily manufactured wrought-iron bath which is not subjected to the radiation of the heating resistances like the crucibles.

Fig. 81 shows an electrode-type salt-bath furnace plant, comprising the furnace, transformer, and control panel, for hardening files, which was taken into service in the course of the past year. The different furnace voltages are adjusted on the control panel and the bath temperature automatically maintained constant by means of a thermo-couple and regulator.

Such furnaces can be rapidly taken into service with the help of a heating-up resistance to melt the salt, which is not electrically conductive in the solid state. As soon as a part of the salt is melted the electrodes can take over the melting process with its full capacity.

Due to this heating-up arrangement the bath need not be emptied when the furnace is shut down, since

Fig. 81. — Electrode salt-bath furnace plant in service.

Current taken directly through the salt for heating purposes. Heated up with special resistance. This design enables the now practically unobtainable wrought-iron crucibles with heat resistant "jacket" for external heating to be replaced by a bath of soft wrought iron. The temperature is automatically kept constant by a thermo-couple and regulator. Suitable for hardening high-speed tools at temperatures up to 1350 °C.

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Fig. 82. — High-temperature pusher-type furnace for 2000° C with nitrogen in heating chamber and hydrogen protecting gas in pusher tube.

After inserting the pusher tube with gas sluices and making the gas and current connections the set is ready for service and can be installed in any position without any additional erection work.

the salt can again be readily melted, no matter whether it becomes lumpy or a solid mass. Such furnaces are therefore also suitable for workshops where continuous operation in the strict sense of the term is not possible. The additional heating-up costs of the salt, however, must of course also be taken into consideration.

In many cases electrode-type salt-bath furnaces permit the salt-bath method of hardening to be retained, despite the shortage of special crucibles, especially where high production is required.

Electric nitriding furnaces have also been developed a stage further during the period under review. A fan fitted in the nitriding pot causes the gas to circulate at a high rate. This permits the nitriding time to be reduced and production thus to be increased, while at the same time results in a deeper and more regular nitriding effect. Although the nitriding plants supplied by the Company to date have proved extremely successful, a further refinement has been introduced in that the driving shaft of the fan is now sealed.

Last summer an electrical equipment was successfully taken into commission in a Swiss *glass works*.

In conjunction with the customer we equipped an existing gas-heated 150 t glass melting furnace with electrical equipment, so that gas or electricity can be employed for heating purposes as and when available. The electrical equipment which comprises essentially one regulating and four furnace transformers has a maximum rating of 1800 kVA.

The electrical energy is conducted to the molten mass of glass by means of electrodes. After exhaustive tests the electrodes were so distributed and connected that the heat developed in the bath meets all the requirements of glass melting technique.

From the very first day it was put into service the supplementary electrical equipment gave excellent results. Due to the direct and wide range of regulation of the heating power, operation of the furnace has been greatly simplified. The productivity of the furnace has been substantially increased, and the flame temperature diminished. As a result maintenance of the furnace lining is reduced, which is of particular importance at the present time. The glass produced is of a quality and uniformity never before attained with gas firing alone, while scrap has been reduced to an extremely small percentage. This electrical heating equipment has thus proved a success in every respect.

With the object of facilitating and furthering the Company's own research work, particularly in connection with heat-resisting steels, *high-temperature furnaces* of a universal type have been developed and have already proved satisfactory under service operating conditions.

These furnaces are particularly suitable for the manufacture of highly fusible sinter materials and the melting of chemically pure, gas-free metals. In view of the rapid development of powder metallurgy, which consists in the sintering of moulded materials made from powders (originally introduced in the ceramics industry) and avoids the disadvantages of smelting, there are bound to be further applications for such furnaces in this comparatively recent field.

These high-temperature vacuum furnaces are usually supplied in the vertical design. They are of the pure radiation type with a water-jacketed steel shell. The temperature gradient between the heating elements and the furnace shell is controlled by concentric radiation protecting cylinders. The insulation of the cover and floor also serves as packing to make a vacuum-tight joint. A complete pump set, comprising preliminary and high vacuum pumps with Brown Boveri direct-indicating vacuum gauge for vacua up to 10^{-3} mm Hg is supplied with the furnace plant. A vacuum of only a few mm is necessary, which has the advantage of giving the heating cylinders a long life; if the thermal treatment of the charge to be annealed necessitates no vacuum the simplest method of operating these furnaces is with nitrogen as protective gas for the heating elements at atmospheric pressure. The temperature is measured optically.

In this connection a horizontal *pusher furnace* built a short time ago is worthy of special mention. This is employed for the sintering of ceramic coatings on molybdenum at 2000° C with hydrogen as protecting gas. As will be seen from Fig. 82 this furnace is supplied with the necessary transformers, apparatus and instruments as a complete unit. The heating elements operate in a nitrogen atmosphere.

For thermal treatment processes requiring pressures lower than 10^{-3} mm Hg, as for instance for the determination of the volumetric gas content of metals by the hot extraction process, a high temperature heating set has been developed with which the heating element is screwed into a water-cooled double metallic cone; this set is suitable for assembly with a quartz tube of a minimum internal diameter of 55 mm. Due to the pre-degassing process developed in the Company's laboratories for research work the gas emission of the heating element at the working temperature can be kept down to a negligible quantity. This small heating set, which is of a length of about 25 cm, renders particularly good service in those cases where high-frequency induction heating equipment is too expensive. Such heating equipments have already been used for assembly with many different kinds of laboratory apparatus. Just recently a heating set of this type was fitted in a high-temperature melting furnace for 1800° C, thus permitting of casting in a vacuum. The vacuum condenser took the form of a water-cooled steel cylinder on the side of which the saggars can be flanged vacuum tight.

The *grass-drying plants* with heat recuperation have proved extremely satisfactory in continuous service. One of these plants produced 350 t of high-class dehydrated grass last summer, a very good and

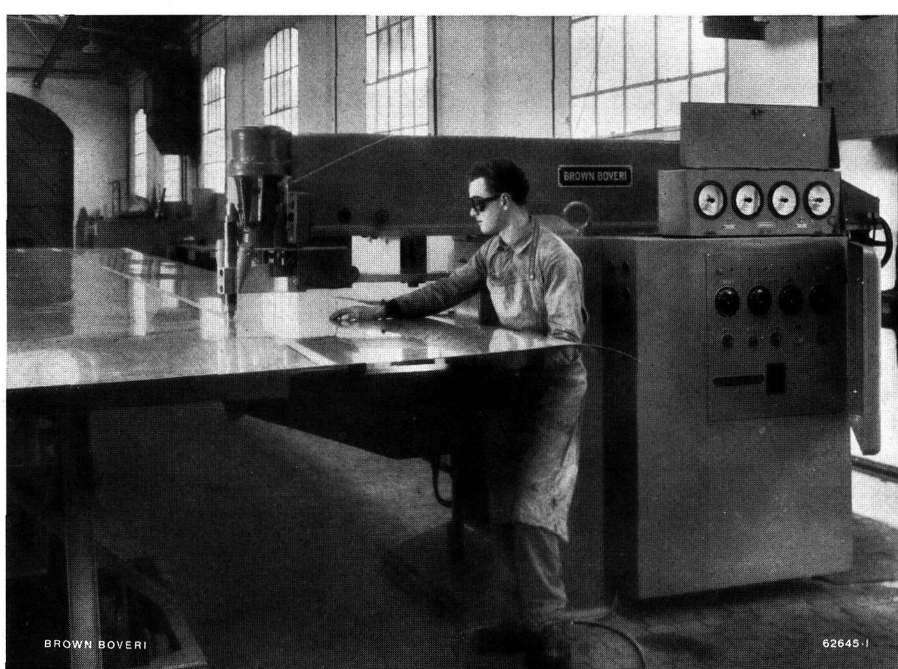

Fig. 83. — Probably the largest spot welder in existence, installed at the workshops of the Swiss Car and Elevator Corporation, Schlieren (Switzerland).

Rating 640 kVA. Any of five different pressure cycles can be selected. The machine is suitable for spot welding sheets and rolled sections of iron and light metals of different thicknesses.

valuable performance in view of the fact that the importation of foreign concentrated fodder into Switzerland has been absolutely impossible for some time.

C. ELECTRIC WELDING.

The electric *spot welding* machine rated 640 kVA for the Swiss Car and Elevator Corporation, Schlieren-Zurich mentioned in the review of progress and work last year has been taken into service (Fig. 83). The electrical details of this machine, which as far as can be ascertained is the largest in existence, were briefly referred to at the time.

To meet the multifarious requirements of coach-building the machine is of the universal type. Five different pressure-cycles can be carried out and once adjusted all take place full-automatically (Fig. 84). Although the usual pressure suffices to obtain good spot welds where thin sheets of all the readily weldable

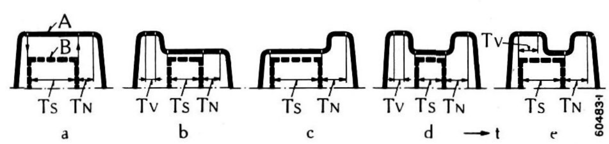

Fig. 84. — The five automatically controlled welding cycles of the Brown Boveri welder shown in Fig. 83, which can be selected arbitrarily.

To meet the conditions involved by different materials and thicknesses, which may entail a different pressure prior to, during, and after welding, several automatically controlled cycles are provided for the electrode pressure and welding time.

A. Pressure. TN. Subsequent pressing time. Tv. Initial pressing time.
B. Current. Ts. Welding time.

steels and light metals (cycle a) are concerned, heavy cross-sections of not readily weldable materials or light metals involve alteration of the pressure both during and after the actual welding process. The initial increased pressure in cycle b creates the necessary contact between the electrodes for the weld. For heavy plates, unwieldy frames, and rolled section constructions, even the maximum admissible welding

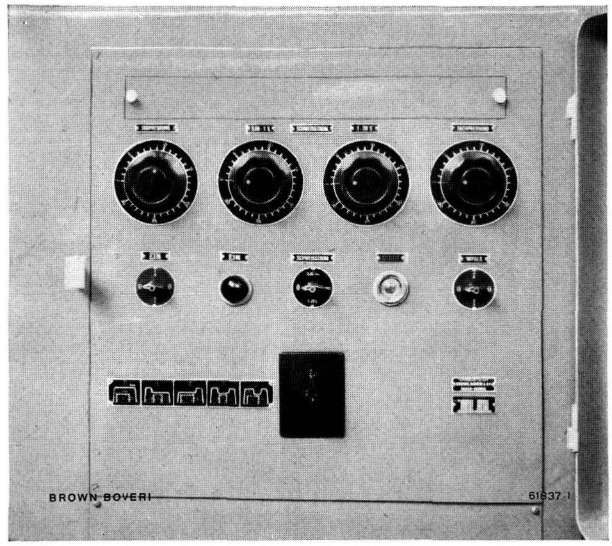

Fig. 86. — Switch panel for regulating the timing of the welding cycles in Fig. 84.

The outer nobs are for the adjustment of the initial or subsequent pressure, those inside for the welding time.

pressure is not sufficient as initial pressure to obtain a faultless weld. Initial pressures of about twice the welding pressure are necessary both for steel and light metal. For very heavy plates and certain light metal alloys it has proved necessary to raise the pressure again after welding to obtain homogeneous spot welds (Fig. 85). With cycles d and e in Fig. 84 both an increased initial pressure and recompression can be applied, thus giving the combined effect of cycles b and c. With cycle d the moment of the drop to the welding pressure is retarded compared to the moment of switching in the current, which has proved indispensable for special steels.

To obtain high-class spot welds the value and duration of the current, the magnitude and duration of the pressure, and in the case of automatic welding cycles also the mutual timing of these quantities must be accurately adjustable, so that uniformly high-class welds are always obtained regardless of the attention and skill of the welder. In addition to the current

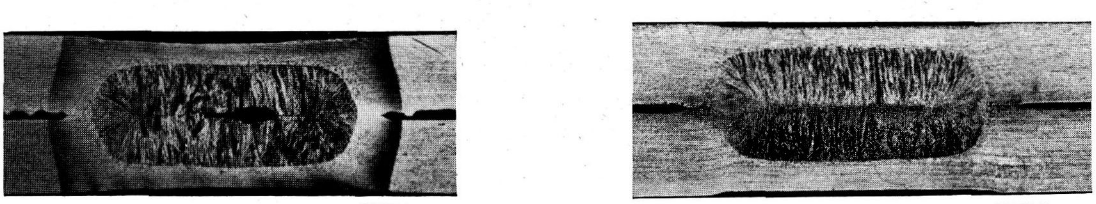

Fig. 85. — Macro-etching of a porous (left) and a homogeneous (right) spot weld.

The Brown Boveri pressure cycle control permits satisfactory, homogeneous welds to be obtained under conditions which hitherto precluded spot welding being applied. The porous weld (left) was obtained without, the homogeneous weld (right) with, pressure cycle control.

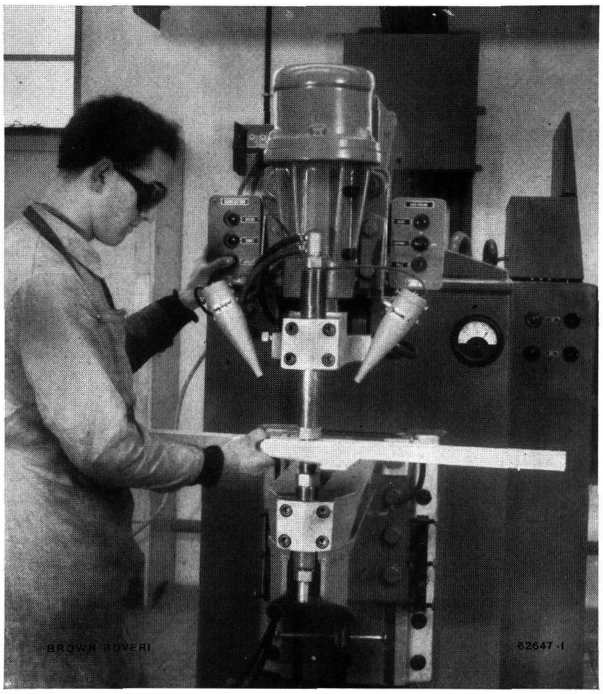

Fig. 87. — Front view of spot welder shown in Fig. 83.

All buttons which have to be operated during the welding operation are arranged near the work.

and time regulation an electro-pneumatic control, with which the pressure increases and reductions are carried out accurately and practically instantaneously in relation to the time, is provided. Notwithstanding these unusual features the operation of the machine is very simple, being restricted to the adjustment of a number of handwheels and switches on the control board shown in Fig. 86. The number of apparatus required is also very small. Fig. 87 is a front view of the spot welder with the electro-pneumatic pressure indicators and the current and time regulating gear. On the right of the machine casing will be seen the built-in ammeter indicating the smoothly adjustable welding current. Fig. 88 shows a welded test specimen consisting of two 8 mm iron plates, welded with the above described machine.

In many light-weight constructions, particularly in aircraft manufacture, spot welding forms a competitor to riveting, which to a certain extent it resembles. Particular attention is being paid to the further development of these machines and apparatus for still higher powers. There can be no doubt that the metal-working industry will employ this advantageous and economic process for the production of metallic joints to an ever-increasing extent.

D. ELECTRIC BOILERS.

During last year, the largest Brown Boveri electric boiler namely a unit for an output of 17 tons of steam per hour at a voltage of 10,000 V (Fig. 89), was built. Due to the fact that the Company's boilers do not contain any ceramic parts in contact with the water, relatively high salt concentrations can be allowed without danger of a flash-over. This fact is of particular importance in the above plant where unfavourable feed-water has to be employed.

E. COMPRESSORS AND BLOWERS.

The first series of systematic investigations on full-size components of centrifugal compressors and blowers which were carried out in the large machinery testing department have now been completed.[1] The aim of this first set of tests for determining the characteristics of wheels and diffusors, is to find ways and means to increase the output and the efficiency of turbo-compressors, and generally to gain a better knowledge of flow phenomena in connection with the compression of air, gases, and vapours. These tests extended over the entire range met with in practice, i. e. from the smallest to the largest volumetric coefficients. In the absence of a practically applicable theory of the flow in rotating wheels really taking

[1] Brown Boveri Rev., 1944, Nos. 1/2, p. 66.

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Fig. 88. — Spot welded 8 mm iron plates.

When two spot-welded plates are pulled apart the material is torn away from the spot, the actual weld remaining intact as shown here.

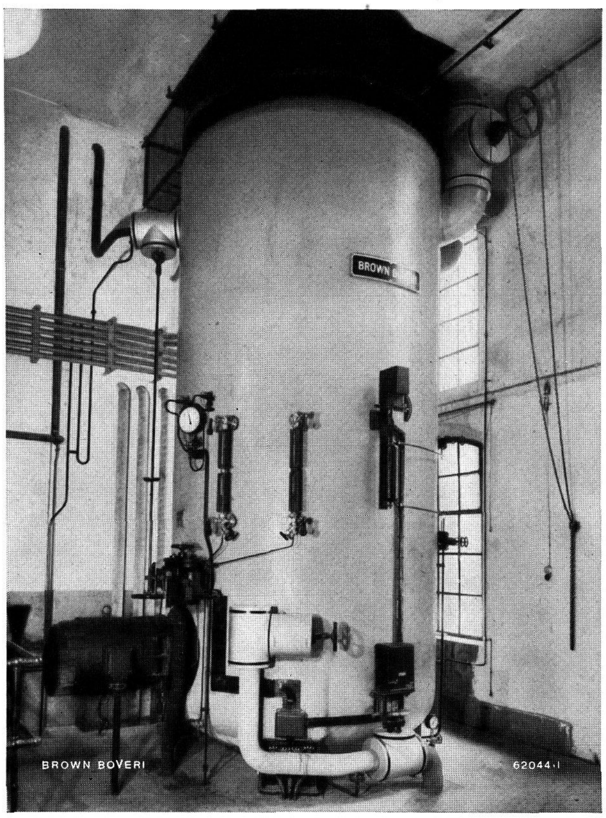


Fig. 89. — High-voltage electric boiler installed at the Attisholz Cellulose Factory and having an output of 17,000 kg/h. Power absorbed 12,000 kW at 10,000 V. Steam pressure 16 kg/cm².

This is the largest Brown Boveri electric boiler built up to the present. It operates entirely satisfactorily in spite of the very high salt content of the feed water. Thanks to the water jet electrode system and to the fact that no ceramic insulating parts are in contact with the water, the boiler operates without flash-over in spite of the high salt content of the water.

into account all the phenomena occurring, only experimental results are able to provide the necessary data for the reliable calculation of centrifugal blowers and compressors.

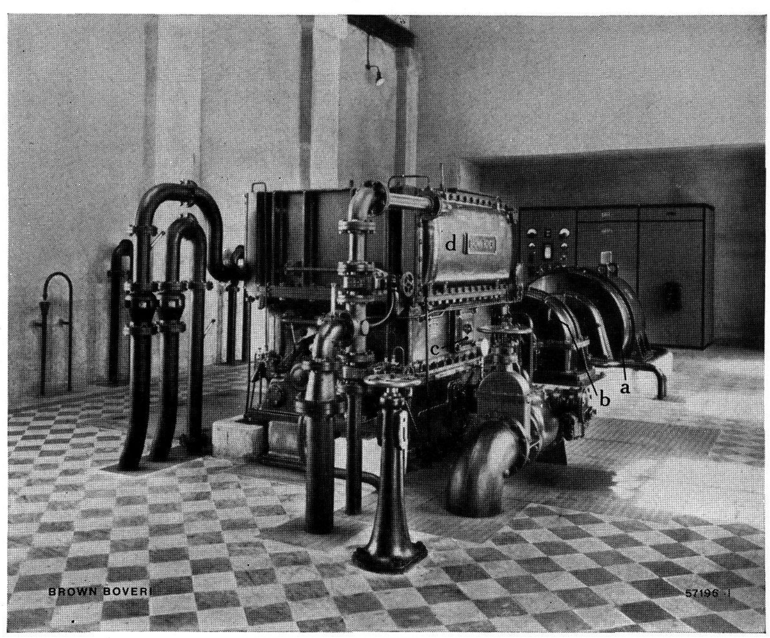
The shape of the wheels has so far been largely determined by manufacturing considerations. As long as the peripheral velocities remain moderate, the three requirements: good flow conditions, sufficient strength and ease of manufacture can be relatively easily taken care of, as has been shown by our well-proved parallel-wall wheel construction with riveted-in blades. The present-day very high peripheral speeds, however, make it necessary to employ new shapes and it will be much more difficult to combine these with the forms required to give most favourable flow conditions. In spite of this suitable solutions have been found.

Heat pumps, which may serve either for heating or for refrigerating purposes, generally employ as a working medium liquids whose vapours have a velocity well below that of sound; compressors for such vapours therefore operate very close to sound velocity. In this case also, wheels were developed which can be easily manufactured and at the same time have a high efficiency.

The steepness of the pressure-volume curve increases, however, with increasing efficiency; the pumping limit is, therefore, unfavourably influenced by the improvement in efficiency. It was hence necessary to find wheel shapes which without reducing the efficiency too

Fig. 90. — "Isotherm" turbo compressor for auction volume of air of 14,000 m³/h.

The delivery pressure is 8 kg/cm² abs. The compressor is driven by a 1530 kW, 5000 V, 50-cycle synchronous motor through a reduction gear. In the picture a is the motor, b the gear and c the compressor casing. The box d contains a cooler and a similar box is arranged below the compressor casing. By means of these liberally dimensioned coolers, to which the air is led after every stage, it is possible to keep the temperature of the air low during the whole of the compression process. The compression approaches the isothermal and is, therefore, effected with the lowest possible consumption of power. Hence the name "Isotherm" compressor.



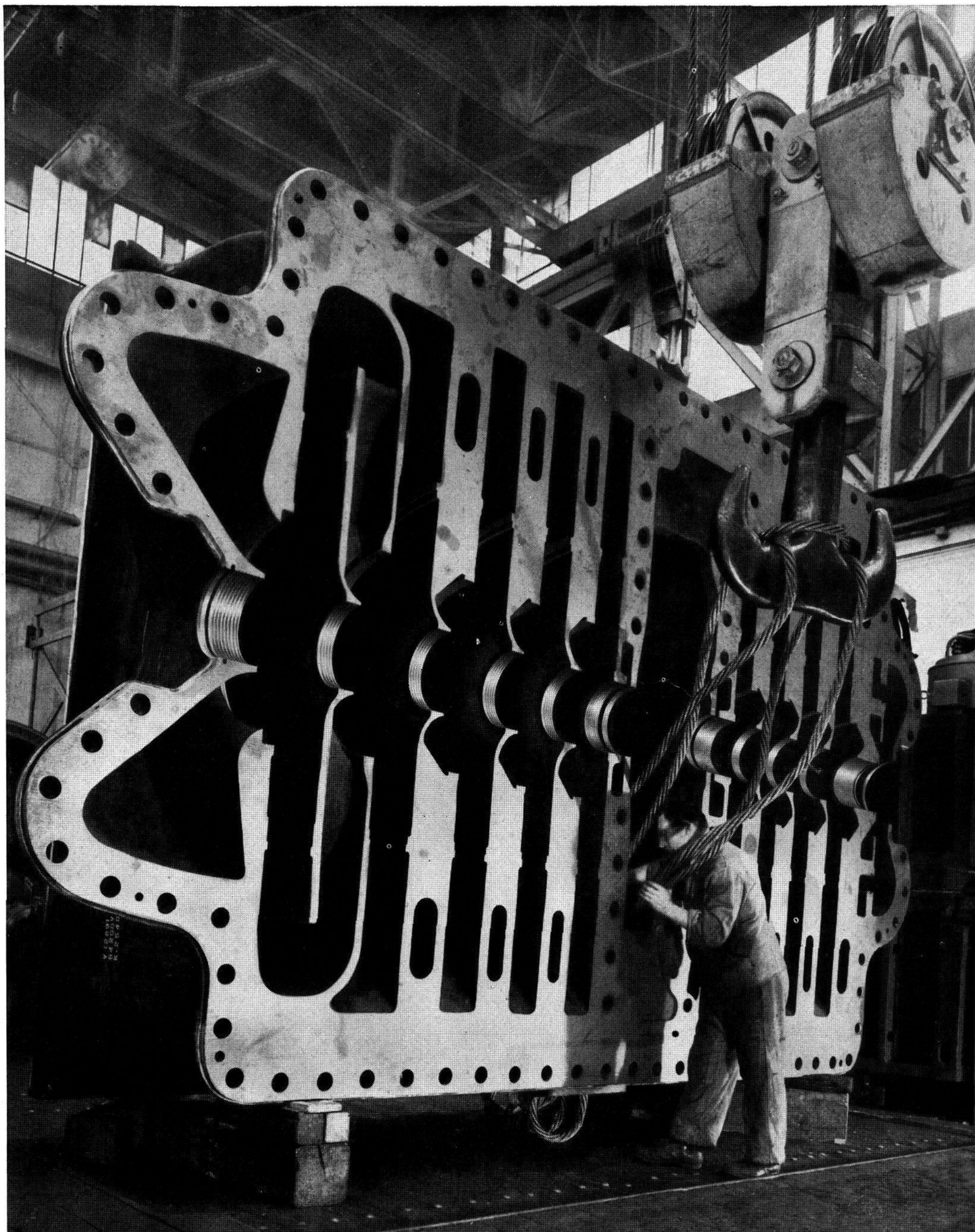


Fig. 91. — Upper part of the casing of a Brown Boveri Isotherm compressor.

This complicated casting made by the Ludwig von Roll'sche Eisenwerke belongs to a compressor having a capacity of 80,000/96,000 m^3/h. It provides a proof of the advanced state of development of Swiss foundry technique. The weight of the casting is 26 t.

much would give a characteristic such as is frequently demanded, rising continuously with decreasing volume, without having to use special anti-pumping devices.

The investigations also covered, of course, diffusors and reversing pieces and their most favourable shapes without exceeding the maximum admissible dimensions. The large scale test plant enabled many problems to be cleared up experimentally or the fundamental data necessary for clearing up such problems to be obtained. Customers will benefit from this knowledge.

1. *Turbo-compressors.*

In spite of all the present-day difficulties and the isolation of Switzerland from the world markets, this year also, orders were received for a number of turbo-compressors. In all, seven compressors of our "Isotherm" construction were ordered for a total delivery quantity of about 450,000 m^3/h and a total driving power of about 40,000 kW.

Apart from compressors for the usual delivery quantities lying between 15,000 and 40,000 m^3/h the orders include some of the largest compressors yet built. One compressor is rated at the seldom specified delivery output of 100,000/120,000 m^3/h. It is driven by an 11,000 kW steam turbine. Another compressor delivers 80,000/96,000 m^3/h, and a third 50,000/65,000 m^3/h. These compressors are intended for coal mines and operate at the pressure of 8 kg/cm^2 abs usual in such installations.

The majority of the compressors ordered will be built according to our well proved "Isotherm" design with cooling after each wheel. Fig. 90 shows a recently supplied example. So many articles [1] have already been published on the "Isotherm" compressor that it may be assumed to be well known by engineers interested in this branch. The name "Isotherm" was given to it because the compression closely follows an isothermal characteristic thanks to particularly liberally dimensioned cooling arrangements. For the same reason, its efficiency is higher than that of earlier designs. When required, however, the well-known former design of compressor with three pairs of external coolers is still supplied. For high powers, the difference in efficiency between the former and the present design is not so large as with smaller units; so that it can still be used for very large delivery volumes.

The above-mentioned compressor orders were placed in spite of the increased costs caused by the war, in order to be able to operate the new installations at full output immediately after the conclusion of the hostilities.

2. *Blast-furnace and Steelworks Blowers.*

Among the orders for blast furnace blowers are two noteworthy units each for 60,000 m^3/h at a delivery pressure of 2·2 kg/cm^2, driven by steam turbines. The steam turbine is still the ideal driving machine, because its speed can be varied as required, and hence it enables the most favourable adaptation of the delivery volume and pressure of the compressor to the requirements of the blast-furnace or converter. As an example of a blast installation equipped exclusively with steam turbines the blast plant of one of the largest steel works in the world is shown in Fig. 92.

In the case of blast furnace blowers, regulation to constant delivery quantity is still preferred. This can be easily accomplished by means of steam turbines. Steelworks blowers with electric drive — a robust, constant-speed, synchronous motor being used as driving machine — can be provided with the so-called "pre-rotation" regulation, which avoids the losses occurring with suction regulation. Pre-rotation regulation gives practically the same consumption of power as speed regulation by means of resistances in the rotor circuit of slip-ring motors. The "pre-rotation" method has already been described [2] on several occasions.

A still more economical solution of the regulation is contained in a suggestion for which a patent application has been filed by the Company and according to which an electric boiler is used as a regulating resistance and steam generated by the absorbed slip energy. The speed regulation is then practically lossless.

Fig. 94 shows an example of one of the various blast blowers supplied for special applications.

[1] Brown Boveri Rev., 1941, Nos. 4/5, p. 108, Nos. 8/9, p. 196; 1943, Nos. 11/12, p. 346.

[2] Brown Boveri Rev., 1943, Nos. 11/12, p. 328.

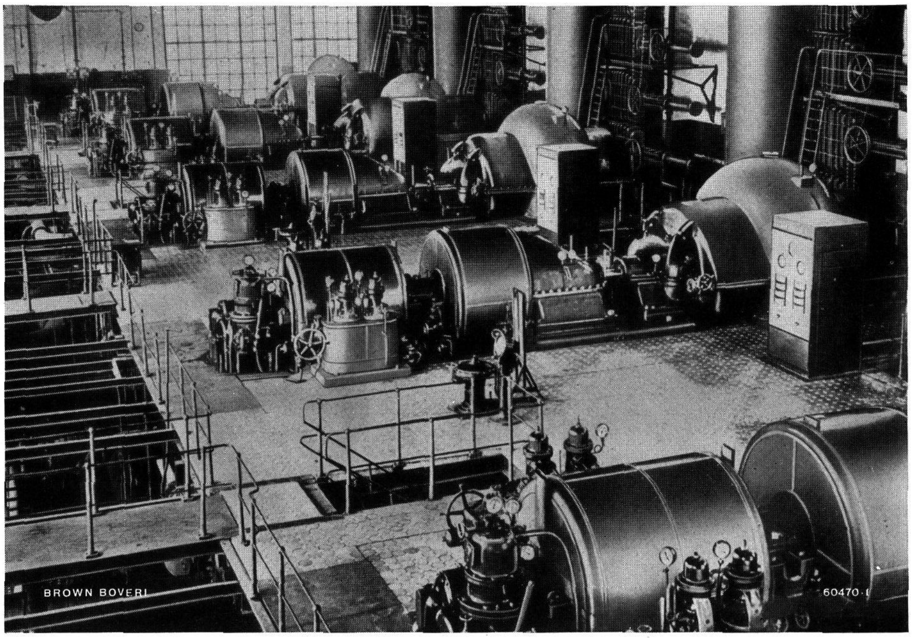


Fig. 92. — **Blast plant of one of the largest steel works in the world.**

This plant is equipped with five Brown Boveri blast furnace blowers, *each for* 156,000/204,000 m³/h suction volume. The blast pressure is 2·6 to 3·5 kg/cm² abs. The compressors are driven by two-cylinder turbines, each for 6300 to 11,000 kW output.

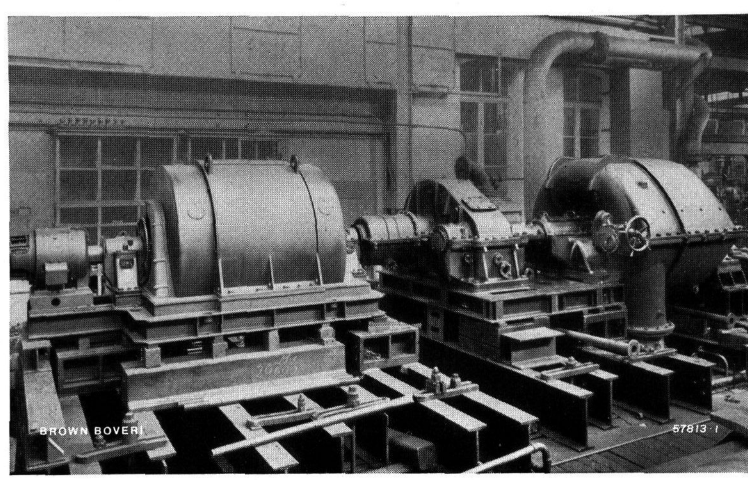


Fig. 93. — **Steelworks blower, compressing 960 m³ of air per minute from about 0·89 to 3·35 kg/cm² abs. The drive consists of a synchronous motor of 3170 kW.**

The blower is provided with the pre-rotation method of regulation. This method is more economical than suction regulation and serves for constant volume regulation *in the case of drives without speed variation* (synchronous motors) and with sudden and large variations of volume of pressure.

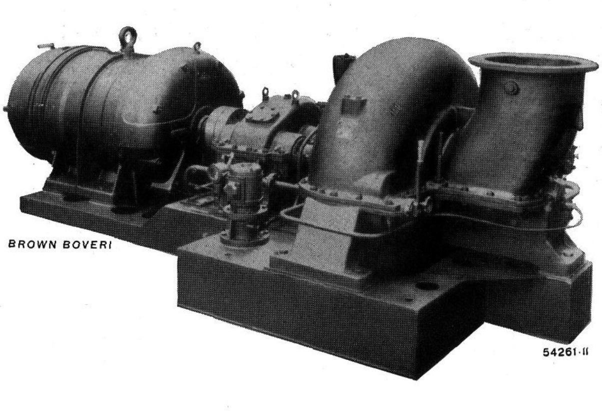


Fig. 94. — **Small single-stage blast furnace blower for overseas.**

Blast quantity 350 m³/min. Suction pressure 0·9 kg/cm² abs. Final pressure 1·5 kg/cm² abs. Because this blower has to be capable of operating with either one or two blast furnaces, and hence must supply different air quantities at a high efficiency, it is provided with diffusor regulation, which can be adjusted by hand. The drive consists of an induction motor of 320 kW, 6300 V.

Above only steam turbines or electric motors were considered for driving the blower. To-day, a third possibility, the gas turbine, can be taken into consideration. In steel works in particular, where blast furnace gas is available in practically unlimited quantities, the gas turbine is likely to be the ideal driving machine of the future for air compressors and blowers. When blast or compressed air is produced, the air compressor for supplying this can at the same time supply the combustion and cooling air for the turbine so that not only is a machine saved, but also the efficiency improved due to the increased air quantity. If, further, the plant is for blast furnaces where the blast has to be highly heated, it is possible, when a gas turbine is used, to combine the heating of the blast and of the power gases driving the turbine. The blast heater then takes the form of a "recuperator" or steel blast heater.

These proposals which are now ripe for putting into practice have been discussed in the pages of this journal on several occasions[1] and a further article on the subject will be published shortly. The steel works engineer is not likely to let them pass unnoticed; the gas turbine is a new development which one day will have as great a revolutionary effect in steel works plants as in its day the large gas engine and later the steam turbine.

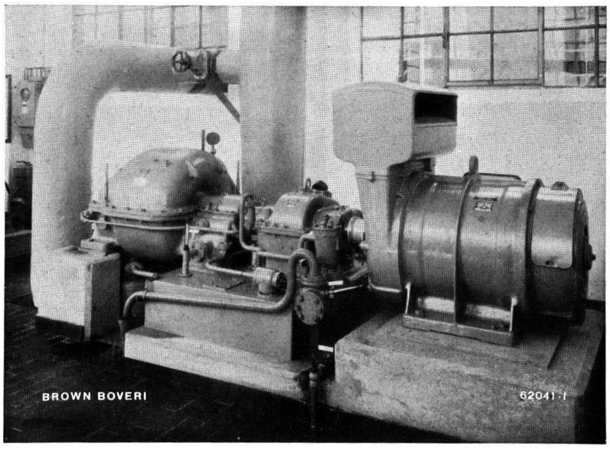


Fig. 95. — Small turbo-blower for aerating fermenting vats in yeast factories.
Delivery volume at first 3000 m³/h; later, after changing the diffusor, the volume can be raised to 7000 m³/h. Delivery pressure 1·7 kg/cm² abs.

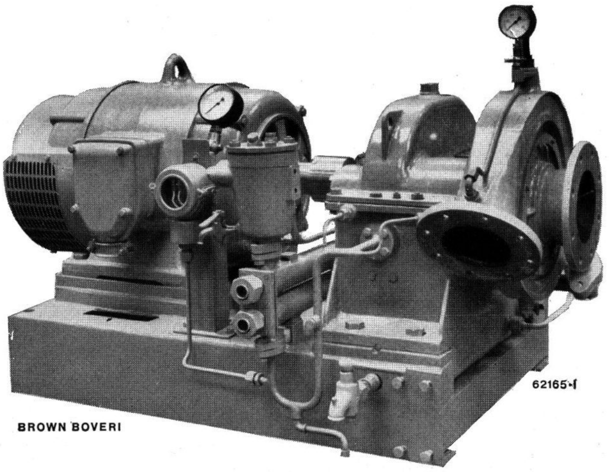


Fig. 96. — Small blower for aerating filters in a water treatment plant.
Suction volume 2000 m³/h. Delivery pressure 1·42 kg/cm² abs. The blower wheel is mounted overhung on the pinion shaft of the gear. The casing is spiral-shaped, so as to act as a diffusor. The centrifugal starter motor enables the set to be remote-controlled.

3. *Blowers for Special Purposes.*

These comprise blowers for the most varied purposes, such as are in particular met with in the chemical industry. Even in the case of small delivery quantities the turbo-blower is given preference due to its even delivery and due to the freedom from contamination of the medium by lubricating oil. Interesting examples of machines delivered during the past year are shown in Figs. 95—97.

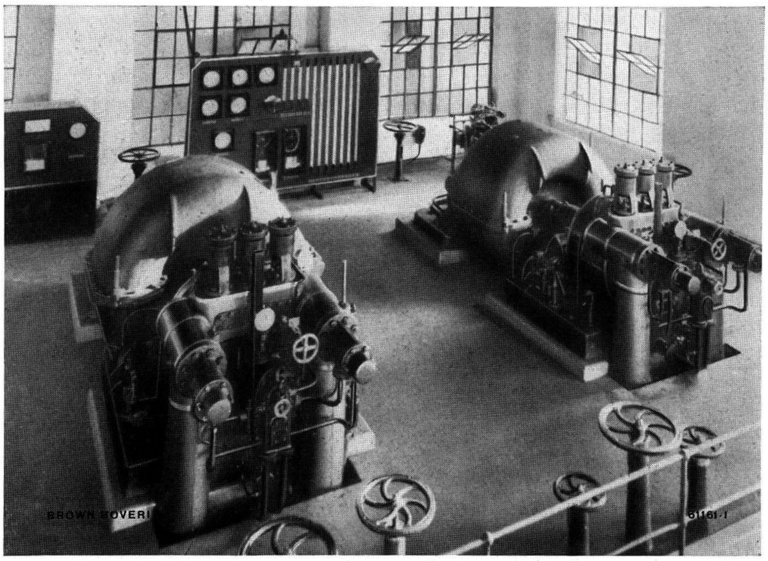


Fig. 97. — Two turbo gas-exhausters for the coke plant of an overseas steel works.
Suction volume each 63,000 m³/h. Pressure rise in the blower 2500 mm w. g. Drive by means of a back-pressure steam turbine. A suction pressure regulator keeps the suction pressure constant. It acts directly on the live steam valves of the turbine.

[1] Brown Boveri Rev., 1941, Nos. 8/9, p. 240 and 1943, Nos. 11/12, pp. 356 and 368.

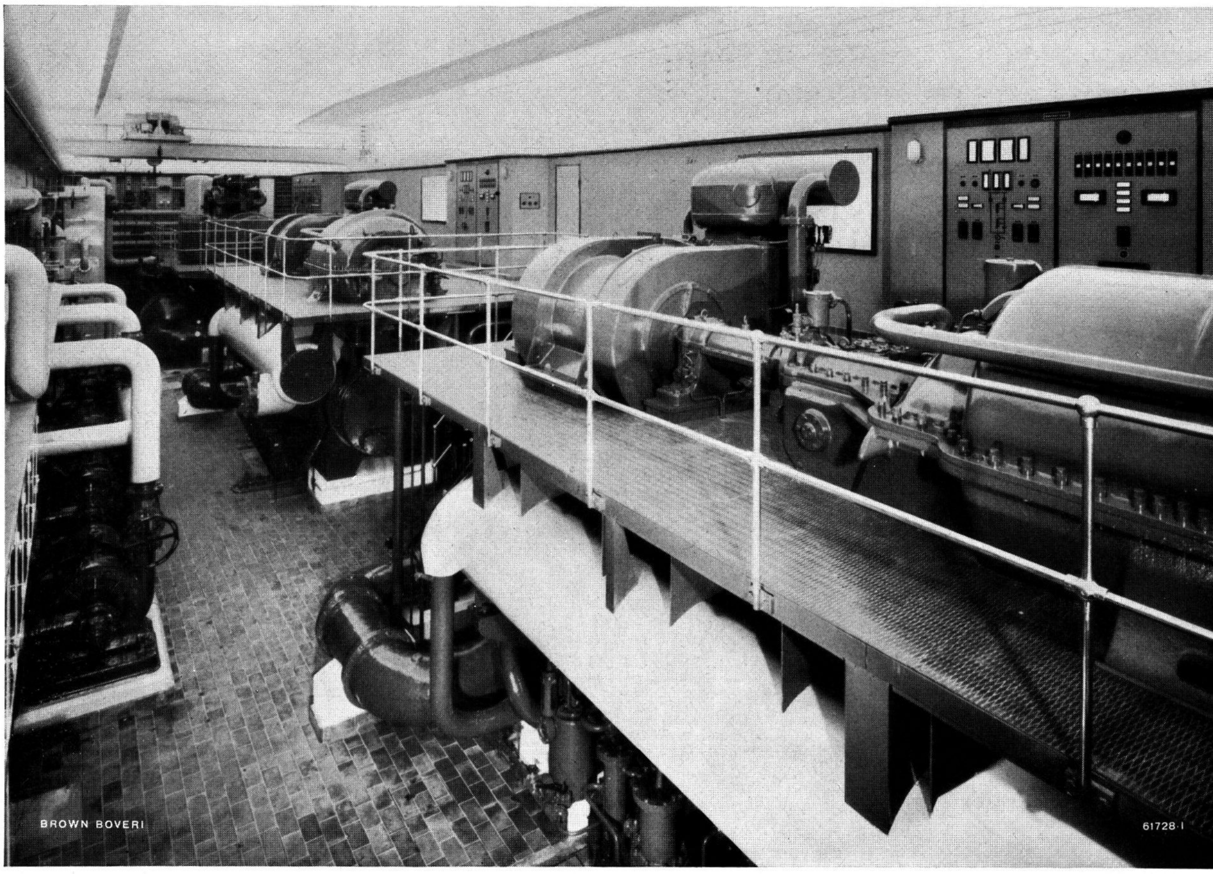


Fig. 98. — Heat pumps in the remote heating plant of the Swiss Federal Institute of Technology Zurich.

Each of the two Brown Boveri thermo-blocs delivers a heat output of 1·5 to 2·5 million kcal/h and requires for this purpose 1200 m³ of water from the River Limmat at 2 to 16° C. Two-thirds of the heat output come from the heat in the water, one-third from the electrical power required to drive the heat pump. The hot water which supplements the heat output of the existing remote heating plant is in this way warmed from 68 to 74° C. The amount of coal saved yearly by this plant is 2800 t.

4. *Heat Pumps for Heating and Refrigerating Installations.*

Continuous intense interest has been shown in heat pumps and heat recuperating installations. In some cases clients have been inclined to put off the realization of such plants. There is a tendency to consider the present difficulties in obtaining coal supplies as a trouble which will soon be overcome. If, however, the conditions after the first world war are remembered, when the maximum price of coal was not reached until two years after the end of the war and the original pre-war price only attained fourteen years later, those who anticipate a continuation of the coal shortage beyond the end of the war and who, therefore, seek to make their plants for the near future as nearly independent of coal as possible, appear to be well advised. The most suitable means for this purpose is the heat pump. It is the ideal heating machine where large quantities of heat are required at moderate temperatures, and which it enables to be done in many cases without coal at all.

So much has already been published on the heat pump[1] that everybody may now be assumed to be familiar with its operating principle and its construction. Some new illustrations of installations which have been supplied are therefore merely given here.

The most interesting plant now existing for the heating of buildings by means of heat pumps is the district heating station of the Swiss Federal Institute of Technology at Zurich. This installation which contains two Brown Boveri thermoblocs each for 1·5 to 2·5 million kcal per hour, was successfully put into service last year. Two-thirds of this heat are pumped out of the heat stored in the water of the river

[1] Brown Boveri Rev., 1943, Nos. 5/6, p. 75 and Nos. 7/8, p. 146.

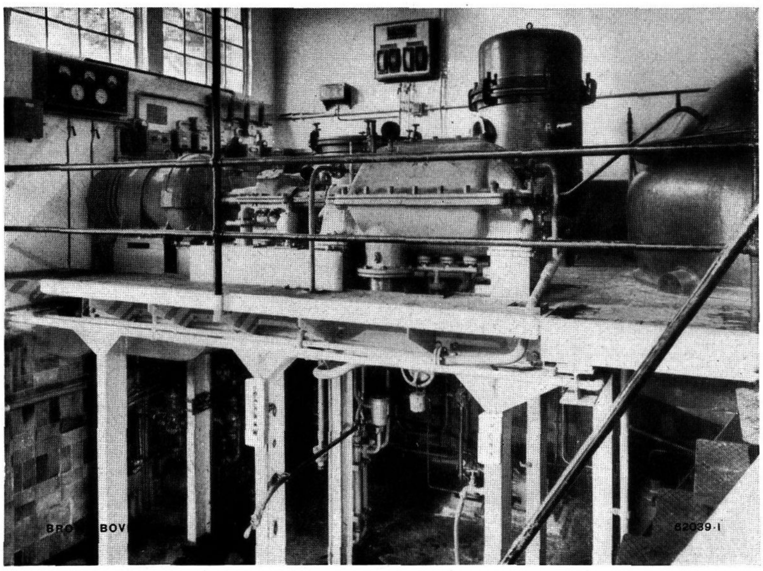


Fig. 99. — Small concentrating and boiling installation of a food products factory for an hourly evaporating capacity of 420 kg.

The thermo-compressor is the ideal heat supplier for materials which are sensitive to heat, particularly in the foodstuffs industry. The use of electric current, together with the absence of smoke and soot producing fuels, results in the greatest cleanliness.

Limmat, the remaining third comes from the electrical energy supplied to the driving motors. The yearly saving in coal thereby achieved, referred to peace conditions, amounts to about 2800 t. *Fig. 98 shows the machine* room with the two heat pump sets. A perspective view was published in last year's review of progress[1] (p. 71, *Fig. 122) which gave a good idea of the* general arrangement of the entire plant.

The particular characteristic and one of the considerable advantages of Brown Boveri heat-pump installations for heating and refrigerating purposes, in the design of which there is hardly any difference, is their concentration into a single block. The entire machine part rests on a boiler shaped shell, which contains the evaporator, the heat exchanger as well as the whole of the working medium. This design avoids all external pipe connections and makes erection on the foundations a very simple matter; further, the set can be assembled and tested at the factory. The erection work on site is, of course, much simplified and can be carried out in a very short time.

[1] Brown Boveri Rev., 1944, Nos. 1/2, p. 71.

5. *Thermo-compressors for Concentration Purposes.*

In order to preserve and to facilitate the distribution of edible products such as milk, fruit and grape juices, etc., it is to-day an increasingly common practice in all countries to concentrate such products. The thermo-compressor is particularly suitable for such concentration processes and at the same time has the advantage, especially important at the present moment, of being entirely independent of coal. The present food position has been very favourable to the introduction of the thermo-compressor. Thus a further number of such installations were supplied during the past *year, two of which are shown in Figs. 99* and 100. Thanks to the considerable amount of work the Company has carried *out in this field*[2], very wide experience has now been obtained.

Various methods of operation and of connecting up, which, for instance, enable an outside steam supply

[2] Brown Boveri Rev., 1942, Nos. 6/7, p. 190.
Brown Boveri Rev., 1943, Nos. 5/6, p. 85.

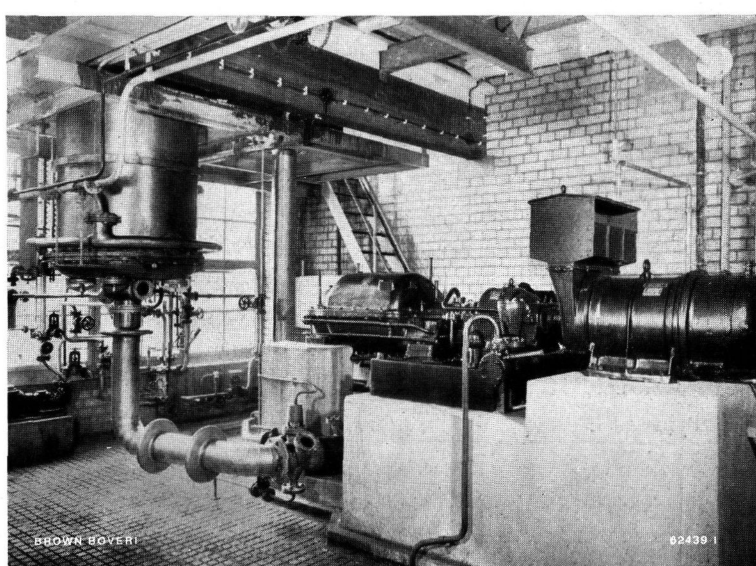


Fig. 100. — Thermal compressor plant in a chemical factory for concentrating various anorganic solutions. Hourly evaporating capacity 1000 kg water.

It is also possible to do away with additional steam in the case of plants operating at pressures above atmosphere and with steam-sealed glands. An additional boiler plant is, therefore, unnecessary.

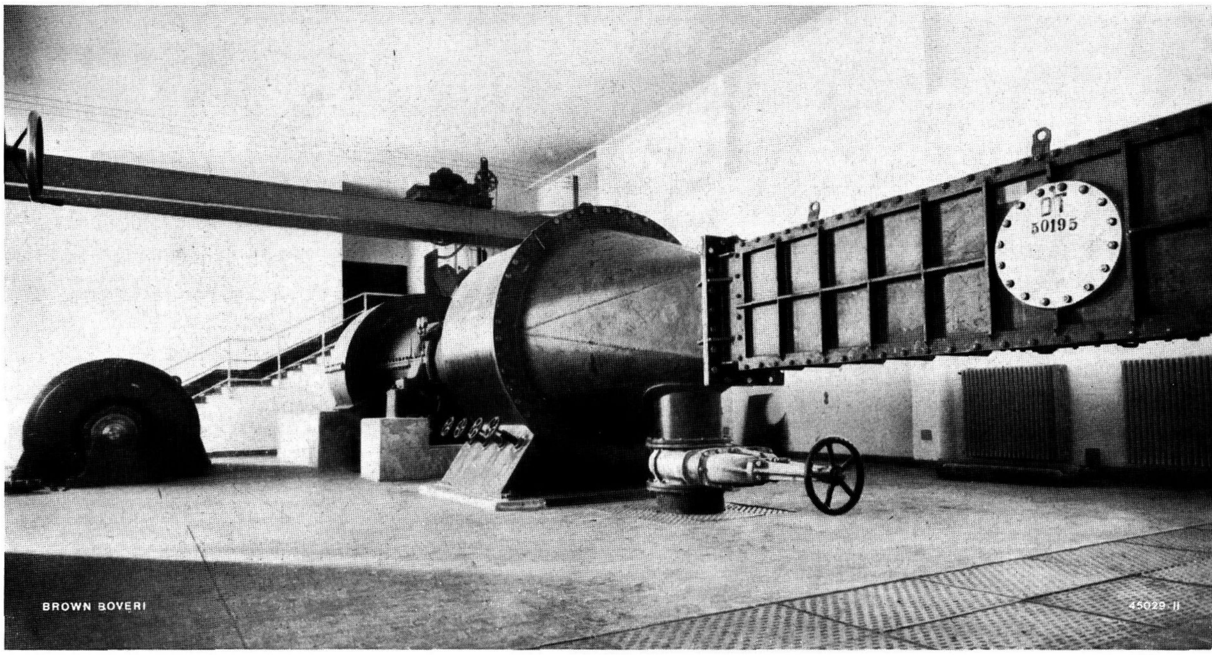


Fig. 101. — Supersonic wind tunnel for aerodynamic research with its accessory machinery.

On the right in the foreground the wind tunnel; the measuring section, in which the model is placed, is under the oval cover. On the left an air cooler and a steadying grid and directly behind it the multi-stage axial blower. The driving motor and its gear are not visible; they are behind the air inlet spiral of the blower. On the left is the converter set. By means of a by-pass connection (visible below the inlet to the tunnel section) which terminates in an ejector, it is possible in the case of small measuring sections to increase the pressure drop over the test part and hence to increase the Mach's number.

to be dispensed with have also been developed. Interested parties can also be advised on regard to the apparatus to be used, and when desired, the Company undertakes the supply of complete concentrating plants as main contractors, in which case the apparatus not manufactured is obtained from specialist firms.

6. *Aerodynamics.*

a. *Wind Tunnels for Aerodynamic Research.*

A large part of the enormous advances in aircraft engineering are due to the knowledge obtained from the investigation of flow phenomena. The main part has here been played by the so-called wind tunnels. Models which it is required to investigate are suspended in such tunnels and subjected to a current of air of definite density and velocity and from the measurable forces exerted on the model its behaviour in a flow of air determined. The air velocities coming into consideration for this purpose can, depending on the object of the investigation, lie below, near to, or above sound velocity, and accordingly a distinction is made between wind tunnels operating below the velocity of sound and those operating above it.

Flow phenomena are, however, of importance not only in aircraft design but also in all types of turbomachinery. Thus it happened that from the start the Company had given attention to flow questions and, therefore, were not unprepared when it became necessary to supply the equipments required for aerodynamic research.

b. *Wind Tunnels operating above Sound Velocity.*

It was in the Brown Boveri works that the first supersonic wind tunnel with a continuous air flow[1] was built to the design of Professor Dr. Ackeret for the Aerodynamics Institute of the Swiss Federal Institute of Technology. The continuous stream of air is supplied by an axial blower absorbing a power of 1000 kW. A further plant of the same type also was supplied with the collaboration of Prof. Ackeret for the aerodynamic research institute at Guidonia, Italy (Fig. 101). Last year, the axial compressor for a third plant was supplied. This compressor which is built for a pressure ratio of 3 over the test section of the tunnel, absorbs 2900 kW (Fig. 102). This pressure ratio enables Mach's[2]

[1] Brown Boveri Rev., 1943, Nos. 7/8, p. 176.

[2] Mach's number is the ratio of the velocity of flow of the medium in question to the velocity of sound.

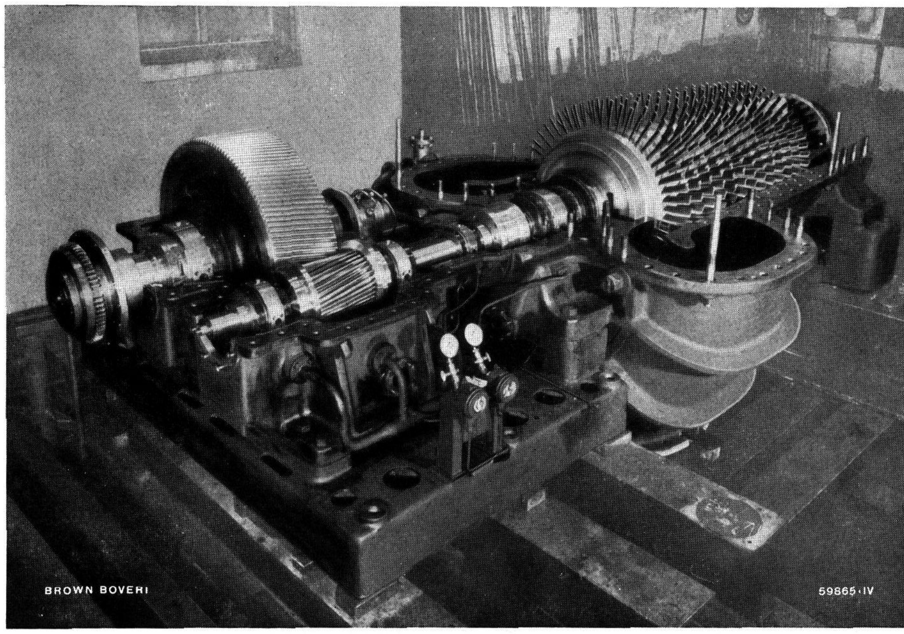


Fig. 102. — Multi-stage axial blower and gear for a supersonic wind tunnel.

Maximum air quantity 48 m^3/s, normal pressure rise from 0·4 to 0·88 kg/cm^2. Maximum pressure increase from 0·38 to 1·44 kg/cm^2.

The pressure ratio of max. 3 enables tests to be made with Mach's numbers up to 2·6, corresponding to wind speeds nearly three times higher than the sound velocity of air.

numbers up to 2·6 to be attained corresponding to air velocities exceeding 3000 km/h.

When making tests in supersonic wind tunnels, it is extremely important that, when once adjusted, the speed of the blower shall remain constant during the test, because to each Mach's number corresponds a definite cross-section of the test length and a definite pressure ratio of the compressor which is fixed by the compressor speed. For keeping the speed constant, the Company employ a special very accurate method of regulation described already in 1939 [1] and for which experimental results are now available. They show the very small insensitivity of this regulating system which amounts to only 0·1 % over a range of 45 to 100 % of the maximum speed and to 0·4 % at about 20 % of the maximum speed. The required speed can be regulated by remote control from the control room. The whole apparatus is

[1] Brown Boveri Rev., 1939, No. 6, p. 141.

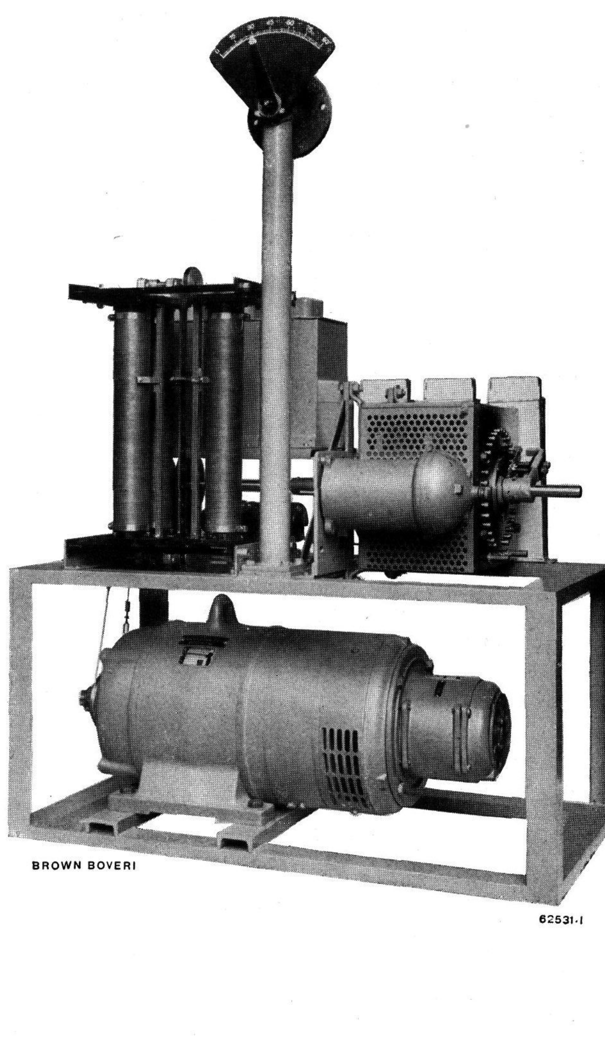


Fig. 103. — Automatic fine speed regulation for wind tunnels.

All apparatus for speed regulation are shown combined in one unit complete for mounting in a switch panel. Below there is the rotary transformer. Above from left to right: a condenser and in front of it the bridging resistance for tuning the two main circuits of the frequency regulator. Further, on a column the scale for indicating directly the adjusted speed value and finally on the extreme right the remote transmitting gear for the electrical repeat signalling in the test control desk.

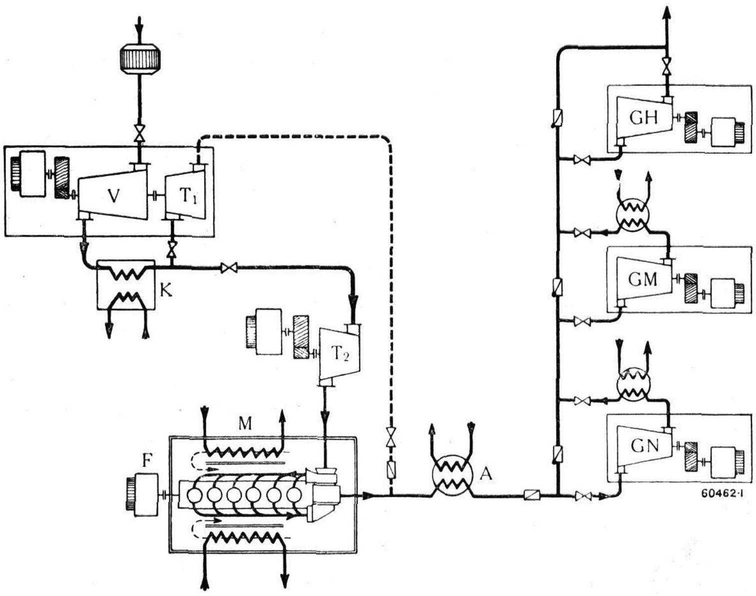


Fig. 104. — Elementary diagram of a Brown Boveri high-altitude test installation for aeroplane engines.

A. Exhaust gas cooler.
F. Brake dynamo.
G_N, G_M, G_H. Gas exhauster.
K. Air cooler for regulating the air humidity.
M. Test engine.
T_1. First air expansion turbine.
T_2. Second air expansion turbine.
V. Pre-compressor for supplying the combustion air.

By means of the two expansion turbines T_1 and T_2 and the cooler K it is possible to reduce the air pressure to 0.10 kg/cm² abs, corresponding to an altitude of 16,000 m above sea level and to —60° C. By means of the gas exhausters, which may be connected either in series or in parallel, the exhaust gas pressure can be reduced to 0.05 kg/cm² abs and the gas exhausted slightly above atmospheric pressure to atmosphere. In order to reduce the work of compression, the exhaust gases at 500 to 800° C are cooled in the cooler A. The main object of compressor V is to reduce the humidity of the air at least 1 g/kg of air. A large part of the exhaust gas compression work is supplied by the air expansion turbines.

mounted together and tested before delivery when it is dispatched as a single unit (Fig. 103).

c. *Wind Tunnels operating below Sound Velocity.*

Work in this field during the past year was limited to projects. What has already been done in the field of wind tunnels operating at velocities below that of sound may be seen from previous publications.[1]

d. *High Altitude Test Plants for Aero-engines.*

The development of high-power aero engines is closely connected with the creation of well-equipped test plants in which the engines may operate under conditions similar to those existing when in flight. For artificially producing such conditions at ground level high altitude test plants have been created. These are provided, in addition to the apparatus for measuring the power developed and the fuel consumed by the engine, with means for expanding and cooling the air to the conditions existing at high altitudes, and for recompressing the exhaust gases to the atmospheric pressure at ground level (Fig. 104). Particularly difficult requirements have to be fulfilled by the regulating devices of such a test arrangement. They must automatically maintain the state of affairs corresponding to the pressure, temperature, and humidity of the air and to the pressure head due to the velocity of the aeroplane at the investigated height. The regulation is particularly complicated by the fact that any variation in one of the quantities to be maintained constant may cause a variation in another and further by the condition that the return to the prescribed condition shall take place very rapidly.

A number of such test plants has been supplied complete and ready for service, while the Company has taken a leading part in the construction of others. These include plants for test heights up to 15,000 m. The Company now possesses considerable experience in this field and new features have been incorporated in the installations which have led to more favourable solutions than those hitherto achieved.

Fig. 105 shows a compressor installation with cooling turbine. In regard to blowers for cooling air-cooled engines on test readers are referred to a recently published article[2].

[1] Brown Boveri Rev., 1943, Nos. 7/8, p. 168.

[2] Brown Boveri Rev., 1944, No. 12, p. 406.

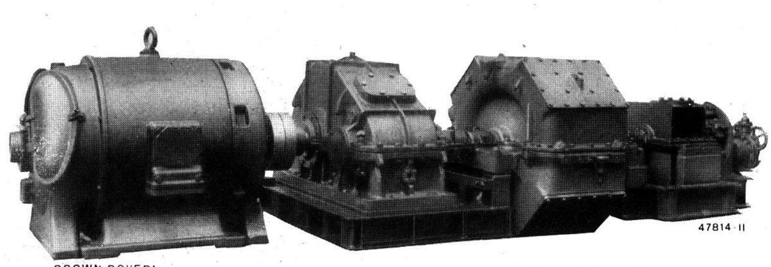


Fig. 105. — Compressor set with cooling turbine for conditioning the combustion air of an aeroplane engine of 1200 to 1400 H. P. output, driven by an induction motor through a reduction gear.

(This is one of the sets designated by VT_1 in the plant shown in Fig. 104.)

7. *Exhaust-gas Turbo-chargers.*

a. *Standard Diesel Engine Superchargers.*

The work on the new standard series of supercharger has now been completed. These standardized superchargers are available from stock for engine outputs from about 200 to 2500 H. P. (supercharged), and so far completed for outputs up to about 6000 H. P. that they, as well as spares, can be delivered very quickly. All supercharging sets are so arranged, that by simply turning round the parts containing the connection flanges, they can be adapted to any make of engine. All supercharger sizes can be supplied with either two, three, or four separate gas inlets, thus enabling the Büchi process to be employed. All casings through which the exhaust gases flow are water cooled and each set has its own lubricating system. The only parts subject to wear in the turbo-charger are the bearings which can be easily replaced (Figs. 106 and 107).

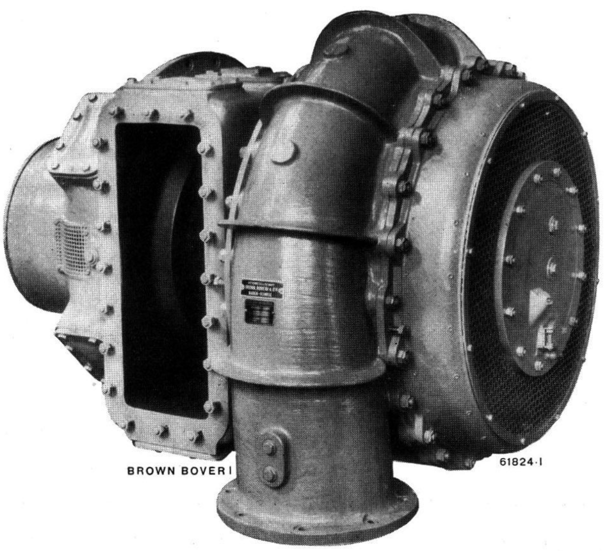


Fig. 106. — Standard exhaust gas charger for engines from 1500 to 2500 H. P. (supercharged).

On the left the turbine. On the right the blower. The Company's standard chargers are the result of more than twenty years' experience in the design and operation of exhaust gas turbo-chargers.

Further advances were also made in regard to the efficiency. The higher the latter, the greater the quantity of the air which can be delivered by the compressor and hence the greater the amount of cooling and scavenging air which has such an important influence on the behaviour of supercharged engines.

Increasing use is also being made of Brown Boveri supercharging sets for Diesel engines for rail traction service. The supercharging ensures a considerable reserve of power of the engine thus, as proved by experience, protecting it against overloading and hence increasing its life and reducing maintenance costs. Supercharging simplifies the mounting of engines of increased power because the additional output made possible by supercharging involves only small increases in weight and space required.

b. *High-pressure Supercharging of Four-stroke Engines.*

In 1923, when supercharging was applied for the first time to existing Diesel engines, supercharging pressures of 1·25 to 1·30 kg/cm² abs, resulting in an increase of the engine output of about 40% were looked upon as sufficient. In the course of time, improvements in the efficiency of the charging units,

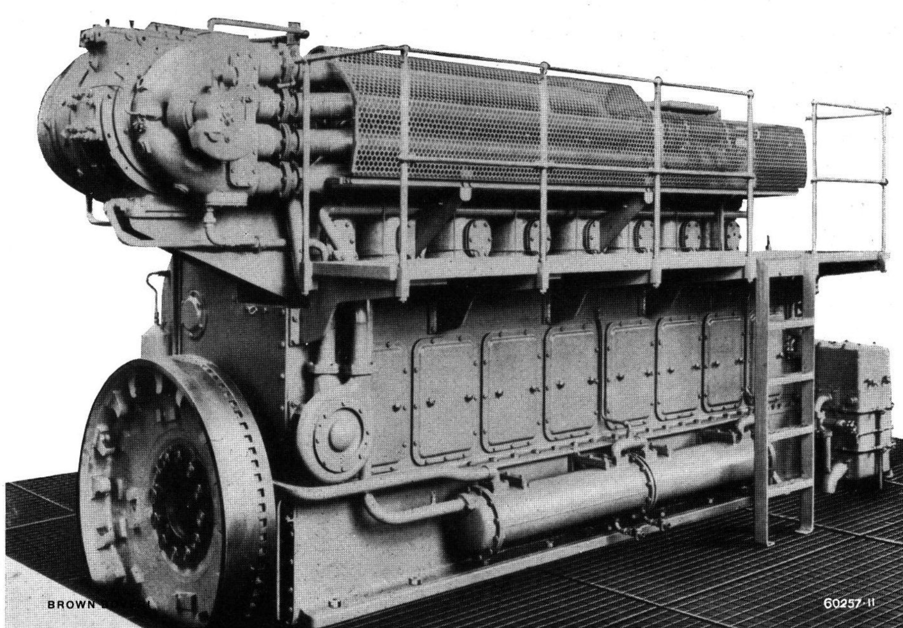


Fig. 107. — Eight-cylinder four-stroke Diesel engine of the Swiss Locomotive and Machine Works, Winterthur, operating on the Büchi principle and provided with a Brown Boveri exhaust gas turbo charger.

The output of the engine is increased by supercharging from 800 H. P. at 500 r. p. m. to 1200 H. P. The supercharger is mounted above the flywheel. With this arrangement no additional space is required. The exhaust gases are led to the turbine through the four collector pipes (Büchi system).

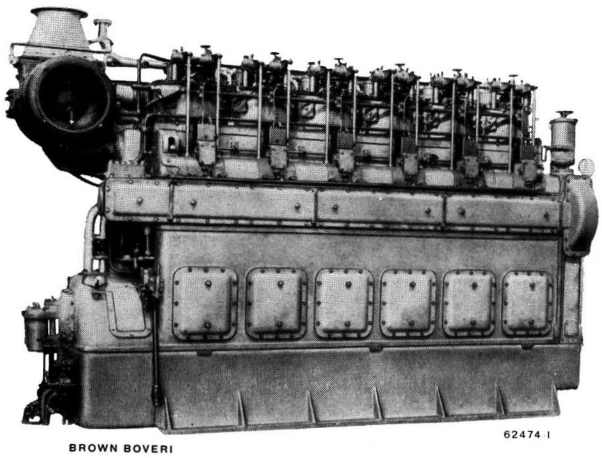


Fig. 108. — Brown Boveri exhaust gas charger on a Sulzer six-cylinder four-stroke Diesel engine supercharged on the Buchi principle.

Power supercharged 900 H. P. at 375 r. p. m. The charging set fits harmoniously in the design of the complete set. Space requirements with turbo chargers are at least 30 % smaller than with unsupercharged machines of the same power. The weight of the machine per H. P. is reduced in the same ratio.

better scavenging made possible by separation of the exhausts (Büchi patent), and other improvements have enabled the supercharging pressure to be raised to 1·4 kg/cm² abs., and hence the now usual power increase of 50—60 % corresponding to a mean effective pressure of 8·5 to 9·5 kg/cm² to be attained.

The Company has now succeeded in increasing the compression ratio of the blower of sets with only a single-stage blower and single-stage gas turbine to more than 2. These superchargers therefore enable much higher charging pressures to be obtained than with the earlier models; indeed if at the same time the charging air is cooled, mean effective pressures of up to 12 and 14 kg/cm² (at normal engine rating) can be obtained, without the temperatures of the exhaust gases exceeding the values usual with non-supercharged engines. This pressure increase corresponds to an increase in the motor power of 100 %.

The increased compression has at the same time brought the question of cooling of the supercharging air into the foreground. A series of coolers adapted to the new charging units and which can be easily mounted on them has therefore been developed. The same water is used as for the cooling of the engine. The method of connection depends, however, on the temperature conditions.

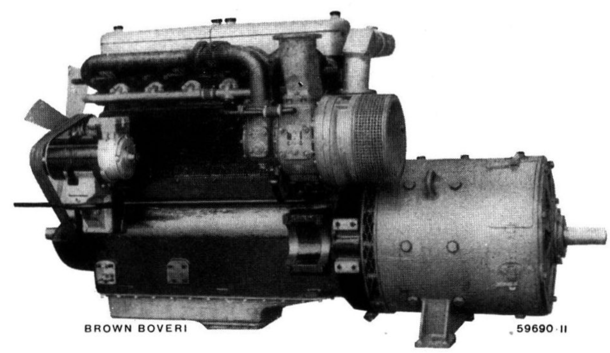


Fig. 109. — Six-cylinder road vehicle Diesel engine built by Ad. Saurer, Arbon, operating on the Büchi principle and provided with Brown Boveri exhaust turbo charger.

This set is directly coupled to a generator and is intended for driving "Peter" snow ploughs. The engine is equally suitable for mounting in Diesel rail coaches and in small locomotives. Diesel engine motor coaches or lorries with Brown Boveri exhaust turbo chargers can be found all over the world.

Fig. 110. — Motor bus of the Swiss Telegraph and Telephone Administration with exhaust turbo-chargers for supercharging an Imbert wood gas generator.

The increase in output obtained with this set is at least 30 %. The set is mounted below the front bumper bar. On each side are the settling containers of the wood gas plant and on top the gas cooler.

The earlier supercharging process enabled the engine to be retained without modification which fact was without doubt largely responsible for its quick and general introduction. High-pressure supercharging, however, involves certain changes, namely strengthening of certain parts of the engine, because with the increase in mean effective pressure the higher degree of supercharging causes an increase in the compression and explosion pressures. In spite of this, there are many cases where high supercharging can be applied without, or with only minor changes to the engine. With the 100 % increase in power, the weight of the four stroke engine is reduced to 40 % of that of the same machine without supercharging. The space required is as much as 40 % smaller for the same output.

High pressure superchargers also find application in cases where engines have to operate at high altitudes above sea level. They enable the full sea level output of the engine to be still obtained at an altitude of 5000 m. This fact is of particular significance for rail and road vehicles which have to overcome large differences of level. Figs. 108 and 109 show examples of supercharging sets built during the past year.

c. *Road Vehicle Engine Supercharging.*

Until recently a small and light set suitable for small road vehicle Diesel engines was not available. In connection with the supercharging of wood gas generators such a small supercharger has been evolved

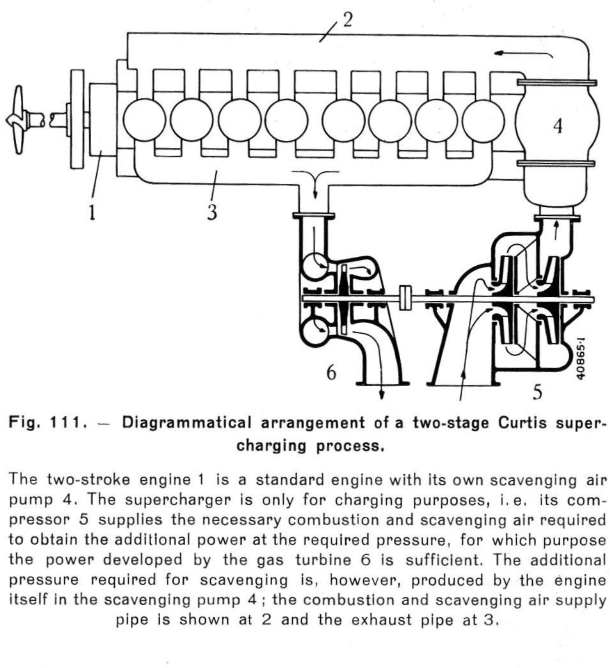


Fig. 111. — Diagrammatical arrangement of a two-stage Curtis supercharging process.

The two-stroke engine 1 is a standard engine with its own scavenging air pump 4. The supercharger is only for charging purposes, i.e. its compressor 5 supplies the necessary combustion and scavenging air required to obtain the additional power at the required pressure, for which purpose the power developed by the gas turbine 6 is sufficient. The additional pressure required for scavenging is, however, produced by the engine itself in the scavenging pump 4; the combustion and scavenging air supply pipe is shown at 2 and the exhaust pipe at 3.

and the way to the general introduction of supercharging for road vehicle engines thus opened. Particular care has to be given in the case of such fast running engines with a large speed range to ensure a proper mixture. Tests made in this connection show that the supercharged engine can also adapt itself to all the requirements of road service. It has further been found that even with the existing engine types considerable increases of output could be obtained without affecting appreciably the weight and the space requirements. Engine makers can, therefore, in many cases continue to build their existing types unchanged, without regard to whether the engine will later be supercharged or not.

d. *Wood Gas Producer Supercharging.*

In spite of the further reduction in road traffic, some interesting examples of supercharged wood gas generators were put into service last year, namely the first installation of this nature for a private car as well as some motor buses and trucks. Fig. 110 shows the method of fitting the supercharger to a motor bus of the Swiss Postal, Telephone, and Telegraph services.

e. *Supercharging of Two-stroke Engines.*

This differs from the supercharging of four-stroke engines in a number of respects because a larger pressure head must be ensured for scavenging and charging and hence also a larger air quantity must be delivered, in spite of the lower exhaust gas temperature. The requirements in regard to delivery pressure and efficiency which are demanded of a supercharger for two-stroke engines are, therefore, much more difficult to comply with than in the case of the four-stroke engine supercharger. The problem is therefore simplified if the scavenging operation is accomplished by the engine itself and the turbo-charger employed for supercharging only. This method is used in the so-called Curtis process (Fig. 111). It represents, if not the simplest solution of two-stroke engine supercharging, at least the solution most easy to execute.

f. *Supercharging of Aero Engines.*

The great importance of supercharging for aero engines in order to enable the altitudes nowadays reached to be attained is well known. As a rule, single or multi-stage compressors are used for supercharging which are driven by the engine itself. Attention has been paid entirely to the exhaust gas turbine driven supercharger. This latter is also likely to find considerable application later in civil aviation and work has therefore been continued in this field.

8. *Brakes for Measuring Purposes.*

The Company builds electrical dynamometer machines for measuring the driving power of mechanically driven superchargers and similar drives[1]. Work in connection with high-altitude and normal altitude test plants for aeroplane and other forms of engines has, however, led to another field: The manufacture of brakes for measuring the power or the torque of engines. A new type of apparatus has been developed for this

[1] Brown Boveri Rev., 1943, Nos. 5/6, p. 119.

purpose, similar to the well known Froude brake. Whereas, however, in the latter the power absorbed is dissipated in the water by shock, eddies, and friction and the adjustment to different loads effected by varying the amount of water in the brake, in the Company's design, the power absorbed is dissipated purely by friction and the load adjusted by regulating the quantity of water circulated per second by means of valves. The pump and the water channels through which the water flows are designed in accordance with the latest knowledge on fluid flow in such a manner as to exclude the dissipation of energy by uncontrolled influences.

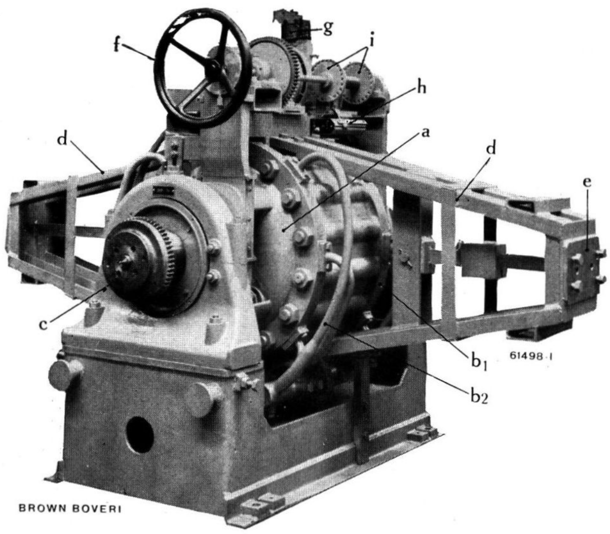


Fig. 112. — Hydraulic water brake, Brown Boveri system.

The new brake enables a measuring range of 1 : 300 to be covered at constant speed and with a measuring accuracy of 0·1 %.

a is the pump and brake case. The cooling and circulating water is supplied and discharged by the pipes b_1 and b_2. The machine to be tested is coupled to the brake by means of the geared coupling *c*; *d* shows the weighing beams, the knife edge being fixed at the flange *e*. Adjustment of the valves with which the rod is regulated is effected by means of the hand wheel *f*, the movement of which is transmitted by means of a chain to the 2×4 threaded spindles of the valves. The valves can also be operated by means of an electric motor which can be stopped by means of the brake magnet *g*, whilst the resistance *h* serves for the remote indication of the momentary position of the valves. The two cams *i* interrupt the operation of the valves as soon as they reach their end position.

In this way absolutely steady running is obtained and a variation of the load over a range of 1 to 300 made possible. The regulation of the load by means of valves is further so effective and so accurate that the torque can be determined from their position alone without having to make use of the balance. Measurement of the torque by means of the balance serves therefore only for checking purposes. The accuracy of measurement is 0·1 %. The moment of inertia of the rotating part of the brake is very small. Hence in the testing of aero engines, it is possible to arrange for the masses of the moving parts to be the same as under flight conditions.

The brake is provided with couplings at each end so that by turning it round, it can be used for either direction of rotation. If desired, the brakes can be made suitable for running in both directions without having to be turned round, in which case the rating is somewhat reduced. The brakes are provided with fine and remote-operated coarse adjustment; they are built in three sizes for outputs up to about 16,000 H.P. at 600 r.p.m.

IV. TRACTION.

A. ELECTRIC TRACTION.

The most important event under this heading during the past year was doubtless the setting to work of the first of the two $B_0' B_0'$ locomotives, series 251, of the Berner Alpenbahn-Gesellschaft (Lötschberg Railway). The Company designed this locomotive in 1943 on its own initiative and submitted it to the Lötschberg Railway. The design met with the approval of *Prof. F. Volmar*, whose death in January, 1945, terminated a period of many years' service as director of this railway company. It was this experienced and far-sighted traction expert who first pointed out that wherever possible the pony axles should be entirely suppressed, especially on locomotives intended for service on mountainous routes, so as to utilize the otherwise dead load for the production of the tractive effort. Subsequently, in the same year, the Company were appointed general contractors by the Lötschberg Railway for two locomotives of this type, and, in turn, entrusted the Swiss Locomotive and Machine Works, Winterthur, with the construction of the mechanical part. The realization of a $B_0' B_0'$ bogie locomotive for a maximum speed of 125 km/h without pony axles is an important advance in electric locomotive design which was only rendered possible by arranging the motors in sprung frames. Nose-suspended motors could not be considered in that a large part of their weight would have rested unsprung on the wheel axles. The individual axle drive of the disc type developed by the Company (Fig. 113) is employed here for the first time on locomotives. It was decided to introduce disc drives on locomotives due to the fact that the trial drive on one axle of a 2 C_0 1 locomotive of the Swiss Federal Railways, series 10,261, behaved extremely well over a distance of 400,000 km and that the disc drives first arranged on the pinion side of the lightweight tramcars of the series 401 of the Zurich Municipal Tramways also gave excellent working results. The disc drive has no parts subject to wear and in consequence needs neither lubrication nor attendance. Further special features of the electrical equipment of the locomotives are the following:—

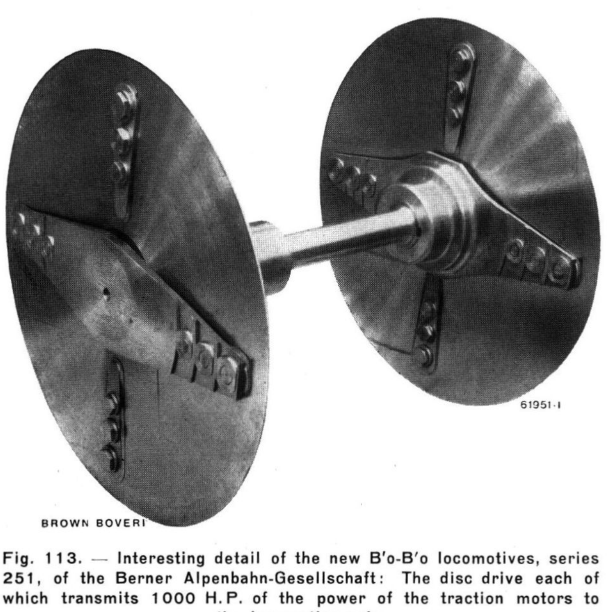


Fig. 113. — Interesting detail of the new B'o-B'o locomotives, series 251, of the Berner Alpenbahn-Gesellschaft: The disc drive each of which transmits 1000 H.P. of the power of the traction motors to the locomotive axle.

The drive requires very little space since its torsion shaft is taken directly through the rotor of the traction motor. The elastic steel discs which are subject to no wear and therefore require neither attendance nor lubrication, take up the relative movements between the motor and driving axle.

An air-blast high-speed circuit-breaker rated 400 A and designed for a working air pressure of 7—9 kg/cm^2 is provided on the primary side for over-current protection purposes. An arc extinguishing chamber with exhaust cooler, isolating switch, and control unit for the electrical remote operation of the circuit-breaker are mounted on the compressed air receiver; the latter is built up from tubes. A crank provided enables the circuit-breaker to be closed by hand, i. e. without compressed air. The weight of the circuit-breaker ready for installation is only about 180 kg or approximately one-third of that of the oil circuit-breakers employed earlier for locomotives. As in stationary plants air-blast high-speed circuit-breakers are now substituted for oil circuit-breakers on a. c. locomotives and all explosion and fire hazards thus eliminated.

The new shell-type transformer with radially-laminated centre limb and annular return magnetic circuit has already been referred to. With this type of transformer the high-voltage control employed on this locomotive can be arranged much more easily, i. e. without additional magnetic return circuit. In any case the type of transformer employed here for the first time on a locomotive, together with the other weight reductions accruing from progress in the design of the remainder of the electrical equipment, has chiefly enabled a one-hour rating of 4000 H. P. to be incor-

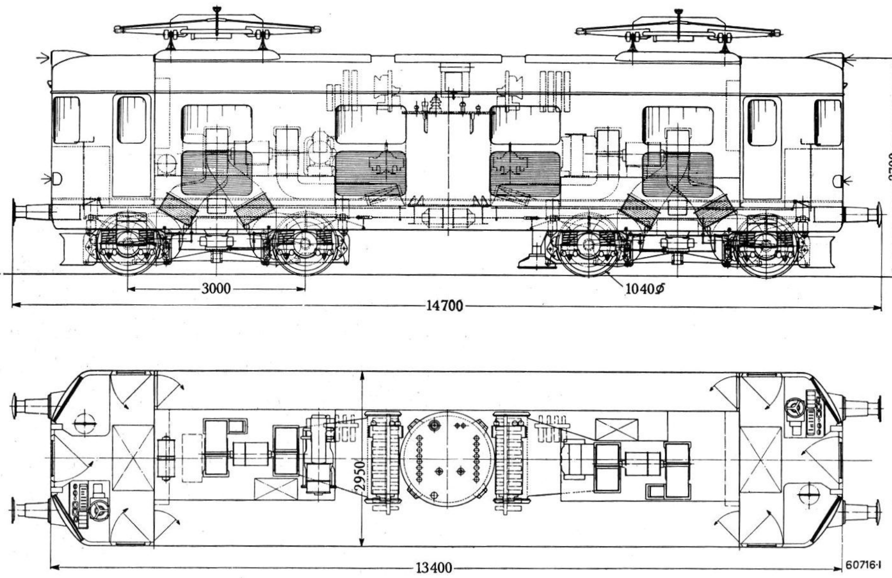


Fig. 114. — Re 4/4 locomotive, series 401, for the Swiss Federal Railways.

These lightweight locomotives with a continuous rating of 2170 H. P. at 89 km/h attain a maximum speed of 125 km/h and weigh only 57 t. They were ordered to replace the earlier motor-vans with the same axle arrangement.

porated in this 80 t locomotive, thus giving a specific weight of only 27 kg/kW. The new locomotive has already proved to be a complete success and represents a big advance, thanks to the progressive policy of the Lötschberg Railway, and in particular to its late director *Prof. F. Volmar.*

The Swiss Federal Railways[1] are also extensively changing over their locomotives to the $B_0' B_0'$ type. In contradistinction to the Berne-Lötschberg-Simplon Railway, however, for which the tractive effort for locomotives chiefly in service on mountain lines can only be developed by utilizing the entire admissible axle loading of 20 t, the Swiss Federal Railways (S. F. R.) locomotive is required to haul express trains through flat and hilly country at an increased running speed. The S. F. R. decided on $B_0' B_0'$ locomotives with a weight in running order of about $4 \times 14 \cdot 25 = 57$ t, a one-hour rating at the wheel tread of 2220 H. P. at 75 km/h, and a maximum speed of 125 km/h (Fig. 114). Contracts for six of this type were placed with the different Swiss engineering firms last spring. Brown Boveri have to supply the traction motors for four locomotives and transformers of the above-mentioned new design and air-blast high-speed circuit-breakers for the primary side, for all six locomotives. The individual axle drives of the Brown Boveri spring type with hollow shaft stub are being supplied, together with the mechanical part of all of the locomotives, by the Swiss Locomotive and Machine Works, Winterthur.

[1] During the past year the Effretikon-Hinwil (22·532 km), Rüti-Wald (6·570 km), Busswil-Solothurn-Herzogenbuchsee (35·03 km), Turgi-Koblenz (13·7 km), Stein-S.-Koblenz (26·124 km), and Payerne-Murten-Lyss (42·198 km) lines were electrified, so that by the end of the year under review 2474·556 km or 85 % of the entire Swiss Federal Railways system was in electrical operation.

The change-over to this new type of locomotive enabled the S. F. R. to dispense with the three RFe 4/4 motor-vans of the 601 series. They were therefore disposed of last year to the Swiss South-Eastern Railway and the Lake of Constance-Toggenburg Railway, after they had been adapted to the different topographical conditions, as shown in the following table, by increasing the gear ratio:—

		Before conversion	After conversion
Ratio		1:3·17	1:4·56
One-hour rating at wheel tread	H.P.	1340	1340
at a speed of	km/h	91	63
Tractive effort at wheel tread	kg	3900	5600
Maximum speed	km/h	125	90

The Swiss Federal Railways ordered seven further shunting locomotives Nos. 16,395 — 16,401 of the proved type Ee 3/3 (Fig. 115), thus bringing up to twenty-one the total of these locomotives, which although unchanged in general construction are 8 t lighter than the sixty old locomotives. This saving in weight was achieved exclusively in the electrical equipment.

Due to the excellent results obtained with the three motor-coaches for the "Chemin de fer de la Gruyère" mentioned in last year's retrospective number, the "Chemin de fer fribourgeois" have placed a contract with the Company not only for the electrical equipment for four standard-gauge heavy motor-coaches of the BCFe 4/4 type for single-phase a.c. at 15,000 V, $16^{2}/_{3}$ cycles, for the Fribourg—Morat—Anet line, but also Simplex bogies with Brown Boveri spring drives; the Schweiz. Industrie-Gesellschaft, Neuhausen will build the coach bogies. There is a definite trend, at least where motor-coaches are concerned, to make motors, drives, and bogies integral. To obtain optimum results this involves leaving their design and supply to the electrical engineering firms. The new 54 t coaches with luggage compartment and a seating capacity of 50 (Fig. 116) will have four motors each with a one-hour rating of 250 H. P. corresponding to a running speed of 60 km/h. Their maximum speed is 100 km/h. Here, too, the transformers will be of the new shell-type with radially laminated centre limb and annular return magnetic circuit. Other features of the electrical equipment are the air-blast high-speed circuit-breaker as primary over-current protection, employed here for the first time on motor-coaches, and which are intended to replace the more or less makeshift roof cut-outs used for the past fifteen years, and the 18-notch electric servo-motor-actuated cam-operated controller and regenerative braking equipment of a simplified type, as derived from that employed on the South-Eastern Railway motor-coaches.

Fig. 115. — Swiss Federal Railways shunting locomotive Ee 3/3.

One-hour rating 710 H.P. at 30 km/h, maximum speed 45 km/h, weight in running order 37·5 t. A further series of these locomotives was delivered during the past year. As a result, steam shunting locomotives have practically entirely disappeared from the Swiss Federal Railways system, thus solving the coal supply problem.

A number of motor-coaches were modernized or converted during the year under review, as briefly touched upon hereafter.

The *Rhaetian Railway* had already had three of their 1′ B 1′ locomotives of the 201 series, originally equipped with a slow-speed Déri repulsion motor mounted high up on the frame, converted to shunting locomotives with a central driver's cab, by the Swiss Locomotive and Machine Works, Winterthur and Brown Boveri. The Déri motor was replaced by a high-speed series-wound motor of the same rating (310 H. P.) which drives the dummy shaft through the intermediary of double gearing.[1] Two more of these locomotives, which no longer meet the requirements of main line service, are now to be modernized,

[1] Brown Boveri Rev., 1943, p. 54.

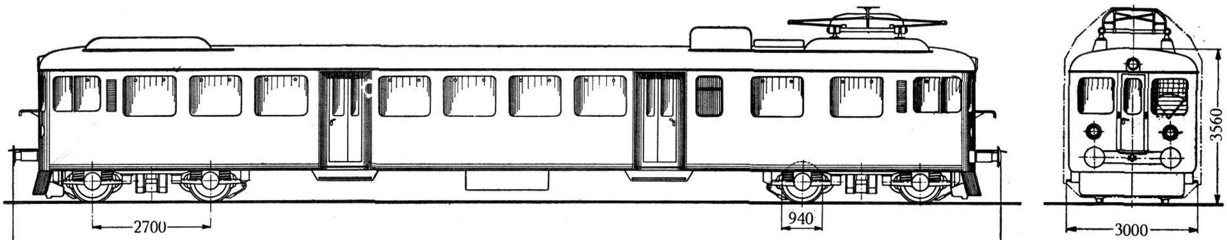


Fig. 116. — One of four motor-coaches for the Fribourg-Morat-Anet line of the Chemins de fer Fribourgeois.

Apart from the electrical equipment Brown Boveri also supplied the bogie of the proved Simplex type with spring drive. The coachwork was built by the Schweiz. Industriegesellschaft Neuhausen. The total weight of the coach with a seating capacity of 50 is 54 t, of which 24 t for the coach body, 12 t for the bogie, and 18 t for the electrical equipment. One-hour rating of four motors 1000 H.P. at 60 km/h, maximum speed 100 km/h.

the coachwork with two driver's cabs being retained (Fig. 117). The drive of the two driving axles over a dummy shaft is likewise again being employed, although the latter will be driven over gearing (to be supplied by the Swiss Locomotive and Machine Works, Winterthur) by a high-speed single-phase series-wound motor with a one-hour rating of 612 H. P. at 985 r. p. m., $16\,^{2}/_{3}$ cycles, corresponding to a running speed of about 42 km/h. The maximum running speed is to be 65 km/h. A new transformer with a continuous rating of 450 kVA is to be fitted. The traction motor and transformer are cooled by a common motor-driven fan set. The locomotives are equipped for d. c. resistance braking with separate excitation of the traction motor. The braking equipment is required to brake the entire weight of the train electrically on the gradients encountered on the line. A motor-driven cam-operated controller with sixteen power notches is used to control the traction motors. This fairly large number of notches for the traction motor rating in question was selected due to the adhesion weight of the locomotives being restricted to 22 t.

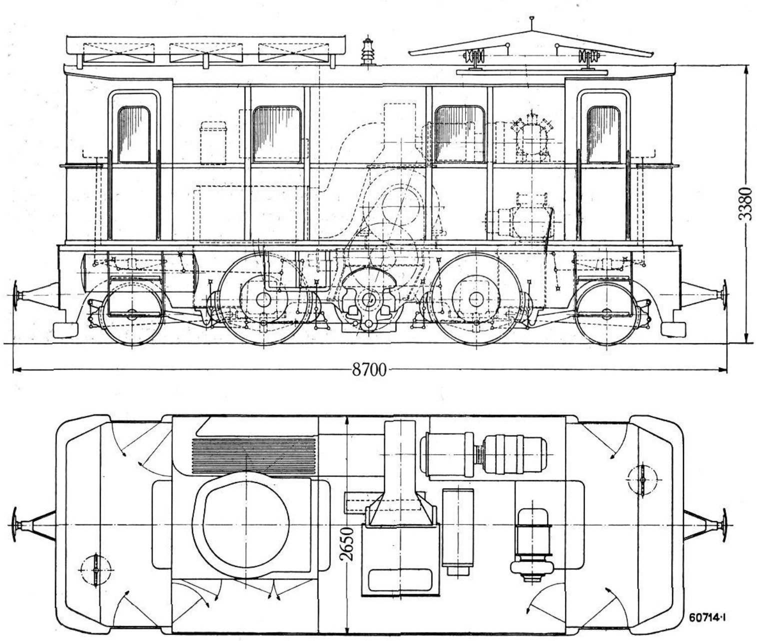


Fig. 117. — 1'B 1' Locomotive, series 201, of the Rhaetian Railway after conversion to double power.

Nothwithstanding the fact that the driving power has been doubled the modern electrical equipment weighs 5 t less than the old (see comparative table above).

The existing auxiliaries, such as vacuum pump set, motor-driven compressor, and lighting and heating equipment, have been retained unchanged, simply the existing converter set being replaced by a more powerful set for 36 V d.c. (lighting and control voltage).

The characteristics *then* and *now* are illustrated by the following comparison:—

	1912	1944/45
One-hour rating measured at wheel tread	310 H. P.	612 H. P.
at a speed of . . km/h	28	41·7
Maximum speed . km/h	45	65
Weight:		
mechanical part . .	19·24 t	approx. 20·1 t
electrical equipment .	17·46 t	" 12·5 t
	36·70 t	approx. 32·6 t
Ballast		" 2·2 t
Total	36·70 t	approx. 34·8 t

Notwithstanding the practically double power and about 2·2 t of ballast the modernized locomotive is not even as heavy as it was formerly.

The *"Chemin de fer électrique Martigny—Orsières"* has also had two of the standard-gauge motor-coaches originally supplied in 1910 and likewise equipped with Déri repulsion motor for single-phase a. c. at 8000 V, $16\,^{2}/_{3}$ cycles, modernized with single-phase series-wound motors, transformers with tappings, and regenerative braking equipment. One of the two motor-coaches now equipped with four motors having a one-hour rating of 175 H. P. was taken into service during the year under review (Fig. 118) and according to measurements made last May gives excellent working results. For instance, according to meter records at the substation the following amounts of energy, as a percentage of the energy consumption, were paid back into the line with differing train compositions:—

Motor-coach alone .	42 t	34 %
Train of	59 t	41·5 %
Train of	100 t	49 %

During the whole time the power factor remained above 0·9, i.e. between 0·92 and 0·95.

It might be mentioned that the railway is 19·4 km long, the difference in altitude between the terminal stations is 434·5 m, the maximum gradient 35 in 1000, and the mean gradient 22·5 in 1000.

Notwithstanding motors of twice the original rating, a compressor of about double the earlier air capacity, a modern lighting installation with converter and battery, regeneration equipment with auxiliary transformer and nepoline condenser, a coach body lengthened from

14·7 to 17·3 m measured over buffers, and the retention of the old bogie, the modernized motor-coach weighs slightly less than before. It was also found that with the new series-wound motors the new motor-coach consumes only about 80 % of the earlier energy for the round up- and down-hill journey *without* taking the regenerative braking into consideration. The new coach thus saves the railway a considerable sum for energy, apart from the other advantages, such as reduced brake block and tyre wear, with the consequent longer intervals between replacement, and prevention of the harmful brake dust.

In 1943, the *Leuk-Leukerbad Railway* decided to increase the capacity of its rolling stock, comprising three motor-coaches for mixed rack and adhesion operation for 1500 V d. c. equipped with Brown Boveri electrical equipment in 1915. This modernization scheme was carried out during the year under review and consisted essentially in the substitution of more powerful motors for the original ones and of a controller in each driver's cab instead of the centrally located controller as formerly. In the case of the mechanical part the gearing was altered, the luggage compartment increased in size, and a gangway provided on one side of the machine compartment. One of the modernized coaches was re-delivered during the year. The following comparison shows what was achieved by modernizing :—

		1915	1943/44
Number of traction motors per coach		2	2
One-hour rating	kW	2×125	2×187
Terminal voltage	V	1500/2	1500/2
Speed uphill	km/h	8·5	12
Trailing load on 160 in 1000 . .	t	30	20—40
Maximum speed	km/h	20	30
Maximum speed downhill on 160 in 1000	km/h	12	16
Running time for entire run uphill	min	60	45
downhill	min	60	35

One of the three motor-coaches for the *Chemin de fer Yverdon—Ste-Croix* was also delivered during the year. This meter-gauge railway, with its 24·3 km long line and gradients up to 44 in 1000, is one of those which it has been possible to electrify under the Private Railway Assistance Bill, the supply being taken from the Swiss Federal Railways at 15,000 V, $16^2/_3$ cycles. The motor-coaches in question weigh 36 t and are of the four-axled BCe $^4/_4$ type built by the Schweiz. Industrie-Gesellschaft, Neuhausen (Fig. 119), for a maximum speed of 65 km/h with four motors having a one-hour rating of 155 H. P.

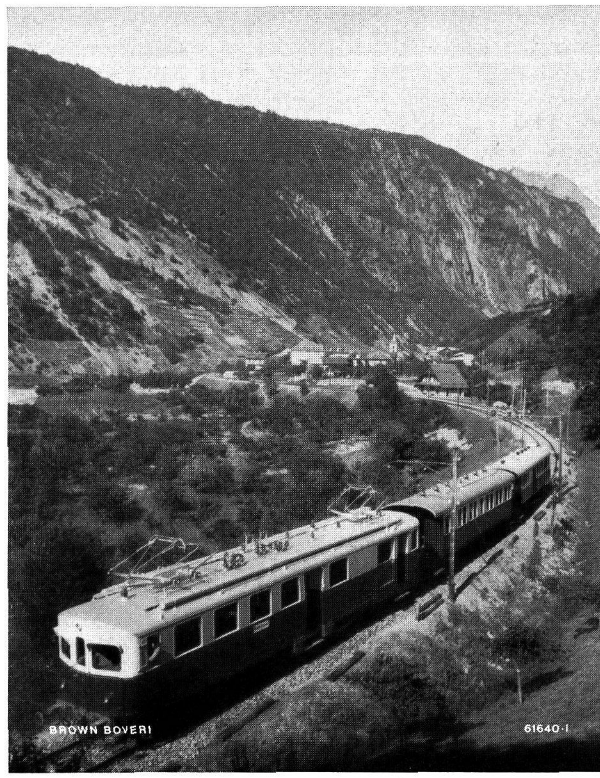


Fig. 118. — Motor-coach train set of the Chemins de fer électriques Martigny-Orsières leaving Bovernier Station.

The motor-coach was modernized during the past year and notwithstanding a 2·6 m longer coach body and double the former motor power weighs slightly less than before conversion. Energy consumption uphill is only 80 % of that with the old equipment. Downhill the regenerative brake permits 34—49 % of the energy consumption uphill to be recuperated.

which drive the axles through Brown Boveri spring drives. A special feature of the electrical equipment is the control by an electric servo-motor-actuated cam-operated controller of particularly lightweight construction with switch units having no magnetic blow-out.

The *Montreux-Berner Oberland Railway* (M.O.B.) also took delivery of the four lightweight motor-coaches electrically equipped by the Company. Seeing that these coaches were recently dealt with in detail in the pages of this journal [1] an illustration of one of the coaches (Fig. 121) will suffice here. It must, however, be stressed that the acquisition of these coaches was entirely due to the initiative of *Dr. Roland Zehnder*, director of the railway for many years past. The effect of the modernization of the track and contact wire system of the M.O.B., at present also in hand at the instigation of Dr. Zehnder, will only be fully felt now that the four modern lightweight motor-coaches are available.[2]

[1] E. Schroeder, Brown Boveri Rev., 1944, No. 8, p. 267.

[2] Dr. R. Zehnder, Bull. techn. de la Suisse Romande 1944, p. 93.

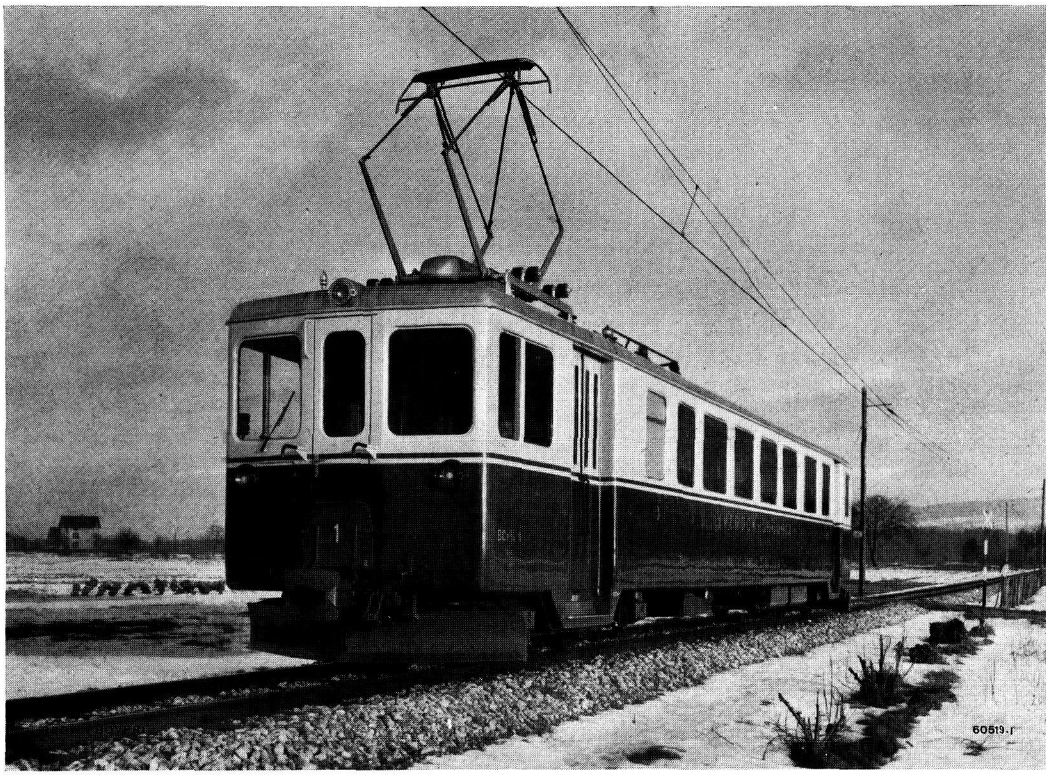


Fig. 119. — One of three motor-coaches on the Chemin de fer Yverdon—Ste-Croix.
Weight of coach 36 t, drive by four motors each with a one-hour rating of 114 kW at 44 km/h, maximum speed 65 km/h. A special feature is the control with twelve-notch servo-motor-actuated cam-operated controller of extremely light and compact design.

The two standard-gauge four-axled motor-coaches for single-phase a. c. at 15,000 V, 16 $^2/_3$ cycles for the *"Chemin de fer Régional du Val de Travers"* were also completed during the year. They are each equipped with two motors having a one-hour rating of 206 kW and driving the axles through Brown Boveri spring drives. The coaches (Fig. 120) are controlled by electric servo-motor-actuated cam-operated controllers. The speed corresponding to the one-hour rating is 54 km/h, the maximum speed 75 km/h. Electric resistance braking is employed on down-hill runs, when the motors are separately excited with d. c. from a converter set.

In the course of the year five further equipments for four-axled lightweight motor-coaches of the 401 series were supplied to the *Zurich Tramways.* Al-

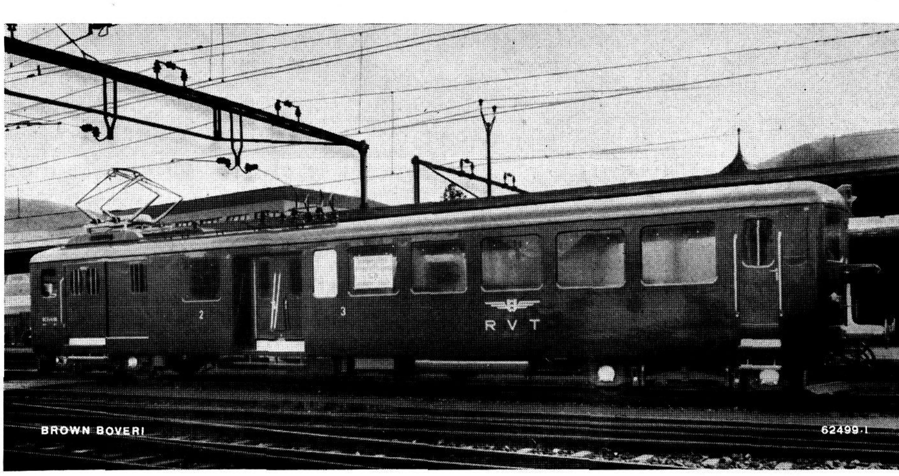


Fig. 120. — Single-phase a. c. motor-coach for 15,000 V, 16 $^2/_3$ cycles, on the Chemin de fer Régional du Val de Travers.
Drive by two motors each with a one-hour rating of 300 H. P. at 1550 r. p. m. This coach is also equipped with the proved Brown Boveri spring drive. Maximum speed 75 km/h.

Fig. 121. — Lightweight passenger train on Montreux — Berner-Oberland Railway, comprising two motor-coaches with multiple-unit control and four new trailing coaches.

The train is driven by one single man who is comfortably seated. Due to the difficult gradient and curve conditions (maximum gradient 73 in 1000, minimum curve radius 35 m) the motor-coaches are equipped with three electrical brakes, regeneration, resistance, and rail brakes, to give maximum reliability.

together there are now fourteen cars of this type with Brown Boveri Simplex bogies in service on the Zurich Tramways, which at present deal with the entire traffic on the very busy No. 4 route (Fig. 126).

This is the lightest and most powerful tramcar so far built with such refined technical equipment and for such a high degree of comfort.

Experience with the cars of this type already supplied has been excellent. They run very quietly at all speeds and loads and take curves smoothly and noiselessly. The twenty-one starting and thirteen braking notches have proved to be sufficient to achieve smooth starting and braking with a high rate of acceleration and deceleration.

A large consignment of locomotives for which the Company built the electrical equipment was delivered a long time ago, but owing to the prevailing conditions could not be definitely accepted until last year. The contract covered twelve heavy express locomotives, axle arrangement (2 Co) (Co 2), for 1500 V d. c. and 1674 mm gauge. These locomotives were intended for the newly electrified Madrid-Avila and Segovia lines of the "Renfe" (Spanish State Railways). This order was placed with the general contractors, the Spanish firm Cia. Auxiliar de Ferrocarriles Beasain, in the autumn of 1935. Half of the electrical equipment was manufactured in the Company's workshops and half in those of the Maschinenfabrik Oerlikon from Brown Boveri drawings. These express locomotives are of practically the same construction as the twelve supplied to the now nationalized Spanish Northern Railway for the Irun-Alsasua line and which have proved very satisfactory. Compared to the earlier locomotives, however, the power has been increased by nearly 30 % and the axle loading from 16 to 17 t. On the maximum gradient of 35 in 1000 the locomotives have to haul a train of a total weight of 700 t at a speed of at least 55 km/h, and on gradients of 10—12·5 in 1000 a train of 1150 t at the same speed. Fig. 122 shows one of these 145 t locomotives which are rated 4200 H. P. at 61 km/h and have a maximum speed of 110 km/h. Special features of the locomotives are: The Brown Boveri individual axle articulated drives on both sides and inside the wheels, and the regenerative braking equipment with stabilizing

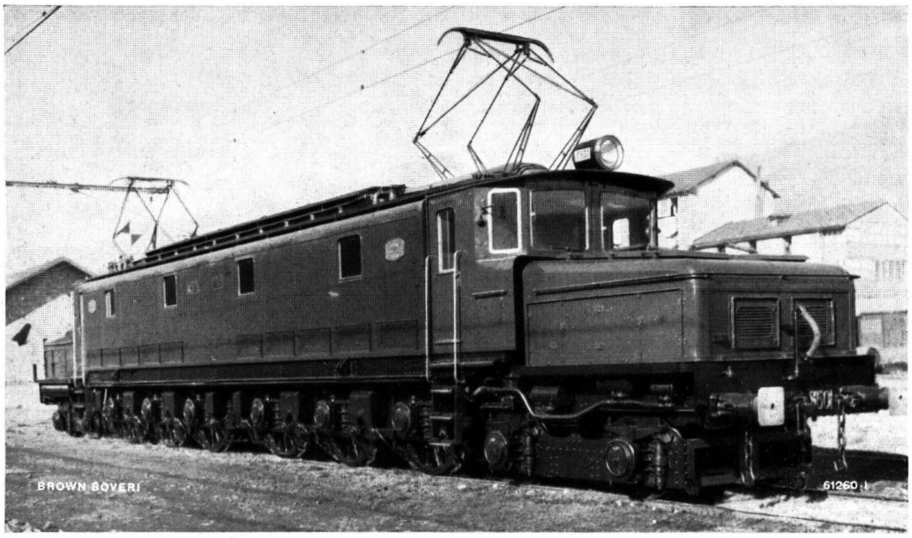


Fig. 122. — One of twelve similar, heavy express locomotives with axle arrangement (2 Co) (Co_2) for operation with 1500 V d. c. on the Spanish State Railway.

One-hour rating 6×700 = 4200 H. P. at 61 km/h, maximum speed 110 km/h.

motor developed by the Company and already applied with success.

A number of *battery-operated vehicles* were supplied during the period under review. The battery-operated industrial locomotive shown in Fig. 123 is for Gisikon Tile Works, the electrical equipment having been supplied to E. Stadler, Zurich, for installation. The motor has a rating of 6·8 H. P.; the radius of action is about 30 km per charge on the level with a trailing load of about 15 t and a tare of 2·7 t, including the battery.

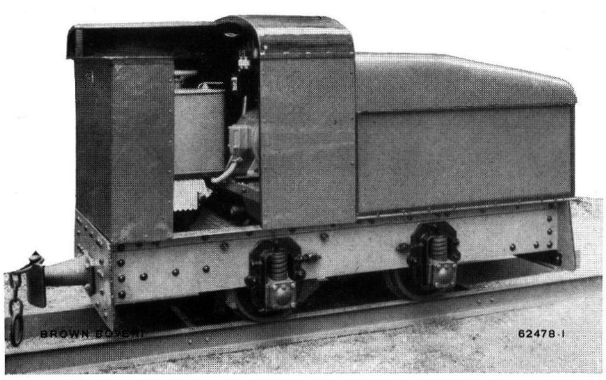


Fig. 123. — Battery-operated locomotive for a tile works.

Weight 2·7 t, one-hour rating of motor 6·8 H. P. The radius of action on the level with a trailing load of about 15 t is approximately 30 km. The conversion of existing Diesel and petrol tractors to battery drive is on the increase, which, apart from the shortage of fuel is in no small measure due to the reliability, cleanliness, and low cost of electrical operation.

Owing to the safe, clean, and cheap operation of these industrial and works locomotives there is an ever-increasing demand for the conversion of existing Diesel or petrol-driven tractors to battery-operated vehicles of this type.

The manufacture of *electric trucks* was taken up in 1940. These prove particularly useful for industrial premises, post-offices, harbours, railway stations, and municipal undertakings, when the battery can be charged during the night with low-rate excess energy. Three basic types of electric truck have been developed, these being characterized by an ingenious form

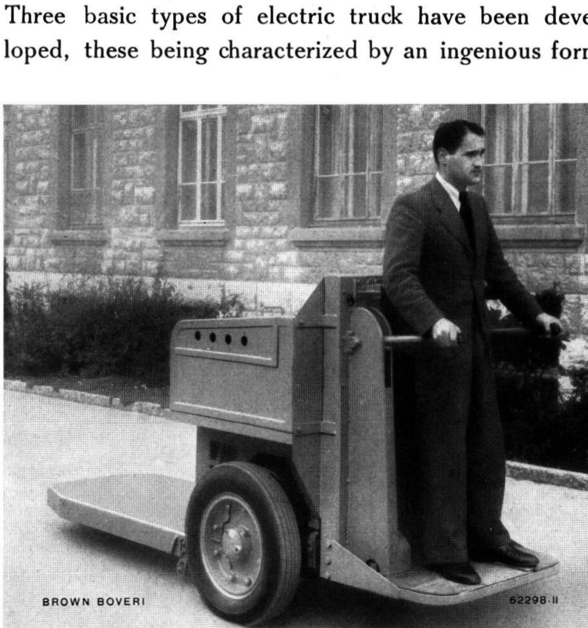


Fig. 124. — Low-lift electric truck.

In addition, apart from the already known platform electric trucks and tractors, the manufacture of high-lift electric trucks has also been taken up. For all of these vehicles the standard parts of the platform trucks, such as the robust two-motor driving axle with noiseless gear drive, combined electrical control and steering gear, and other equipment on the driver's platform, are used as far as possible.

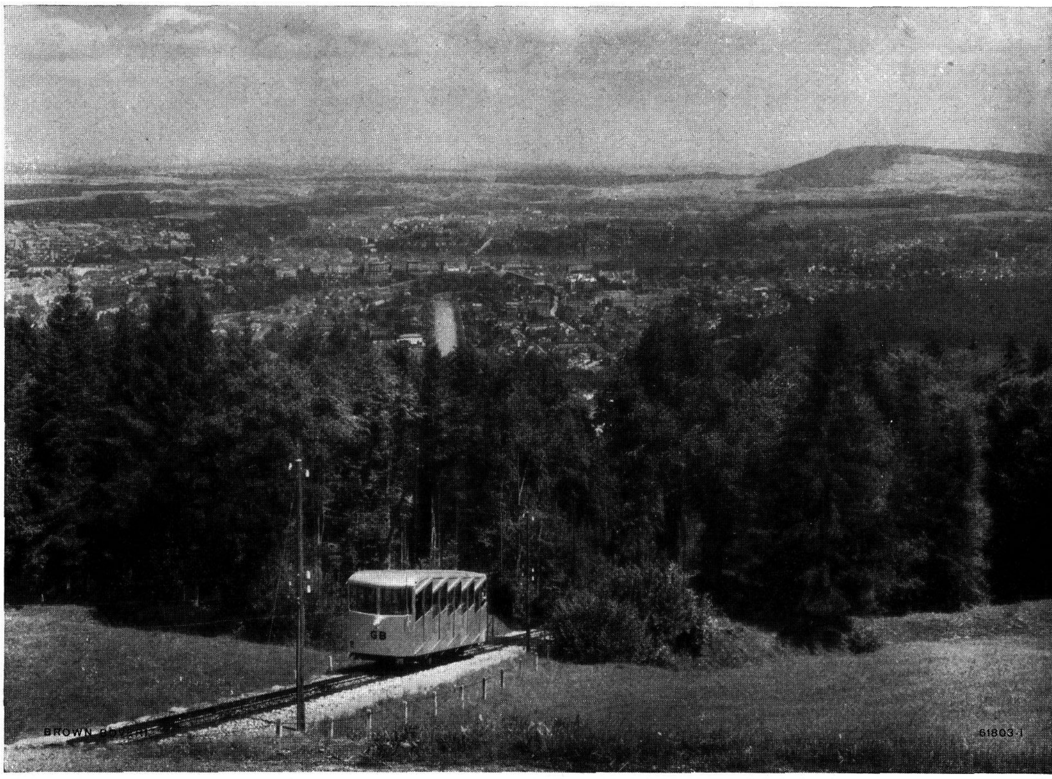


Fig. 125. — View of Gurten Railway with one of the modernized motor-coaches. In background the town of Berne.

By increasing the passenger carrying capacity of the cars and raising the speed the capacity of this funicular railway has been more than doubled. This involved increasing the power of the electric drive. The existing Brown Boveri 62 kW motor, which saw service for more than 45 years without trouble of any importance, has therefore been replaced by a 103 kW motor. At the same time Brown Boveri also changed the railway over to automatic service with remote control from the car, this being the sixth railway to be so equipped by the Company.

of steering combined with the electric control, a double motor capable of withstanding heavy overloads and designed to form a block with the rear axle, and the electrical differential.

This new type of drive operates practically noiselessly and is characterized by slight gearing wear and moderate maintenance costs. Fig. 124 depicts a low-lift electric truck supplied to the Balsthal Paper Mill during the year.

Apart from the standard types of electric trucks and electric tractors low and high-lift trucks have been developed and put in hand. As far as possible standard parts of the platform trucks, such as driving axles and driver's platform with apparatus and steering gear are utilized.

In the funicular railway field the modernization of the *Gurten Railway* is of particular interest. This railway was the second funicular railway with electrical drive to be taken into service in Switzerland in 1898. The driving motor was of the three-phase type rated 62 kW. During the more than 45 years of service no trouble of any importance was ever encountered. At the beginning of 1944, owing to the increased traffic, the railway was modernized by raising the power of the motor to 103 kW at 380 V and introducing automatic operation with remote control from the car. The operation of the railway now only requires two men, apart from the relief men. These control the entire driving equipment over a transmission line running along the track on telephone poles. Starting, running, and stopping are regulated by an electrically actuated cam-operated controller. The braking process in particular is so controlled with a d. c. braking dynamo and resistances that the cars practically always come to rest at the same point at the terminal and intermediate stations, immaterial of the loading of the cars. By increasing the passenger carrying capacity to 100 per car (instead of 60) and raising the speed from 2·0 to 3·3 m/s this approximately 1 km long railway can now transport on the average 800 persons instead of 360 per hour, while the travelling time has been reduced from 9 to 5 $^1/_2$ min (Fig. 125).

The Company specialize in automatic equipment for funicular railways, the Gurten railway being the sixth system to be so equipped in Switzerland.

Fig. 126. — Lightweight tramcar series 401 with trailers on the Zurich Municipal Tramways.

This car is doubtless the most modern of its kind in Europe. Notwithstanding the degree of comfort afforded and the high power of its four motors (total one-hour rating 240 H.P. at 600 V) its weight empty of 13·4 t is remarkably low.

In the *Diesel-electric traction* field turbo-charged Diesel engines are increasingly being employed.[1] Exhaust turbo-charging boosts up the engine power to such an extent that all present traction problems can be solved with such engines and it is therefore playing a big part in the present development of lightweight high-power Diesel-electric rail vehicles. Even for medium and low powers it is difficult to conceive Diesel engines without turbo-charging in future.

B. GAS TURBINE LOCOMOTIVES.

The Brown Boveri gas turbine locomotive was in regular daily service for nearly 300 days on the Stein-Säckingen section until the summer of 1944 and during this time covered more than 50,000 km. It had then, unfortunately, to be withdrawn from service owing to the lack of oil fuel. During the said period the locomotive fully proved its serviceability and fulfilled the specified conditions. It was, therefore, definitely taken over by the Swiss Federal Railways on October 1st, 1944.

Particulars of the gas turbine locomotive were published in the reviews of progress for the years 1942 and 1943.[2] Interested parties are referred to these. The gas turbine is likely to become of considerable importance for locomotive work especially in districts where long journeys have to be accomplished and cheap oil fuel is available, but there is difficulty in obtaining water.

In view of the importance which the Company attaches to the gas turbine, work has been continued on its development. This development work was concerned mainly with increasing the power output and it was found possible to increase the output of the power plant which can be mounted on one locomotive to 4000 H.P.

[1] See pp. 59—61 of this number.

[2] Brown Boveri Rev., 1943, Nos. 1/2, p. 58.
Brown Boveri Rev., 1944, Nos. 1/2, p. 85.

V. HIGH-FREQUENCY AND COMMUNICATIONS ENGINEERING.

This sphere of activity was dealt with in detail in the Special High-Frequency Engineering Number of the Brown Boveri Review of September, 1944, so that attention can be confined here to a brief survey of the subject matter treated in that issue.

A copiously illustrated article contained information about the essential details of our special transmitters for wireless broadcasting and long-distance telephony and telegraphy. Such transmitters were manufactured first for short and medium wavelengths. In addition, short-wave transmitters were built for long-distance telephony and telegraphy which are specially suited to transoceanic communication. All these transmitters have given an excellent account of themselves during the time they have been in service.

Fig. 127. — Part of a machine and erection shop for transmitters in the Company's factory for high-frequency equipment. The manufacture of such products, which require little material but a large number of working hours, is especially desirable on account of the difficult position of Switzerland with regard to raw materials and in view of her highly skilled workmen.

The activity of the Company in the field of ultra-short-wave and decimetre-wave transmitting and receiving equipment forms the subject matter of two articles in the special number. It may be added that work in this field, especially for wavelengths below 1 metre, is being carried on intensively and with good results. In a short time information will be published about special, relatively simple decimetre-wave sets, which are destined to attain a position of considerable importance in communications engineering, mainly for civil purposes, and which should open up new fields of application.

As it has always been the Company's aim to develop new processes for the heat treatment of industrial materials, attention has been devoted for a long time to the industrial applications of high-frequency engineering. Articles on the hardening of plastics in high-frequency fields and on the surface treatment of metals with special reference to the surface hardening of steels have been published. In this connection it may be mentioned that in recent months valuable results have been obtained with the high-frequency hardening of synthetic resins which will be of interest to the industry concerned. Also for the hardening of steel parts, new tests have yielded results on the basis of which orders were received from Swiss firms at the end of last year. Brief mention may also be made of tests with high-frequency for the regeneration of rubber.

Two articles were devoted to work in connection with large and small sealed-off transmitting valves. The plans made some years by the Company ago to manufacture special valves to its own designs, primarily for its own plants and sets, have already proved to have been laid on a sound logical basis. If these valves, especially those for very short wavelengths, could not be produced to-day it would no longer be possible to deliver ultra-short-wave and decimetre-wave directional wireless sets in view of the difficult conditions prevailing on the international valve market. Apart from this consideration, the manufacture of special valves was also justified from a purely technical point of view in order to be able to produce sets with special characteristics according to new ideas. As a typical example attention is drawn to the previously mentioned directional wireless communication using wavelengths below 1 metre.

Information about the essential components of the Company's communication equipments was given in the reports concerning research and developmental work on the construction of filters. Great interest was shown, for example, in new electrical filters, using piezo-electric crystals cultivated according to methods based on the work of Prof. P. Scherrer, which possess other properties than those filters employing natural crystals. Research on piezo-electric crystals is proceeding. On the one hand, the final design details of complete piezo-electric crystal filters which can be inserted in a set as unit components in a similar manner to ordinary valves are being concluded. Parallel to this work, which is more a matter of pure design, research work is also being continued with other crystals than those already examined.

Modulation transformers, which form an important component of the large transmitters with plate modulation of a class C, high-frequency output stage, have been the subject of theoretical treatment from a new standpoint, and their manufacture has provided units giving excellent results in practice. Further details of these transformers and also of new high-frequency impedance matching units, of electrical filters composed of coils and condensers, and of the high-quality powdered-iron cores necessary for such filters are to be found in the previously mentioned special number of this journal.

Fig. 128. — Assembly of small and medium-size valves up to 1 kW.

The various components of the valves, such as cathode, grid, plate and connecting leads, are assembled in this room to give complete internal units for valves. In the foreground can be seen a grid winding machine for the series production of grids for small valves. The development of high-frequency sets for new fields of application also compelled the Company to manufacture the necessary special valves, particularly as the purchase of valves from other manufacturers became more and more difficult during the war.

Information concerning work on carrier current communication for electricity supply systems, comprising telephony and supervisory control, is contained in the number of this journal issued in October, 1944. Interesting orders have recently been received for this type of equipment including some from abroad. The plants in service in Switzerland have proved thoroughly satisfactory. Developmental work is being carried on in this field also and many extensive practical tests are still necessary in order to clear up, amongst other problems, certain questions in connection with propagation conditions. In the number of this journal published in November, 1944 an article on this subject appeared which dealt with the influence of hoar-frost on the propagation of high-frequency waves along high-voltage transmission lines. The demand on the part of electricity supply organizations for equipment for supervisory control, telemetering, and remote regulation over power transmission lines, pilot lines or in conjunction with directional decimetre-wave sets is becoming more and more pronounced. A special article is to be devoted to this subject at a later date.

chassis and earth connections, disposition of the smaller components, etc. It is consequently the duty of the engineer in charge of the test room to control manufacture in such a manner that the completed set fulfils the demands made on it.

For these reasons, special methods of testing are necessary. The workshops test all components and complete sets for correct manufacture according to design. All parts which can affect the good behaviour of the set in service are submitted to the test room for mechanical and electrical checking according to a previously determined test programme.

Fig. 129. — View of one of the workshops in the Company's factory for high-frequency equipment.
Small wireless sets are wired in this shop. Interesting orders have already been booked for large series of sets.

In order to give readers some idea of the severe demands which have to be met in *testing small wireless sets,* the following description is included:—

It is required of small wireless sets for military and commercial purposes that they should work reliably, according to the use to which they are put, despite vibration, moisture and extremes of ambient air temperature and barometric pressure. Dimensions and weight must be confined to a minimum. The numerous components which go to make up a wireless set, such as resistors, condensers, coils, valves, etc., are therefore generally assembled in light alloy housings. The electrical connections require a comprehensive system of wiring with numerous soldered joints (Figs. 129 and 130).

In contrast to apparatus for power current, the behaviour of a wireless set in service is vitally affected by details which cannot be exactly considered in advance on the drawing board, such as wiring layout,

Testing is carried out in accordance with test specifications which prescribe the mechanical checks and the permissible limiting values for the electrical tests in such a manner that the completed set must of necessity fulfil the guaranteed conditions stipulated. For the larger component units and for complete sets, it is worth while, in case of series manufacture, to provide special testing appliances which ensure a rapid and, above all, reliable testing routine (Fig. 131).

The most severe demands are most certainly those made on aeroplane wireless sets, which are exposed to continuous vibration and rapidly changing climatic conditions. Of the numerous tests, the following paragraphs contain a brief description of how and with what auxiliary appliances the suitability of the sets for these special conditions is checked.

The behaviour of a set under the influence of vibrations is revealed by the *vibrating table* (Fig. 132), the table-top, to which the set to be tested is fastened by screws, being caused to execute sine-wave oscillations by means of a motor and eccentric weights. The amplitude and frequency of the oscillations can be varied between about 0 and 1 mm, and 0 and 70 cycles per second respectively.

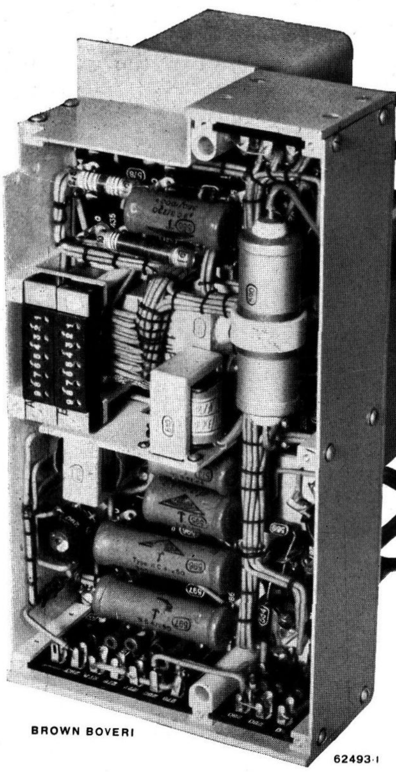


Fig. 130. — Rear view of a modulation amplifier for a transmitter as an example of the complex wiring of modern wireless sets.

Our high-frequency products are not laboratory assembled units but are sets of which the last detail is carefully designed and which are especially well suited for rational manufacture.

The sets are first of all subjected to vibrations of continually changing frequency for about 15 minutes in order to test their mechanical stability, and are then carefully examined for mechanical defects, especially for loose screws or components, badly soldered joints, etc. After the electrical tests, the sets are again mounted on the vibrating table, switched on as in normal service, and subjected to a vibration test with an amplitude and frequency corresponding to the actual conditions to be expected. During this test the set must not show any defects and, above all, it is required that frequency variations of a transmitter or receiver due to vibrations should remain within permissible limits, e. g. within $\pm$ 50 cycles per second for a telegraphy transmitter. This corresponds, for a frequency of 10 megacycles, to a variation of the capacity or inductance of the tank circuit of 10^{-5}, and is an indication of the severe demands which must be made on the stability of tuning condensers, coils, valves and wiring.

The constancy of behaviour under varying climatic conditions is examined by tests in an *air-conditioned cubicle* (Fig. 133), in which temperatures from -40^0 C to $+60^0$ C, humidities up to 100 % and barometric pressures corresponding to altitudes from 0 to 20,000 metres can be obtained at will.

The conditions in an aeroplane vary greatly within a short time, e. g. during a dive from a high altitude, the ambient temperature may rise in a few seconds from -40^0 C to $+20^0$ C with a simultaneous heavy deposit of dew on the cold parts of the set. This places very severe demands on the frequency stability. It is generally required that the frequency should not vary more than 0·003 % per ^{0} C, which means that the temperature coefficients of the condensers and coils in the tank circuits should be of the same order of magnitude. The housing of the tuning condenser, the coil formers, the shielding, etc., must be rigid and must not show any permanent deformation under the influence of temperature changes. The method of testing is determined by these requirements.

Chassis parts, tuning condensers, coils, variometers, etc., of the oscillator are artificially "aged" by means of repeated warming and cooling.

The tuning condenser or the variometer is built into a test oscillator and the temperature coefficient determined from the change of frequency when warmed up to about 60^0 C.

The complete set, for example a transmitter, is placed in the air-conditioned cubicle, switched on as in normal service and its mechanical and electrical behaviour examined as a function of varying temperature, humidity, and barometric pressure. The mechanical drives must not bind, the power output must not change, no flashovers must occur under reduced pressure and, above all, frequency variations must not exceed the permissible limits. The influence of ice and dew formation can be observed. If the transmitter is to be exposed

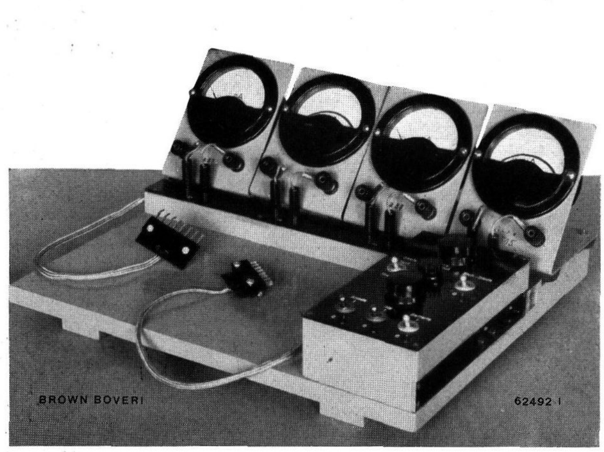


Fig. 131. — Unit for testing part of a receiver.

Testing of apparatus produced in large series must be carefully adapted to the flow of material through the factory in order to prevent stoppages.

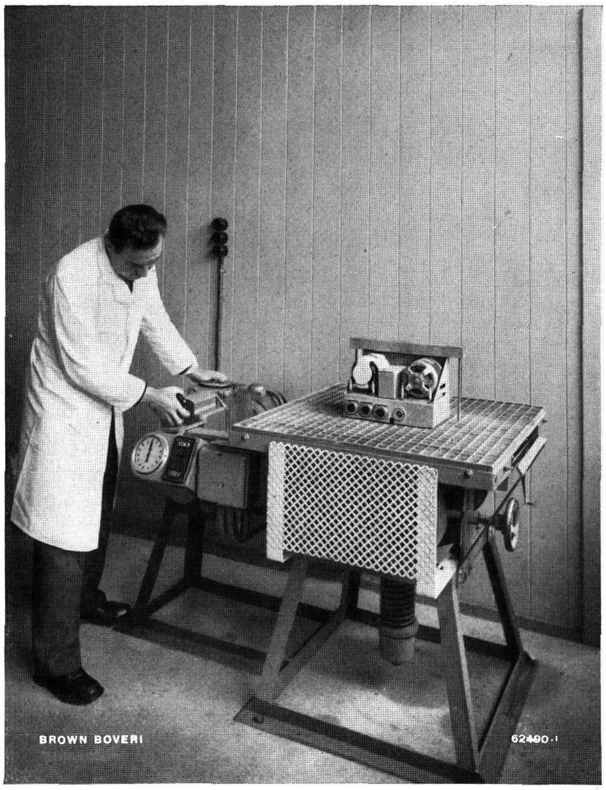


Fig. 132. — Vibrating table for testing wireless sets.
The table-top is made to execute sine-wave oscillations by means of a motor and eccentric weights. The frequency is adjustable from 0 to 70 cycles and the amplitude from 0 to 1 mm.

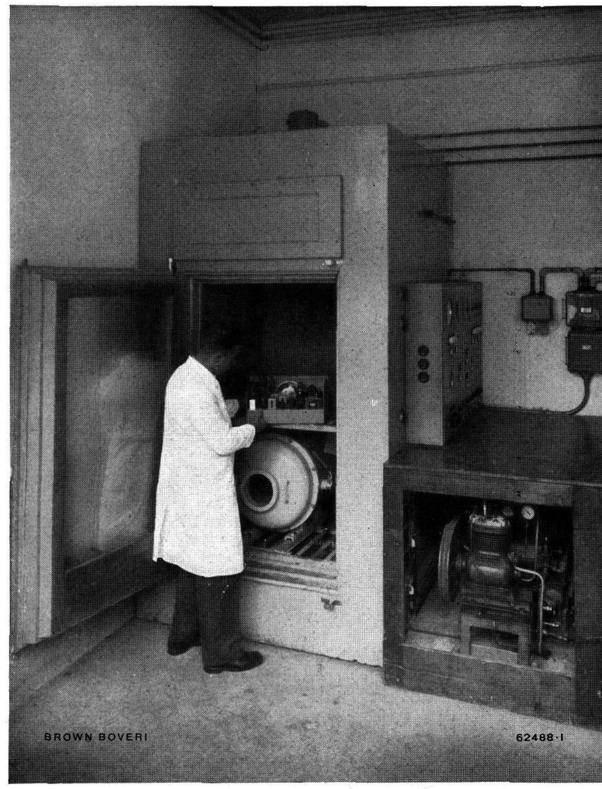


Fig. 133. — Air-conditioned cubicle with reduced pressure container for testing wireless sets.
The temperature can be regulated between $-40°$ C and $+60°$ C, the humidity up to 100 % and the air pressure corresponding to altitudes up to 20,000 metres.

to rain, it must also work reliably when sprayed with artificial rain.

In view of the fact that sets must successfully withstand these tests, it is naturally possible to give an extensive guarantee of their service reliability.

On the basis of carefully developed test plans, test specifications with corresponding test reports and appliances, it is thus possible to determine a test routine for every set, after passing which the set must of necessity satisfy the conditions imposed. The vibrating table and the air-conditioned cubicle are indispensable appliances for the testing of sets under conditions similar to those met with in practice.

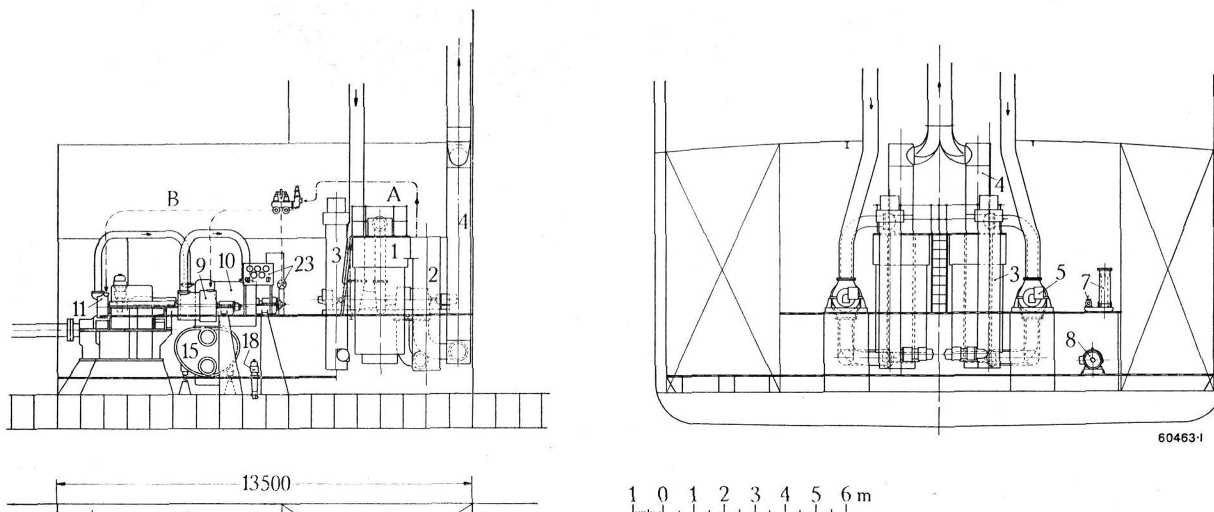
Fig. 134. — Testing tables for the electrical checking of valves.
Static and dynamic checks are made on these tables.

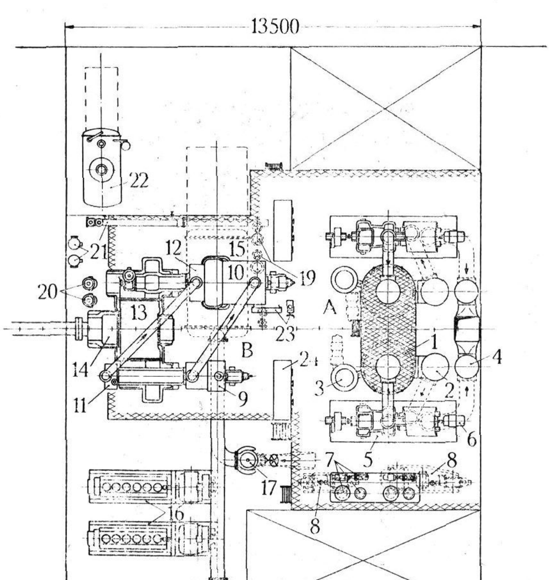
VI. MARINE EQUIPMENT.

A. VELOX STEAM GENERATORS FOR SHIPS.

Little has been heard during the past year of the Velox boilers supplied by the Company for ships, due to the fact that the ships in question have either been laid up or have been used for war purposes. An interesting report was, however, published in the April number of last year of the Bulletin of the Bureau Veritas [1] on the 30 t/h Velox boiler of the S. S. Athos II, in which the author writes on the experience obtained with the Velox installation and on its particular suitability for passenger ships. There has been no lack of projects for the post-war period. These projects have shown repeatedly how advantageously the Velox boiler can be installed and how extraordinarily simple and clear the complete

[1] Bull. Techn. du Bureau Veritas, April, 1944, p. 23. Brown Boveri Rev., 1944, No. 11, p. 367.





A. Boiler plant.

1. Combustion chamber with evaporators.
2. Superheater.
3. Separator with circulating pump.
4. Economizer.
5. Charging set.
6. Starting motor.
7. Fuel pumps, preheater and filter.
8. Feed pumps.

B. Main machine.

9. High-pressure turbine.
10. Low-pressure turbine.
11. Astern turbine (high pressure).
12. Astern turbine (low pressure).
13. Double gear.
14. Propeller thrust block.
15. Condenser.

C. Auxiliary machines and devices.

16. Diesel engines.
17. Cooling water pump.
18. Condensate pump.
19. Steam-jet air ejector.
20. Lubricating oil pumps.
21. Oil coolers and filters.
22. Raw water evaporators.
23. Control stand with measuring instruments.
24. Control and instrument board for the boilers.

Fig. 135. — Arrangement of a ship's drive with Velox boilers for a freighter of 6000 S. H. P.

The boilers together with the main driving machinery and the auxiliary machinery including two auxiliary Diesel engines of 120 H. P. each are in the same compartment and hence easily attended. Thanks to the small dimensions of the Velox boiler there is still a liberal margin of space, when the total boiler and engine room volume is less than 13 % of the gross volume of the ship. It should be noted that the Velox boiler does not require any large chimneys for the exhaust of the gases, a small pipe being sufficient. The efficiency of the Velox plant, including all auxiliaries, but without feed pump, is 92 %. The total weight of the Velox plant with $2 \times 12/16$ t/h boilers, together with all auxiliary machines and the exhaust pipe to the chimney, but excluding feed pumps, amounts to $2 \times 26 = 52$ t. The fuel consumption of the complete plant for a steam pressure of 40 kg/cm², temperature 400° C, and 28° C cooling water, is 270 g/S. H. P.

machinery installation becomes when the dimensions, the design, and the method of operation of the boiler make it possible to place the machinery and the boiler in the same room, as is nearly always the case with the Velox boiler. Both the machinery and the boiler can be observed from the control stand. Further, as the latter operates entirely automatically the attendance is reduced to a minimum.

sets of Diesel engines of which far more than 1000 units of the most varied sizes are in operation in ships.

Further it might be mentioned that with the Velox there is no special need to keep the steam pressure low. If in the most modern ships the steam pressure is still limited to 32 kg/cm^2, it is because more simple operation is expected with such a pressure, and especially in order to economize on the cost of tube material. In the case of the Velox boiler the active heating surfaces are so small that the extra costs for a somewhat higher quality material do not play an important part. On the contrary it will be advantageous to choose a higher pressure (50—70 kg/cm^2), especially when the propelling machinery consists of turbines, in order to obtain high efficiencies and hence low fuel consumptions.

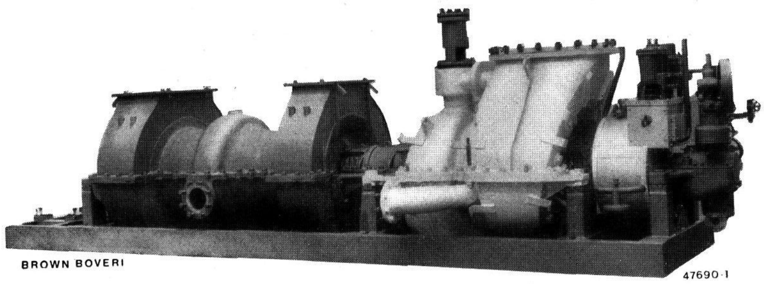


Fig. 136. — Supercharging set for a Velox marine boiler.

This supercharging set is for specially high charging pressures (up to 3·2 kg/cm^2), such as come into consideration for forced boilers. For rapid acceleration the set is provided with a steam turbine as auxiliary and regulating machine.

As already mentioned on page 4, various definite confirmations of the reliability of service of land installations have recently been received. It is certainly permissible to consider this experience with land installations as a guide for marine installations because operation in ships is in no way rougher than in many land plants and there is no difference in the design of the boiler. It is true that a special design[1] which is suitable in cases where a small weight and height are necessary, or where both the pressure and the output are high (over 75 kg/cm^2 and 100 t/h) has been developed. But in this design also, which is really only a different arrangement, the individual parts are the same as in the standard arrangement. It is recalled incidentally that the only trouble had with the Velox boiler, namely the obstruction of the gas passages by means of ash in the case of fuels containing a large amount of ash, has long been overcome by returning to the old arrangement with a separate superheater.

One machinery part which has continuously rendered good service is the supercharging set (Fig. 136). This is emphasized because as an unusual element in boiler installations, it sometimes give rise to doubt in the minds of conservative marine engineers. In this connection it might be recalled that engineers have also become accustomed to the supercharging

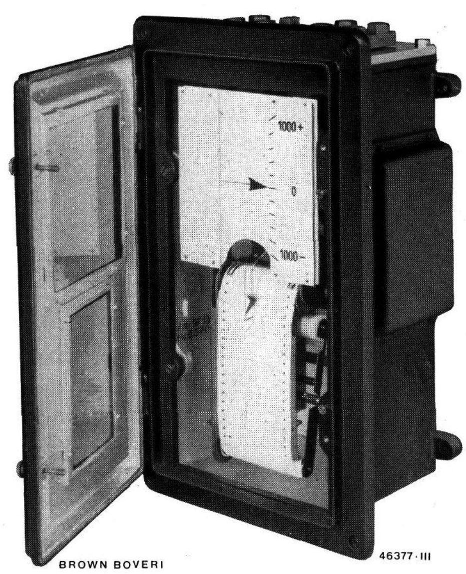


Fig. 137. — Nivometer for indicating the water level in steam boilers.

The instrument indicates and records the water level. It can be mounted in any convenient place near the boiler. By means of adjustable contacts it is possible to operate an alarm device when the water level is too high or too low. The instrument has neither diaphragms nor glands and, therefore, requires practically no maintenance. It has proved specially satisfactory on ships.

[1] Brown Boveri Rev., 1942, Nos. 9/10, p. 251.
Brown Boveri Rev., 1944, Nos. 1/2, p. 5.

1. *Nivometers.*

A product, which has been well received in shipping circles, is the Nivometer, an instrument for indicating and recording the water level in boilers. A naval authority has purchased forty-seven of these in a short time. This instrument (Fig. 137) is accepted by boiler supervising authorities as a second water level indicating device. It consists of a U-shaped tube of non-magnetic steel. The tube is partly filled with mercury. An iron ball floats on the surface of the mercury and the movement of this ball is followed by the poles of a permanent magnet which is pivoted outside the U-tube and operates the indicating and recording mechanism. The part which is under the boiler pressure is completely closed, i.e. there is no gland or bushing of any kind, which makes the instrument also particularly suitable for very high pressures.

B. MARINE TURBINE INSTALLATIONS.

In projecting steam turbine propelling plant for ships, where the operating conditions are not specified, the Company always endeavours to design the plant in such a manner, that the operating costs are not higher than for a normal marine Diesel engine plant. For this purpose, it may be assumed that the average price of bunker oil amounts to about two-thirds of that of Diesel oil and that the lubricating costs of the Diesel engine amount to about 10 % of the fuel costs. On this basis, the fuel oil consumption of the steam plant must be about 275 g/B.H.P.h if the operating costs of the two types of machinery

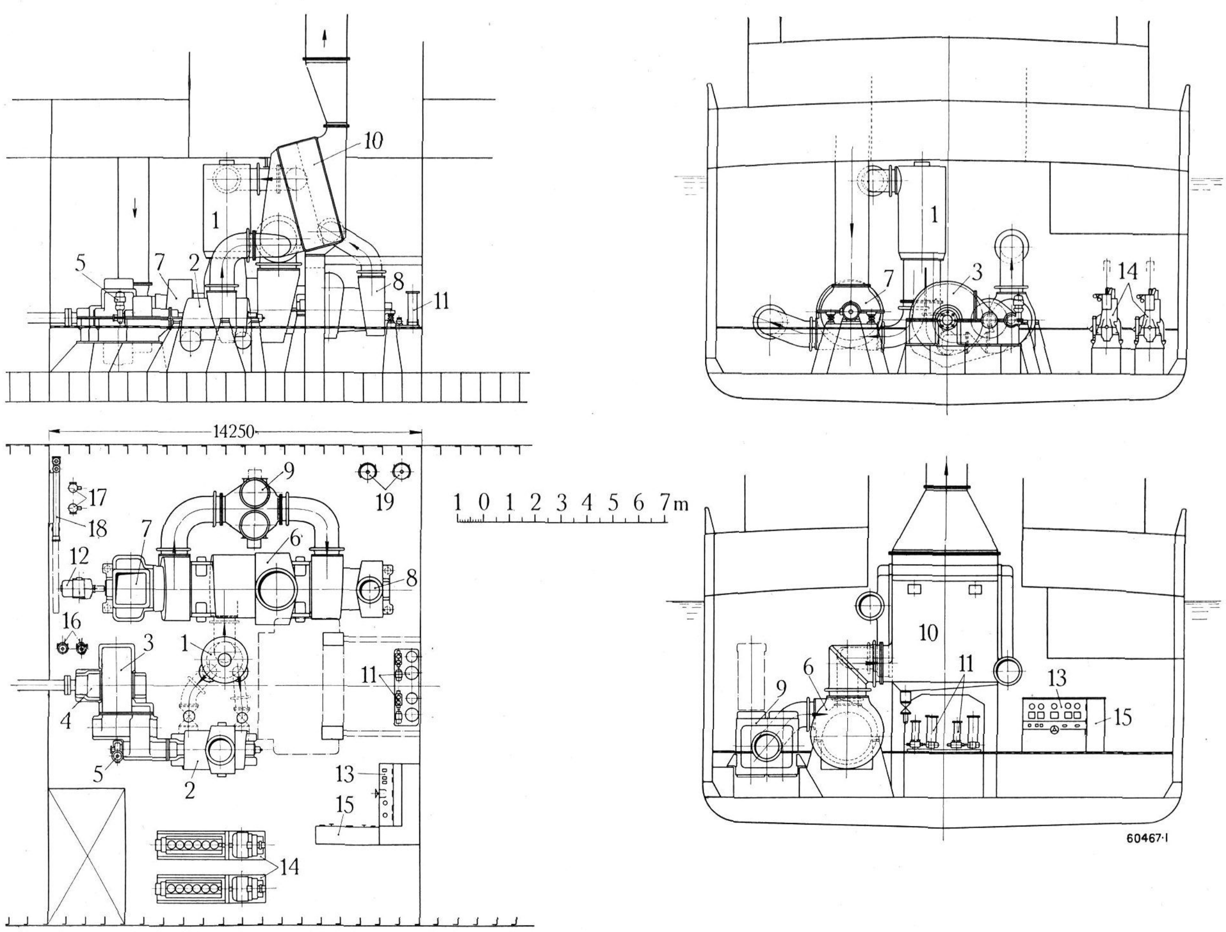


Fig. 138. — Combustion turbine plant of 6000 H.P. output for a merchant ship.

The driving gas for the useful power output turbine and for the turbine driving the compressor is supplied by the same combustion chamber. The fuel consumption obtained with a relatively small recuperator and with single-stage recooling of the air is 260 g/S.H.P.

1. Combustion air.
2. Useful output turbine (this embodies also the astern turbine)
3. Double gear.
4. Propeller thrust block.
5. Shaft rotating device.
6. Driving turbine for compressor.
7. Compressor I
8. Compressor II
9. Intermediate cooler.
10. Recuperator (air heater).
11. Fuel pumps, filter and preheater.
12. Starting motor.
13. Control desk.
14. Diesel generators.
15. Distribution board.
16. Lubricating oil pumps.
17. Lubricating oil filter.
18. Lubricating oil cooler.
19. Cooling water pumps.

are to be the same. A fuel oil consumption of 275 g/B.H.P.h corresponds to a plant efficiency of 23 %, a figure which, in the case of land plants, is not considered especially high, and which can just as easily be attained in marine plants if modern land practice in regard to pressure and temperature is followed.

Certain tendencies in this direction could definitely be noted last year. The proposal of English shipbuilders to employ in future a steam pressure of 32 kg/cm² and a steam temperature of 400 °C with boilers having 85 to 86 % efficiency is already an advance. These values are, however, insufficient to enable the required fuel oil consumption to be attained under unfavourable circumstances, for instance, when the temperature of the cooling water is high. The pressure must be higher and the boilers must be still more efficient. High pressures and especially high temperatures make it, however, necessary to use turbines.

In regard to marine turbines nothing much need be reported. The most important facts were published not long ago [1] and since then there has not been anything special to report. The new auxiliary turbines (p. 7), however, which, because they can be used for high steam pressures and temperatures represent the simplest and most reliable driving machine for all ships' auxiliaries, are worthy of special note.

C. THE COMBUSTION TURBINE FOR SHIP PROPULSION.

When in 1938, on the basis of serious studies and tests, the prospects of the gas turbine were for the first time announced [2] to the public and when in 1939 the first practical result [3] of these studies and tests could be shown — this was the 4000 kW combustion turbine shown at the Swiss National Exhibition — few people believed that the gas turbine would have to be reckoned with as a prime mover in the near future. Shipbuilders especially, who generally will only consider machinery which had at least proved itself for a long time on land, could not be expected to show more than a theoretical interest in the gas turbine. As, however, can be noted from reports in the English technical press, not only has a commission been created in America to study the application of the gas turbine to ships, but according to the same source, four gas turbines have already been ordered from various firms in order to make a start. Brown Boveri also have a number of serious projects under study. It may, therefore, be assumed that the gas turbine will also be found in ships at a not too distant date.

Combustion turbine plants for ships have already been illustrated and described in their principal details in previous publications. [4] The illustrations on the opposite page refer again to a 6000 S.H.P. installation for a freight ship. The installation comprises two turbines and two-stage compression with intercooling but with only one combustion chamber. One turbine drives the compressor, the other turbine delivers the useful output. This turbine unit also embodies the reversing turbine. The fuel oil consumption with the relatively small recuperator of 1450 m² heating surface corresponding to ¼ m²/H.P. is 260 g/S.H.P.

If it is assumed that the price of bunker oil is two-thirds of that of Diesel oil, the operating costs of the gas turbine plant illustrated will be the same as those of a good Diesel engine installation. In regard to weight and space taken up, the gas turbine is more advantageous than the Diesel installation. The same may be expected to apply to the initial costs and to the maintenance costs.

Bunker oil was deliberately mentioned as the fuel coming into consideration, in contradiction to the suggestions made during a discussion on gas turbines in America. According to the Company's experience, cheap bunker oil is quite suitable for gas turbines and does not need to be replaced by gas oil or Diesel oil. As has been reported under Section C "Combustion Turbines", in gas turbine locomotive service no difference has been found between operation with gas oil and operation with heavy oil; both are suitable and have been consumed without causing any harmful consequences. This considerable freedom in regard to the choice of the kind of fuel is an important advantage of the Brown Boveri combustion turbine.

Up to the present, projects have been based on the use of a propeller with fixed blades and of a reversing turbine incorporated in the useful output turbine. A better solution is, however, provided by the variable pitch propeller. Now that the A. B. Karlstads Mekaniska Werstad, Karlstad, has been able

[1] Brown Boveri Rev., 1942, Nos. 9/10, p. 227.
Brown Boveri Rev., 1943, Nos. 1/4, p. 66.

[2] Brown Boveri Rev., 1939, No. 6, p. 127.

[3] Brown Boveri Rev., 1940, No. 4, p. 79.

[4] Brown Boveri Rev., 1942, Nos. 9/10, p. 239.
Brown Boveri Rev., 1944, Nos. 1/2, p. 96.
Brown Boveri Rev., 1944, No. 10, p. 350.

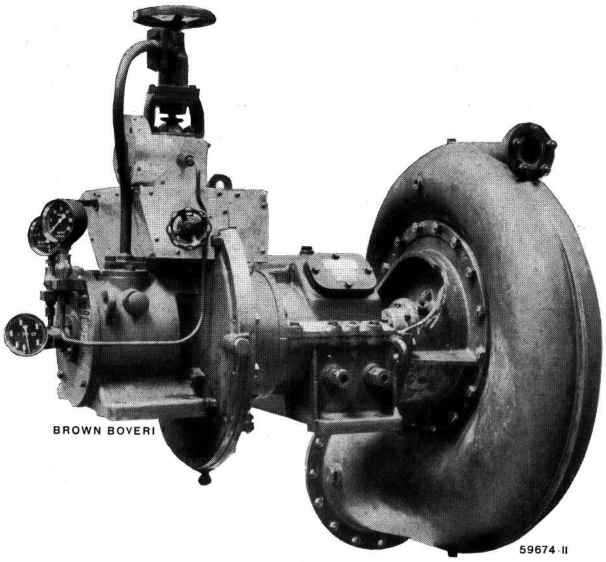


Fig. 139. — 60 H. P. small turbine with reduction gear for 5000/750 r. p. m. for driving a ship's cooling water pump.

Starting and attendance of the set are as simple as with an electric motor.

to build variable pitch propellers for twice 3500 S. H. P. and to apply them with success on an ocean-going steamer (Suecia) of 7000 H. P. in service between Sweden and the U. S. A., the use of such propellers in connection with gas turbines can soon be reckoned with.

D. GEARS FOR SHIP DRIVES.

It is already known that the Company builds large marine gears and has supplied the largest existing gears for transmitting 80,000 S. H. P.[1] No opportunity of doing any such work presented itself during the past year. A large number of smaller gears, however, were built so that the total number of gears supplied now exceeds 2500. The total power transmitted by these gears exceeds $3^1/_2$ million H. P. The well-equipped gear workshops of the Company, which are provided with special machines, are able to execute any order received in regard to both quality and quantity.

E. SHIP AUXILIARIES.

As already mentioned in the section on small turbines (p. 7, Fig. 10), the series of small turbines has been completed by the addition of further types for outputs up to 500 H. P. These turbines, due to their simplicity and to their appropriate design, are particularly suitable for use in ships. In regard to reliability and simple attendance, they are fully equal to electric motors. Compared with the old reciprocating engine auxiliaries, they have the great advantages of higher economy, of absence of oil in the exhaust steam and of smaller space requirements. They can also be operated by high pressure steam so that as far as they are concerned, it is not necessary to keep to low steam pressures in ships.

These new small turbines embody an impulse wheel with a single row of blades; the shaft is supported

[1] Brown Boveri Rev., 1942, Nos. 9/10, p. 276.

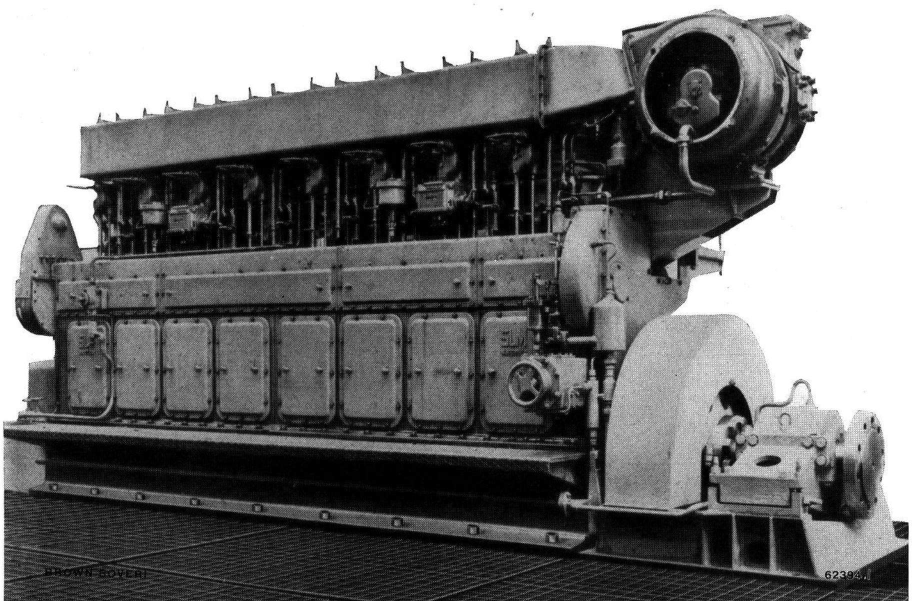


Fig. 140. — Four-stroke Diesel engine of the Swiss Locomotive and Machine Works, Winterthur, for driving a ship of 1200 S. H. P. provided with Brown Boveri turbo-charger operating on the Buchi principle.

The charging set enables the output of the engine to be increased by about 50%. As it was possible to mount the charging set directly above the flywheel, a very compact arrangement was obtained.

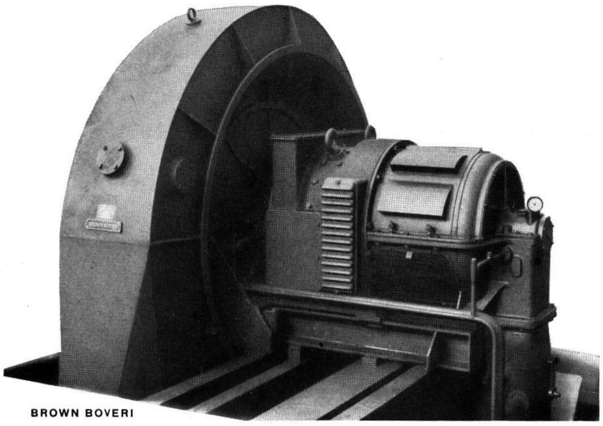


Fig. 141. — Scavenging blower for 1300 m³/min, 1·033/1·263 kg/cm², 2250 r. p. m., driven by a direct-current turbo motor of 580 kW.

The blower wheel is mounted overhung on the shaft extension of the motor in order to make the length of the set as short as possible. The largest scavenging air blowers driven by direct-current turbo motors supplied for two-stroke marine Diesel engines were built by Brown Boveri.

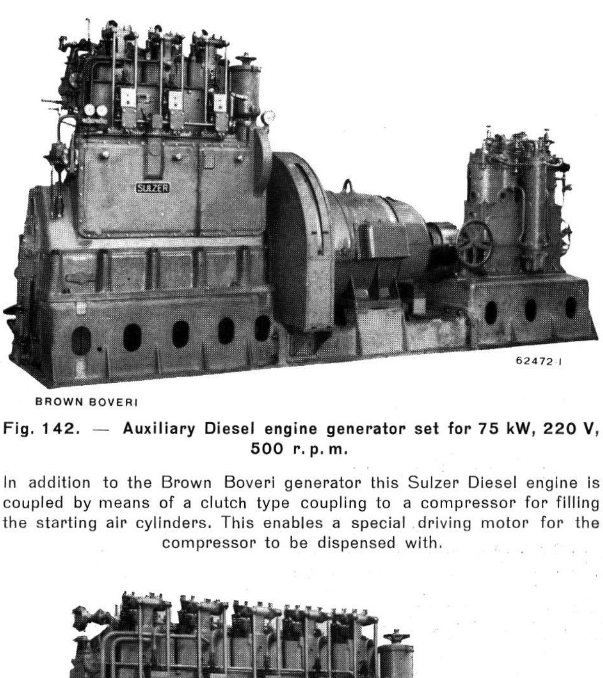


Fig. 142. — Auxiliary Diesel engine generator set for 75 kW, 220 V, 500 r. p. m.

In addition to the Brown Boveri generator this Sulzer Diesel engine is coupled by means of a clutch type coupling to a compressor for filling the starting air cylinders. This enables a special driving motor for the compressor to be dispensed with.

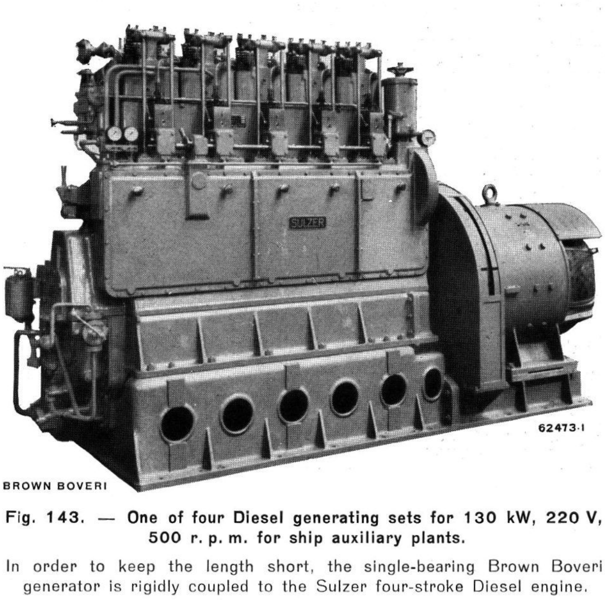


Fig. 143. — One of four Diesel generating sets for 130 kW, 220 V, 500 r. p. m. for ship auxiliary plants.

In order to keep the length short, the single-bearing Brown Boveri generator is rigidly coupled to the Sulzer four-stroke Diesel engine.

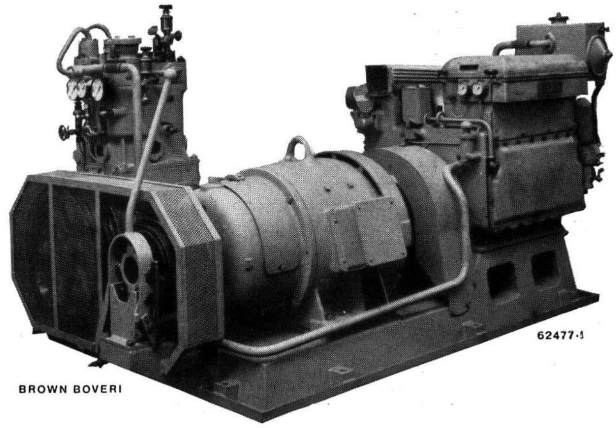


Fig. 144. — Compact arrangement of the ship auxiliary set. The 36 kW, 220 V, 1000 r. p. m. Brown Boveri direct-current generator is coupled to a 60 H. P. two-stroke opposed-piston Sulzer Diesel engine.

The free end of the generator shaft drives a Sulzer compressor by means of a pulley provided with a clutch.

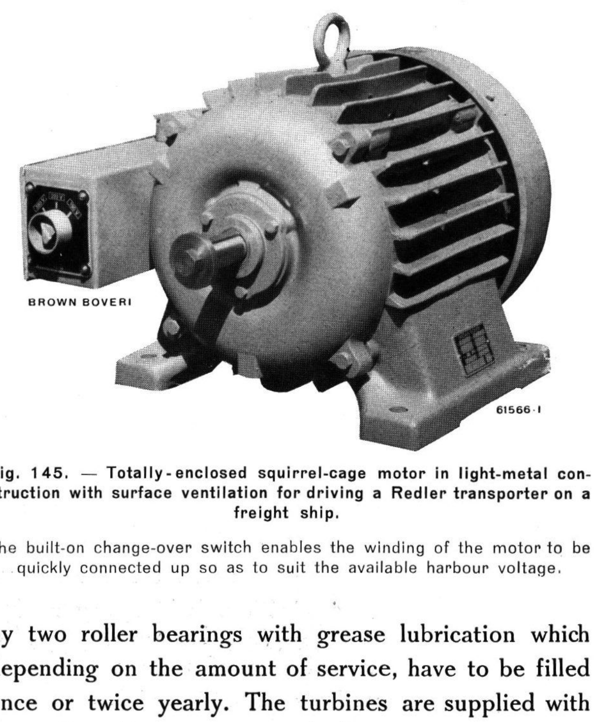


Fig. 145. — Totally-enclosed squirrel-cage motor in light-metal construction with surface ventilation for driving a Redler transporter on a freight ship.

The built-on change-over switch enables the winding of the motor to be quickly connected up so as to suit the available harbour voltage.

by two roller bearings with grease lubrication which depending on the amount of service, have to be filled once or twice yearly. The turbines are supplied with a mechanical governor and with an independant overspeed protecting device except in cases when the type of machine driven makes one or other of these devices unnecessary.

An important ship auxiliary is the Brown Boveri exhaust gas turbo-charger for increasing the power of four-stroke Diesel engines both for the main driving engines and for auxiliaries (Fig. 140). The use of supercharging enables the weights and the space requirements of the engine to be considerably reduced, thus enabling the four-stroke engine to compete again with the two-stroke engine. The low-pressure supercharging process used up to the present has enabled the output of ships' Diesel engines to be increased up to 60 %; with the high-pressure super-charging process it is possible to obtain power increases up to 100 %.

Up to the present over 1200 ships have been equipped with the Company's superchargers. The individual powers vary between 150 and 5500 H. P.; the total output of the supercharged engines amounts to over 1·2 million H. P. Among the largest supercharged ships' Diesel engines are the four ships of the Silver Line for which the superchargers were supplied already in 1929. These are mentioned again here because during the recent overhaul of the machinery equipment of one of these ships it was found that the superchargers which had been in service for more than fifteen years were still in the same excellent condition as when they were supplied.

Apart from supercharging blowers for four-stroke Diesel engines, mention should also be made of scavenging blowers for two-stroke engines driven by turbo-motors and which should find use in various post-war installations. Scavenging blowers with electric motor drive are employed mainly in ships which possess a large auxiliary electric power system and operating under conditions enabling the blowers to be electrically driven without having to increase appreciably the power of the plant installed. The Company supplied the largest scavenging blowers for ships driven by direct-current electric motors yet built, namely for the big motor-ships "Oranje" (3×12,500 S. H. P), "Saturnia" (2×14,000 S. H. P.) and "Stockholm" (3×11,000 S. H. P.). The driving machines of these scavenging blowers are direct-current turbo-motors of specially compact and light design (Fig. 141).

In spite of the limited possibilities of delivery orders were also received during the past year for the complete electrical auxiliary equipment for ships, among which were fourteen Diesel generators of 75 kW, 220 V, 500 r. p. m. for rigid coupling with Sulzer Diesel engines. Two of the Diesel engines per ship drive not only the generator but also a compressor which is connected to the second shaft extension of the generator through a clutch coupling (Fig. 142). This makes it possible to do away with the electric motor otherwise usually employed for driving the compressor, thus appreciably reducing the auxiliary electric power. Fig. 143 shows one of four Diesel generators of 130 kW, 220 V, 500 r. p. m., of single bearing design, supplied for rigid coupling with Sulzer four-stroke engines, an arrangement which reduces the length of the Diesel sets to a minimum. Another set which was delivered during the past year is illustrated in Fig. 144. This set consists of a Sulzer 60 H. P. two-stroke opposed piston Diesel engine coupled to a Brown Boveri direct-current generator, the second shaft extension of

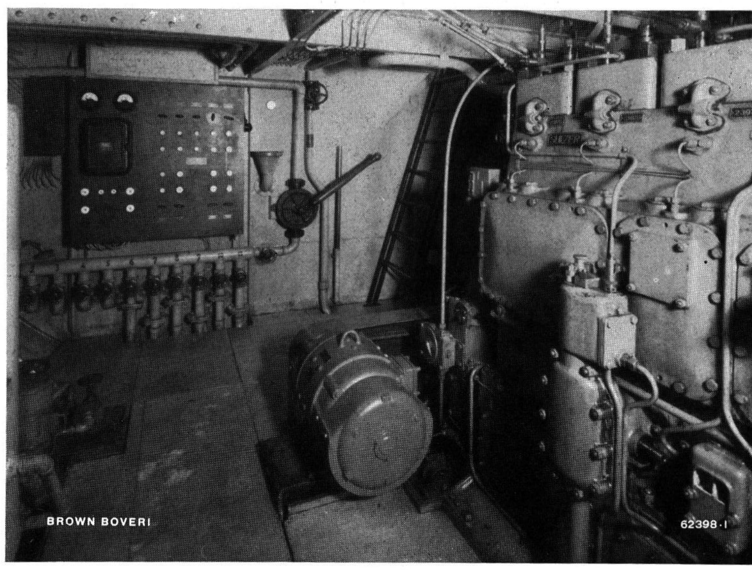


Fig. 146. — D. C. generator for a 6·5 kW, 110 V, ship's lighting plant, Helux system, driven from the propeller shaft.

The plant consists of distribution switchboard with automatic voltage and charging regulator for automatically connecting and disconnecting the dynamo from the lighting network, for regulating the voltage at varying propeller speeds and for loading and controlling the charging of the battery. Up to the end of 1944 over 1000 automatic voltage regulators, current regulators or automatic synchronizers for ships auxiliary power plants were supplied.

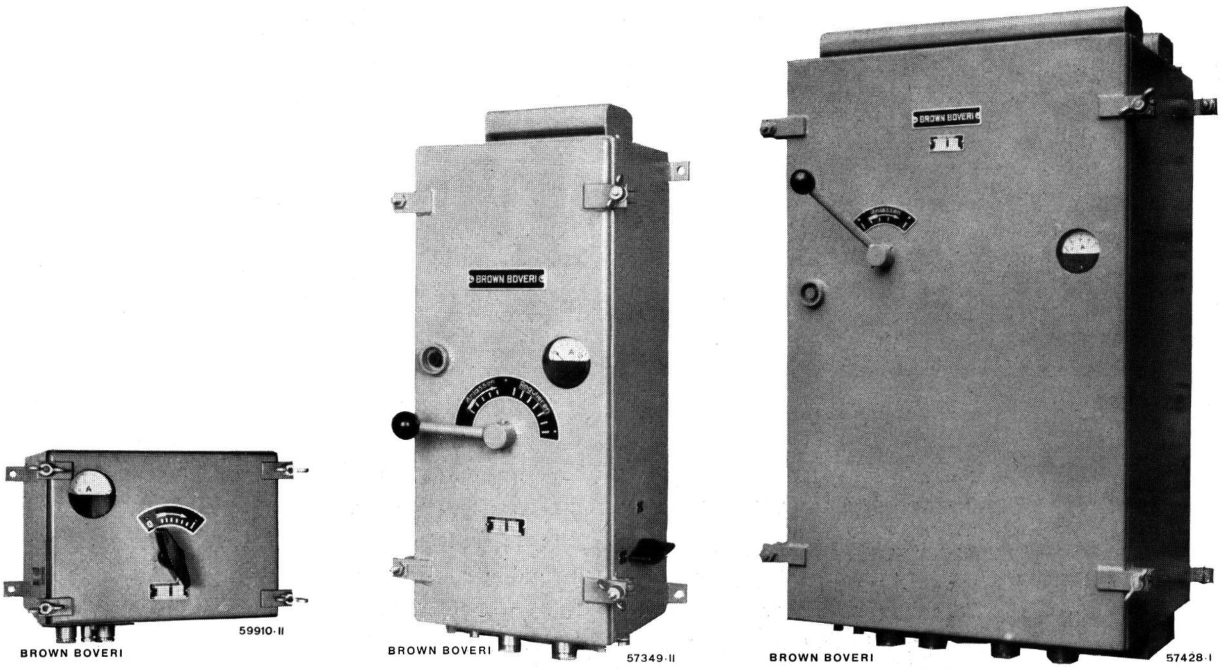


Fig. 147. — Marine-type starters for different sizes of direct-current motors.

The two smaller starters are of the face-plate type for a maximum of 35 and 75 A. respectively. In the case of the largest starter strong switching elements having a max. current capacity of 400 A. are operated by a cam shaft. All starters are provided with over-load, as well as no-voltage releases and can be supplied with isolating switches and ammeter.

which drives a Sulzer compressor through a clutch-pulley.

Among the orders received, mention may be made of a Ward-Leonard drive for a fishing net capstan gear allowing the same flexibility of operation as a reciprocating steam engine. For this purpose, the Ward-Leonard generator is provided with a strong differential compound winding, thus ensuring that the power absorbed by the capstan motor when, for instance, the net gets caught, is limited to an amount which is admissible for the supply system. An interesting order was also obtained for a large number of three-phase motors for driving transporters on freight ships (Fig. 145). As different voltages are available in the different ports, the motors for these transporters are provided with built-on change-over switches enabling the winding connection to be altered in the simplest manner to that most suitable for the available voltage.

F. ELECTRIC MARINE DRIVES.

In recent years interest in the electric propulsion of ships has considerably increased. The advantages of this form of propulsion, which cannot be merely expressed in terms of money, weight or space, are being increasingly recognized and appreciated by shipping companies due to the good experience and results obtained with such plants. During the past year, therefore, a considerable number of interesting projects for electrical drives in conjunction with post-war plans have been worked out, the majority of these projects being for Diesel-electric ships with a. c. transmission and generators operating in parallel. By using high-speed Diesel engines very favourable conditions as regards weight and space are obtained.[1] The good results obtained with the first merchant vessel equipped with a Brown Boveri drive which has now been in service for more than seven years, have been especially noted in the marine technical press.[2] According to this report the electrical equipment of this ship has functioned perfectly; the only damage which occurred was in the propeller motor when the ship was scuttled by its crew; it was found possible, however, to put the motor back into service again after being dried out. The ship is in regular service since 1940 under the name "Noesanivi" with a Dutch crew and has run with continued success and efficiency. This report disproves the opinion sometimes expressed that the Diesel-electric drive is too complicated for merchant ships and requires a specially trained crew; if this really were the case, it would have been im-

[1] Th. Egg.: "The Diesel-Electric Three-Phase Propulsion of High-Powered Ships". Brown Boveri Rev., Sept./Oct., 1942 (Special Marine Number), p. 240.

[2] The Motor Ship, Sept., 1943.

possible for a strange crew to have taken over the ship and kept it in regular service so soon after it had been put into order again. Furthermore, the number of engineers and machinists on this ship is not greater than on a ship of the same size, tonnage, and speed, with direct Diesel engine drive.

Interesting projects for Diesel-electric drives with direct-current transmission were also worked out, those dealing with trawlers being worthy of special mention. Since it is becoming increasingly necessary for fishing vessels to seek out more remote fishing grounds, modern fishing vessels require a larger radius of action, higher speeds, and bigger engine powers. The vessels must be capable of being at sea for three weeks or more at a time without having to return to harbour, so that large refrigeration chambers are required for the catch and the auxiliary electrical power plants have to be constructed for much higher outputs than formerly. Furthermore, great importance is attached to a very reliable propelling plant. This is achieved with the arrangement shown in Fig. 148 by dividing the propelling power between two Diesel sets, which when one Diesel engine becomes defective enables the vessel to continue its voyage without interruption at a reduced speed equal to about 80 % full speed. Since the Diesel engines can always run at normal speed in the same direction and as a result of the electrical transmission all overloading of the Diesel engines is avoided, the plant is much less stressed than with a direct reversible Diesel engine drive, and the cylinders and pistons require far less frequent overhauling. The main Diesel engines 1 in addition to driving the main generators 2 which supply the propelling motors 3, also drive large auxiliary generators 4. These generators in parallel with the auxiliary Diesel generators 5 supply the auxiliary power network of the ship during trawling when the propeller shaft only requires about 70 % of the full shaft power. The main Diesel engines can thus be fully employed also during trawling, whilst the auxiliary Diesel-generator sets 5 need only be constructed for a considerably smaller output than if they have to supply the entire electric auxiliary power, which for trawling and refrigeration may amount to as much as 50 % of the total propeller shaft power. The auxiliary dynamos are so dimensioned that even when a main or auxiliary Diesel-generator set ceases to operate trawling operations can continue with a reduced propelling power. With this arrangement it is also unnecessary to provide a special Ward-Leonard Diesel

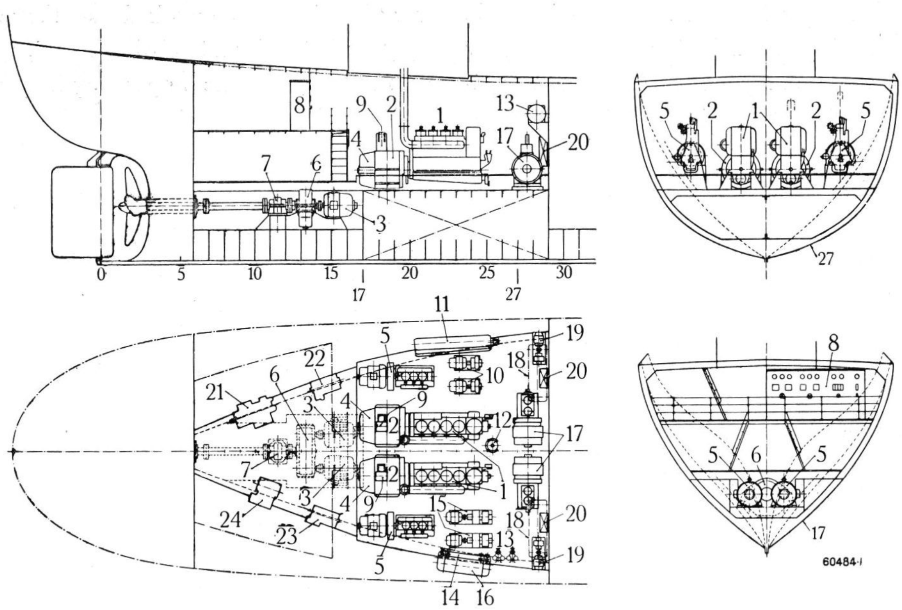


Fig. 148. — Arrangement of the machinery of a 1100 S.H.P. trawler with Diesel-electric d.c. drive.

Electrical transmission enables the power of the main Diesel engines which is not required during trawling to be used as auxiliary power.

1. Main Diesel engines.
2. Main d. c. generators.
3. Propeller motors.
4. Auxiliary generators.
5. Auxiliary Diesel-generator sets.
6. Gearing.
7. Propeller thrust block.
8. Switchboard.
9. Change-over switch.
10. Compressors.
11. Air cylinders.
12. Standby oil pump.
13. Oil filter.
14. Oil cooler.
15. Salt- and fresh water pump.
16. Fresh water cooler.
17. Compressor } Refrigerating plant.
18. Condenser } Refrigerating plant.
19. Circulating pump } Refrigerating plant.
20. Regulating valves } Refrigerating plant.
21. General service pump.
22. Ballast pump.
23. Fuel transfer pump.
24. Sanitary pump.

Welding a fabricated motor casing.

This construction enables weight and raw materials to be saved. Brown Boveri d. c. and a. c. welding sets provide the best means for producing all kinds of first-class arc welds. The d. c. welding sets cover a series of types for a welding current range of 15 to 750 A, and the welding transformers a range of from 38 to 500 A, the current ranges of the individual types being suitably limited. For welding services with more than six stationary welding sets multi-point welding sets which are very economical in operation are constructed.

generator set for the trawl winch motor, because one of the auxiliary generators 4 arranged in booster connection with the auxiliary power network provides a sufficiently flexible drive for the trawl winch.

Since firstly the speed of Diesel engines which are independent of the propeller can be selected higher than with a direct Diesel drive, secondly the auxiliary Diesel-generator sets can be made smaller, and thirdly no special Ward-Leonard Diesel generator set is required for the trawl winch, price and weight of a Diesel-electric drive for a trawler are not higher and the space required is smaller than the corresponding values for a direct Diesel drive. Furthermore, since electrical transmission enables the machinery to be arranged very favourably — the Diesel-generator sets can be located independently of the propeller shaft — the Diesel-electric drive will doubtless frequently be used for deep sea trawlers after the war.

K. Sachs. W. G. Noack.
(D. S., E. G. W., Hv., Op.)

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