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THE BROWN BOVERI REVIEW

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BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND). VIEW OF A PART OF THE ERECTION HALL.
In the foreground:— big gear wheels for marine propulsion.

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PROGRESS IN BROWN BOVERI DESIGN DURING 1939.

Printed in Switzerland.

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THE BROWN BOVERI REVIEW

THE HOUSE JOURNAL OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)

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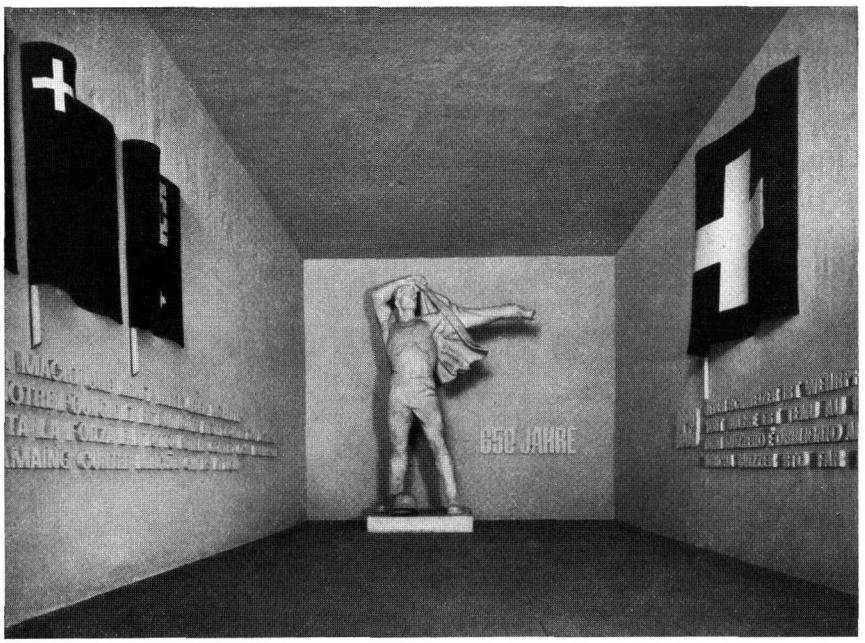
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PROGRESS IN BROWN BOVERI DESIGN DURING 1939.

INTRODUCTION.

IT is a tradition with us to devote the first number of the year to a survey of progress achieved in the course of the preceding year.

1939 was marked for us as the year of the fifth Swiss National Exhibition, held in Zurich, which opened on the 6th of May and closed on the 29th of October 1939. In the introduction to the double number April / May, 1939 of The Brown Boveri Review, which we devoted to our exhibits in the Exhibition, we ventured to express the hope that this magnificent expression of national unity would meet with the success which it deserved. To-day, we can truthfully say that these wishes have been more than fulfilled despite — or perhaps because of — the stormy times during which the Exhibition was open. It will remain a living memory of a proud achievement, with most of us for many years to come.



For us, as a manufacturing concern, which, in order to exist, must constantly strive towards new technical successes, the fundamental, indeed the guiding principle of the Exhibition as expressed by National Councillor A. Meili has a special significance: — the unswerving will to demand the utmost from every collaborator and, above all, the conviction of the necessity of holding to all delivery times assented to, which latter point is not only a duty, but a point of honour.

This should, indeed, be a guiding principle for us, in all our dealings, just as in a wider sense the "High Way", most marked feature in the Exhibition, with the deep symbolism of its statuary, best expressed in Brandenberger's splendid work, was the incorporation of the military spirit of Switzerland and her preparedness to defend her frontiers against all agressors.

This principle can well be applied to the humble labours of the working day, in so far as it expresses an unswerving will to maintain our own position in the export industry, by the honest labour which helped to gain it for us.

I. POWER PRODUCTION.

A. STEAM POWER PLANTS.

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1. *Velox power stations.*

THE "San Lorenzo" Velox power station (Argentina) was in constant service during the year 1939. The two Velox steam generators with the steam turbines and generators belonging thereto have to cover the power requirements of a crude-oil refinery and run either singly or together, according to requirement. Although the quality of the feed water left much to be desired, at the beginning, and although the requirements of service made it necessary to use much raw water, the plant ran continuously and maintained uninterrupted service. This is another proof that the Velox steam generator is no more sensitive than any other type of steam boiler to feed water which is not perfectly satisfactory.

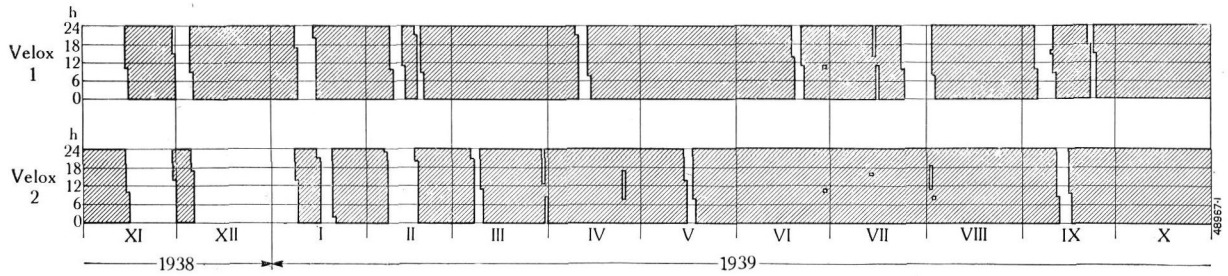


Fig. 1. — Oparating diagram of the Velox steam generators in the San Lorenzo power station for the year November, 1938 to October, 1939.

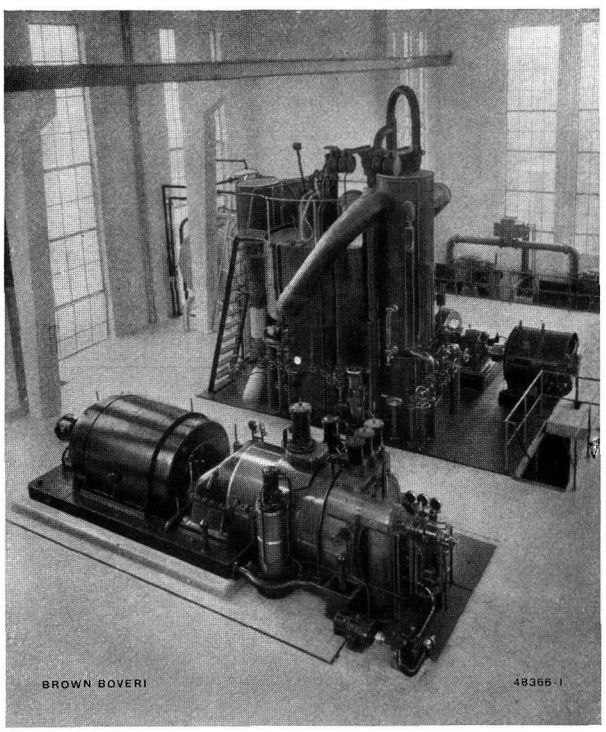


Fig. 2. — Velox steam generator for producing 28 t/h of steam at 15 kg/cm² abs and 300° C, with the mixed-pressure condensing steam turbine belonging thereto and turbo-generator, 2100 kW.

Two sets of this type are mounted in the **San Lorenzo** oil refinery of the Yacimientos Petrolíferos Fiscales (Argentina).

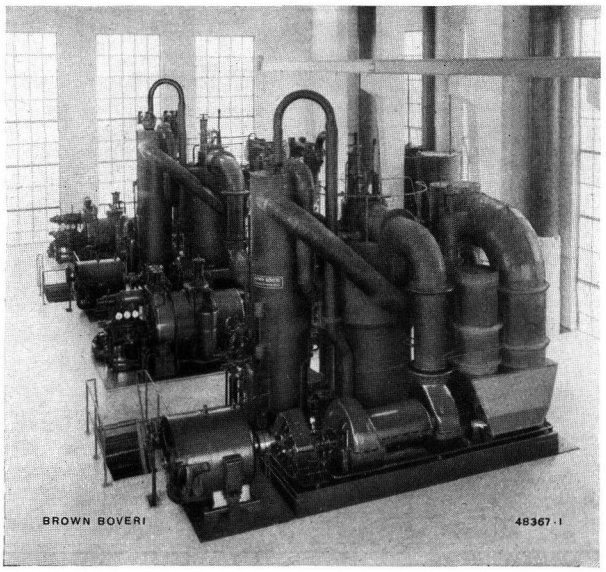


Fig. 3. — General view of the San Lorenzo oil refinery of the Yacimientos Petrolíferos Fiscales (Argentina).

The power station contains two Velox steam generators for a steam production of 28 t/h each at 15 kg/cm² and 300° C, and two mixed-pressure condensing steam turbine sets, each for 2100 kW. The steam generators and the turbines are placed beside one another in the engine room, there is no boiler room. The power station has been in continuous service since 1938.

The following example shows how quickly the Velox steam generator reacts to trouble occurring in service and is able to meet it, thanks to automatic regulation.

In one case, the flame of one of the Velox steam generators went out, suddenly, whereupon the other Velox immediately took over the double delivery of steam. The first Velox was ignited again, at

once, and had hardly taken over load when the flame of the second one went out in its turn; the first and newly started unit immediately took over the double load. After this interchange of load delivery had taken place again, another quality of fuel oil was used. Investigations showed that the first oil had become diluted with no less than 50 % of water and even more.

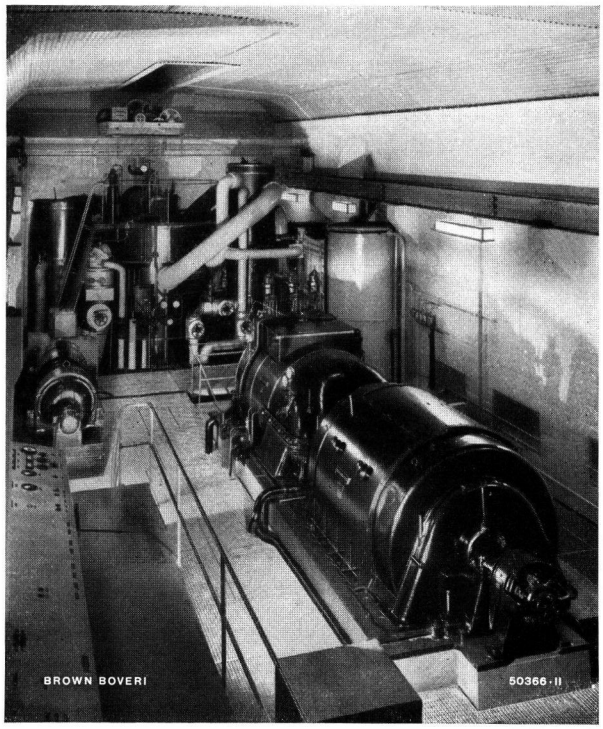


Fig. 4. — Underground power station with Velox steam generator for a steam production of 44 t/h at 24 kg/cm² and 415° C (in the background) **and the condensing steam turbine set belonging thereto for 9400 kW** (in the foreground).
On the left, the switchboard will be seen, with the Ward-Leonard set for the Velox steam generator behind it.

In another case, a pipe line of 100 mm bore burst in an oil-refining apparatus and the oil gas from the burst pipe gushed out into the combustion chamber of the oil-refining apparatus. The latter exploded and, in an instant, everything was ablaze. Our erecting engineer wrote to us as follows:— "The steam extinguishing apparatus was in action immediately. Luckily both Velox were running and could at once give the maximum output so the fire was extinguished within five minutes.

In both cases it is due to the rapid intervention of the automatic regulation that these cases did not develop into service breakdowns.

Two other Velox power stations were set to work, in 1939. Both are stand-by plants which had to be protected against air raids. Here, the small overall dimensions of the Velox steam generator are valuable assets as, otherwise, the cost of making the plant bomb-proof might have been nearly prohibitive.

One of these plants is in Berne and was described in detail in The Brown Boveri Review[1]. To summarize:— the station consists of a 9400-kW turbo-generator driven by a steam turbine and of a Velox steam generator producing 44 t/h of steam at 24 kg/cm² abs, 415 ° C. The whole plant is lodged in a tunnel blasted out of the solid rock face.

A similar plant was delivered to one of the Baltic states. This was an entirely automatic power sta-

[1] The Brown Boveri Review, August 1939, page 193.

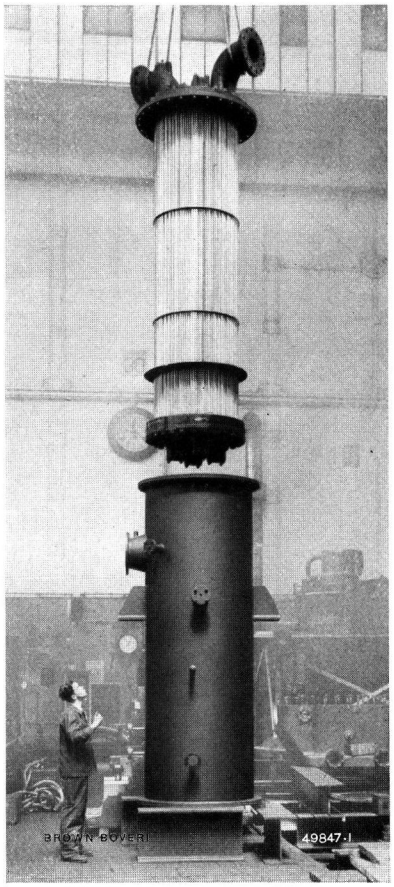


Fig. 5. — High-pressure feed-water heater for a 50,000-kW turbine.
Steam pressure 8 kg/cm² abs.
Water pressure 40 kg/cm² abs.
Water temperature 135—160° C.
Heating surface 200 m².
The illustration shows the dismantling of the stack of tubes in our shops.

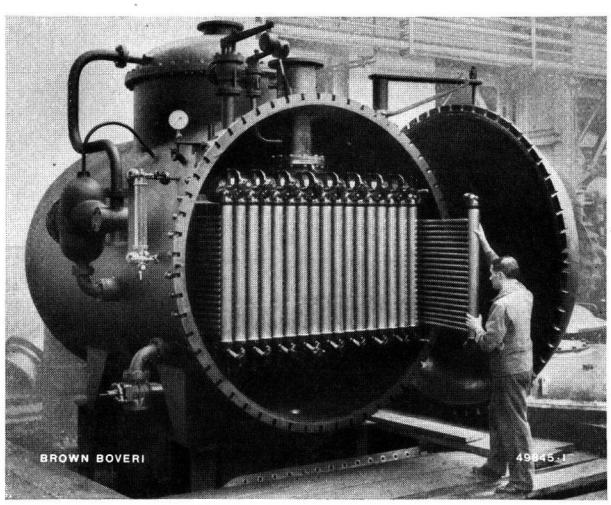


Fig. 6. — Raw-water evaporator for an output of 10 t/h.
Hot-steam pressure 4 kg/cm² abs.
Exhaust-steam pressure 2 kg/cm² abs.
As can be seen, each heating element can be taken out separately and cleaned. The illustration shows the raw-water evaporator in our shops.

tion which starts up from cold state as soon as the voltage fails on the ordinary supply network. To begin with, a small Diesel engine is started automatically; then the auxiliary machines and the Velox steam generator start in proper sequence also automatically; finally the generator is switched on to the network automatically. This plant was successfully put to work at the beginning of October 1939. We think this worth mentioning as a proof that our firm can meet its delivery obligations even in times of political strife.

A complete power station was ordered, this year, for a cement mill and this also in October. This plant comprises two Velox steam generators to deliver each 20 t/h, a steam turbine, a turbo-generator for 3700 kW, a switchgear plant and transformers.

Further, a complete power station was ordered for a plant of the Bataafsche Petroleum Matschappij in Curaçao. As the fuel to be used is refuse oil and chiefly solid asphalt the clients stipulated a boiler of a type which had given good results in other plants, when using this kind of fuel. Werkspoor as subcontractor will build the boiler in question while Brown Boveri will deliver the whole plant, comprising among other material, a 10,000-kW steam turbine with generator, transformers and switchgear plant.

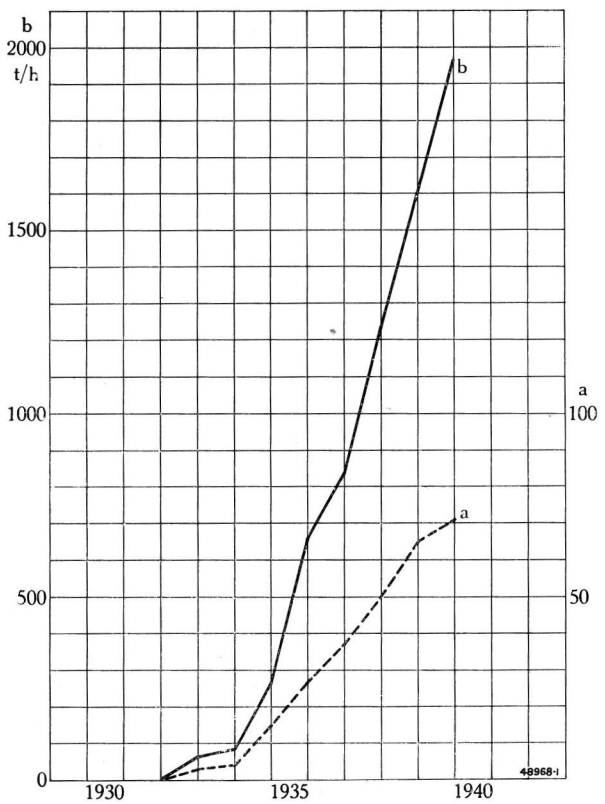


Fig. 7. — Stationary Brown Boveri Velox steam generators.
Number and output of all the Velox steam generators delivered:
a. Number. b. Total output.

2. *Velox steam generators.*

Despite the increasing political unrest which marked the last twelve months, the number of orders received held up well. During recent years, Brown Boveri and their concessionaries took orders, every year, for Velox steam generators for a total steam delivery of between 350 and 400 t/h.

We had the opportunity of designing two Velox steam generators for a maximum output of 100 t/h each. These are the biggest built up to date. It should be noted here, however, that these are units using blast-furnace gas as fuel. As this is a poor fuel gas, great quantities of combustion gas are generated and the boilers must be made considerably bigger than would otherwise be the case. A Velox unit of the same size but using oil fuel would generate 160 t/h of steam.

We also got an order for two big Velox steam generators for Cia. Italo Argentina de Electricidad in Buenos Aires (Argentina). These will be placed in the Pedro Mendoza power station, Buenos Aires. Each unit generates 80 t/h of steam at 16 kg/cm^2 abs, 340^0 C. These units are, however, designed from the first so as to be able to deliver the same amount of steam at 38 kg/cm^2 at 450^0 C, later on. Apart from the three Velox steam generators for the Oslo Electricity Works (Norway), these are the biggest oil-fired Velox steam generators ordered from us.

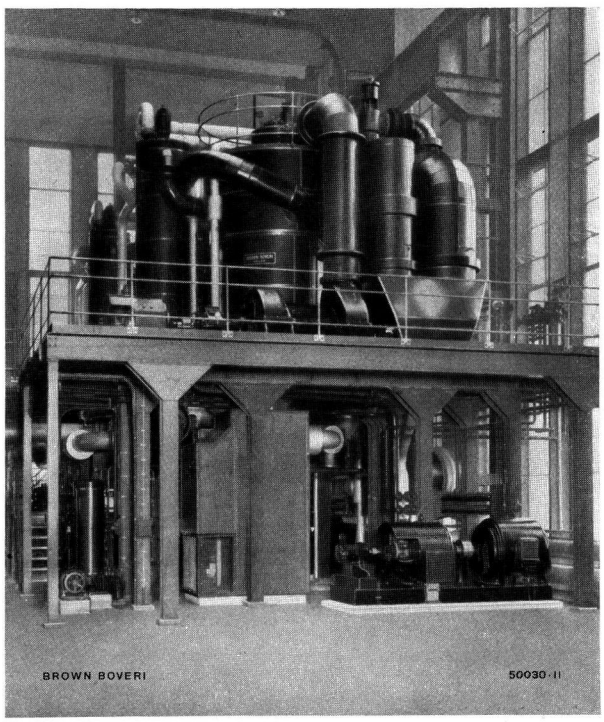


Fig. 8. — Velox steam generator in the Velsen station of the Provinciaal Electriciteitsbedrijf van Noord Holland.
The two Velox steam generators have a steam production each of 50 t/h at 31 kg/cm^2 abs and 425^0 C.

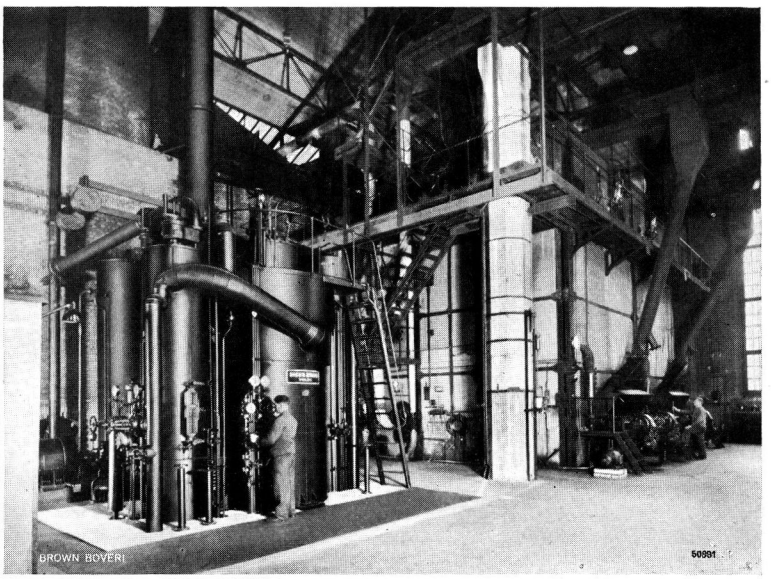


Fig. 9. — Velox steam generator for a steam production of 20 t/h at a pressure of 40 kg/cm² abs and 450° C.

This Velox steam generator is mounted in the boiler house of our works in Baden (Switzerland). It delivers steam for our steam-turbine test beds and is also used for demonstrations. In the background, there are two inclined-tube boilers for a steam production of 18 t/h each.

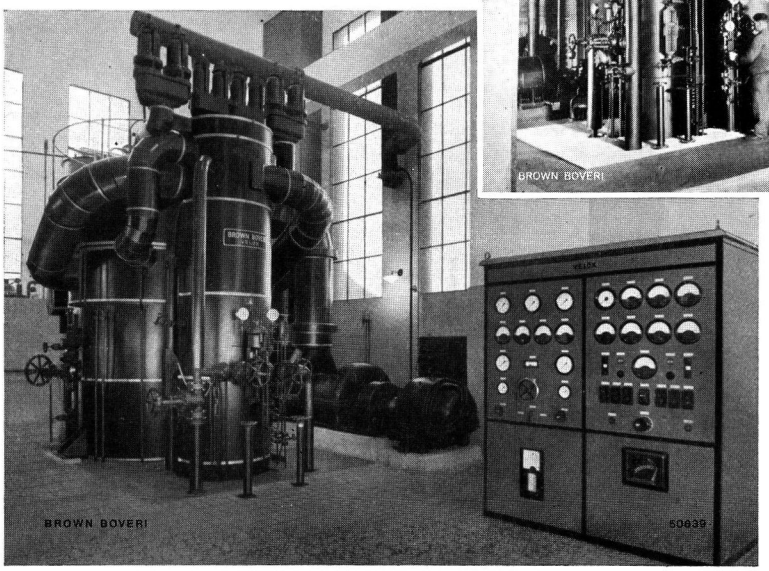


Fig. 10. — Velox steam generator of the Finsen power station of the Frederiksberg Electricity Works (Denmark).

Steam production 42 t/h at 40 kg/cm² abs and 440° C. For the time being the steam generator will operate at 15 kg/cm² and 375° C (this explains why there are numerous safety valves).

In the spring of last year the first Velox unit in Denmark was set to work. It is relatively small having a steam output of 9 t/h at 40 kg/cm² abs and 450° C. It belongs to the Ford Motor Company A/S in Copenhagen.

A considerably bigger Velox steam generator was set to work in October in the Frederiksberg Electricity Works. The steam output is 40 t/h at 15 kg/cm² and 375° C; the Velox is designed to be able, at a later date, to deliver the same steam output at 40 kg/cm² abs and 440° C. The municipality of Frederiksberg forms part of the city of Copenhagen and is entirely enclosed, to-day, by Greater Copenhagen. The little space taken up by Velox steam generators is a valuable asset in this kind of plant. Room for boilers of other types would either be impossible to find or mean an excessive outlay of money at the present-day cost of ground.

Two Velox steam generators, each for a steam output of 50 t/h at 31 kg/cm² and 425° C were taken over, last spring by the Velsen power station of the Provinciaal Electriciteitsbedrijf van Noord Holland.

3. *Steam turbines.*

The first *two-cylinder* steam turbine with a double-ended low-pressure part, built to our new design, that is to say with completely welded medium-pressure—low-pressure rotor body, was put into service in the year 1939. The design was described in some detail in our last year's report[1]. Thanks to its excellent features, this design has met with a very favourable reception. It shortens considerably the overall length of the turbine, while maintaining a high efficiency because the turbine is, in reality, a *three*-cylinder one, only the medium and low-pressure parts are now combined in *one* cylinder. This is made possible thanks to the rotor being welded throughout. The welded rotor is sufficiently stiff to permit of combining the medium and low-pressure parts without an intermediate bearing. The turbine in question is running in the Twentsch Centraal Station voor Electrische Stromlevering in *Hengelo* (Holland). Its output is 32,000 kW at 3000 r. p. m.

[1] The Brown Boveri Review, January/February, 1939, pages 4—6.

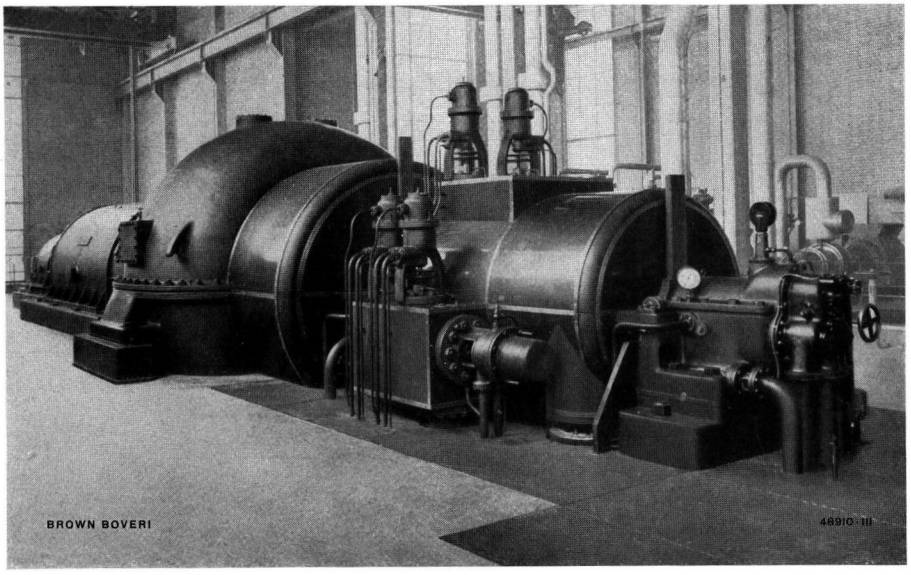


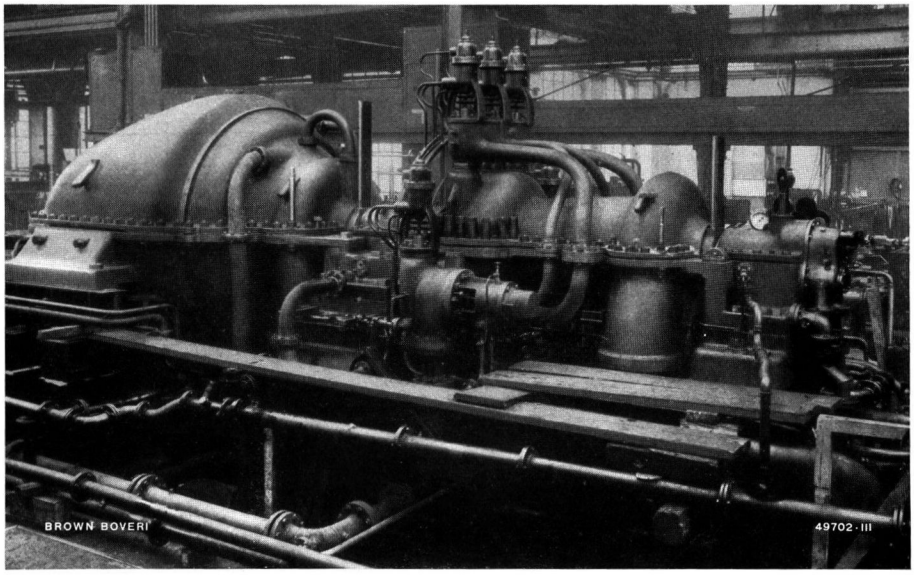
Fig. 11. — Two-cylinder condensing turbine with double-ended low-pressure part for 30,000 kW at 3000 r. p. m. Steam pressure 41—50 kg/cm² abs, temperature 430—460° C, coupled to a three-phase turbo-generator for 10,500 V, 50 cycles.

Delivered to the Twentsch Centraal Station voor Electrische Stroomlevering E. V. Hengelo (Holland).

Fig. 12. — Two-cylinder condensing turbine with single-ended low-pressure part for 25,000 kW at 3000 r. p. m. Steam pressure 36—43 kg/cm² abs. Temperature 430—470° C.

Delivered to the Société de Transport et d'Entreprises Industrielles (Sofina) Bruxelles, for the Auvelais power station.

The illustration shows the turbine without casing on the test bed in our works.



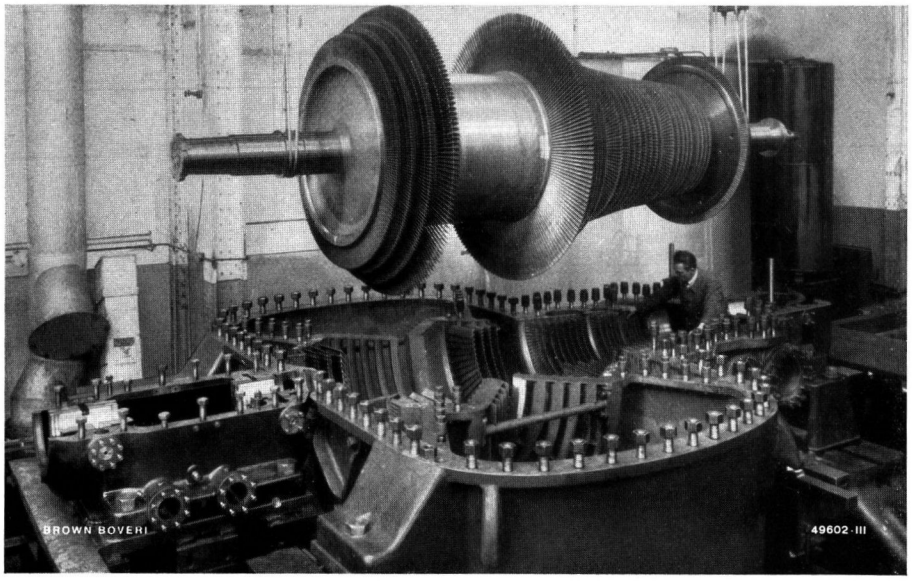


Fig. 13. — Single-cylinder condensing turbine with double-ended low-pressure part for 32,000 kW at 3000 r. p. m. Steam pressure 12·5 kg/cm². Temperature 350° C.

Delivered to the Warshaw Electricity Works (Poland), where an almost identical set has been running since 1937.

The illustration shows the rotor and lower half of the housing on the test bed in our works. The rotor is welded throughout and has no shaft passing through it.

Three similar machines have been delivered and are now being erected, these are for considerably bigger outputs, namely: 50,000 kW at 3000 r. p. m. each.

A single-ended low-pressure part suffices for turbines of the lower output range; thus a two-cylinder 25,000-kW unit at 3000 r. p. m. was delivered to the *Société Financière de Transport et d'Entreprises Industrielles (Sofina)*, in Brussels, for the *Auvelais* power station.

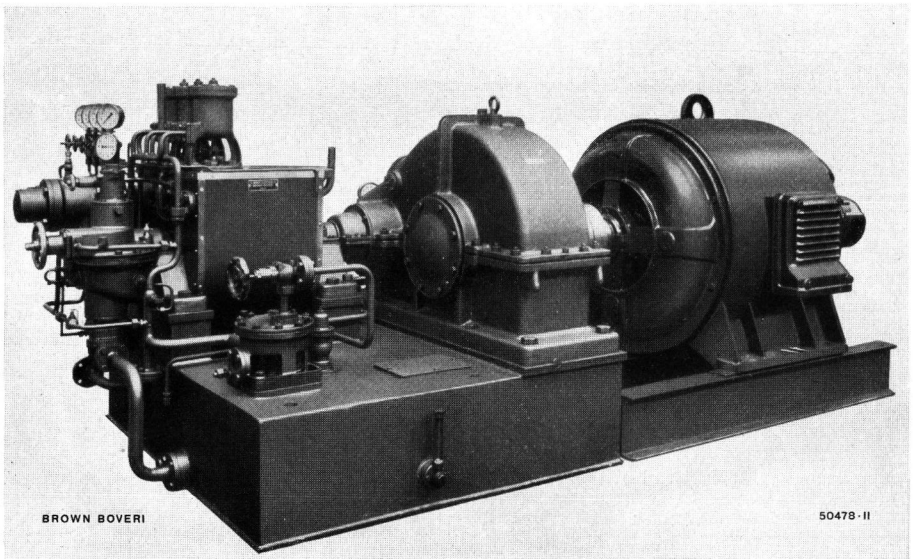


Fig. 14. — Small turbine for 420 kW output with reduction gear and generator. Speed of the turbine 13,800 r. p. m. Speed of the generator 1500 r. p. m.

Delivered to a plant in Norway.

A single-cylinder 32,000 kW steam turbine, having double-ended low-pressure part, along with its generator, was delivered by us to the *Warsaw Electricity Works*. A unit which is almost entirely similar was delivered in 1937 to the same clients.

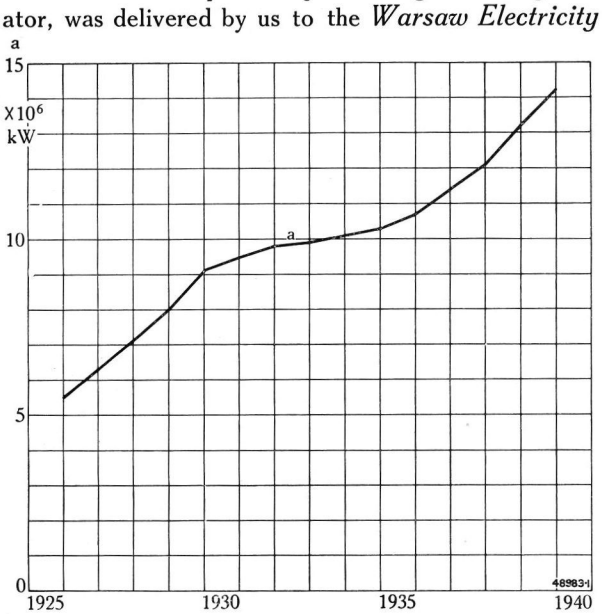


Fig. 15. — Stationary Brown Boveri steam turbines.

a. Total output.

We delivered a 30,000-kW single-cylinder turbine, similar to the Warsaw unit, to the *State Electricity Commission of Victoria* (Australia) for the *Newport* power station. The generator of this set is worthy of note, being built for a terminal voltage of 22,000 V.

The single-cylinder turbines of the lower output range are also provided with single-ended low-pressure parts. The turbine delivered for the Zwolle power station (Holland) is an example of this. It delivers 25,000 kW at 3000 r. p. m.

An interesting design is that of a primary high-pressure turbine delivered to the *Fiat* concern in Turin, for the *Mirafiori* power station. This unit works under live steam at a pressure of 95 kg/cm² abs at 440 ° C and the back-pressure is 10·5 kg/cm² abs. In order to obtain as pure feed water as possible for the high-pressure boiler, the exhaust steam is condensed in a steam converter. The low-pressure steam generated is used to drive steam hammers and presses and is finally led to a low-pressure condensing turbine working at a steam pressure of 1·5 kg/cm² abs.

We have now building two further plants of this type. One is a 9000-kW primary turbine which will be placed in the *Schiehaven* power station (Holland) to work at a steam pressure of 70 kg/cm² abs at 480 ° C. The back pressure is 14 kg/cm² and the steam exhausted from this turbine is led without intermediate reheating to an older Brown Boveri three-cylinder condensing type turbine. The other plant consists of two primary back-pressure turbines, building for the *Grozavesti* power station (Roumania). The output is 15,000 kW per unit at 125 kg/cm² abs and 490° C. Here, the back-pressure is 22 kg/cm².

The sum of the orders received by the whole Brown Boveri concern remains approximately the same as it was in the year 1938, and exceeds a total of 1 million kW. The orders received by the Baden shops have suffered from the efforts of many countries towards autarchy and the numerous clearing arrangements and commercial restrictions; further the outbreak of hostilities obviously did nothing to improve

business. Despite these obstacles, we took orders for a total of 250,000 kW, last year. This gives us confidence that we will be able to further develop the manufacture of Brown Boveri steam turbines and maintain the good name they have acquired, this by keeping in the van of progress as regards design, by good service to our clients and by maintaining a high standard of manufacture.

4. *Turbine governing systems.*

On account of the increasing number of steam power stations which have been connected up to big transmission networks, in the course of recent years, the problem of the governing of the steam turbines has come to the fore, again. There are two problems which are of primary importance:— Firstly the adjustment of the turbine governing gear itself to the requirements of parallel service and, secondly, the various needs of network regulation proper.

When a big number of generators are running in parallel on a network, the frequency and speed, respectively, are identical everywhere. Ordinary turbine governors with falling characteristic give a determined load for each frequency. The frequency is used as a kind of signal for the governing of all the turbines; when the frequency on the network drops the turbine governors cause the turbines to deliver more power and, when it rises, to give less power.

If it is desired that, when frequency changes occur, *all* the turbines should share uniformly in the change in output, the governor characteristic curve of speed in function of load must be identical for all the turbines. Unfortunately this is not the case. In general, the turbine-governing devices link the speed of the turbine and the lift of the nozzle valve by a simple law. But the amount of steam admitted and, therefore, the load is *not* proportional to the lift of the valve. With the help of collars fitted on the valve seats and cam shafts for the valve control it is possible to make the output approximately a linear function of the frequency, but if the steam pressure deviates from its standard value divergencies will creep in, again.

The Brown Boveri hydraulic control has proved sufficiently precise, in the great majority of cases and there are no reasons whatsoever for giving up this very sensitive governing system. When very special network conditions have to be fulfilled, it is possible to meet the severest requirements by the addition of a simple apparatus which can be put in at any time.

The new governor comprises a frequency regulator and an output regulator. These two regulators actuate, together, an oil valve in such a manner that the desired relationship between output and frequency is attained.

The regulator is easy to adjust in service so that the *inclination* of the output-frequency curve can always be adjusted at any time, to meet service requirements. At short circuits of the generator or at break-down of a line, the frequency regulator shuts down the turbine.

With the new type of regulating gear in service, the sleeve of the standard speed governor is set so high that the speed governor is out of action, but it intervenes immediately if the speed rises to inadmissible value.

The same regulator can, fundamentally, be used for electric network regulation, according to *Darrieus*. In order to prove this, we must briefly recall the fundamental laws laid down by *Darrieus* for the regulation of big networks.

When several power stations, each supplying its own network, have also to deliver determined blocks of power to a common network connected to them all, or else take a determined block of power therefrom, it is well known, that the frequency can only be regulated by *one* power station, the other stations regulating the power delivered to the common network. If, now, one power consumer belonging to the network of one power station is cut out, the power delivered by the station to the common network will suddenly increase, the frequency on the whole network will increase and the power contributions of the other stations to the common network will drop. This means that all the power stations will start regulating. The station dictating the frequency will lower its output in order to get the frequency back to the proper value, but all the other stations trying to keep up constant output will increase their output and will, thus, increase the disturbance.

It is clear that the only right thing would be that the other power stations *should not regulate at all.* The trouble certainly originated from the first power station, alone, and if it were regulated out, the equilibrium would be re-established automatically in all the other power stations. *A perfect regulating system for power stations supplying a common network must be in a position to discriminate between disturbances on the network proper of any one of the station or disturbances coming from outside.* It must only respond to the first class of trouble and not at all to the second, that is to say not to external trouble.

Darrieus' reasoning is as follows:— A power station with its own consumer network, but also delivering power to a network connected to it, is considered. It is assumed that no trouble arises on the network proper of the station. Now the frequency

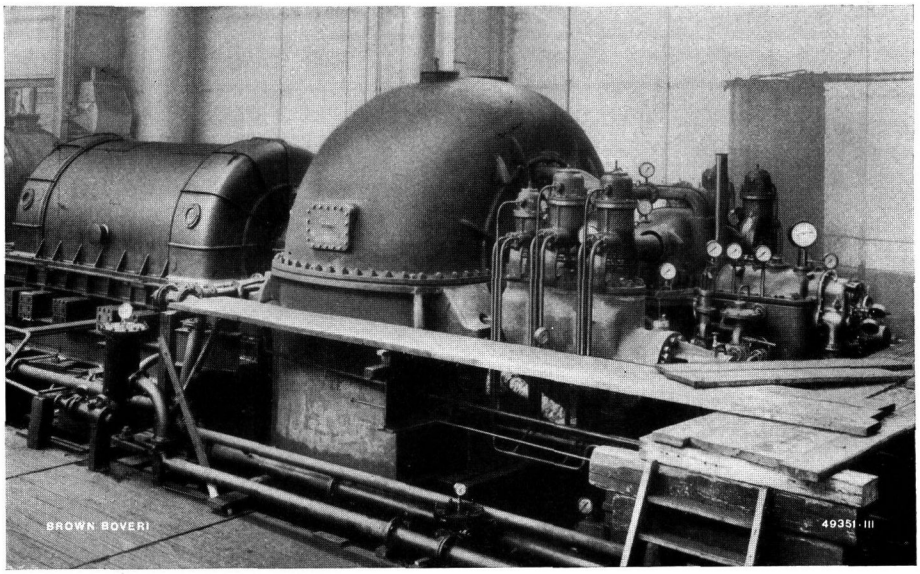


Fig. 16. — Single-cylinder condensing turbine with double-ended low-pressure part for 30,000 kW at 3000 r. p. m. Steam pressure 18—20 kg/cm² abs. Temperature 370—400° C.

Delivered to the State Electricity Commission of Victoria for the Newport power station. It should be noted that the generator is wound for 22,000 V.

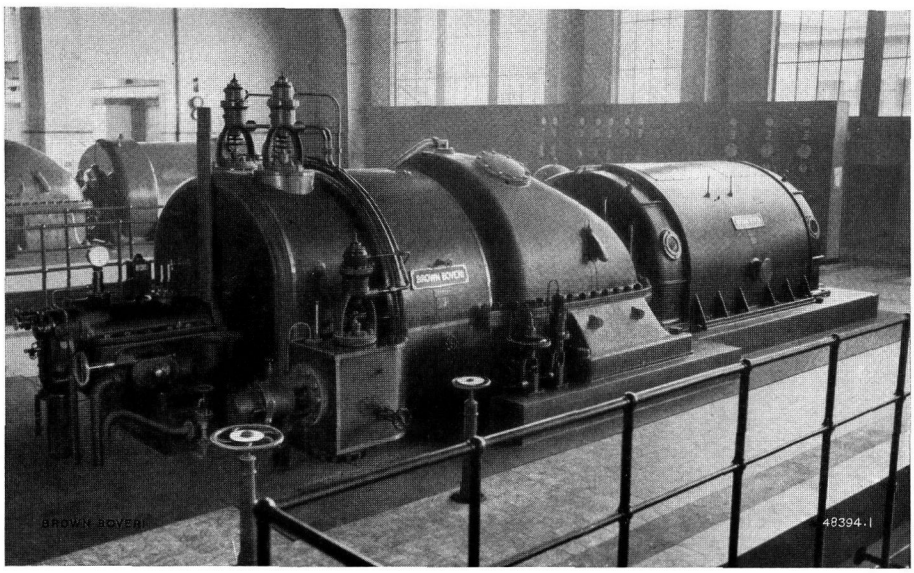


Fig. 17. — Single-cylinder condensing turbine with single-ended low-pressure part for 20,000 kW at 3000 r. p. m. Steam pressure 35—43 kg/cm² abs. Temperature 410—450° C.

Delivered to the N. V. Electriciteitsfabriek Ijsselcentrale in Zwolle (Holland).

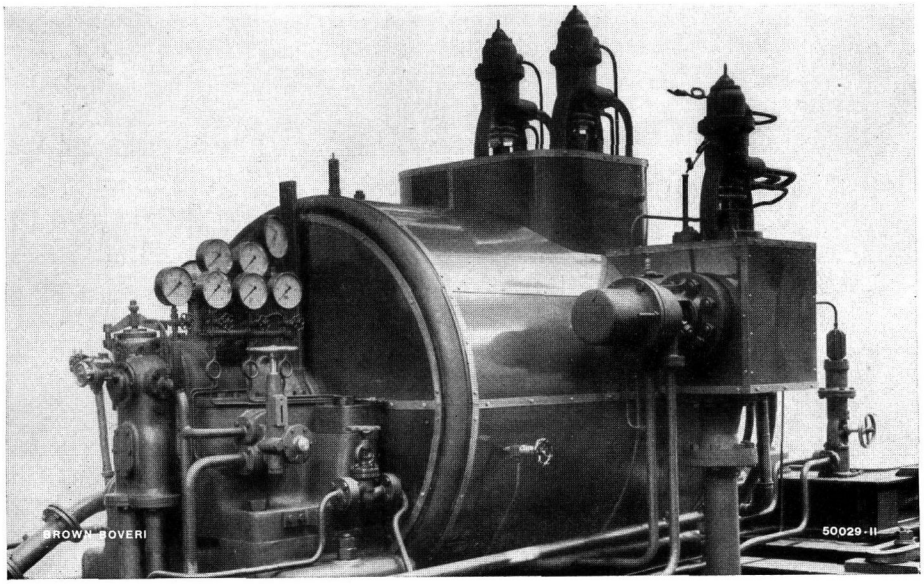


Fig. 18. — High-pressure primary turbine for the Fiat firm in Turin (Italy) for the Mirafiori power station. Output 7000 kW max. at 3000 r. p. m. Steam pressure 95 kg/cm² abs. Temperature 440° C. Back-pressure 10·5 kg/cm² abs.

The illustration shows the turbine on the test bed in our works.

is assumed to rise on the common network, for some reason. This influences the amount of power delivered to the common network, for two causes:— First under the rising frequency, the power station will reduce its output in accordance with the falling output frequency curve it works to; secondly, in so far as there are chiefly motors branched on the system proper of the power station, these will take more power under the higher frequency. The power contribution to the common network will *drop* by these amounts, in which process the first factor generally plays the most important part.

By the increase in frequency, the power contribution to the common network has been reduced. The *network regulation must not intervene despite this,* because *no* trouble has arisen on the network of the power station itself. This is attained, according to *Darrieus,* by carrying out the regulation of the network, that is to say the regulation of the power contributed to the common network, by means of an output-frequency regulator. The output drop given by the latter at increasing frequency is set bigger than the output drop of the turbine governors of the power station proper, this by the amount of the increase in output taken by the consumers of the power station. A regulating device like this will not react on external changes. If on the contrary a power decrease occurs on the network of the power station, the regulator immediately intervenes because an increase in power contribution occurs in conjunction with an increase in frequency.

In this way, it is possible to connect any number of power stations to a common network without causing hunting. There is now no longer a distinction between "frequency-maintaining" and "output regulating" power stations. As, further, the correct setting of the network regulator is independent of the characteristics of the common network and only depends on the properties of the network proper of the power station under consideration, every station can set its own network regulation, on its own account, and in such a way that it will not be troubled by reactions coming from the common network.

5. *Turbo-generators.*

Development work in this field has been pursued chiefly with the object of further reducing the losses of turbo-generators, in view of the great importance frequently attached to attaining the most economical operating conditions possible. A greater utilization of materials of the very highest grade, improvements in machining, based on tests and close study of the problem, made a further reduction of the losses feasible. This, at the same time, meant that less cooling air was required as well as a smaller cooling equipment, while a saving in space was effected. The difference in efficiency between air cooling and hydrogen cooling, to which we also gave our attention, has been yet further reduced and our clients apparently continue to be of the opinion that the advantages of hydrogen cooling are not worth the complications inherent thereto.

For some types of generator, we have redesigned the cooling system altogether so that it now differs considerably from the older system; in fact, it is now based on aero-dynamical properties, in every detail.

As regards insulation problems and their solution, which had rather appeared to have reached a more or less definite stage of achievement, work was pursued in our laboratories and has shown the way to still greater improvements; these will benefit particularly high-voltage generator, a type of machine which we continue to consider as the true solution of the future as regards units of large output.

Years ago, we started systematic investigations to explain the process by which *travelling waves penetrated* the stator windings of generators and motors. These tests were brought to a temporary conclusion, in the present year, and, in the essential, have led to the following results:—

(a) The different phase windings react to travelling waves very independently of one another. This is because only an insignificantly small magnetic coupling acts between them on account of the dispersion of the flux in the core resulting from these very rapid processes and also because the capacitive coupling in the coil ends is weak.

(b) According to the surge impedance of the lead and winding and to the number of phases implicated, a voltage appears across the terminals caused by reflection of the wave and which may attain twice the value of the wave. As, however, the flash-over voltage of the terminals determines the amplitude of the penetrating wave, the amplitude of the incoming wave on the line plays no important part and the voltage across the terminals is the reference magnitude.

(c) The wave penetrates each phase winding, as it would a low-pass filter circuit with a surge impedance of about 1500 to 2000 ohms; the incoming wave fronts are much flatter than the voltage rise at the entry on account of the upper limit frequency of the low-pass filter circuit; as the waves penetrate further, they get still flatter.

(d) The first coil encountered by the wave is subjected to the biggest stressing. Under unfavourable conditions, it has to stand up to voltages of 75—100 % of the surge voltage across the terminals, according to the steepness of front of the incoming wave and to the number of coils per pole and per phase.

(e) The penetrating wave is again broken and reflected at the neutral point according to the laws of reflection for line branching. In the case of a wave penetrating all three phases simultaneously, total reflection occurs on the neutral point; as, however, the front of the wave is very much flattened here, as compared to the steepness at the terminals, the stressing of the coils remains nevertheless below that to which the coil at the entrance point is subjected and the voltage against earth also only attains about 1·4 to 1·8 times the voltage across the terminals.

(f) Inside a single coil, the voltage is distributed, according to the number of turns and the size, nearly linearly, because the turns of the coil are closely coupled magnetically even without influence due to the section of the core.

As an example, we give the case of the penetration of a rectangular wave into the winding of a high-voltage motor, which phenomenon was investigated with a cathode-ray oscillograph. The investigation covers the three following cases:— Wave penetration on one, on two or on all three phase leads, simultaneously. By reflection, voltages of 162, 138 and 119 % of the incoming wave, respectively, are produced across the terminals. The maximum stressing of the first coil attains about 75 % of the terminal voltage in all three cases. The distribution of the voltage inside the coil is, approximately linear; as, with the arrangement of the winding used here (Fig. 22) it may happen that the 6th and 29th turns are adjacent, a voltage amounting to 50 % of the terminal voltage may appear between the said conductors, under the most unfavourable conditions. This arrangement of the winding, which is no longer used by us, is, therefore, not unfavourable on account of the inequality of voltage distribution inherent thereto but because it is possible that wires, electrically far apart, are really close to one another in space.

B. GAS TURBINES.

We already mentioned in last year's report[1] that we had booked an order for a 4000-kW gas turbine plant. This plant was finished and delivered in the course of the year 1939 and it has been described, on several occasions[2]. It is the first gas-turbine set ever delivered purely for the generation of electric power. This alone justifies a further mention of the plant, because the completion of this first combustion gas turbine means the realization of a dream which has occupied the minds of inventors and engineers, the world over, for more than a hundred years.

To the electricity works of the Swiss town of Neuchâtel and its director Mr. Martenet is due the credit of having had both the courage and the necessary confidence in us to place an order for a type of machine which had never been built so far, and which was required for a new peak-load and stand-by power station. We take the opportunity of stating that, about 35 years ago, Mr. Martenet showed himself to be the pioneer he still is, to-day: he was one of the first engineers on the Continent to equip a power station with a steam turbine. The value to technical progress of men like this, who are ready to take the responsability for introducing innovations of the true worth of which they are convinced, is indeed great.

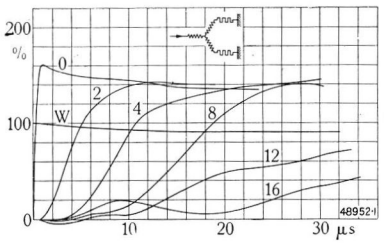


Fig. 19. — Penetration by a travelling wave of a high-voltage stator winding.
Wave only on one phase.
W. Original wave.
O. Voltage across terminals.
2, 4, 8, 12, 16. Voltage after 2nd, 4th, 8th, 12th and 16th turn respectively.
Ordinates: Voltage in percentage of the incoming wave.
Abscissae: Time in micro-seconds.

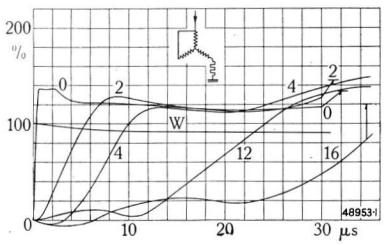


Fig. 20. — Penetration by a travelling wave of a high-voltage stator winding.
Wave on two phases simultaneously.
W. Original wave.
O. Voltage across terminals.
2, 4, 12, 16. Voltage after 2nd, 4th, 12th and 16th turn respectively.
Ordinates: Voltage in percentage of the incoming wave.
Abscissae: Time in micro-seconds.

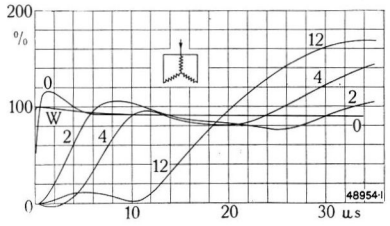


Fig. 21. — Penetration by a travelling wave of a high-voltage stator winding.
Wave on all three phases simultaneously.
W. Original wave.
O. Voltage across terminals.
2, 4, 12. Voltage after 2nd, 4th and 12th turn respectively.
Ordinates: Voltage in percentage of the incoming wave.
Abscissae: Time in micro-seconds.

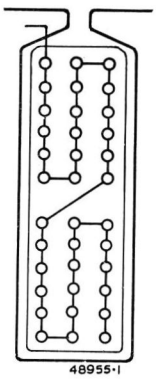


Fig. 22.

Arrangement of the winding in the slot of the high-voltage winding under test. (See Figs. 19, 20, 21.)

[1] See The Brown Boveri Review of January/February, 1939, page 7.

[2] See The Brown Boveri Review of April/May, 1939, page 103 and of June, 1939, page 127.

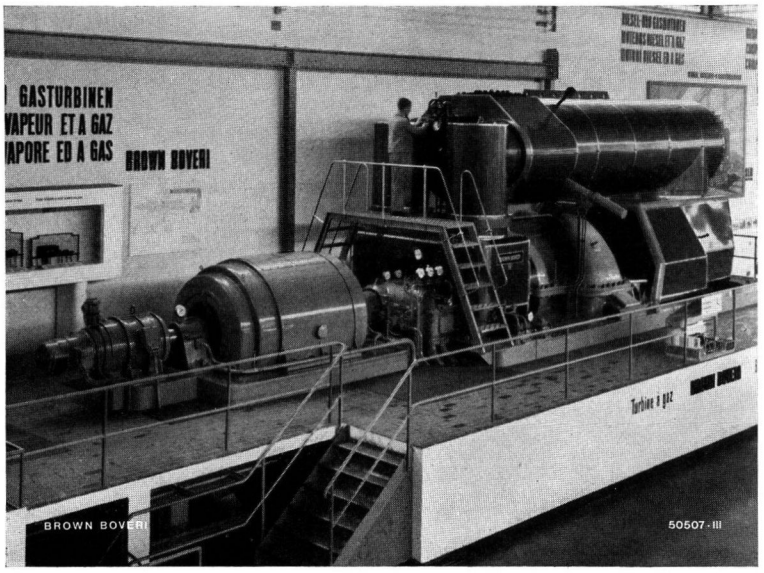


Fig. 23. — 4000-kW Brown Boveri combustion gas turbine in the Swiss National Exhibition in Zurich.

On the left:— Exciter, starting motor and 4000-kW turbo-generator set.
On the right:— 12,000-kW axial compressor and 16,000-kW gas turbine.
Above:— the combustion chamber, in which the compressed air is heated up to 600° C to drive the gas turbine.

It is true that, in conjunction with Velox steam generators, gas turbines had already been built by Brown Boveri and were running and that numerous units were operating in chemical plants, but none of these machines came anywhere near the size of the Neuchâtel unit. It will be recalled that the useful power available from a combustion gas turbine is the difference of the output of the turbine and the power consumed by the compressor; thus the 4000-kW unit of the Neuchâtel Electricity Works is composed of a 16,000-kW gas turbine and 12,000-kW compressor.

The confidence placed by the directorate of the Neuchâtel Electricity Works in this new type of machine as well as in our firm has been fully justified by the results. Manufacture of the set, which it was intended should occupy a prominent place among the engineering exhibits of the Swiss National Exhibition, in Zurich, was unfortunately delayed by a big forging for the compressor having to be rejected twice in succession. However, once this difficulty had been overcome we were able to carry out the acceptance tests on the 4th of July, 1939, in Baden.

Dr. A. Stodola agreed to act as expert at these tests and, despite his advanced years, insisted on supervising the work personally. Dr. Stodola has always taken an active interest in the development of the gas turbine, and it was a real pleasure to us that it was granted to this eminent scientist in the field of turbine design to be able to take over the supervision of the tests in question. The results thereof will be reported on elsewhere and we would only say that the fuel consumption was some 5% below the figure guaranteed.

After the tests had been completed, the gas turbine set was exhibited in the Swiss National Exhibition, Zurich, and shown to visitors running, every day. The gas turbine set is now being erected in Neuchâtel.

Finally, we would summarize the advantages of the gas turbine. Its chief superiority to the steam turbine is that *no cooling water* and *no steam boiler* are required. Therefore, the gas turbine can be put up anywhere. This is a great advantage for a stand-by or emergency power station, as the station can be located in the centre of power consumption and long transmission lines or cables avoided. As there is no boiler to be fired, starting time is very short and the plant is always ready for service. For outputs of some thousands of kilowatts, the gas turbine is cheaper and smaller than a Diesel engine of the same output. For subterranean bomb-proof plants this compactness is a factor of great importance.

It is true that, as regards fuel consumption, the gas turbine cannot compare, in its present stage of development, with the steam turbine; the gas turbine for the Neuchâtel Electricity Works attains a thermal efficiency of about 18% without heat exchanger. With a heat exchanger, the efficiency can be brought up to 23% but this means an increased expenditure on the plant. For peak-load and, still more so, for emergency and stand-by plants, the bigger fuel consumption however plays no part at all as compared to first capital investment.

As has been said already, the effective output of a combustion gas turbine is the difference between the output of the turbine and the power consumption of the compressor, so these machines are relatively big in relation to the effective output produced. It will be obvious that the future of the gas turbine will be very bright indeed once it is found possible to increase the effective output. We may add that promising pioneering work with this aim in view is going on.

C. DIESEL POWER STATIONS.

1. *Diesel engines.*

Every year, Brown Boveri delivers a considerable number of charging blowers driven by exhaust-gas turbines, for the charging, according to the Büchi process, of Diesel engines. These sets are described in

the chapter on Blowers and Compressors, see page 43 of this number.

2. *Diesel generators.*

The most marked feature of this field has been the further development of the *emergency Diesel-electric set.* The uncertain political conditions of the day have produced an exceptional demand for sets of this kind. Here, the outputs called for are

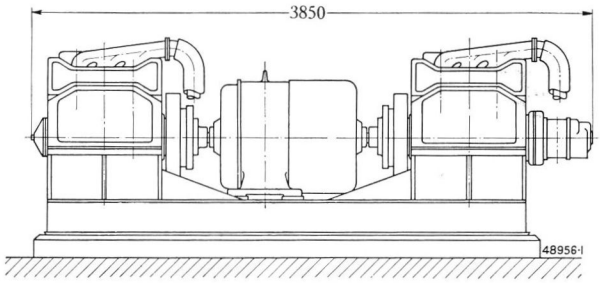


Fig. 24. — Brown Boveri-Sulzer Diesel-electric emergency set.

not only of the order of 10 to 100 kVA formerly encountered, but are often in the 200 to 400 kVA range. When the power of the Diesel engine exceeds a certain figure, compressed air has to take the place of electricity for starting the set, this for reasons of economy. Starting by compressed air, when it has to be automatic, is not as simple and easy as electric starting. For this reason a double drive is

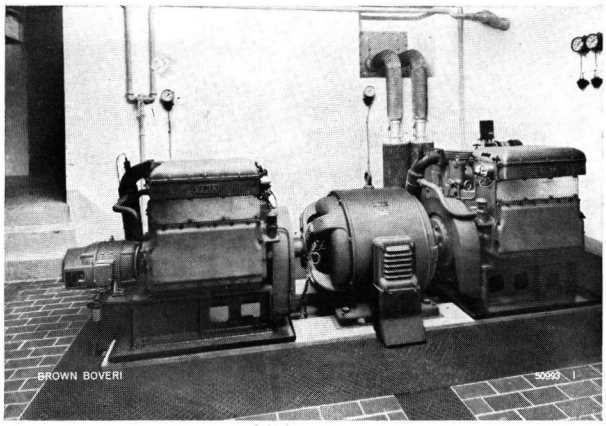


Fig. 25. — Diesel-electric emergency set 210 H. P., 1500 r. p. m.

often resorted to, that is to say, drive by two Diesel engines each of half the power required (Fig. 24); this allows of utilizing the simpler and speedier electric starting. Fig. 25 shows a plant of this kind in a modern business building.

D. HYDRAULIC POWER STATIONS.

1. *Generators.*

In our last report we mentioned the vertical-shaft generators each built for 22,000 kVA, 75 r. p. m., 11,000 V, 50 cycles, for the *Rekingen power station* on the Rhine (Fig. 26).

Mention can also be made again of the *Juan Carosio* power station (formerly designated as Barbablanca) belonging to the *Empresas Eléctricas Asociadas, Lima.* This power station, a description of which appeared in The Brown Boveri Review [1], is equipped with three horizontal-shaft generators each built for 17,500 kVA, three transformers of the same out-

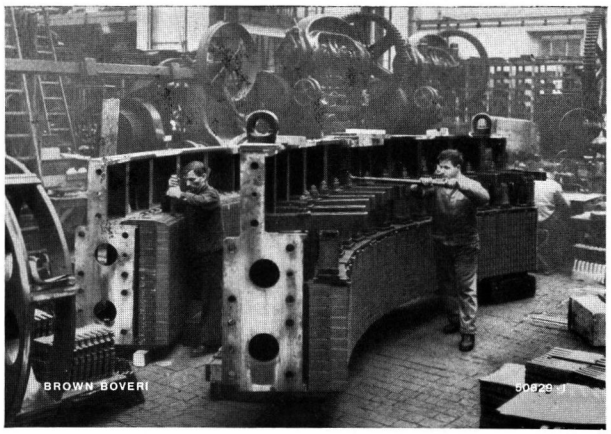


Fig. 26. — Part of the stator of a generator 22,000 kVA, 75 r. p. m., 11,000 V, 50 cycles.

put, a low-voltage switchgear plant and high-voltage switchgear plant with air-blast high-speed circuit breakers and a control room with light diagram.

Last year, a number of *automatic power stations* were built among which the following should be mentioned.

The *Ermal supérieure* power station of the *Cia. Eléctrica Hidráulica de Porto* which has a vertical-shaft three-phase generator of 2400 kVA, 500 r.p.m., 2000 V, 50 cycles and a switchgear plant with the apparatus for semi-automatic and remote-controlled operation. Starting is by hand. Service and regulation is taken care of by a remote-control device based on the *relay-combination system* which will be explained in some detail further on. Mention should also be made of the two *Zepayautla* and *San Pedro* power stations of the *Cia. de Luz y Fuerza de Toluca, Mexico.* These stations are equipped with generators of 860 and 480 kVA, respectively, 1000 r. p. m., 3300 V, 50 cycles, and are entirely automatic in operation. A system of supervisory relays looks after the putting into service and cutting out of the power stations, this both under normal service conditions and when a defect develops, a difference being made between transient and permanent defects.

[1] The Brown Boveri Review of October, 1939, page 227.

Finally the rarity of D. C. generators, to-day, make it appropriate to include here two D. C. generators mounted in tandem each for 2750 kW, 500 r. p. m., 400/500 V, each 5500 A to be coupled to a single hydraulic turbine and for the Ackersand power station of the Lonza Elektrizitätswerk und Chemische Fabriken A.-G. (Fig. 27).

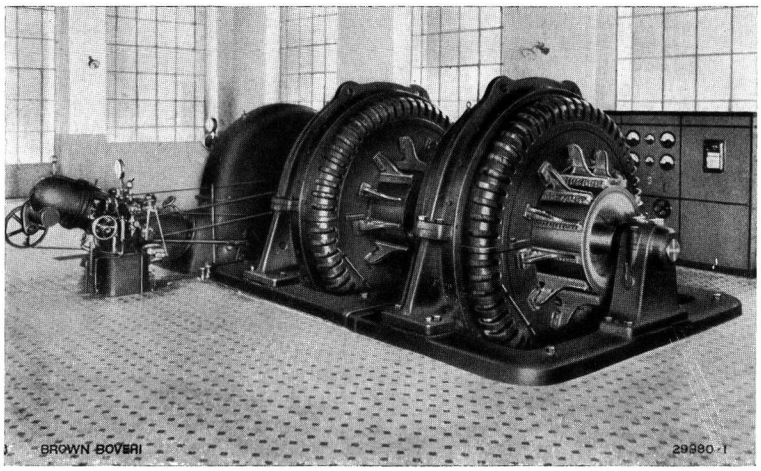


Fig. 27. — Ackersand power station of the Lonza Elektrizitätswerke und Chemische Fabriken A.-G., Basel (Switzerland). D. C. tandem generator 2750 kW, 500 r. p. m., 5500 A, 500 V.

2. *Transformers.*

In the course of last year, we found it necessary to take up a problem which has been frequently discussed, namely:— the transmission of big blocks of power over very long distances at very high voltage (400 to 500 kV). This problem is encountered, for example, when studying the possibility of using the sources of power available in Central Africa for the benefit of the industrial regions nearer the coasts; it also occurs when investigating power transmission from Scandinavia to the mainland and is met, very probably, in Russia, as well.

Apart from our investigations into the various branches of high-voltage technology such as circuit-breaker design, network protection etc., which will be mentioned in subsequent chapters, we have devoted study to the design of very high-power and very high-voltage transformers.

Systematic work has been done in the investigation of the economic and scientific problems inherent to *big transformer* design. Among these problems are those of the mechanical forces set up by currents encountered in modern regulating transformers in conjunction with the distribution of the taps, the problems of surge voltages, resonance, higher harmonics, voltage regulation, noise, cooling and especially insulating materials.

Not only the length of life and reliability of a transformer, but the total losses, dimensions and weight depend to a great extent on the qualities of the solid insulating materials utilized, on the way these materials are manufactured and the more or less skillful use made thereof in the transformer design. It is, thus, comprehensible that continuous laboratory tests have to be carried out to get new angles on the question, to confirm assumptions made and to explain phenomena shown up by practice. The present-day demand for as big outputs per unit as possible combined with the highest voltages for transformers which have to be freightened by rail and road calls for all the knowledge available on the properties of insulating material and makes it necessary to try to improve materials already in use and bring out new ones. The problem is made more difficult by the varying behaviour of different insulating materials as regards dielectric stresses at ordinary and at high frequency and for short or long duration. Both kinds of stressing demand independent tests. The well-known processes for the insulation of windings and coil turns against surge voltages have given very satisfactory results and there are well-founded reasons to believe that means and ways will be found to relieve still further the coil turns from the stressing they are subjected to from surge voltages, this in simple manner and without complicating the design. Thanks to the test plants we have at our disposal, to-day (impulse generators of several million volts and very perfected cathode-day oscillographs) we are able, when testing transformers, to reproduce very faithfully the conditions met with in practice, so that it is no longer necessary to await the results of years of practical experience.

Fig. 28 shows a portable transformer mounted on a special truck and hauled by an automobile.



Fig. 28. — Portable transformer.

3. *Circuit breakers.*

Under the impressions gained from the developments of recent years in general and from our own experience in particular we had become more and more convinced of the superiority and the future of the air-blast high-speed circuit breaker. Last year, however, exceeded all our most sanguine hopes in this respect. It should be said, here, that the very reliable reclosing device developed by us for breakers

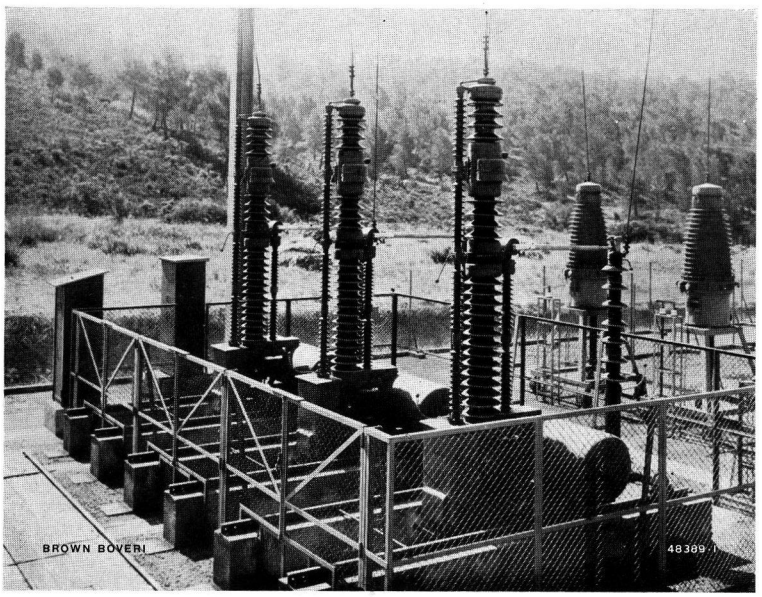


Fig. 29. — Air-blast high-speed circuit breaker 160 kV, with rapid reclosing device on each phase.

of the high-voltage range and described in some detail in our last year's report, did a great deal to help the air-blast high-speed breaker to conquer new ground.

Network tests were carried out in July of last year, on the occasion of the setting to work of the first 160-kV breakers equipped with the reclosing device. The line tested is 112 km long. It is equipped with a set of 160-kV air-blast high-speed circuit breakers at each end. One of the breakers (Fig. 29) had to rupture about 20 service short circuits and carry out a like number of reclosings. As the oscillogram (Fig. 30) shows, the total short-circuit duration was 0·1 s, divided into 0·05 s for the breaker and 0·05 s for the relay. During all these tests, the contacts were neither overhauled nor changed and the same contacts are still in service to-day. There is no other kind of breaker known in which such rapid successive closing and breaking operations could be carried out by the same contact elements with hardly any wear on the contacts at all. The network in question had its neutral point earthed so that single-pole breaking and reclosing tests were the principle subjects of investigation. The deionizing of the track of the arc at the point of short circuit was carried out perfectly despite the influence of those phases which had not been interrupted. It is true that for various reasons no tests on the maintenance of stability in the network affected could be made on this occasion. We know, however, from other tests which we have made that the interval during which the line is deprived of voltage can be made very long, in the case of single-pole opening and reclosing, without endangering network stability. This has the advantage that in the rare cases in which several lightning discharges occur, there need be no fear of service interruption. Earth-fault protection during storms is, thus, complete even on networks with earthed neutral point.

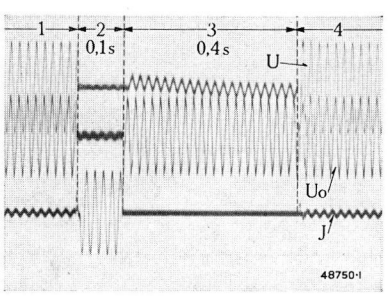


Fig. 30. — Oscillogram of opening and reclosing carried out by an air-blast high-speed circuit breaker 160 kV.

1. Normal service before fault.
2. Duration of arc short circuit.
3. One line conductor dead.
4. Resumption of service.

U. Voltage of line conductor subjected to arc short circuit.

U_o. Incoming voltage to the Bagnols substation.

J. Current in line conductor subjected to arc short circuit.

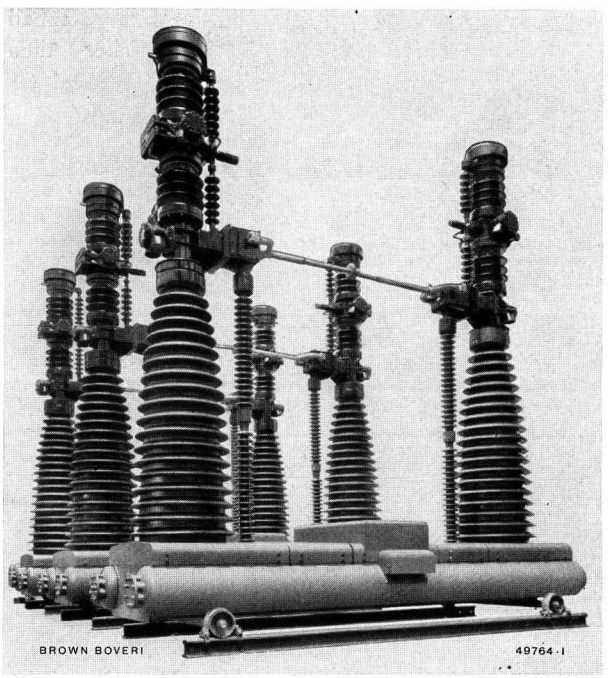


Fig. 31. — Three-phase air-blast high-speed circuit breaker set 220 kV, 630 A.

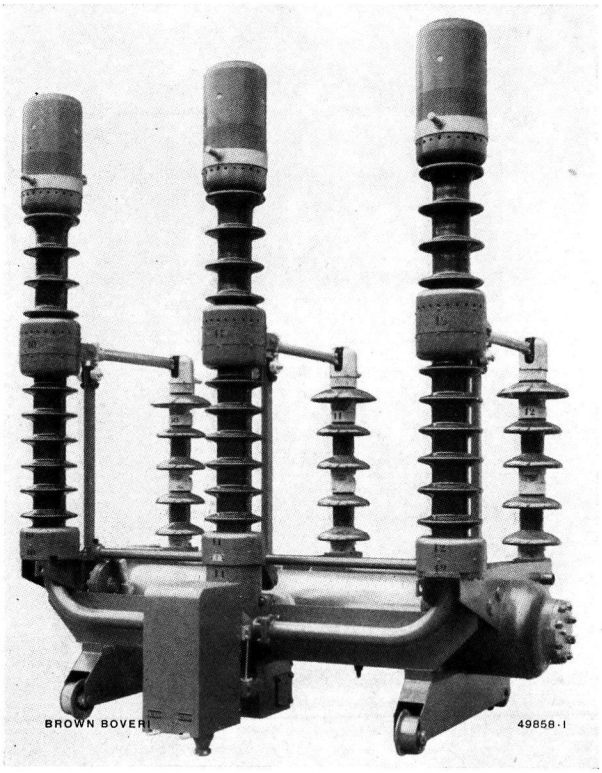


Fig. 32. — Three-phase air-blast high-speed circuit breaker 87 kV, 630 A, for indoor erection.

The results attained in service with our air-blast high-speed circuit breakers have led us to pursue breaker developments along the lines already followed. In our last year's report we gave an illustration of a model of the 220-kV air-blast high-speed circuit breaker then being built. Fig. 31 of the present number shows the completed breaker in question, as it was exhibited at the Swiss National Exhibition in Zurich, 1939.

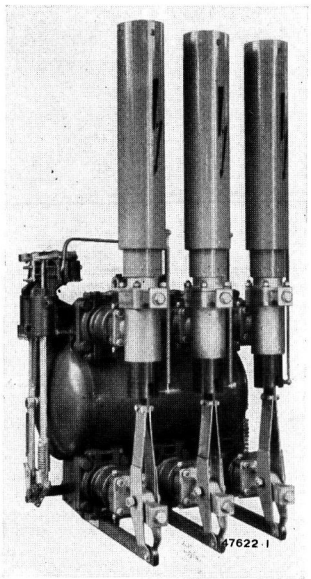


Fig. 33. — 11-kV air-blast high-speed circuit breaker with arc rupture in 2 stages. Rupturing capacity 750 MVA.

As mentioned in last year's report, it was, further, found necessary to develop air-blast high-speed circuit breakers for high voltages for indoor erection. Fig. 32 shows the newly developed 87-kV breaker of the series in question, a large number of which have been built in the course of the past year.

The opinion has been expressed, in various quarters, that the air-blast high-speed circuit breaker was not suitable for interrupting big loads. Our experience has led to exactly the contrary conclusion. Rupturing tests were carried out, last year, both in an English and in a Dutch high-power testing plant with our air-blast high-speed circuit breakers and these prove that if the design is correct these breakers will stand up to the severest requirements. The slight contact burning and easy supervision of the active parts were recognized as being special advantages of this type of breaker. Fig. 33 shows the breaker for 11-kV rated voltage which ruptured 750 MVA with a current of 30,700 A r. m. s. in the Dutch plant (Fig. 34).

As is known, the question of the interrupting of lines under no load has been the subject of recent discussion and was dealt with in the report No. 109 of the CIGRE. In this report, it was pointed out that, when lines under no load were interrupted, reignitions of the arc in the breaker could easily occur and be the cause of high over-voltage. It was, further, asserted that these breaker over-voltages were independent of the type of breaker used. It must be said, here, that when a line under no load is interrupted it remains charged. The recovery voltage between breaker contacts is small, at first, and the extinction of the arc is an easy matter. 1/100 second later, however, the double operating voltage appears across the breaker contacts and may lead to reignitions. Contrary to the point of view adopted in the above-mentioned publication, this can only occur if no measures are taken to deionize the track of the arc as quickly as possible after the current has passed through zero. We were able to prove the truth of this in the tests carried out on the 150-kV line which has already been mentioned.

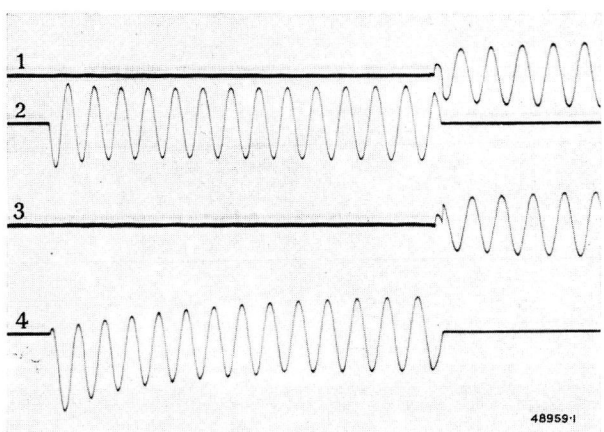


Fig. 34. — Oscillogram of the opening of an air-blast high-speed circuit breaker 11 kV.

1. Voltage phase R = 10·7 kV. 3. Voltage phase S = 10·7 kV.
2. Current „ R = 30·7 kA. 4. Current „ S = 30·7 kA.
Rupturing capacity 750 MVA. The current duration is set to 0·28 s.

When rupturing with our air-blast high-speed circuit breakers, no reignition phenomena were detected and therefore, no over-voltages due to this cause (Fig. 35). However, with breakers, the design of which simply makes such short breaking times an impossibility, reignition of the arc gap and resultant oscillations and over-voltages do occur, because the rupturing time is too long and therefore, the deionization process of the arc gap insufficient. Tests showed that, with a breaker of this kind, rupturing required 3 to $4\,^1/_2$ cycles after separation of contacts and the number of reignitions was 3 to 5. Our own tests showed conclusively that the air-blast high-speed circuit breaker is the most suitable one to interrupt lines under no load without causing over-voltage phenomena. For this reason, there is no necessity to provide special insulations for the arcing chambers of breakers which have to interrupt lines under no load, as is the case in breakers where there is a danger of reignition phenomena.

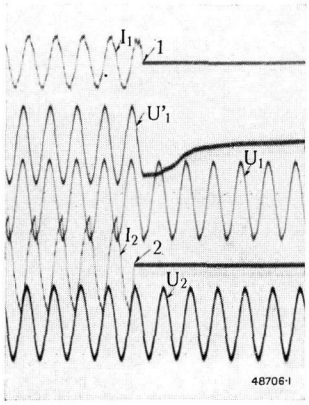


Fig. 35. — Rupturing of a 150-kV overhead line under no-load by means of an air-blast high-speed circuit breaker.

1. Rupturing current phase 1.
2. Rupturing current phase 2.
I_1. Charging current phase 1.
I_2. Charging current phase 2.
U_1. Busbar voltage phase 1.
U'_1. Voltage of the line phase 1.
U_2. Busbar voltage phase 2.

We also carried out exhaustive tests on the cutting out of transformers under no load. It was only necessary in rare cases to reduce the voltage occurring during switching operations by means of resistances.

Although we grade our normal air-blast high-speed circuit breakers not only as regards rated voltage and current but as regards rupturing capacity, as well and, in this way, go as far as possible to meet the needs of the market, there still remains a certain demand for breakers the rupturing capacity of which exceeds considerably the highest values listed. While, in the case of oil circuit breakers there is a very restricted possibility of increasing the capacity of the breaker, the air-blast high-speed breakers have much greater possibilities. In general, it can be said that it is possible to build them with rupturing capacities to satisfy all the conditions met with today. As an example of this, mentions should be made of the order we booked for the Victoria Falls and Transvaal Power Co. Ltd. (South Africa), which is interesting, both as regards capacity of the breaker and the number of breakers. This order comprises 39 breakers for 20 kV and 30 for 40 kV rated voltage

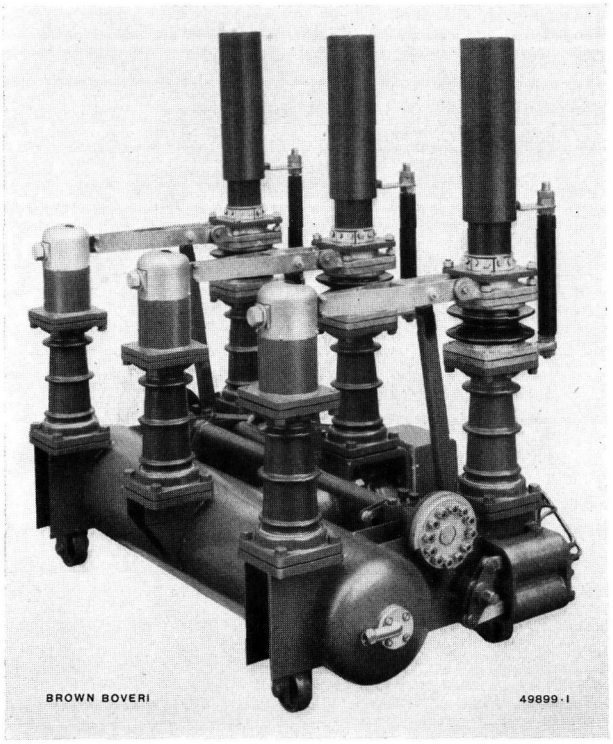


Fig. 36. — Three-pole air-blast high-speed circuit breaker 20 kV, 1000 A.

with rupturing capacities of 1000 and 1500 MVA respectively. These are the highest rupturing capacities ever obtained for breakers of this voltage range. Figs. 36 and 37 show the breakers in question and Figs. 38 and 39 show the rupturing oscillograms.

However, despite the success met with in the development of the air-blast high-speed breaker, there is every probability, in our opinion, that the oil circuit

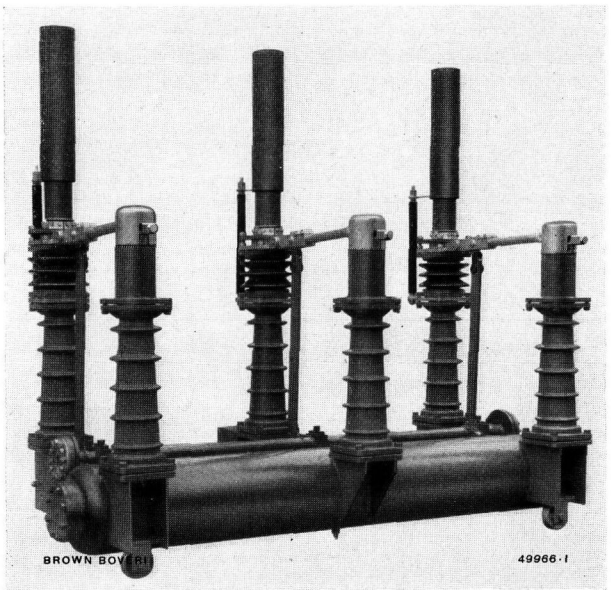


Fig. 37. — Air-blast high-speed circuit breaker 40 kV, 630 A.

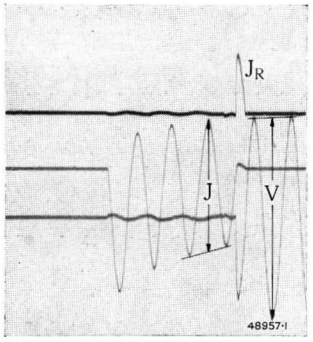


Fig. 38. — Oscillogram of the opening of an air-blast high-speed circuit breaker type DV 20 m 1000. Test on one breaker pole.

J. Ruptured current = 19·5 kA.
V. Rupturing voltage = 18·2 kV, corresponding to 21 kV line voltage.
J_R. Current in resistance.
Corresponding to a three-phase rupturing capacity of
$19{\cdot}5 \text{ kA} \times 21 \text{ kV} \cdot \sqrt{3} = 710 \text{ MVA}$.

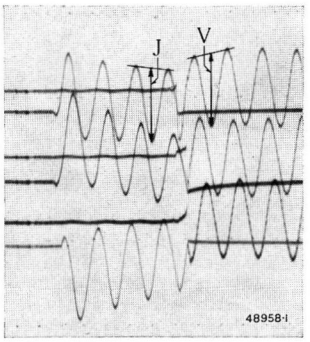


Fig. 39. — Oscillogram of an opening of an air-blast high-speed circuit breaker type DV 40 k 1500.

J. Ruptured current = 9·8 kA.
V. Rupturing voltage per phase = 24·5 kV, corresponding to 42·5 kV line voltage.
Corresponding to a three-phase rupturing capacity of
$9{\cdot}8 \text{ kA} \times 42{\cdot}5 \text{ kV} \cdot \sqrt{3} = 720 \text{ MVA}$.

breaker will continue to hold its position for moderate rupturing capacities and moderate voltage ranges, on account of its relatively low price. For this reason we decided to modernize our oldest series of oil circuit breakers having rectangular oil tanks and horizontal traverse. The resulting new series of oil circuit

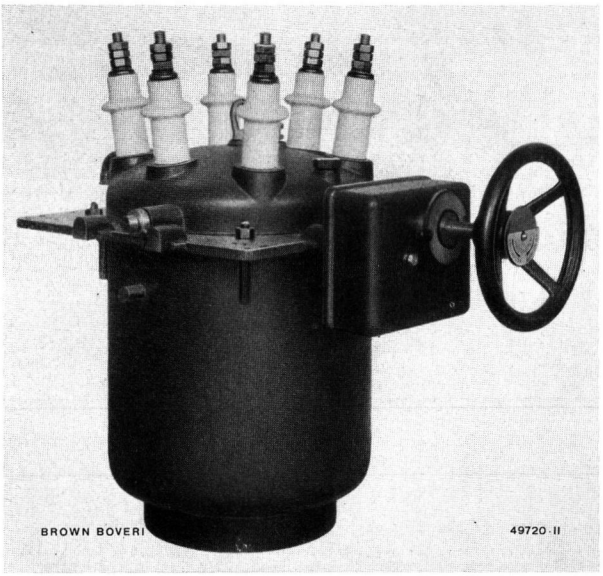


Fig. 40. — Three-pole oil circuit breaker 11 kV.

breakers have round oil tanks and covers and vertical insulation (no traverse between poles) for voltages up to 10 kV and currents up to 630 A. These have, in consideration of the simplicity of their design, remarkable rupturing capacities which go from 50 to 120 MVA and they meet all the requirements of breakers generally located at the extremities of distribution systems. Fig. 40 shows a breaker of this series for a rated voltage of 11 kV.

4. *Network regulation and regulators.*

For some time past, we have been working on the development of devices for remote control, remote metering and remote regulation. This very wide field of activity was brought to a definite stage of completion in the course of last year. We have developed three different systems to meet the various operating conditions met with in practice.

(a) *The line combination system Type LK.*

This system is characterized by its simplicity. It is employed where several pilot lines, free from outside influences, are available and the controlling and controlled stations are not more than 5 km apart. The equipment normally operates with a d. c. voltage of 48 or 60 V, maximum 100 V, and is designed for a pilot cross-section 0·5—1 mm^2.

The remote-control system utilizes combinations of the available pilots which correspond to definite selector positions. Of the n pilots available, two are always combined for each selector position. With n pilots, $n\ (n-1) : 2$ or with polarization rectifiers $n\ (n-1)$ combinations or selector positions can be achieved. The $(n-2)$ pilot wires remaining in each position are available for control, indicating regulating or metering purposes.

(b) *The single-impulse system Type EI.*

The single-impulse system is used where only two pilots are available which are free from outside influences. The number of impulses which can be transmitted with this system, however, is normally limited to twenty-five control and twenty-five indicating impulses, but the maximum possible is 100 control and 100 indicating impulses. This number will be found adequate for the majority of cases.

As in the case of the line-combination system Type LK, the single-impulse system equipment also operates normally with a d. c. voltage of 48 or 60 V, maximum 100 V, but has the advantage that it can be used for greater distances between controlling and controlled stations, i. e. up to about 20 km.

With this system, single impulses are transmitted over the pilots. These being employed for both advancing the selectors and control and indication purposes. If an order is sent from one station or the other, both selectors start rotating, make one complete

revolution and return to the zero position. Since with this system an order is allotted to each selector position, the selectors will transmit the desired order when passing the corresponding position. This occurs within 0·2 to 10 seconds. Different orders can also be transmitted during the same revolution.

(c) *The impulse combination system Type IK.*

This system is not restricted in its application. Length, current system and degree of interference with the two available pilots are practically immaterial, although these details must be taken into account when projecting the equipment. With d. c. currents of 48, 60 or 100 V, up to about 30 km can be allowed between controlling and controlled stations, while in the case of a. c. transmission the distance is, practically, unlimited. Moreover, by superposing a frequency outside the normal telephone band on already existing signalling or telephone lines, separate pilots can be dispensed with for remote control purposes, while if appropriate carrier-current transmission equipment is used, the high-voltage line can also be used for remote control, regulating and metering purposes.

The impulse combination system found an interesting practical application in the d. c. power-transmission line from Wettingen (near Baden) to Zurich, put up for the Swiss National Exhibition. The remote control equipment allowed of remote control and supervision of the mutator set in Wettingen from the Zurich end, which simplified service of the whole transmission system. In this way all switching and regulating processes could be initiated and supervised from one post, and telephone communication between Wettingen and Zurich was also possible, as well. Here, the transmission of remote control and regulating orders as well as telephone messages were carried out by carrier current transmission and on the same wire as the 50-kV d. c. power transmission.

The *control relay,* already mentioned in these yearly reports, which with its rolling contacts is similar to our quick-acting regulator, but which, contrary to the latter, impart its regulating orders by impulses and not continuously, was redesigned and modernized in the course of last year. Its field of application has been considerably widened. The *impulse regulator* which is the name given to this relay, to-day (Fig. 41) is intended for intermittent regulating processes and can be used equally well for a. c. and d. c. For a. c., it can serve as a voltage regulator for the control of induction regulators, tap switches etc. then as current regulator, minimum-load regulator in plants working in parallel with outside networks, when parallel operation has to be maintained without interchange of active power; it can also be used as phase regulator and as frequency regulator, for example to influence the speed adjusting device of a prime mover in order to compensate the static of the governor of the latter. For d. c. the impulse regulator can be used as a voltage regulator, current regulator and power regulator.

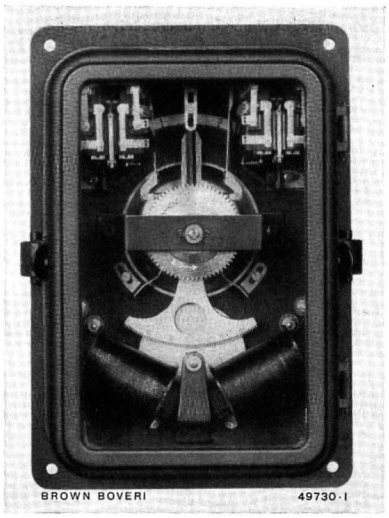


Fig. 41. — Brown Boveri impulse regulator.

5. *Relays.*

As is generally known, we have done much pioneering work in the *relay field* since the first period of relay developments under C. E. L. Brown, and we have devoted much study to the application of this type of apparatus. To-day we have available a big number of different kinds of relays suitable for the protection of machines and networks which meet every practical modern requirement. In the last number of The Brown Boveri Review of last year[1] we took the opportunity to describe the working processes of all the different types of Brown Boveri relay so that we can confine our-

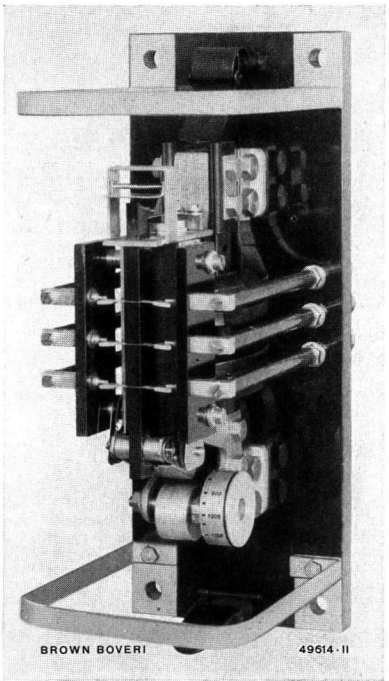


Fig. 42. — Instantaneous-action main-current relay Type HBH for direct current.

[1] The Brown Boveri Review of November/December 1939, page 247.

selves, here, to enumerating the most important novelties in relay design brought out during the past year.

Fig. 42 shows the *instantaneous-action main-current relay for direct current, Type HBH*, for rated voltages up to 3000 V, which is a primary protection against over-currents suitable for vehicles and for stationary plants.

The *minimum impedance relay Type ZA* (Fig. 43) is characterized by its precision up to the highest currents, that is to say it has very advantageous drop-out conditions. It acts as soon as the ratio voltage/current set for is no longer attained and is

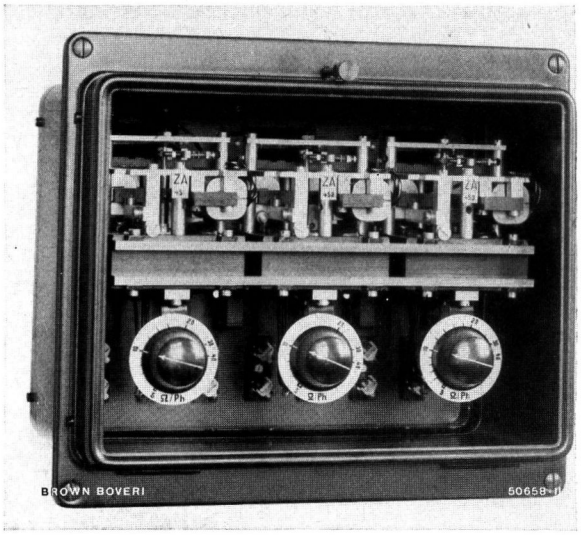


Fig. 43. — Three-pole minimum impedance relay Type Z A with adjustable pick-up impedance.

used either alone or in conjunction with other relays as protection against short circuits, in special cases. A case in point would be, for example, that of a power station during a period of low load with only some of the generators working, so that a short-circuit current occurring may be smaller than the full-rated current with all the generators running. The same conditions are found when a defect develops on a line linking up a small power station and a high-power network.

An especially important creation dating from last year is the *rotating-field distance relay Type L 3* (Fig. 44). This relay is for the protection of meshed overhead networks. It combines the advantages of the *impedance relay* and of the *reactance relay*. The rotating-field relay is insensitive to arc resistance at the point of short circuit, on which the impedance relay partly depends, further the rotating-field distance relay is not sensitive to compensating currents superimposed on the short-circuit current in networks which are rather unstable, as is the case for the reactance relay. The principle applied in the rotating-field distance relay in order to measure the distance away of the fault consists in utilizing an impedance equivalent in reduced ratio to the network to be protected. In this way, very short time lags, great insensitiveness to fault resistances and great precision in estimating the distance of the fault (no longer dependent on a moving measuring element) have been attained. One single organ of the rotating-field relay acts simultaneously as measuring and directional element. As Fig. 44 shows, all the apparatus to protect a three-phase branch is lodged in a case and easy to supervise. The case contains testing terminals as well to which, as Fig. 44 also shows, a new type of *testing apparatus* can be connected at any time. This apparatus serves to establish the current and voltage conditions on the relay terminals which are created when faults develop on the network. It allows of reproducing the conditions of two- and three-pole short circuits

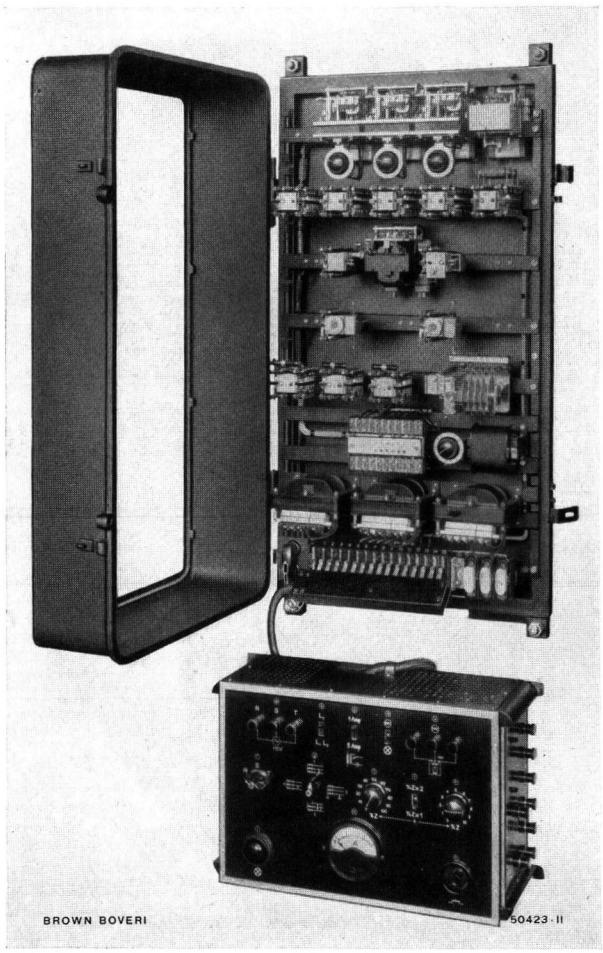


Fig. 44. — Rotating-field distance relay Type L 3 with testing apparatus connected up.

and of single and double earths between any phases. The distance of the fault can be set, here, with great precision (close steps).

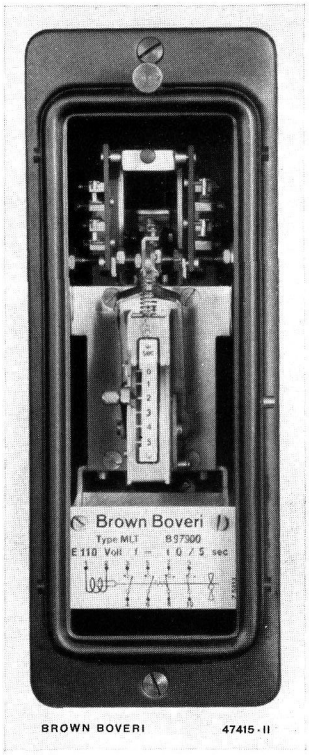


Fig. 45. — Brown Boveri time relay.

The *time relay* (Fig. 45) is an auxiliary relay for time settings for all kinds of protective and control connections; the time-setting range can be designed for settings as desired from 0 to 2 s up to 0 to 300 s.

Finally, mention must be made of our *small contactors* with 8 to 16 contacts which find an application as auxiliary relays with a large number of contacts for a great variety of protective and control connections. The contacts can be of the make or break type and the contactors have signal and push-button for hand operation, if desired, further they can have adjustable retardation at pick-up or drop-out.

6. *Switchgear plants.*

Last year, as well, we delivered a large number of indoor switchgear plants mostly equipped with air-blast high-speed circuit breakers. These plants did not depart in design from the forms already described here on several occasions. However, the development of *metal-clad switchgear cells* is worth noting. By utilizing compressed-air voltage transformers, all combustible or explosive elements are eliminated from these cells. Thanks to this innovation, the metal-clad switchgear cell comes into its own.

For a plant of this kind, we built a switchgear equipment with 108 truck-type panels, with 100 three-pole air-blast high-speed circuit breakers for 3150 V, 1000 to 1400 A and with 290 bushing-type current transformers (see Figs. 46 and 47).

It was, however, *outdoor plants* in which air-blast high-speed circuit breakers of the highest voltages found a place in switchgear deliveries of the past year. Here, there are few new fundamental problems to be solved because the air-blast breaker can always be

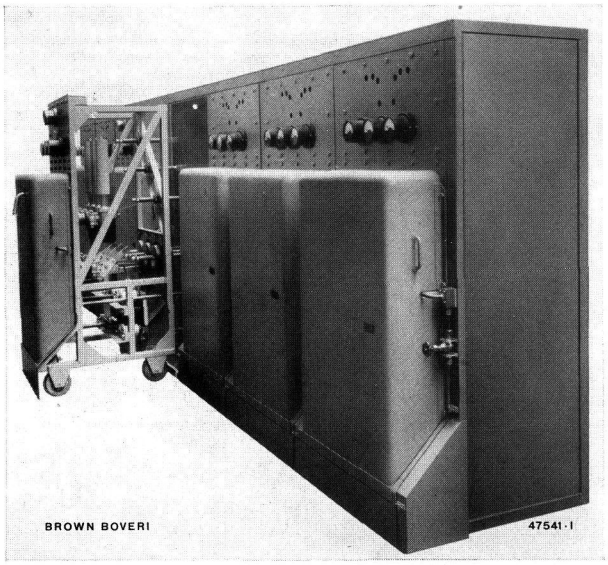


Fig. 46. — Metal-clad switchgear plant 3·3 kV, with air-blast high-speed circuit breakers mounted on trucks.

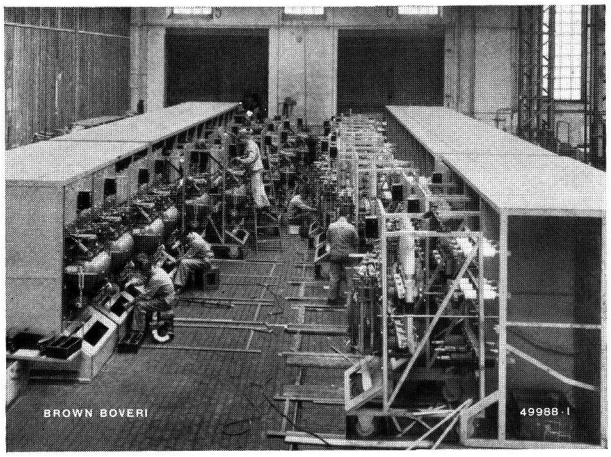


Fig. 47. — Erection of a metal-clad switchgear plant with air-blast high-speed circuit breakers mounted on trucks.

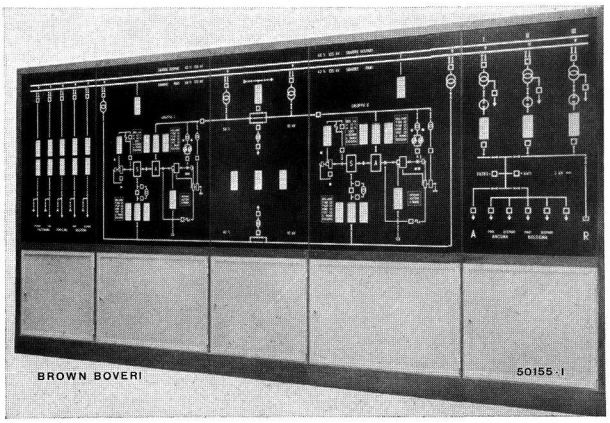


Fig. 48. — Light diagram for five 125-kV lines, a frequency converter and 3 mutator sets.

put in in the place of the oil circuit breaker with small oil filling which featured the preceding breaker development period. On the other hand, there were different difficulties to be overcome as regards the generation and distribution of compressed air.

Control rooms with light diagrams. — Of these several were built. The biggest (Fig. 48) comprises five incoming 125-kV lines, a frequency converter of 20,000 kVA and three mutator sets for the supply of the contact wire at 3 kV. We will give a detailed description of this light diagram in a future number.

A further development was the improvement of switchgear plants in small and bigger *automatic* power stations. It was the emergency sets, already touched on here, which were the motive for certain innovations being introduced. The *automaticity* of *mutators* was, also, simplified. As will be recalled, the automaticity of mutator plants consisted of a time switch and a reclosing apparatus for the control of the set and vacuum set, of a vacuum meter with contact device and a further switching apparatus.

This whole gear has now been simplified by being lodged in one single piece of apparatus (Fig. 49). The set breakers are controlled by a time switch according to a program determined in advance and can always be influenced by remote control. The vacuum pump set is also switched in and out by the time switch according to values set, by experience, in advance. Direct control according to the state of the vacuum has been eliminated. There is a multi-pole change-over switch for cutting out the automaticity after which control of the mutator plant must be carried out by hand.

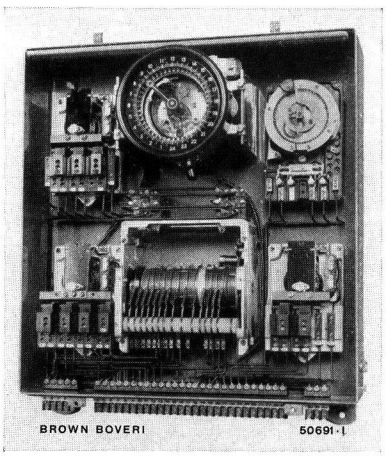


Fig. 49. — Switching apparatus for the automaticity of mutator sets.



Fig. 50. — Small rectifier for charging storage batteries.

Small switchgear equipments have been brought out for vehicular and portable generator plants; the bigger sizes are mounted on trailers for motor cars and the small size can be carried by one man.

Fig. 50 shows a *small rectifier* in the form of *selenium cells* combined in a casing with its switchgear apparatus.

II. POWER DISTRIBUTION AND CONVERSION.

A. TRANSFORMERS.

Decimal index 621.314.

The comments already made on the subject of power-station transformers are valid, in every respect, for substation transformers.

The problem of dimensioning *distribution transformers* properly is one which is studied periodically. By distribution transformers, we mean the units which transform medium network voltages to consumer voltages. The reason of their importance is the part they take in the total capital outlay of a big network, in the total no-load losses incurred and in wattless current consumption. After having based the dimensions of these transformers on certain standard calculations with fixed ratios of iron and copper losses at full load, a system followed generally for many years, we find to-day a conviction gaining ground that the outlay on the transformer should be considered in relation to the cost of operation that is, chiefly, to the cost of the annual losses and that, practically always, it is more advantageous to put in a transformer with low annual loss costs and low wattless current consumption even although it is more expensive to acquire.

In order to discover the most advantageous solution taking losses, wattless current consumption and cost all into account, new calculations and tests were made. Here, it was again shown that it was not possible to grasp the real conditions by a calculation of minimum losses. Only calculations taking into account the variation of iron and copper losses, wattless power consumption, short-circuit voltage, cooling and amount of material used can give real results. Fig. 51 gives examples of curves which result from painstaking calculations of this nature.

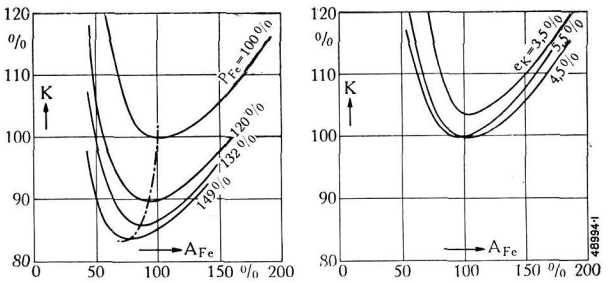


Fig. 51. — Cost curves for three-phase transformers 50 cycles, 100 kVA, 10,000/400 V, star/zigzag connection.
Costs K (including oil) in function of the section of the legs A_{Fe}.
Left:— For different iron losses A_{Fe}; short-circuit voltage constant.
Right:— For different short-circuit voltages e_K; losses constant.

The measurement transformers profited from the advances achieved in big transformer design and the reliability, economy and precision of the former have all improved.

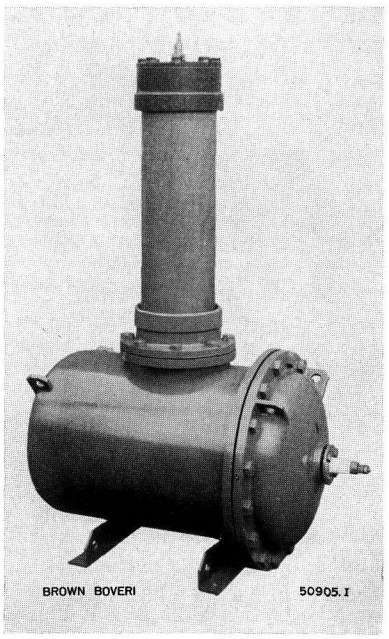


Fig. 52. — Single-phase compressed-air potential transformer for 64-kV rated voltage.

The dimensions of measurement transformers are especially a function of the properties of the insulating material used. The improvement in the quality of the sheeting has also been beneficial. The tendency to eliminate oil from switchgear plants has led to the development of *compressed-air voltage transformers* (Fig. 52), these are very suitable to plants where air-blast circuit breakers are mounted and where a compressed-air generating equipment is, therefore, available.

B. DISTRIBUTION-SYSTEM PROTECTION.

This was a field of some controversy during the past years, but a satisfactory degree of order has been gradually evolved and it can be said that only a few questions — and these mostly of secondary importance — await solution to-day.

The results of single-pole earth faults due to direct strokes of lightning that is to say of the over-voltages created by reignition of the arc to earth, which experience shows make up 70 % of all faults encountered on networks, have been remedied by us by putting in *extinction coils*, a measure we advocated years ago. Some of these extinction coils built by us in recent years are among the biggest of their kind yet produced. In networks the neutral point of which is straight earthed or through a low resistance, the utilization of breakers with automatic quick-acting reclosing devices can be a useful form of earth-fault protection. But even in networks with neutral point earthed through an extinguishing coil, the automatic reclosing feature on the breakers can form a valuable complement to the protection against the effects of storms, because the breakers thus equipped take care of the 20 to 25 % of arc short-circuit accidents which are not mastered by the extinguishing coil and which might otherwise cause service break down. In this way the number of cases of trouble leading to service break down is reduced to a small percentage.

A similar protective measure is formed, under certain conditions by the *protector tubes*. These are placed in parallel with all the line insulators, if possible, and act as spark gaps. When the voltage exceeds the admissible value, these tubes act, lead off the energy of the lightning stroke and instantly cut the current which would follow. The protector tube, of which Fig. 53 shows a 15-kV type, is composed of an inner and an outer gap with an arc-extinguishing tube. The current to be cut after the flash-over is either a capacitive earth current or an inductive short-circuit current. The rupturing quality of the tube is based on the vaporization of the inner wall of the tube through the action of the arc itself. When it works properly, only a half cycle is needed to break the current so that, in service, the functioning of the arrestor is hardly noticed. However, the rupturing capacity of the protector tube is limited, for which reason we consider the automatic high-speed reclosing feature on the breakers as being the simplest method, in most cases, in order to allow of carrying on service after a fault has occurred.

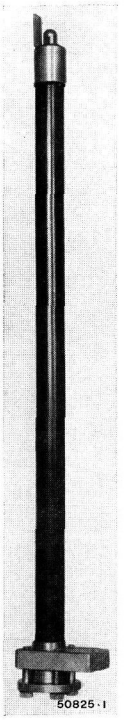


Fig. 53. Protector tubes for 15-kV rated voltage.

The *protection of switching and transformer stations* is best looked after, in our opinion, by *the coordination of the strength of insulation*. The Brown Boveri Review has already published an article on our work in this field[1]. The functioning of safety spark gaps is not a drawback to service when these gaps are combined with breakers for high-speed reclosing or with protector tubes. In switching and transformer stations, devices to bring down the over-voltage are not necessary. But for plants of low and medium service

[1] The Brown Boveri Review of August, 1939, page 179.

voltages our *Resorbit lighting arrestor* is an excellent protection against over-voltages. We have succeeded in so increasing the conductive capacity of the Resorbit lighting arrestor that it can handle quite considerable amounts of energy. A type for as high as 5000 A absorption capacity has been developed.

C. THE COUPLING OF SYSTEMS.

The Lütschental plant of the Jungfrau Railway was a milestone in the development of system coupling. It was put to work in the last days of 1938 and has worked satisfactorily ever since. With the help of one single grid-controlled mutator the two three-phase networks of the Jungfrau Railway and the Bernische Kraftwerke are coupled together so as to allow of an interchange of power between them. The plant has been described in detail[1] so that we need say no more about it, here.

D. DIRECT-CURRENT POWER TRANSMISSION.

Power transmission by three-phase current or alternating current in any form, the development of which owes so much to C. E. L. Brown, to whom is chiefly due the first practical power-transmission experiment of the year 1891 (Laufener power transmission), presents certain inherent drawbacks — self induction and capacity phenomena — which limit its scope. We have reached the conviction that the solution of this problem of the transmission of big blocks of electric power over very long distances lies in the utilization of high-voltage direct current produced in mutators, the universal type of converter. Last year we were offered the welcome opportunity of making a trial plant, to a small scale it is true, but one which allowed of drawing valuable conclusions for future developments. This is a power transmission of 500 kW at 50,000 V d. c. from the Wettingen power station, near Baden (belonging to the Zurich Electricity Works) to the Hall of Electricity in the Swiss National Exhibition in Zurich.

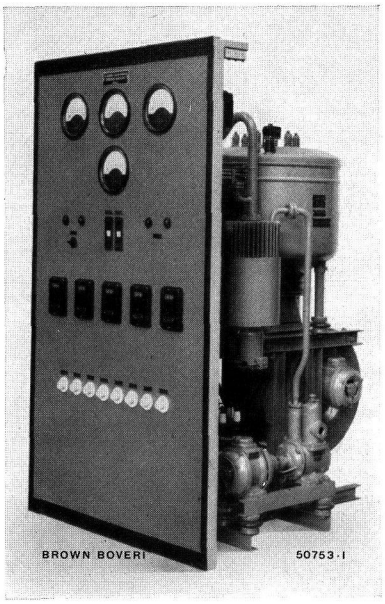


Fig. 55. — Mutator bloc 200 kW, 575 V, 348 A, for the Drammen tramway service.

Fig. 54 shows the station at the receiving end of the line with its single mutator unit to convert the incoming d. c. into three-phase current for distribution to the network of the town of Zurich. We would refer, here, to an article on this plant in The Brown Boveri Review[1]. It is our hope that the realization of this practical d. c. power transmission plant will be a milestone in electrical developments as was the aforesaid Lauffener power transmission.

E. MUTATORS.

The development of mutators with direct air cooling has led to units of big current output. Tests with 5000 to 6000 A go to show that heavy currents can be handled perfectly reliably by air-cooled mutators. We would refer specially to Type AL 56 for 3150 A and 600 V. For smaller air-cooled sizes our mutator blocs are meeting with a ready reception.

Fig. 55 shows a 200-kW, 575 V, 348 A air-cooled mutator bloc for the Drammen Tramway service.

We now build mutators up to 24 kV and 1200 kW as air-cooled units for broadcasting stations.

Further a big number of standard-type mutators with water cooling were delivered last year, among the most important being units for electro-chemical purposes. Thus, for the Arvida plant in Canada (Fig. 56), already mentioned here several times, we delivered five complete double mutator sets for a total of 52,600 A up to a max. of 620 V (32,600 kW). This equipment is for the enlargement of the melting-bath electrolytic mutator plant.

[1] The Brown Boveri Review, 1939, page 117.

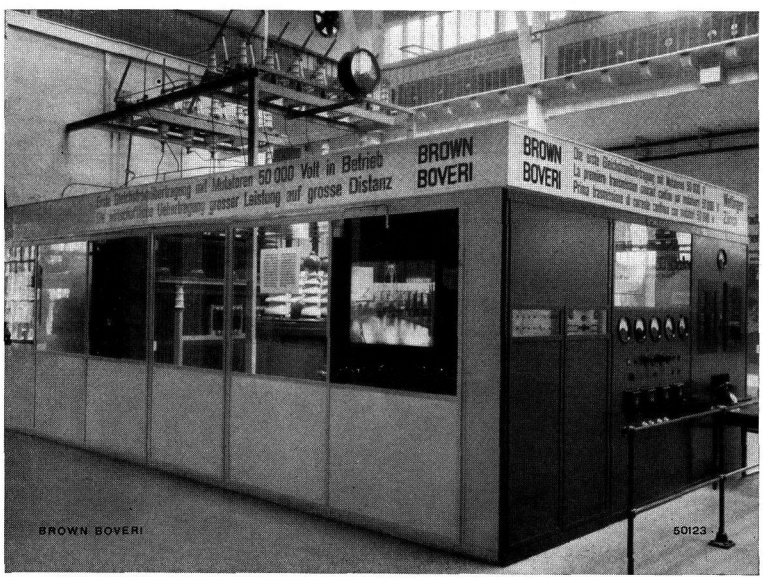


Fig. 54. — Direct-current power transmission by means of 50,000 V mutators, between Wettingen (near Baden) and the Swiss National Exhibition in Zurich.

[1] The Brown Boveri Review of April/May, 1939, page 92.

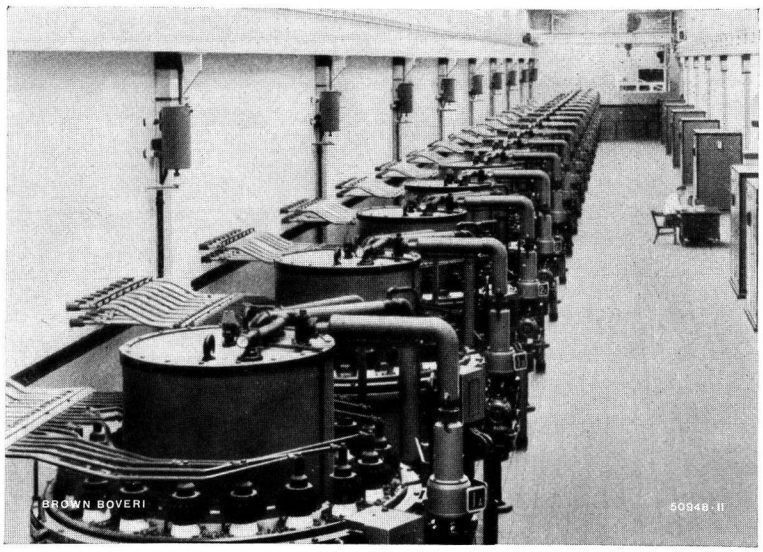


Fig. 56. — Arvida mutator plant of the Aluminium Company of Canada. 18 Brown Boveri mutators for a total of 94,700 A at 575 V, output 54,450 kW.

By this order, the client shows tacit recognition of the superiority of mutators to the older rotary converter plant.

Still more important is the order from another aluminium plant and comprising six double mutator sets for a total of 72,000 A, max. 800 V, thus for a total of 57,600 kW. Each set is composed of an auto-regulating transformer with regulation on the secondary side, and a simple six-phase mutator transformer.

A Swiss aluminium plant with a total mutator output of 8000 kW, 23,000 A at 350 V was enlarged by a double set giving 4025 kW and 11,500 A. The whole plant was provided with a device to regulate to constant current strength by grid control through the agency of a newly-developed d. c. measurement transformer with oil-pressure servo motor.

Finally we got the order for a portable mutator substation with two mutators from the *Cia. Paulista de Estrados de Ferro*, São Paulo (Brazil). We had already delivered the electric equipment of a locomotive to this company some years ago. This new mutator plant is interesting not only because of its big dimensions and output but also because of the special mutator equipment with controlled grids for power recuperation and compounding. The plant is for totally automatic operation and the automatic d. c. feeder switches of both outgoing feeders have automatic reclosing devices. The equipment is mounted on two railway trucks each about 20 m long and so coupled together that they form a unit. On the first truck are mounted the primary breakers, the two mutators each of 3000 kW and 3000 V, the transformers, the cooling sets and the grid controls while the other truck has the apparatus for automatic service, the protective and metering devices as well as the choke coils and d. c. breakers.

F. A.C.-D.C. CONVERSION IN ROTATING MACHINES.

Last year, in relation with an enquiry received for heavy currents at very low voltages we took up once again the problem of the design of *unipolar machines* and reached a satisfactory solution. These d. c. machines, which have been built from time to time, during the last decades, never proved a success because the tendency was always to make them for relatively high voltages. This was only possible by having a big number of slip rings in series and by running the machine at relatively high speeds; the first measure was unfavourable to the reliability of operation of the machine and the second measure made current collecting a difficult matter. The solutions sought, in earlier days, as concerns the collecting of the very heavy currents had no success at all and the manufacture of this type of d. c. generator was given up, all the more so as the difficulties inherent to very long commutators were well known at the period. On the other hand the unipolar machine seemed an absolute necessity for the generation of extremely heavy currents at very low voltages. These are conditions for which mutators cannot be used. To meet the requirements of the special cases under consideration, a solution is found by the elimination of slip rings altogether, and providing for straight current collecting from the rotor itself. Fig. 57 shows one of the unipolar machines built by us last year, for 13 V, 30,000 A and 735 r. p. m., driven by a three-phase induction motor.

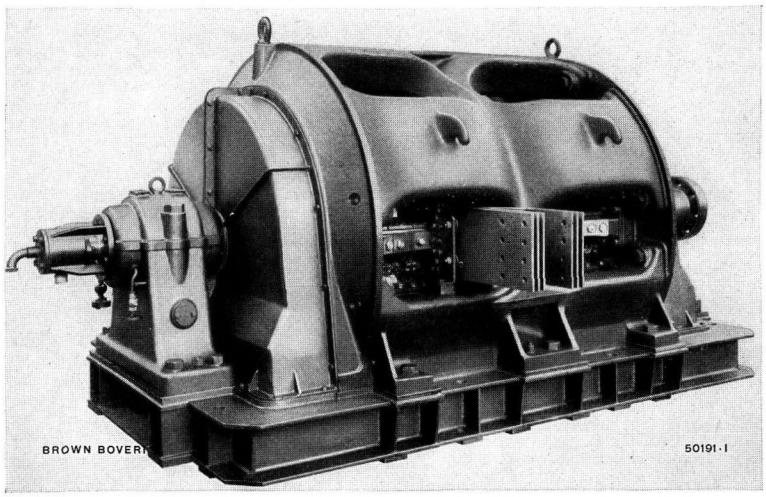


Fig. 57. — Unipolar machine, 13 V, 30,000 A, 750 r. p. m. for supplying aluminium furnaces.

III. OUR PRODUCTS IN INDUSTRY, TRADE AND AGRICULTURE.

A. DRIVES BY ELECTRIC MOTORS AND THE APPARATUS BELONGING THERETO.

Decimal index 621.34·

Our *three-phase shunt commutator motor,* in pipe-ventilated design, found numerous applications for the drive of ring-spinning frames and doubling frames in the *cotton* and *worsted industries.* Variable-speed drives also found practical application in other branches of the textile industry. Thus, ring-spinning frames have recently invaded the *carded-wool industry* and taken a place beside the self-acting mule which, alone, had held the field, up till to-day. Here, it is of great importance that the speed be adjusted to suit the momentary spinning conditions and the same applies to the automatic speed regulation to maintain constant thread tension (Fig. 58).

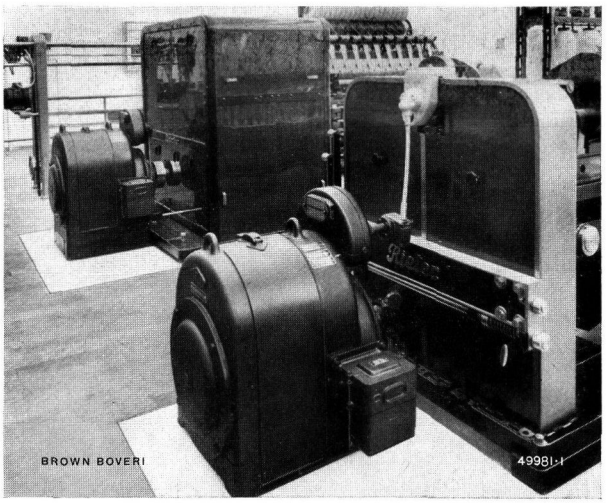


Fig. 58. — Variable-speed drive in a cotton and ring spinning machine for carded wool by Messrs. Rieter & Co., by a Brown Boveri three-phase shunt commutator motor with spinning regulator.

In the *Rayon industry* variable-speed drives are increasingly demanded for ring doubling frames and especially for those machines on which bobins with cylindrically wound layers of thread are made. The advantages of automatic speed regulation by the twist regulator can be summarized as follows:—

Constant thread tension and, therefore, an even twist, coils of uniform wound hardness and of resistant quality, winding space on coils better utilized, considerably increased production as a result of a higher average working speed (Fig. 59).

Increased interest was shown for the *individual drive of cards* in the cotton industry and a large number of these drives was delivered, in various designs, in the course of last year, for drives through chain or belt (Fig. 60). In the case of older cards made for transmission-shaft drive, existant auxiliary belt drives often prevented the putting in of individual drives. However, by suitable transformation of the card, at very moderate cost, it was found possible, in many old mills, to introduce individual drives, which have proved most successful.

Combing machines have also been supplied, in considerable number, with individual drive (Fig. 61) this especially for spinning mills using Egyptian cotton. These machines are called on to start and stop frequently. Therefore, a contactor is made use of for the switching in and out of the motor. It is controlled by the control rod on the machine, through the agency of an auxiliary switch.

In the electric drives of paper-making machines, there has been an increasingly marked tendency, in recent years, to turn the machine into a single unit, the *electro paper-making machine.* Apart from the saving in space thus effected, the chief reasons for this transformation were the disadvantages inherent

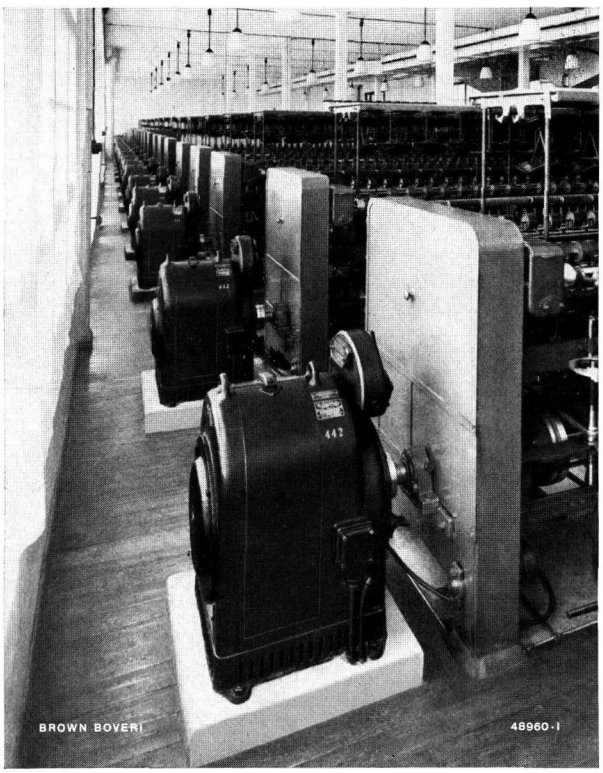


Fig. 59. — Ring doubling frames for the Rayon-industry with variable-speed drive by means of three-phase shunt commutator motors with twist regulator, for constant thread tension in the manufacture of bobins with cylindrically wound layers.

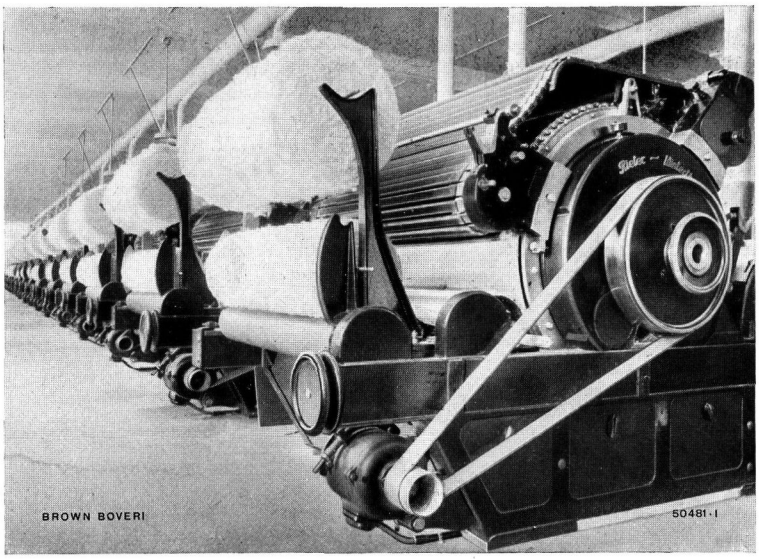


Fig. 60. — Individual drive of cards in a Swiss Egyptian-cotton mill.

to the drive of the dryer by big gear wheels, which characterized the machines used up till to-day. Frequently, the dry section consists of up to 60 steam-heated cylinders of from 1·2 to 1·8 m diameter which are combined by gear wheels, into one or several sets. Each set is driven independently. The big gear wheels required have correspondingly high peripheral speeds all the more marked the higher the speed of the paper-making machine itself. They, consequently, often give rise to noise and considerable losses of power. Further, these big gear wheels make the machine rather inaccessible on the driving side.

It is true that improvements have been introduced to mechanical drives, in recent years, but the defects of the drives just described can really only be got rid of by going in for electric drive. Here, each cylinder, or each couple of cylinders, is driven by a motor. This allows of dividing up the drying section into a number of groups, an advantage in machines making special grades of paper, because the considerable changes in the length of the paper in its journey through the drying section can be duly taken into account by corresponding adjustments of the relative speeds of the cylinders.

In the drive shown in Fig. 62, each pair of drying cylinders is driven by a motor through a worm gear. Fig. 63 shows a machine in which each cylinder has its own drive. In this case, the motor and reduction gear form a unit. The gear-wheel housing is mounted over the prolonged shaft end of the drying cylinder. Drives of this kind can be built to run practically noiselessly and under satisfactory efficiencies while the space taken up is small.

For drives of this kind, there are special regulating devices for setting and maintaining the paper draw. These are placed in a switchgear panel, apart from the drive proper, and are specially protected from drip or spray water.

Special regulating devices are required for the electric *sectional drive of combined cardboard-making machines*, which are equipped with cylinder wires and with a fourdrinier part. These regulating devices are necessary in order that the paper coming from the cylinder wires and fourdrinier part may be formed into compact cardboard sheet, without wrinkling or squeezing. These machines have very long felts running over a big number of rolls of which at least two are driven. It is of importance that the felt should not be made to work as transmission agent itself and be stressed and damaged, thereby. Regulating devices have been brought out for the drive of these cardboard-making machines which meet the special requirements of manufacture. Fig. 64 shows a combined cardboard-making machine, which was originally equipped for drive from a transmission-shaft and was then made over for electric sectional drive, with the regulating devices above-mentioned. The illustration shows how little room is taken up by the new drive while the old transmission-shaft drive filled nearly all the available space. If this were a new plant, the driving sets would be placed close to the machines, which would allow of making the building very much smaller than it is.

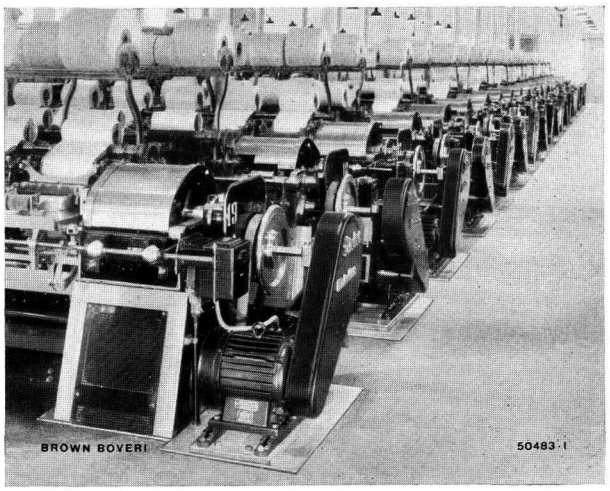


Fig. 61. — Individual drive of combing machines with contactor control, in a Swiss spinning mill, using Egyptian cotton.

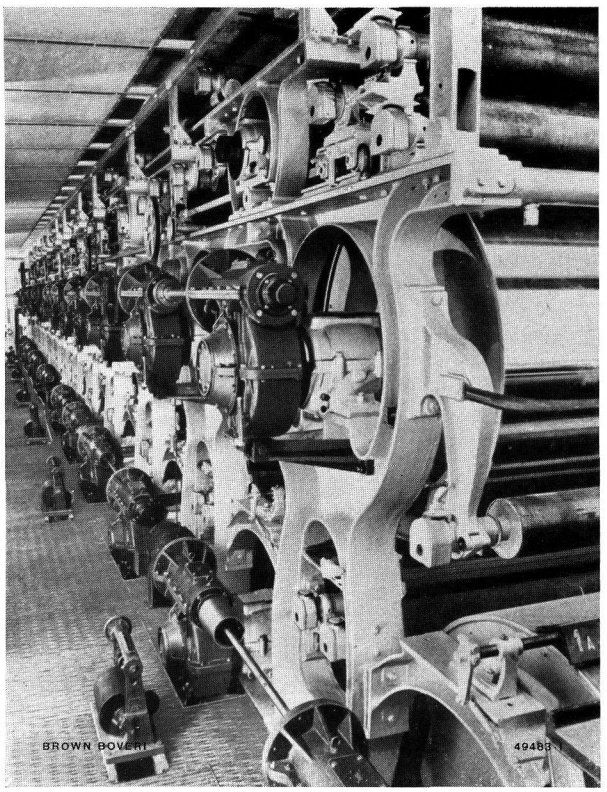


Fig. 62. — Sectional drive of a paper-making machine of 3050 mm wire width and 180—270 m/min.

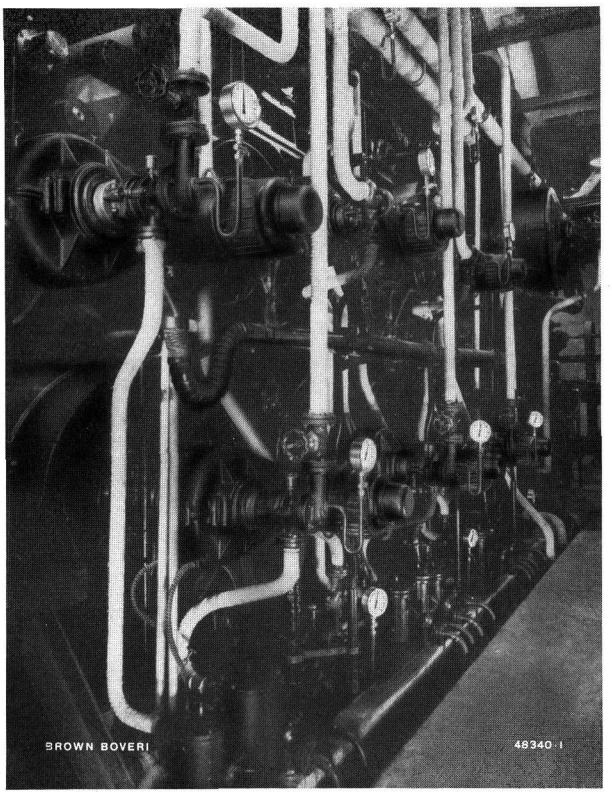


Fig. 63. — Sectional drive of a paper-making machine of 2450 mm wire width and 30—150 m/min.

Smaller paper-making and cardboard-making machines driven from a main transmission shaft are advantageously equipped with a three-phase shunt commutator motor. Machines of this kind have, often, a very wide range of working speeds. In order to be able to work at a satisfactory efficiency and power factor, two driving motors of half the output, instead of one big one, are used. Each motor can be coupled to the pinion shaft of a speed-changing gear through the agency of a clutch type flexible coupling. At speeds below about 50 % of the maximum, only one motor is used, which is correspondingly well utilized. For the higher range of speeds the other speed step of the reduction gear is used in conjunction with both motors. With this arrangement, one motor acts as stand-by for the other.

Fig. 65 shows a drive of the kind described, which is also equipped with an automatic device for very precise maintenance of the paper speed adjusted to.

In the small and medium-size *printing press drives*, the speed of which must be variable over a wide range, the three-phase shunt commutator motor has been used extensively. A deciding factor for this success of the three-phase shunt commutator motor

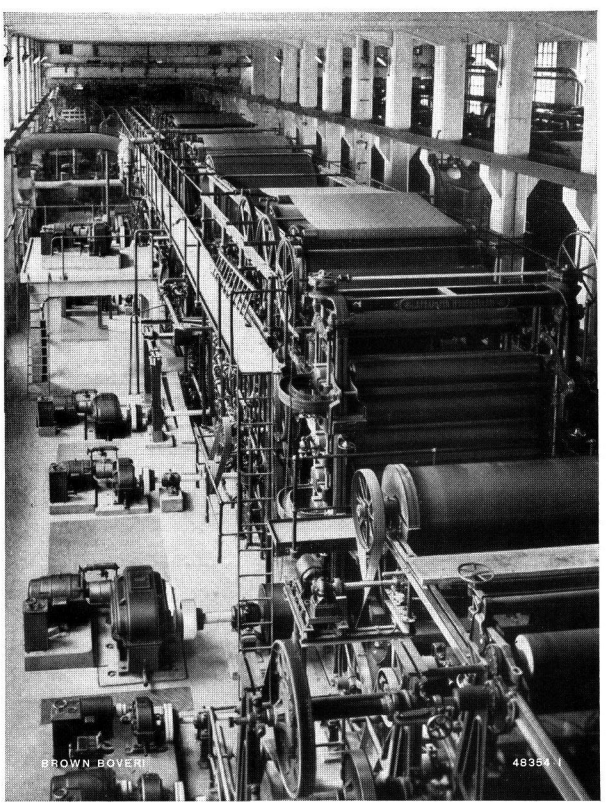


Fig. 64. — Sectional drive of a cardboard-making machine of 2450 mm wire width and 7—70 m/min.

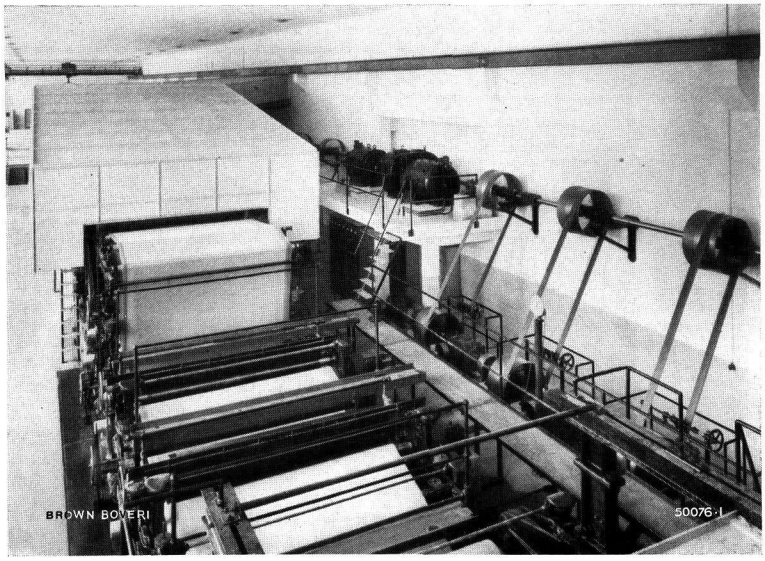


Fig. 65. — Drive of the variable speed part of a cardboard-making machine of 5—120 m/min.

is its great adaptability to the range of speed variation required and to push-button control which is being increasingly demanded. Fig. 66 shows two non-relief printing presses driven by two 4·5 H. P. three-phase shunt commutator motors with push-button control.

Switchgear apparatus for use in industries has been developed in recent years, because the manifold applications of motors to industrial drives have created a demand for very adaptable apparatus. Certain lines of apparatus have been completed in the course of last year and of these we would describe a few in the following paragraphs.

The interest awakened by the *small motor protection switches* Type NH1 for manual operation and NM1 for coil operation made it appear desirable to bring out a design with metal housing besides the one with insulating housing, this in order to make the switch suitable to every industrial plant (Figs. 67 and 68). The new types NHT1 and NMT1 have strongly built housings of steel sheeting with a tight fitting. The openings for the leads on the upper and lower housing facings can, according to requirements, be closed by simple cover pieces or have pipe branches or cable end boxes fitted to them while the upper opening can be fitted with an ammeter. These switches, in their original design, are built for 6 and 10 A rated current, but, when fitted with reinforced silver contacts, they can be delivered for 15 A. The same housings are used for the switches for manual and for coil operation.

The series of our *push-button plates* and *push-button boxes* has been extended so that we have on stock push-button designs with 1 to 8 push-button switches (Figs. 69 and 70). The switches can be made distinguishable by having buttons of different colours — black, red, green — and also by indication plates. The buttons are somewhat countersunk to protect them from accidental damage by contact, but are very easy to operate. Signal lamps with glass covers of different colours or blocking switches to be actuated by hand or by a key can be put in in the place of push-button switches, if desired (for example several push-button switches and a lamp).

New relays *Type KC* have been brought out to replace the over-current relays Type KB. These new relays are designed with 1—2—3 poles and in three sizes of 0·5—25 A, 25—160 A and 160—250 A. They are chiefly intended for the protection of motors and lines against dangerous overloads. The relays are provided with short-circuit proof, directly-heated thermal-release devices of the latest design, having short metal strips, similar to those built into motor-protection switches and which have been so successful. When the tripping element acts, a making or breaking



Fig. 66. — Drive of a non-relief printing press by Brown Boveri shunt commutator motor 4·5 H. P., which can be regulated between 650 and 2000 r. p. m.



Fig. 67. — Small motor-protection switchbox with single pipe branch.



Fig. 68. — Small motor-protection switches with double cable-end box and ammeter.



Fig. 70. — Left:— Plate with two push-button switches, blocking switch with control button and signal lamp.
Right:— Box with the same parts but with blocking switch for plug-key operation.

contact is actuated which is inserted on the tripping circuit of the motor switch. The metal housing has openings above and below to bring in the leads; these can be fitted with the usual connection parts (pipe branches, cable-end boxes, etc.). The new relay (Fig. 71) is not only suitable for flush mounting on switchgear panels but also for building on to shunt commutator motors, for which the protection offered by a relay in the secondary circuit is of great value in certain cases.

The high voltage switching cubicles Type B (Fig. 72) have been developed, the new oil circuit breaker Type OG being incorporated therein. These cubicles are intended for control and protection of motors

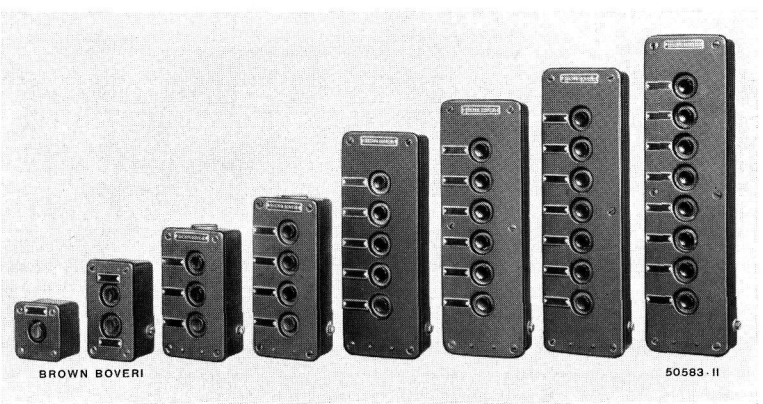


Fig. 69. — Brown Boveri push-button boxes.

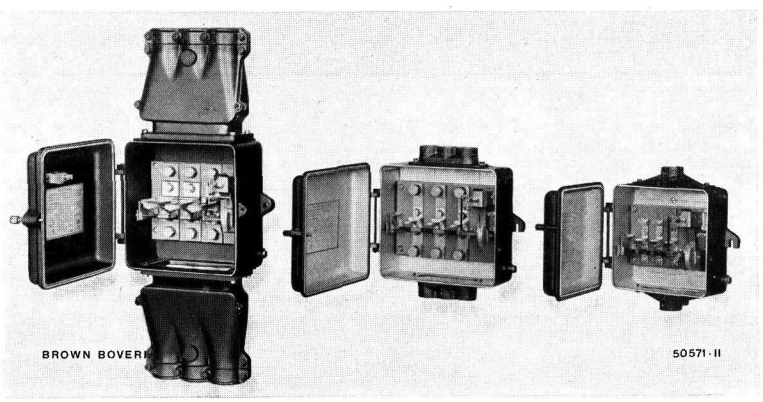


Fig. 71. — Over-current relays for 160—250, 25—160 and 0·5—25 A, with built-in directly-heated series thermal releases and provided with different connecting parts for bringing in the leads.

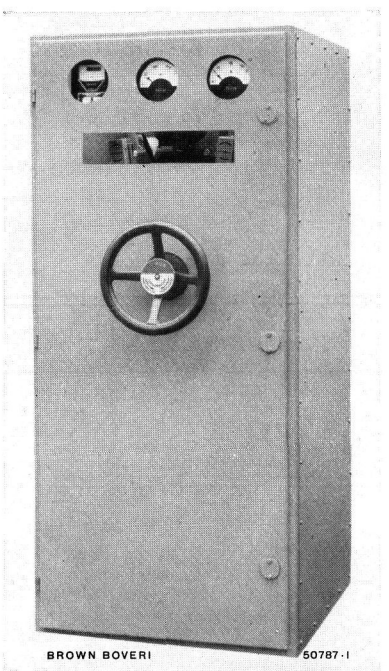


Fig. 72. — High-voltage switch cubicle for manual operation of the oil circuit breaker, with two built-in series thermal relays ammeter, voltmeter and kWh-meter.

and transformers and they meet the requirements of industrial plants as regards rupturing capacity of high-voltage breakers. Type B 4 i for 3700 V rated voltage and 400 A rated current has a maximum rupturing capacity of 50,000 kVA, Type B 6 i for

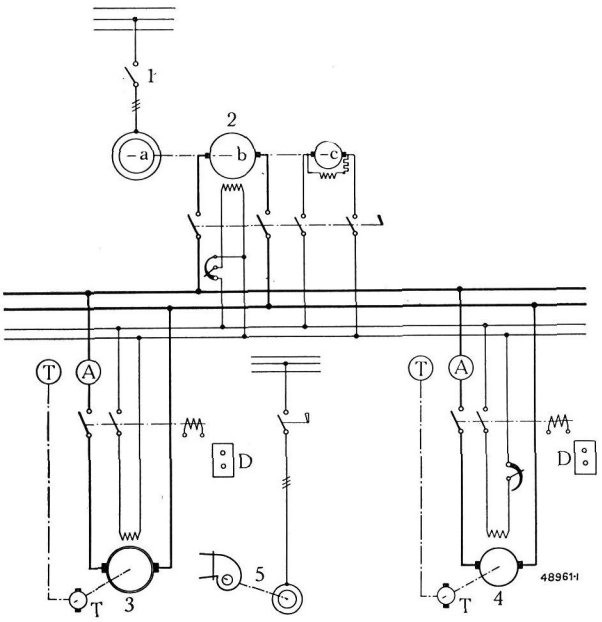


Fig. 73. — Foundamental diagram of connections of a rotary kiln drive, in Ward-Leonard connection.

1. Main circuit breaker.
2. Ward-Leonard control set.
3. Driving motor of rotary kiln.
4. Driving motor of charging device.
5. Fan set for artificial cooling of motor 3.

A. Ammeter.
D. Control push buttons.
T. Speed-indicating device.
a. Three-phase motor.
b. Ward-Leonard dynamo.
c. Exciter.

6400 V rated voltage and the same rated current has a rupturing capacity of 75,000 kVA. By combining standard apparatus built in series, these high-power switching cubicles are relatively low in price. Numerous variations in the design allow of meeting practically every requirement called for in practice. The breakers can be delivered for manual operation or for remote control using the new type of power-storage (spring) drive. With the help of disconnecting switches which are located in the lower part of the cubicle, the apparatus can be made dead for purposes of overhauling and can thus be made accessible without danger.

Among material delivered for the *cement industry* mention should be made of the equipment for the drive of three rotary kilns for a cement mill in South America. These kilns call for 40 to 55 kW driving power and a speed range of 1 : 4 which is exceptional for machines of this kind. Further, each kiln has a 7·5-kW motor to drive the gear for charging the kiln with material, the speed of which has to be varied along with that of the kiln and in the same proportion. This problem was solved by using d. c. motors in Ward-Leonard connection, as shown in diagram Fig. 73. Each kiln has a control set with a Ward-Leonard dynamo of 70 kW output, with exciter and driven by a three-phase high-voltage motor. The motors are switched in from the burner platform and brought up simultaneously to the desired working speed by manipulation of the field rheostat of the dynamo. The speed of the charging device is, thus, always automatically regulated in function of the speed of the rotary kiln. There is, however, another rheostat which allows of acting on the speed ratio of the two machines up to about $\pm$ 30 %. The great advantage of this drive is its easy supervision and simple operation. This plant has been running, since it was taken over to the entire satisfaction of the clients.

The exceptional speed-regulating qualities of the three-phase shunt commutator motor of the Schrage system are constantly opening up new fields of utilization for it. A very interesting example of this is offered by the drive of a *machine for making spun concrete pipes* (Fig. 74).

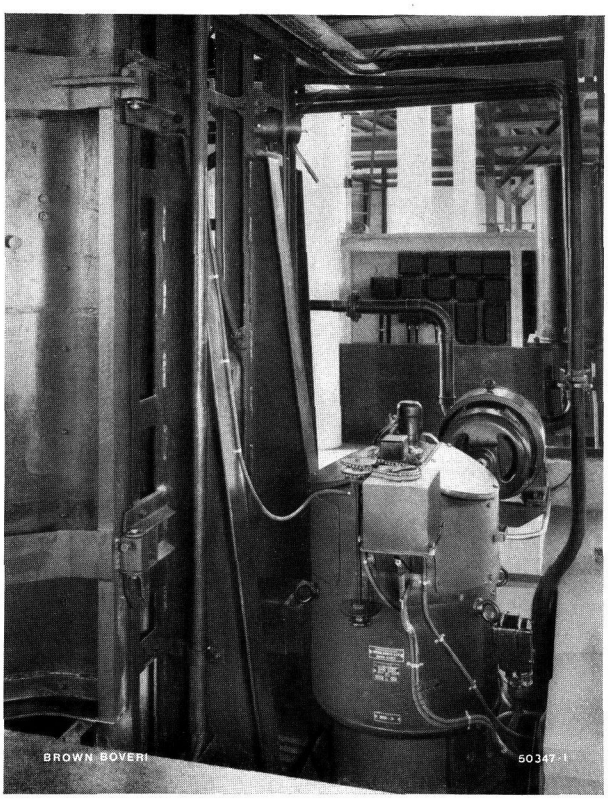


Fig. 74. — Stüssi-vertical machine for making spun concrete pipes, patent of the International Siegwartbalken Co. Lucerne, driven by a vertical shunt commutator motor 24 kW, 1500/230 r. p. m., with special control.

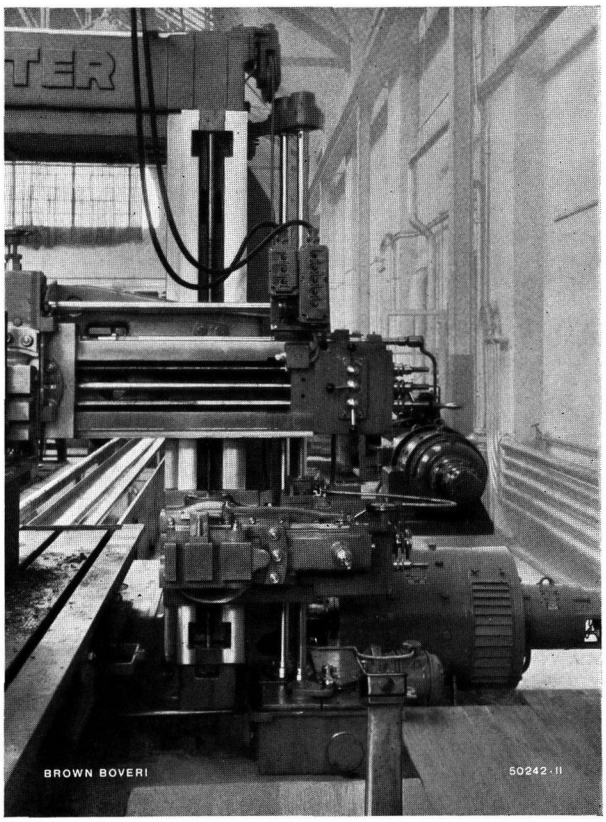


Fig. 75. — Billeter & Klunz-planing machine with Brown Boveri rapid reversing Ward-Leonard drive.

Planing motor with built-on stabilizer, Ward-Leonard converter set in the background.

The machine works so that light pipes can be spun at high speeds of rotation and heavy pipes can be spun at low speeds of rotation. As a series of identical pipes is always manufactured at one time, the desired speed for the motor is set in advance and then the motor is switched in by simple depression of a push-button and accelerated automatically until it reaches the speed set for. To stop the motor, it is first braked down electrically and then stopped. The original feature of the drive is that when heavy pipes are being spun the brushes of the motor are automatically displaced slowly while being automatically displaced faster for light pipes until the low and high spinning speeds respectively are attained. This working process is not only desirable from the technical point of view but has the big advantage that, by adaptation of the acceleration to the mass being worked on, the motor is utilized over the whole working range at its full power capacity, which means using a smaller size of motor than would otherwise be the case.

We wish to refer summarily to numerous equipments delivered and technical innovations introduced in the field of machine-tool drives; among which there are some interesting applications of the shunt commutator motor. We brought out a *stabilizer* for d. c. speed regulated drives in conjunction with our *rapid reversing drives* for *planing machines* (touched on in our last year's report). The duty of this stabilizer is to maintain the speed of rotation very precisely, independently of the load (Fig. 75). In ordinary regulated drives, the speed drop from no load to full load is the more marked the wider the range of speeds. The stabilizer inserted on the excitation circuit reacts so sharply to every variation in speed of rotation caused by a change in the load that, even under the effect of big load peaks, the speed drop is compensated in a few tenths of a second. The oscillogram of Fig. 76 gives, as example, the speed characteristic of the motor driving a planing machine the speed of which can be regulated between 100 and 800 r. p. m. In the example taken, it is running at 100 r. p. m. and the load has been suddenly increased from about zero to nearly full load. It will be seen that the speed has only faltered very briefly and been regulated up to its full value again within 0·35 s. It will be clear what this means when it is recalled that without the stabilizer the speed would drop to near half its value and remain at that figure. As the stressing of the tool and the work make it inadmissible to adjust the no load speed higher by that amount which corresponds to the drop in speed to be expected, the usefulness of the stabilizer for machine tools will be appreciated.

For the drive of planing machines, the stabilizer has the further advantage that there are not only relatively short reversion times of the table when going over from a high cutting speed to the reversing speed but that the reversion times are about the same when dealing with a high or a low cutting speed. Thus, there is always sufficient time for carrying out the auxiliary processes, namely to raise the tool and displace it during the reversal of the table.

Among equipments delivered for the *rubber industry*, mention can be made of 5 drives for a pneumatic tire works in Roumania. These are drives for 4 mixing mills and of a Banbury mixer by 5 squirrel-cage motors of each 150 kW with starting transformer and contactor control (Fig. 77).

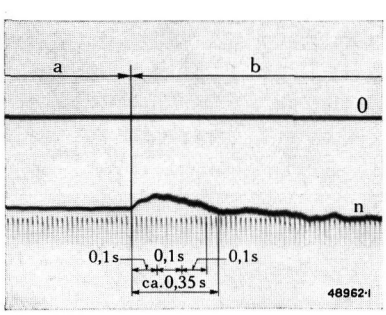


Fig. 76. — Oscillographic record of the speed characteristic of a motor driving a planing machine, the speed of which can be regulated between 100 and 800 r. p. m.

a. No-load.
b. Load.
o. Zero line of speed.
n. Speed of planing motor.

The severe conditions imposed as regards the braking of the motors



Fig. 77. — Rubber mixing mills and Banbury mixer driven by Brown Boveri squirrel-cage motors each of 150 kW, 735 r. p. m.

in order to protect the operators, were fully satisfied by using d. c. braking. In case of danger, an emergency switch is tripped by the safety rod which cuts off the motors from the three-phase supply and connects them to the 220-V d. c. supply. The oscillogram of Fig. 78 shows that after a switching time of 0·105 s, the motor is stopped after an effective braking time of 0·78 s. From the instant at which the emergency switch is tripped, the motor when running empty only accomplishes $6^1/_2$ revolutions. The loaded motor is even stopped considerably sooner than this.

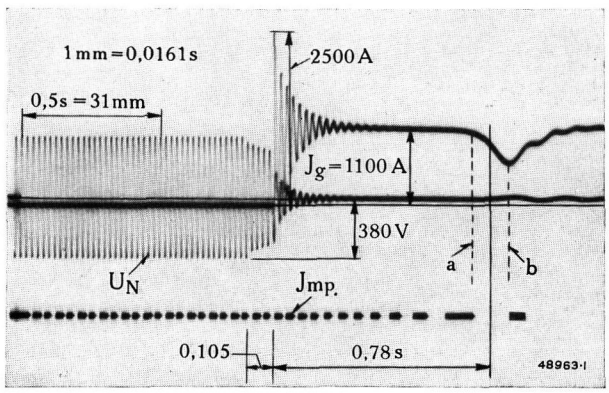


Fig. 78. — Oscillographic record of the d. c.-braking of a 200 H. P. three-phase squirrel-cage motor 380 V.
a. Motor still running. b. Motor at a standstill. U_n. Network voltage. J_{mp}. Impulse diagram; 2 interruptions and 2 impulses = 1 rotation.

Table-glass is now made according to a new American method by a continuous process. Up till now, the rolled glass was finished on big grinding and polishing tables of 10—12 m diameter and requiring about 300 kW to drive them. By the new method the glass is taken from the furnace, rolled, drawn, ground and polished in a continuous process. The drive of the various parts of the manufacturing plant, which is several hundred metres long, has to assure the proper collaboration of the different partial processes.

On the basis of our experience with drives of paper-making machines, for which the requirements are similar, we put a sectional drive into a European glass factory. This equipment comprises 10 d. c. motors to drive the drawing rollers and a big number of three-phase motors to drive the grinding and polishing tables. The d. c. motors are fed from a Ward-Leonard set. There are quick-acting regulators which maintain the armature and excitation voltage of the Ward-Leonard generator constant, automatically. The speed ratio between the motor of the roller press and the first motor of the drawing roller is maintained constant by an electric draw regulator, as in a paper-making machine. The whole operation is supervised and controlled from a central control post near the furnace. Safety devices are available so that if the supply of a. c. current fails, the operation of the draw plant can be kept up.

The *electrical equipment of a conveying plant for unscreened coal* to be run entirely automatically, in a big gas works was put to work, last year. A d. c. motor, 52 kW, in Ward-Leonard connection drives the main winch and moves the loaded coal trucks along a horizontal line at a speed of about 4 m/s. The travelling speed of the truck is brought down to 1 m/s on an inclined-plane.

The plant is set to work by depressing a push-button. All the successive processes, such as starting-up, travelling at reduced speed on the inclined plane, at full speed on the level, approaching a station at creeping speed, stopping, restarting after a certain adjustable pause, etc. are automatic. As loading and unloading at the stoppages are also automatic, the trucks must be stopped on exactly the right point. This is attained, among other means, by an electro-hydraulic thrustor combined with a gravity brake which stops the equipment rapidly but without shocks at the desired points. Fig. 79 shows the main winch with the electro-hydraulic thrustor.

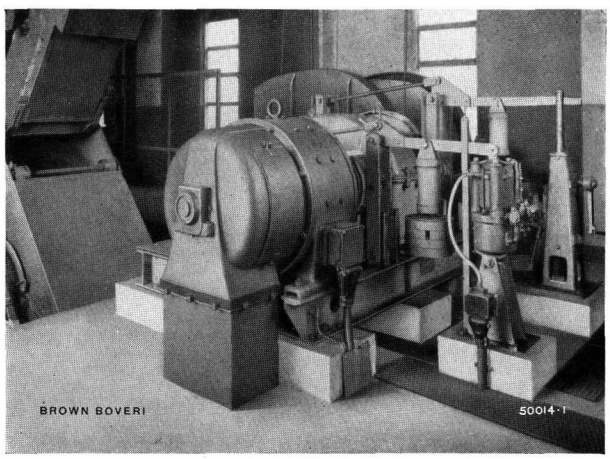


Fig. 79. — Winch of a conveying plant for unscreened coal with d. c. motors 52 kW and automatically working stop brake actuated by electro-hydraulic thrustor.

By laying over a simple change-over switch, the automatic operation of the plant is cut out and each movement of the coal truck can be carried out separately, as desired. The connections in this plant are so made that the control processes take place in proper sequence. By utilizing a selector switch of special design and a new switching process it was found possible to meet all the conditions imposed by relatively simple means, and — which is more important — it was found possible to reduce considerably the number of auxiliary and control lines and, thus, to greatly increase the service reliability of the plant. The selector switch allowed of trying out the whole equipment in the shops, before delivery, and of making whatever adjustments were necessary so that much time and work were saved when the plant was put up.

Last year, we again delivered a large number of our *electro-hydraulic thrustors* of the bigger type for a lifting capacity of 2000 cm/kg and of the smaller type for a lifting capacity of 500 cm/kg. As in former plants, these are chiefly used for actuating automatic holding brakes for hoisting and conveying equipments and have given excellent results on account of their rapid and smooth action. As compared to brake-raising magnets, it is generally recognized that the power they take is very low. Further, the damping device can be adjusted over a wide range allowing of adjusting the thrustor to the needs of each case; thus, the mechanical drive and brakes of the equipment are relieved of unnecessary stressing.

Fig. 80 shows an interesting application of the electro-hydraulic thrustor for the hoisting gear of a loading plant. Here, two electro-hydraulic thrustors are used for the twin drum winch. In order to prevent faulty switchings, the two brake-raising apparatus must always have the same lifting and falling times, a condition which it fulfilled by the electro-hydraulic thrustor. The advantages of the equipment as compared to the former brake-raising magnets was quickly recognized in this plant.

The series of *three-phase motors with external fan cooling* has now been extended to 390 kW, for voltages up to 6600 V and speeds up to 3000 r. p. m.

Fig. 81 shows a motor of this kind with centrifugal starter, for 92 kW, 500 V, 3000 r. p. m. Apart from the design with centrifugal starter, these motors are also built with slip-ring rotors and squirrel-cage rotors. The efficient cooling allows of small overall dimensions although the motors are very strongly built. These motors meet the severest service requirements

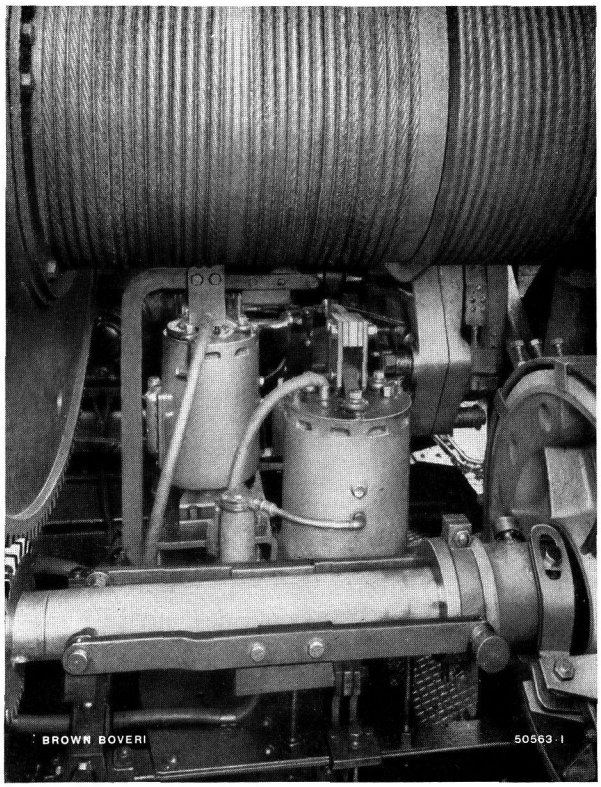


Fig. 80. — Electro-hydraulic thrustor with built-on heating device in the hoisting gear of a high-capacity loading plant.

and are especially suitable for heavy industries, for the chemical industry, etc.

Mention should be made of the setting to work of the complete electrical equipment of a travelling *crane* for a modern *foundry*. The crane has a carrying capacity of 20 t and is shown in Fig. 82. The hoisting gear is driven by a 35-kW d. c. motor in Ward-Leonard connection while the traversing gear and the gear to displace the crane are driven by a three-phase induction motor in standard reversable connection.

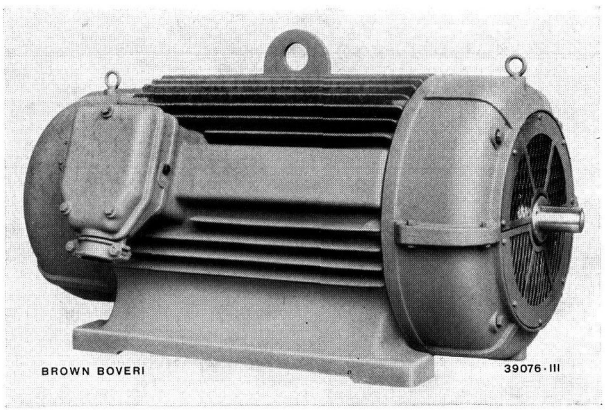


Fig. 81. — Three-phase induction motor 92 kW, 3000 r. p. m., 500 V, 50 cycles, totally enclosed with centrifugal starter.

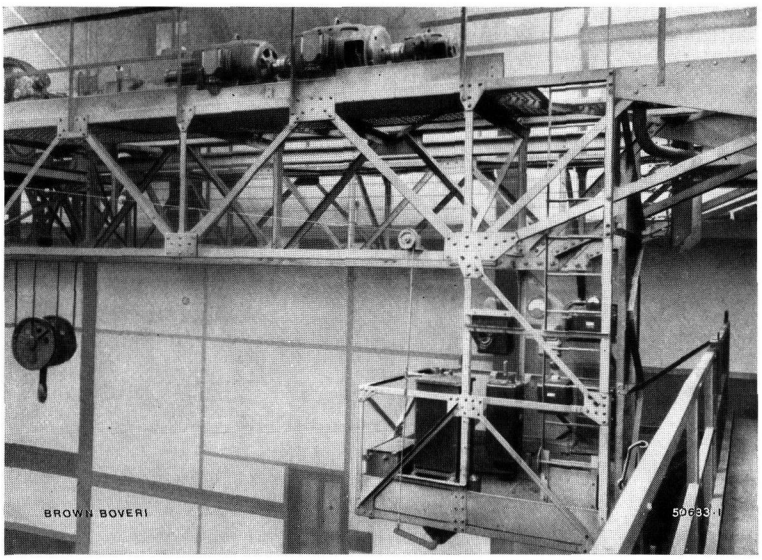


Fig. 82. — 20-ton travelling crane in a foundry. Hoisting gear in Ward-Leonard connection, traversing gear and crane displacement gear operated by three-phase Brown Boveri induction motors.

In order to utilize the advantages of Ward-Leonard control, a controller of special design with a big number of steps was chosen. Thanks to this big number of steps, on both control sides of the controller, it is possible to regulate the speed closely and continuously, a very important point in foundry service.

The whole electrical equipment was designed according to the most modern conceptions, special attention being paid to making it impossible that faulty switchings be carried out, due to careless control.

We and our concessionaries got orders for a number of interesting *electrical equipments for rolling mills*, in the course of last year. Fig. 83 shows an Ilgner converter set to supply rolling-mill motors in a big modern rolling-mill plant. This converter set comprises 5-d. c. generators of 2260 kW, peak load 8000 kW, speed 432—522 r.p.m. The generators are driven by two three-phase induction motors.

Thanks to our wide experience in the field of variable-speed regulation and that of the coordination of speeds of different sections of a machine, we have always been in a position to satisfy the requirements of rolling mills which are getting progressively severer as regards production and rolling speed. Thus, for example strips up to 2 m in width are rolled, to-day, in wide strip mills with delivery speeds of the material of about 10 m/s. D. C. motors of about 5000 kW are used to drive these rolling mills. The big load fluctuations to which the different frames are subjected, make severe demands on the regulating devices which must, of course, act constantly and rapidly. To meet these severe demands, a device for the coordination of speeds was brought out in conjunction with mutators which regulates the speed of the various motors both quickly and precisely while maintaining that undulation of the material being rolled which was adjusted to.

Another interesting regulating device is used on cold strip mills in which the material has to be rolled under a strong pull, for technical reasons. In order to attain this pull, separately driven spools have been mounted on both sides of the rolling mill. One single quick-acting regulator supervises the constance of the pull exercised by each spool during the rolling operation and also, if necessary, during stoppages. It is also possible to readjust the pull after every pass and every reversal of the mill, respectively.

We and our concessionaries got numerous orders for the *electrical equipment of winding engines*. Some of these were for outputs of over 3000 kW. All these equipments have our single-lever control and brake block. Some winding plants having induction

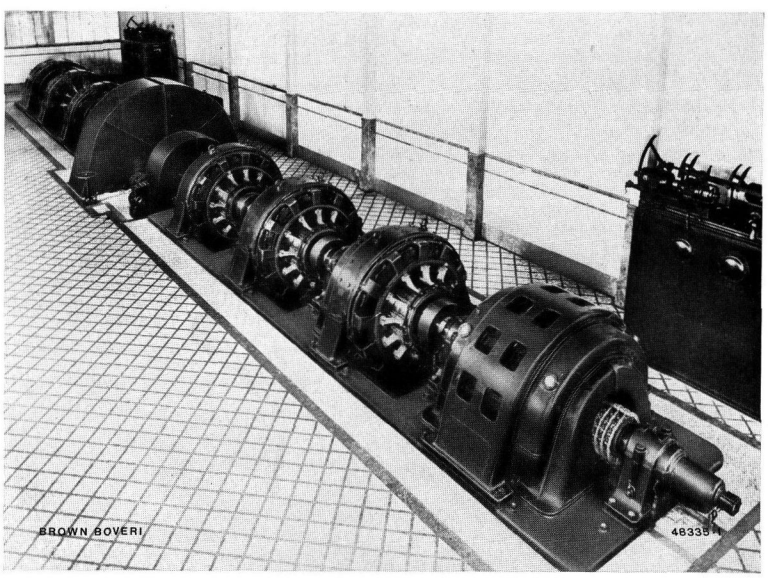


Fig. 83. — Double-Ilgner converter set for supplying rolling mill reversable motors, composed of: 5-d. c. generators 2260/8000 kW, 522/432 r. p. m., as well as two three-phase induction motors 3020 kW.

motors with an output of about 1000 kW at 6600 V are equipped with a new type of stator change-over switch on the principle of the air-blast high-speed circuit breaker. To meet the high switching frequency which characterizes winding-engine plants, this air-blast stator switch was made very strong (Fig. 84).

On account of the excellent results attained, in recent years, with electrical equipments having *shunt commutator motors* to drive rotary boring plants, we got a number of similar orders last year. The motors for the boring gear are designed for continuous speed variation in the ratio of 1 : 3. The pumps belonging thereto, also driven by shunt commutator motors, can be speed-regulated coutinuously in the ratio 1 : 2. With the special operating conditions

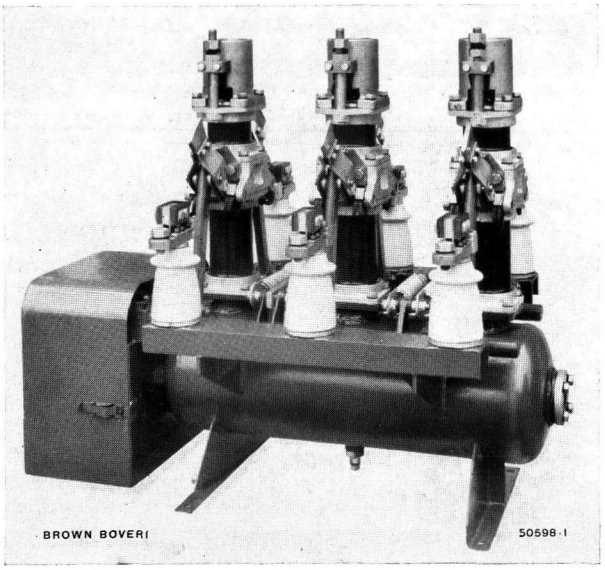


Fig. 84. — Three-phase air-blast change-over switch 11 kV, 400 A, for high switching frequency.

inherent to boring plants, the properties peculiar to the shunt commutator motor are made good use of, as it is possible to regulate the speed, without losses, and corresponding to the boring conditions.

B. ELECTRIC ARC WELDING.

No new development work was found necessary, in this field, during the last twelve months. All requirements of present-day welding practice have been proved to be entirely fulfilled by the series of our instantaneous-reaction welding machines which reached a final stage of development, last year, with units delivering up to 750 A. The same comments apply to welding transformers.

C. ELECTRIC FURNACES.

We and our concessionaries delivered a large number of furnaces in the course of 1939, for a variety of purposes. Four ceramic tunnel kilns of big output which were already mentioned in last year's report, were put into service. The results attained with these exceed the guarantees and show the principles we have been following in our endeavour to improve big ceramic tunnel kilns have been the right ones. Fig. 85 shows a double tunnel kiln for the firing of hard porcelain in a Norwegian plant.

In the small and artistic ceramic industries the electric chamber kiln is taking the place of the fuel-fired kiln. In order to allow of flexible adaptation to market demand, ceramic works show a preference for a series of small chamber kilns which they can form into batteries according to momentary needs (Fig. 86).

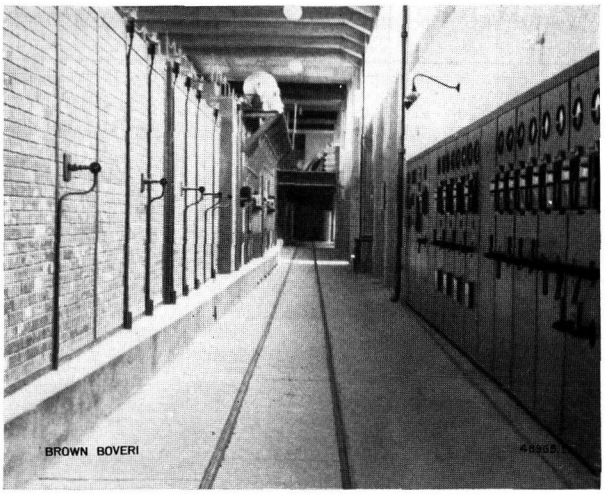


Fig. 85. — Electric double tunnel kiln, abt. 70 m long, for the firing of hard porcelain. Power input 450 kW. On the right the switchboard and all the measuring instruments belonging thereto can be seen.

Our leading position in the field of bright annealing of metals and steels has been maintained by further development of the Grünewald bright annealing process and especially by a new design of continuous process furnace. For wire-making works, we have developed complete plants for the reducing bright annealing of rolled wires according to the pot process and also to the draw bright-annealing process (Fig. 87). Further plants were developed for bright patentizing of steel wires using the Elfström bright-annealing process. We delivered some plants for the bright hardening of steel strips and for the bright annealing of strips and wires of stainless material. For the bright



Fig. 86. — Ernst Bodmer & Co., Zurich, pottery works. Electric furnaces for the glost firing of artistic ceramic work. Maximum temperature 1000° C. Firing volume per furnace 0,5 m³, power input 25 kW, 500 V, 50 cycles.

annealing of small parts, utilizing a protective gas atmosphere, drum type annealing machines, allowing considerable recuperation of the heat from the cooling down of the wares, have been built. Annealing machines of this kind require a minimum of attendance and work more economically than fuel-fired furnaces even at current-tarifs which are advantageous to the power supply companies. Fig. 88 shows a Swiss plant of this kind, for 36-kW power input.

Among a large number of arc furnaces with basket charging, mention can be made of one for a foreign plant having a capacity of 30 t and one, for a Swiss iron and steel plant, with a capacity of up to 12 t (Fig. 89). We have held to the electro-hydraulic system of electrode control in all these furnaces. In the place of the regulation to constant current, the new plants have regulation to constant arc resistance. The advantage is the elimination of electrode breakages and the absolute prevention of the immersion of the electrode end in the melted bath. Both advantages mean cheaper operation and assure the manufacture of soft steel with very low carbon content. This latter advantage is of great importance in the making of stainless steels. The property of the regulation to regulate to constant arc resistance assures unequalled stability of regulation because if one electrode becomes inactive the voltage impressed on the furnace by the furnace transformer is uniformly distributed automatically to the two remaining electrodes, so that no hunting occurs.

For the precise regulation of big furnace units to constant power input, we have developed a new type of regulator which allows of controlling valves of the biggest dimensions so that the power taken by the furnace is maintained constant with a margin of $\pm$ 0·5 % (Fig. 90).

For electro-thermal plants we are building, among others, two furnace units of each 12,000 kVA input for reducing iron ore. Further there are some carbide, ferro-silicium, and ferro-chromium plants taking up to 6000 kW, now in service (Fig. 91).

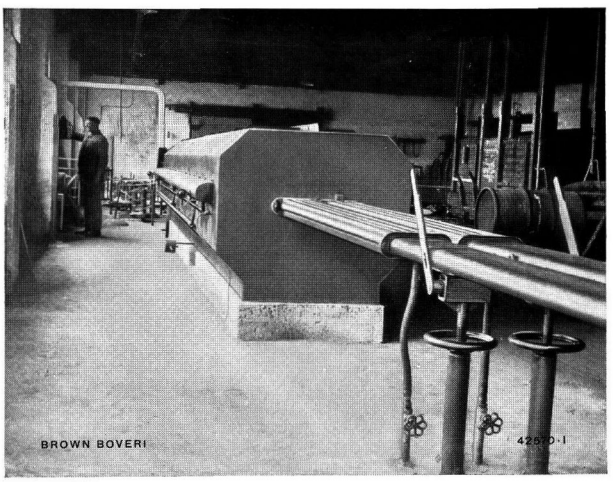


Fig. 87. — Continuous furnace for simultaneous bright annealing of eight wires of stainless material. Maximum temperature 1150° C, production per hour 100 kg of wire, power input 59 kW.

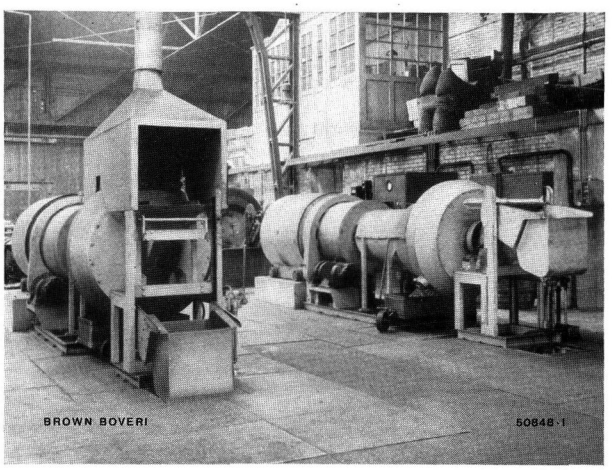


Fig. 88. — Two drum-type bright annealing furnaces 36 kW, 750° C, for the bright annealing of small metallic parts under a protective gas atmosphere.

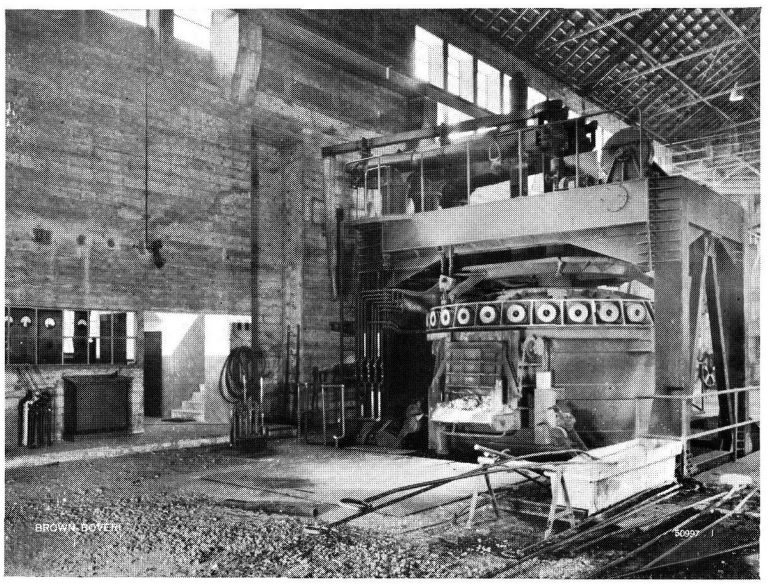


Fig. 89. — Electric steel-melting furnace of 10—12 t capacity. Power input 3200 kW, with automatic electro-hydraulic electrode control. Basket charging.

For the needs of small plants for making small quantities of special steels, for melting pure nickel and nickel alloys and for metal alloys having a high melting point, we took up the construction of rocking arc-melting furnaces. These furnaces are built for a capacity of 360 kg (Fig. 92).

Hot galvanizing furnaces have been considerably developed, up to the biggest dimensions, after it had been proved that the first big hot galvanizing furnace gave such exceptionally good results (Fig. 93).

It is becoming increasingly evident that the *electric cremation furnace* is superior to any other furnace used for this purpose and meets all requirements as regards piety and hygiene. These circumstance and our wide experience in this field of development

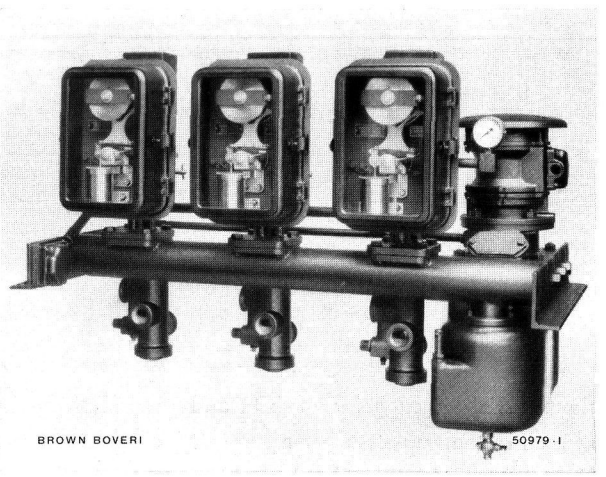


Fig. 90. — Electro-hydraulic electrode regulator.

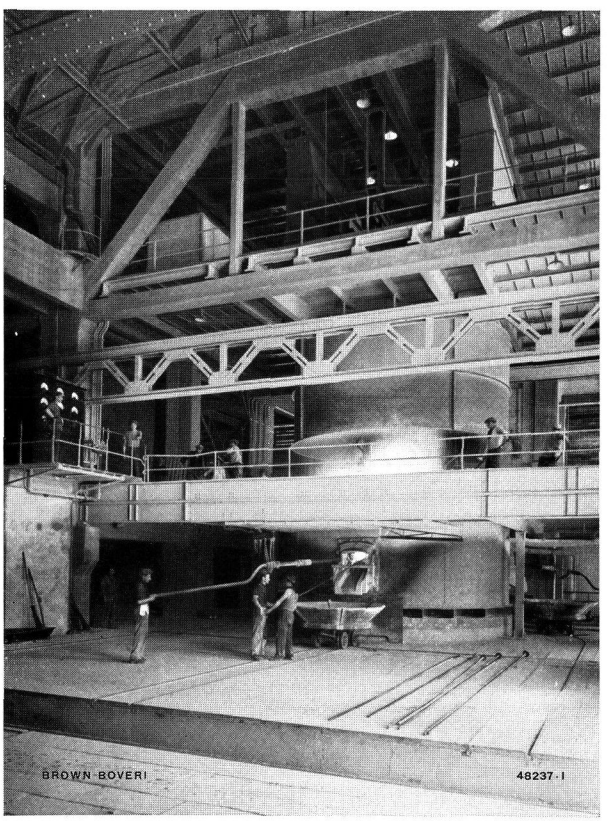


Fig. 91. — 6000-kW three-phase carbide furnace of Brown Boveri design.

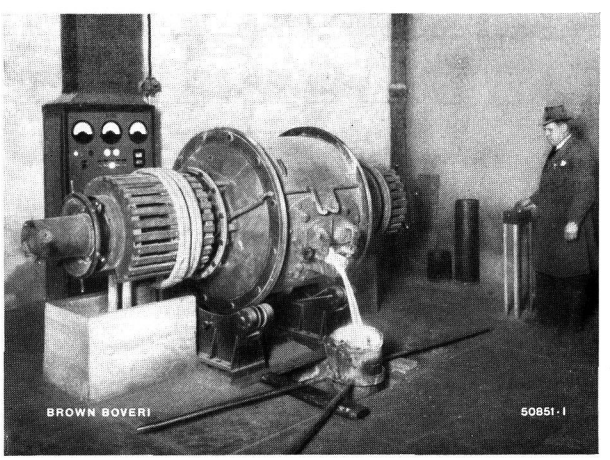


Fig. 92. — Rocking arc-melting furnace of Brown Boveri-Mazières design, for melting pure nickel and nickel alloys. Capacity 300—360 kg.

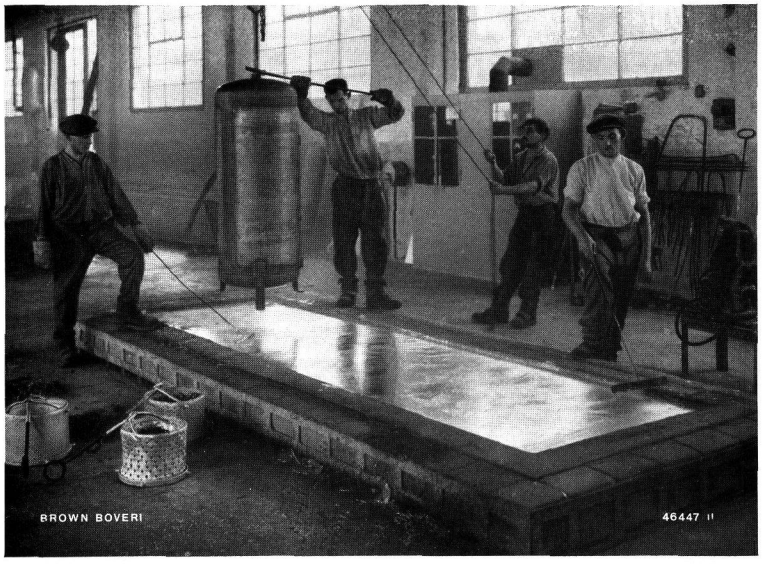


Fig. 93. — Electric hot galvanizing furnace with automatic temperature regulation for the hot galvanizing of iron parts. Temperature of bath 460° C. Production 7—10 t of galvanized iron per hour. Power input 180 kW.

however, which have been marked by an upswing in business, the power-supply companies found other and more advantageous outlets for their surplus power so that the number of orders booked for electric boilers fell slightly. The political tension of last year reversed the trend once again, because the electric boiler has the advantage of being independent of coal, which is an imported product in Switzerland. Thus, in 1939, we were able to book orders for electric boilers for a total power input of over 32,000 kW.

The majority of Brown Boveri high-voltage boilers are installed in Switzerland, but there is also a not inconsiderable number in foreign plants. Several boilers have been delivered to the neighbouring countries France and Italy, and there are others in Spain, in Finland and even two in Venezuela.

The success of the Brown Boveri electric boiler is due to two features:— Firstly, upkeep costs for the replacement of insulators and wear on electrodes are exceptionally low; secondly, the Brown Boveri high-voltage electric boiler can be regulated so rapidly and precisely that automatic operation is feasible even under the most difficult service conditions.

explains the considerable number of orders we have received in the course of 1939, for plants at home and abroad. Fig. 94 shows a cremation furnace plant in Karlstad (Sweden).

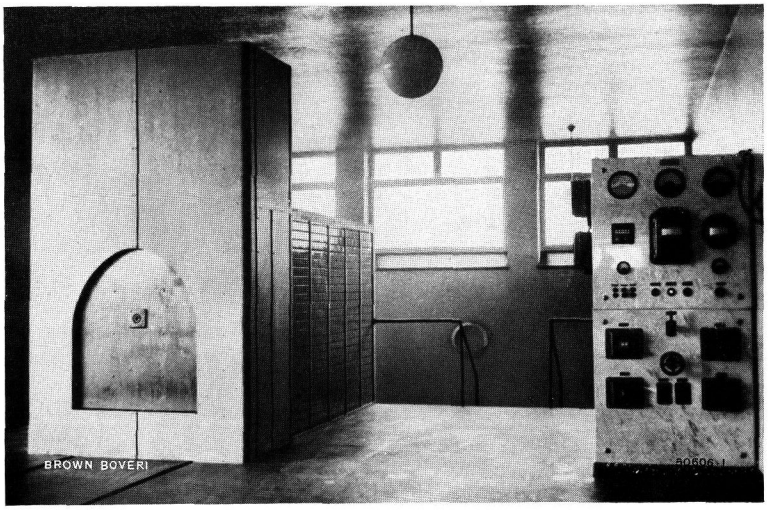


Fig. 94. — View of an electric cremation furnace of Brown Boveri design.

D. THE ELECTRIC BOILER.

Brown Boveri build electric boilers to two fundamentally different designs:— high-voltage electric boilers with water-jet electrodes and low-voltage electric boilers with immersed electrodes.

1. *High-voltage boilers.*

We started building these boilers in the year 1933. After what may be termed the growing pains of the first two years had been overcome, and the practical experience acquired, in the meantime, turned to good account, the number of boilers ordered and the outputs thereof rose rapidly. In the years succeeding the industrial crisis, there were a considerable number of hydraulic power stations running under partial load only, which led the power-supply companies to encourage the use of electric boilers and offer attractive metering tariffs to boiler users. In recent years,

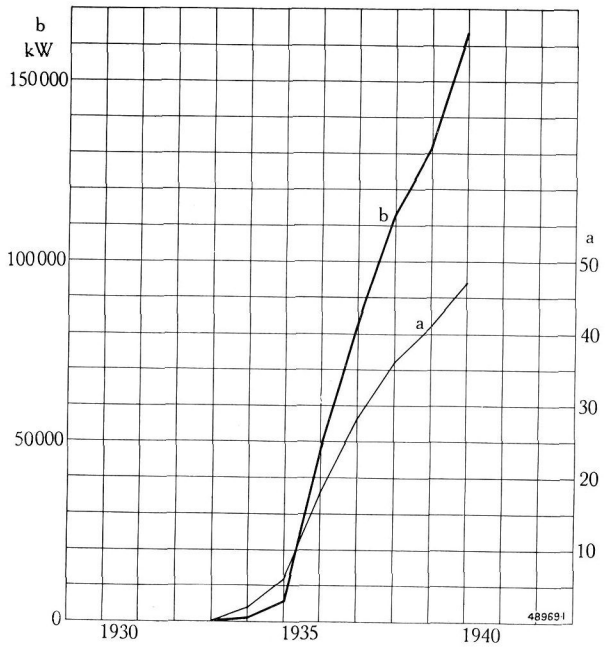
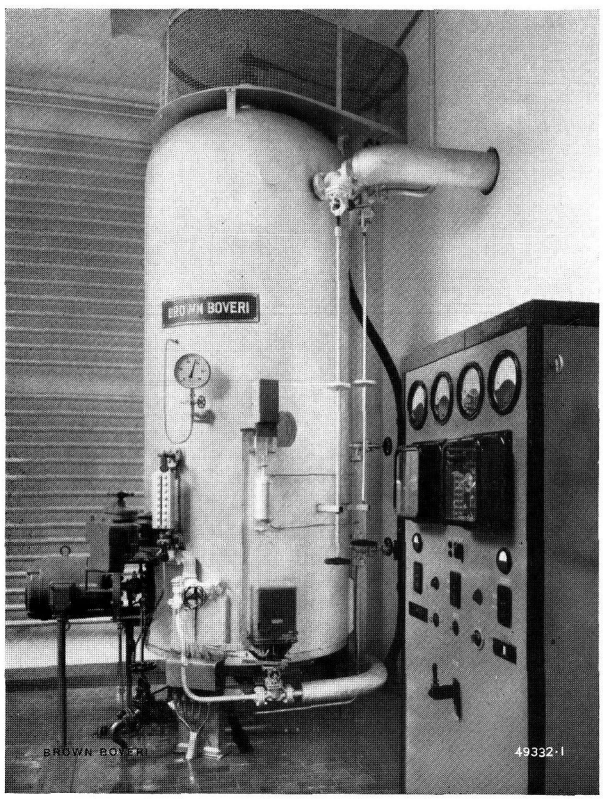


Fig. 95. — Number and total output of Brown Boveri high-voltage electric boilers:

a. Number.
b. Output.

Regulation can be made to suit all practical requirements met with in service. A combined power and pressure regulation presents special advantages.



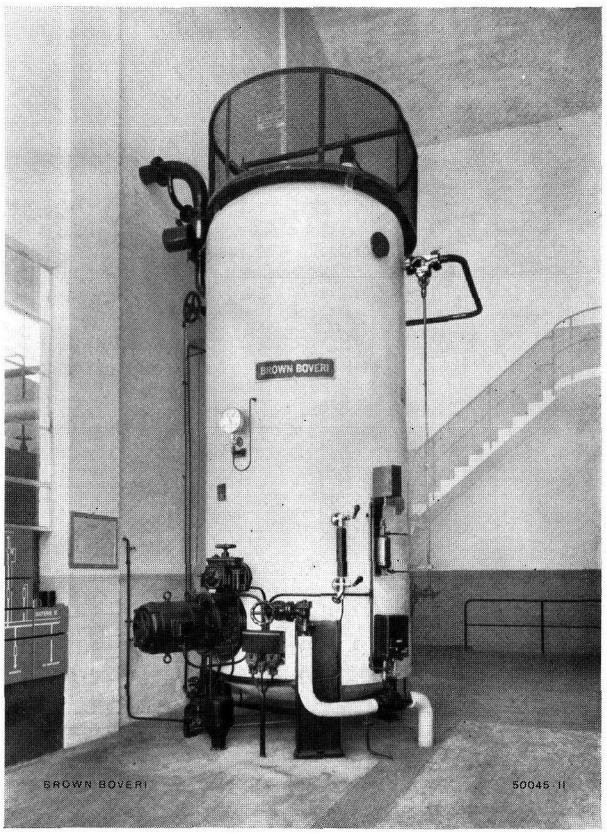


Fig. 97. — High-voltage electric boiler for 4500 kW, 16,000 V, 11 kg/cm² abs. Delivered to the Cardboard Factory Niedergösgen A. G., Niedergösgen (Switzerland).

The pressure is maintained constant for all electric power inputs below a given figure; if, however, the maximum power input figure adjusted for is attained, regulation from this point onwards is to constant electric-power input. When the steam consumption gets too big, the admissible power input is not exceeded.

The supply of feed water and the blow-down can also be regulated automatically, the regulators for these duties being also of Brown Boveri design.

2. *Low-voltage boilers.*

For small outputs, between 100 and 2000 kW, such as are required for central-heating plants, laundries, dairies, etc. Brown Boveri build low-voltage boilers

Fig. 96. — High-voltage electric boiler for 2200 kW, 6000 V, 29 kg/cm² abs. Delivered to the soap works of Messrs. Friedrich Steinfels A. G., Zurich (Switzerland).

On the right:— The switchboard with automatic output- and pressure regulators. In front of the boiler and below, electrically actuated feed water valve; above, the automatic feed water regulator. On the left:— the servo-motor for regulating the boiler; below, the motor for the circulating pump. The pressure generated here is an exceptionally high one for an electric boiler.

with immersed electrodes. The upkeep costs of these boilers is also very low. The regulation is of similar design to that used with the high-voltage boiler. For very small boilers and when simple regulating requirements only have to be met, a simpler type of regulating gear is fitted.

Brown Boveri have developed their own system for connecting the low-voltage boiler to central-heating systems, the output of the boiler being automatically adjusted to transitory requirements. In winter, the low-voltage boiler can be made to work in parallel with fuel-fired boilers and to take over the whole heating duty in spring and in the autumn.

E. BLOWERS AND COMPRESSORS.

1. *Turbo-compressors.*

In 1939, as in previous years, a considerable number of centralized compressed-air plants were built or extended. We received, accordingly, numerous orders for turbo-compressors. No less than 23 compressor sets were ordered dealing with a total of 7,000,000 m^3/h of air and requiring a total coupling input of abt. 64,000 kW.

Special mention may be made of two turbo-compressors each to deal with 100,000 m^3/h and each with a power input at the coupling of 9000 kW. They are driven by Brown Boveri steam turbines and are still, to-day, among the biggest single-cylinder turbo-compressors built so far. Another compressor, for 55—77,000 m^3/h, is worthy of note as also one for 50,000 m^3/h.

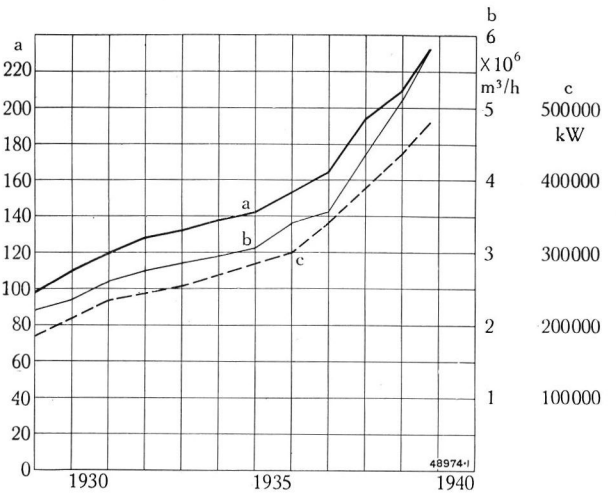


Fig. 99. — Turbo-compressors ordered from Brown Boveri, Baden (Switzerland).

a. Number.
b. Volume of suction air.
c. Output at coupling.

Most of these compressors are built with cooling of the air after each impeller, according to our latest design. The coolers are placed above and below the compressor, the designs being such that the air passes by the shortest way and with the minimum of pressure loss from one impeller, through the cooler, to the next impeller. With this design, the compression process practically follows the ideal isothermal line and, therefore, takes place with the lowest possible power consumption. Further, all the compressors have a recuperation turbine which prevents pumping at low loads and also prevents loss of power which cannot otherwise be avoided when the blow-off valve is operated. For these reasons the Brown Boveri turbo-compressor with cooling after each impeller stage is extremely economical to operate and its reliability is proved by

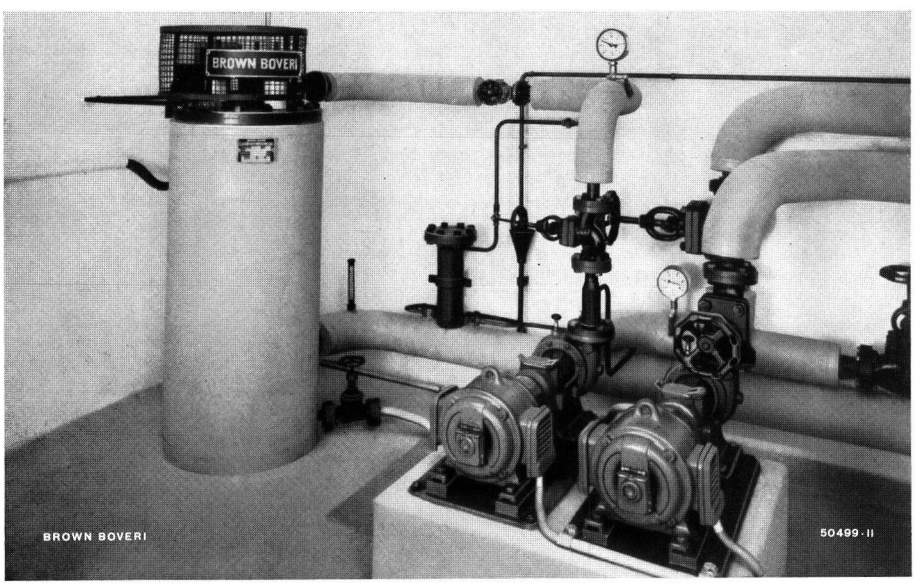


Fig. 98. — Low-voltage electric boiler for 160 kW, 500 V, 2 kg/cm² abs, delivered to the Electricity Works Jona-Rapperswil A. G., Jona (Switzerland).

The boiler works as a hot-water boiler with a 10 m^3 accumulator for central-heating purposes. The circulating pumps are seen in the foreground.

its being found to-day in plants all over the world. Our clients have welcomed this latest compressor design and sales are steadily rising.

Cooling after each impeller stage has the further advantage that a great part of the moisture contained in the air and which is condensed into water by the compression of the air, is eliminated by the numerous coolers. This type of Brown Boveri turbo-compressor, therefore, delivers compressed air which contains relatively little moisture. It is possible to add yet another cooler after the last stage, which is built on to the cooler casing of the compressor so as to form a harmonious whole with it, and this is done when it is

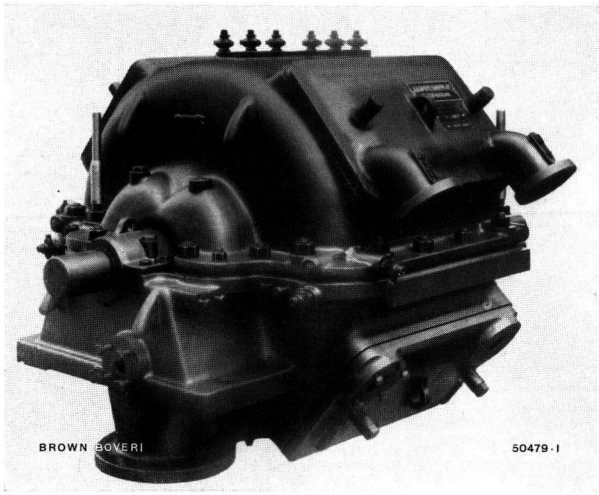


Fig. 100. — Turbo-compressor with jacket cooling for compressing 4800 m³/h of air to 4.5 kg/cm² abs, speed 15,000 r. p. m. Drive through reduction gear by a three-phase induction motor of 450 kW.

Delivered to a physical laboratory for demonstration- and development tests. On account of the compressor being placed in proximity to sensitive physical instruments, it was necessary to balance the rotor with great precision, and also to be certain that running should be noiseless. The compressor can be started and stopped from different points by means of push-button remote control.

desired to extract still more moisture from the air.

As is well known, the efficiency of power transmission by compressed air is relatively low, because nearly all pneumatic tools work without expansion; this is because the pneumatic tool is then lighter and also because with 100 % admission the control mechanism is simpler. Recently, however, compressed-air motors in which the air is allowed to expand and

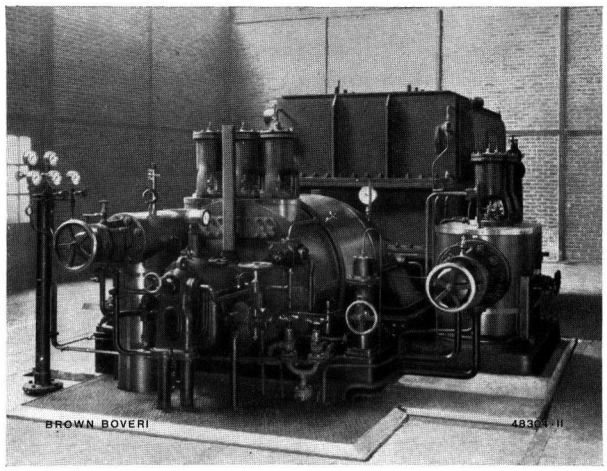


Fig. 101. — Turbo-compressor with cooling after each impeller wheel, for compressing 27,000 m³/h of air to 8 kg/cm² abs. Drive by a Brown Boveri mixed-pressure steam turbine, for a steam pressure of 26 kg/cm² abs and 380° C, and 11 kg/cm² abs and 280° C respectively.

For each steam pressure there is a main stop valve with the nozzle valves belonging thereto.

do useful work, are being increasingly utilized on account of the better efficiency. However, this is only practical when the compressed air is sufficiently dry, because it cools down considerably during expansion and if it is too humid there is a danger of ice formation in the compressed-air motor. For this reason, the effective extraction of moisture from the air, effected by the Brown Boveri turbo-compressor with cooling after every impeller stage, is becoming increasingly important, especially so when the compressor is provided with a

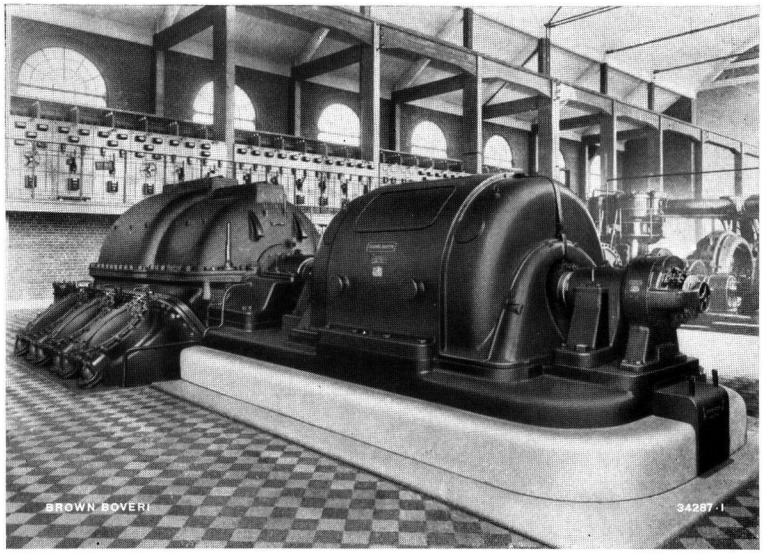


Fig. 102. — Turbo-compressor with coolers built on at the sides, for compressing 54,000 m³/h of air to 7 kg/cm² abs. Speed 3000 r. p. m. Drive by Brown Boveri synchronous motor for 5200 V, 5300 kW, with a power factor of 0.85, leading.

The current surge at starting is limited by the starter, so that it does not exceed the rated current. Delivered to a coal mine.

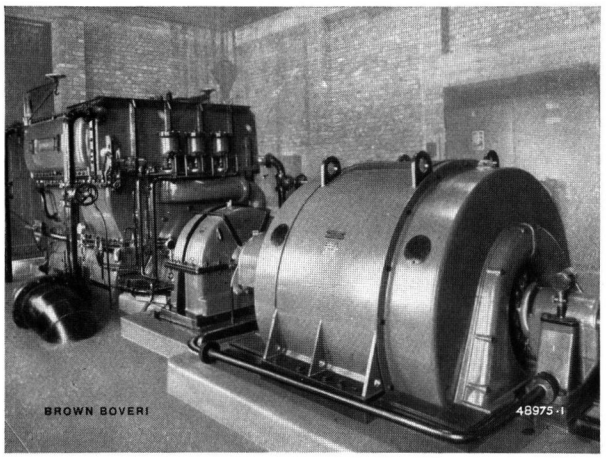


Fig. 103. — Turbo-compressor with cooling after each impeller wheel for compressing 25,000 m³/h of air to 8 kg/cm² abs. Drive through a reduction gear by a synchronous motor for 1925 kW, power factor 0·7, leading. Starting is effected by means of a starting transformer.

Delivered to a gold mine in South Africa, in which there are now five similar compressors running. On the front of the compressor the oil-pressure controlled valve of the recuperation turbine which prevents pumping.

built-on after cooler. In such cases, it is recommendable to build in a water separator, placed after the last cooler.

As the tendency is towards the generation of electric power in big central thermal plants and distribution of the power electrically, electric drive is being called for increasingly for compressors. For such cases, Brown Boveri recommend the true synchronous motors with cylindrical rotor milled in one piece for the two-pole design and with massive rotor and salient poles for the design with four poles and more.

The massive rotor of synchronous motors is a well-known, rugged design, less liable to trouble than is the laminated rotor of an induction motor. Apart from this advantage, increased excitation of the synchronous motor causes it to deliver a leading current for improving the power factor of the network.

The synchronous motors are started up in a simple manner, by means of starting transformers. Changing from one transformer tap to the next is carried out by a special Brown Boveri connection without interruption of the current and without current surge. If necessary, it can be arranged that the starting current should not exceed the full-load current. Brown Boveri have already delivered a large number of turbo-compressors driven by synchronous motors for outputs up to 5000 kW and which have now been running satisfactorily for several years.

2. *Blowers for blast furnaces and steel works.*

During the year 1939, many blast-furnace plants and steel works were enlarged and modernized. Some new plants were also laid down, particularly in those overseas countries which are striving to make themselves independent of iron imports.

19 blast-furnace blowers were ordered from our firm in the course of last year. These deal with a total of

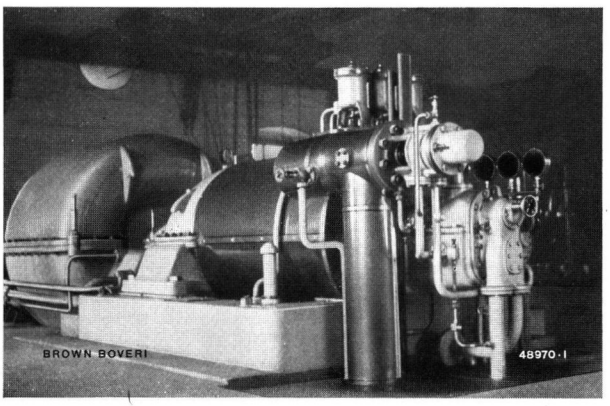


Fig. 104. — Blast-furnace blower for compressing 60,000 m³/h of air to 2·1 kg/cm² abs. Speed 3800 r. p. m., driven by a Brown Boveri steam turbine for 1700 kW.

Delivered to an iron works overseas. The simple oil-pressure governing, without rods, of the steam turbine, should be noted.

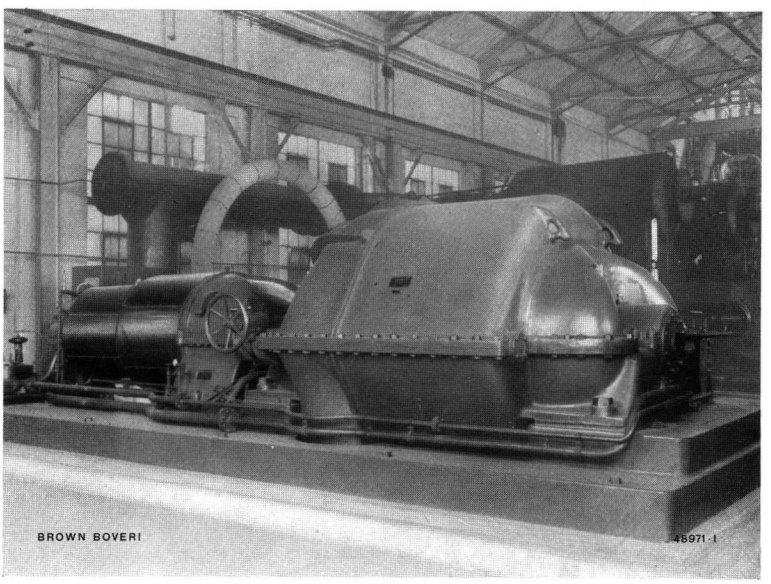


Fig. 105. — Blast-furnace blower for compressing 70,000 m³/h of air to 3·1 kg/cm² abs. Speed 3600 r. p. m. Drive by steam turbine. Delivered to an iron works by our concessionary, the Allis Chalmers Mfg. Co.

By means of the hand-wheel shown in the illustration, the moving diffusors can be adjusted so as to displace the pumping limit. In America, there are, among others, nine blast-furnace blowers of Brown Boveri type now running, which are, on an average, each for 130,000 m³/h of air, with a coupling power input of 6800 kW, each.

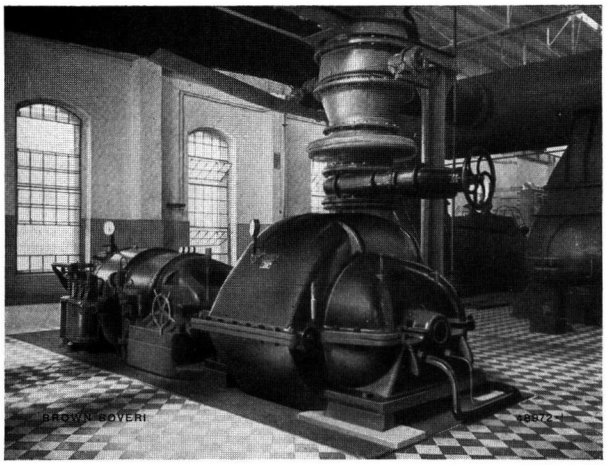


Fig. 106. — Blast-furnace blower for compressing 66,000 m³/h of air to 2·0 kg/cm². Speed 4600 r. p. m. Drive by steam turbine 1850 kW built by Messrs. Franco Tosi.

The hand-wheel shown in the illustration allows of adjusting the diffusors so as to displace the pumping limit.

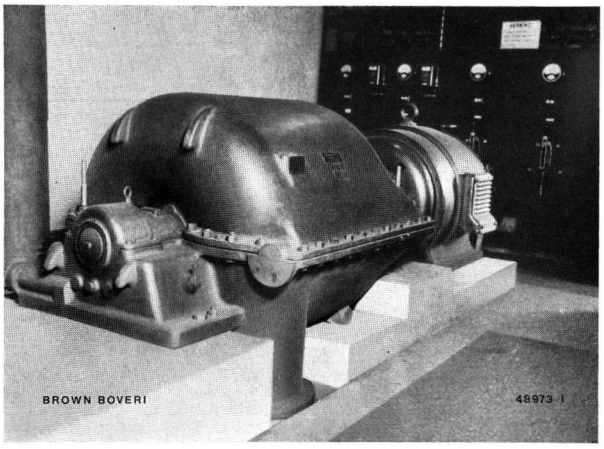


Fig. 107. — Blast-furnace blower for compressing 18,000 m³/h of air to 1·5 kg/cm² abs. Speed 3000 r. p. m. Direct drive by three-phase induction motor of 350 kW.

Delivered to a Scandinavian iron works for a blast furnace which is operated by charcoal, and which produces high-grade iron.

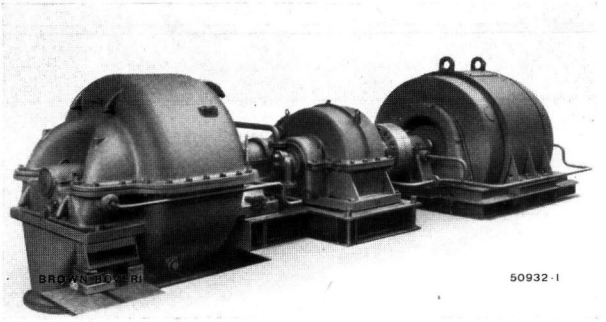


Fig. 108. — Blast furnace for a converter for compressing 42,000 m³/h of air to 2·1 kg/cm² abs, speed 5700 r. p. m. Drive through a reduction gear by a synchronous motor of 1540 kW with a power factor of 0·9, leading.

Three converter blowers of this kind are being built for a new nickel works. Starting is by means of starting transformers, and the torque is 20 % of its full rated value at a standstill and 45 % at synchronizing. The air pressure is regulated automatically by suction throttling.

1,500,000 m³/h and have a total power input measured at the coupling of about 60,000 kW. Only one of these blowers is equipped for electrical drive. This electric drive is by means of the Brown Boveri Scherbius system of speed regulation without losses, for a speed range from 20 % below to 20 % above synchronous speed. The other blast-furnace blowers are either for drive by Brown Boveri steam turbines or *Brown Boveri gas turbines operating with blast-furnace gas.* Interest for drive by gas turbines for blast-furnace blowers is growing.

It is generally acknowledged, to-day, that for a determined charge and given composition of the ores, a constant weight of air per unit of time must be delivered to the blast furnace. All these blast-furnace blowers are consequently equipped with Brown Boveri automatic regulation to constant quantity of air. The quantity of air desired at any moment can be adjusted to on an instrument column placed near the blower. About 75 % of all blast-furnace blowers are also equipped for manual adjustment of the diffusers, so that the pumping limit can be displaced in the most economical manner. The earlier requirement of regulation to constant air-blast pressure is only specified and built for in rare cases, to-day.

Recently, blast-furnace men have been discussing again the question of the most advantageous temperature for the air blast. Up till now, 700 to 800 ° C was considered desirable and only rarely, higher temperatures up to about 1000 ° C were used. Recent systematic tests seem to indicate that for certain ores better results are reached with lower blast temperatures. In conjunction herewith it would be possible to use all-metal air-blast preheating stoves and in this respect it seems worth mentioning that one of the aforementioned blast-furnace blowers with gas-turbine drive, which we have in hand, is provided for operation with a *super-charged metallic air-blast preheating stove,* the gas turbine and the air-blast preheating stove having a common combustion chamber.[1]

Brown Boveri also took orders last year for several big blowers for converters. Among these are two steel-work blowers each for a volume of indrawn air of 70,000 m³/h to be compressed to 3·5 kg/cm². They are each driven by a live-steam turbine of about 4000 kW and meet the fluctuating requirements of the converter by speed variation, which is done through

[1] The Brown Boveri Review of Jan./Feb. 1939, page 34.

remote control. The Brown Boveri oil-pressure governing system is very suitable for this purpose.

We also took an order for three blowers for nickel converters in a new nickel works. Each blower compresses 38,000 m^3/h of indrawn air to about 2 kg/cm^2 abs. The smooth operation of a nickel converter makes it unnecessary to provide for speed control and the drive of each of the three blowers is by a 1200-kW Brown Boveri synchronous motor. Regulation to constant delivery pressure is carried out by throttling on the intake side.

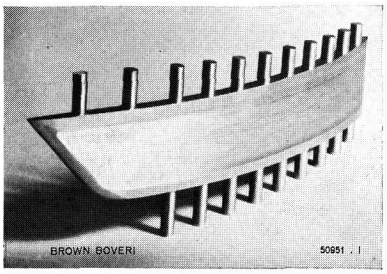


Fig. 109. — Blade of a Brown Boveri impeller wheel.

The rivets are milled out of the solid. The reinforced rim gives the rivets a good holding surface. The blade is made of high-grade special steel.

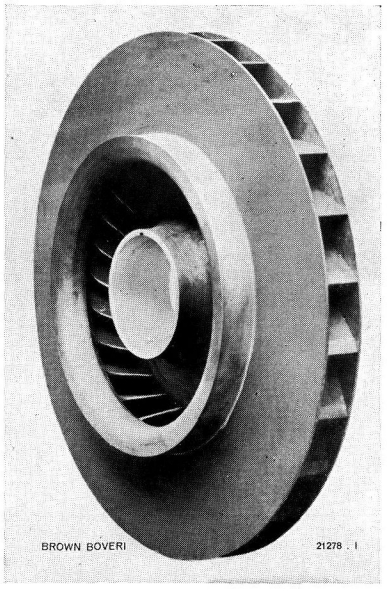


Fig. 110. — Brown Boveri blower impeller wheel.

For gas turbines, as well, with low peripheral speeds Brown Boveri uses in principle the same strong construction with forged discs and counter-sunk riveted blades. The wheels are entirely smooth outside and inside. The countersunk rivet heads are well protected against erosion and rust.

3. *Gas blowers and other blowers for special purposes.*

The majority of gas blowers ordered from us were to be used as gas exhausters for the gas from coke ovens. As the difference in pressure which these blowers had to generate is low, they run at a low peripheral speed and the mechanical stressing of the rotor is correspondingly low.

For all gas blowers, Brown Boveri use, in principle, the same impeller-wheel design as for high-speed compressors and blowers. The discs of the impellers are forged and turned from high-grade material and the blades are made of special steel

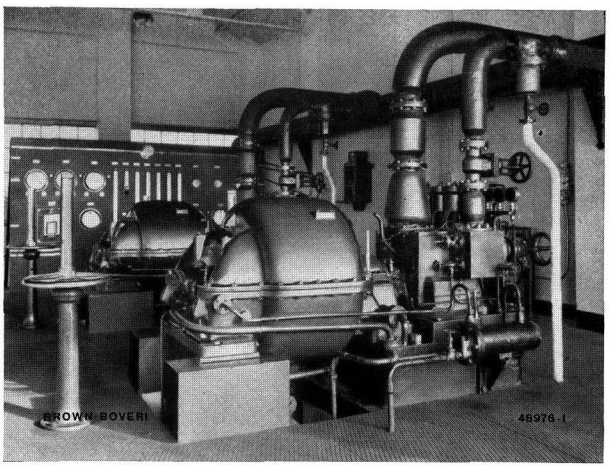


Fig. 111. — Two turbo-gas exhausters for delivering 12,500 m^3/h of coke-oven gas of 400 mm W. G. low pressure to 1400 mm W. G. high pressure. Speed 6100 r. p. m. Drive by a back-pressure turbine of 90 kW.

Delivered to an iron works by our concessionary Messrs. Richardson, Westgarth & Co.

The gas exhausters are so regulated automatically that the suction pressure in the manifold is maintained constant.

of great strength. Rivets are used to secure these blades to the discs on each side and these rivets are machined out of the solid blade. The rivets are

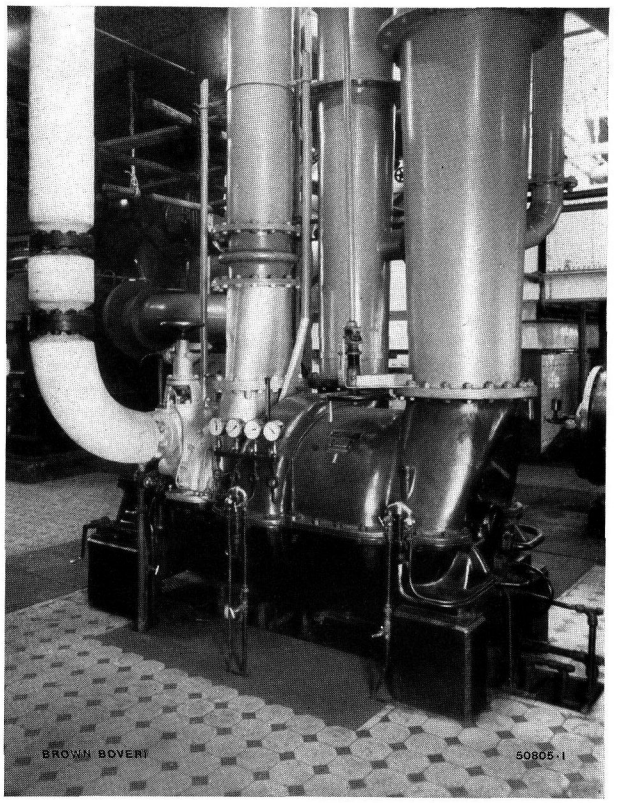


Fig. 112. — Gas booster for compressing 29,000 m^3/h of lighting gas to 1·5 kg/cm^2 abs, drive by a back-pressure turbine of 465 kW output.

Delivered to a gas works in Australia. Turbine and booster are combined and have a common shaft with only two bearings. The control is through a main valve, the nozzle valves are manually controlled, which makes the governing very simple.

countersunk in the discs and the rivet heads finally milled to a smooth surface with the outside of the disc.

A wheel built up like this presents an entirely smooth surface, outside and inside and, thanks to its strength, is subject to very little wear or corrosion. Tar and dirt get much less hold on the smooth surfaces. Experience has shown that these strong Brown Boveri impeller wheels remain in satisfactory running

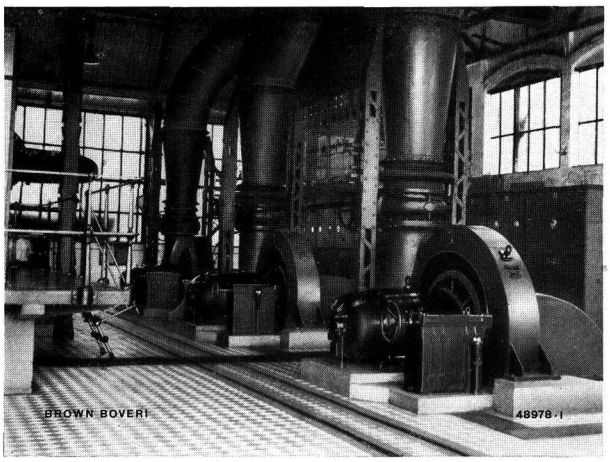


Fig. 113. — Single-stage turbo-blower for delivering 48,500 m³/h of air against a pressure of 900 mm WG. Speed 3000 r. p. m. Drive by three-phase induction motor 210 kW.
The impeller wheel of the blower is mounted overhung on the motor shaft. Four blowers of this type have been delivered to an iron works for copper-cupola furnaces (the fourth blower cannot be seen in the illustration).

order far longer than light, cheaply put together sheet-metal wheels and, therefore, are cheaper in the end despite higher first costs.

In all coke-oven gas blowers, the clogging of the blower by the coal tar contained in the gas has to

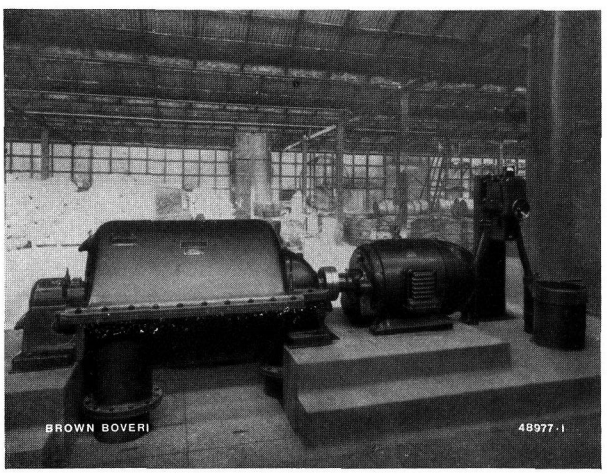


Fig. 114. — Turbo-blower for compressing 6000 m³/h of air to 1·5 kg/cm² abs, speed 3000 r. p. m. Drive by a three-phase induction motor of 125-kW output.
Delivered to a yeast factory in Australia. The compressed air is led to the fermenting vat.

be reckoned with. If the gas contains a large amount of tar, the blower gets rapidly clogged, the balance of the rotor and the thrust may be affected. This may give rise to faulty running and even to a bearing defect.

Recently, the blower has been called on to act as tar separator as well and to reduce the tar content of the gas from 6 g/m³ to 0·3 g/m³ for example. Although this duty can also be accomplished, we consider that its fulfilment tends to detract from the major objects which should guide the blower operation. We consider that it is not advisable to let a high-grade machine deal with gas containing such a large proportion of tar and thus expose it to be damaged by abnormally heavy deposits of foreign bodies. The first principle to be adhered to should be to keep tar out of the machine as far as is possible, this by placing an efficient tar separator before the blower, in which the gas is freed to a great extent of tar by washing devices, slow-running centrifugals or, as has been done lately, by an electrostatic process. Gas efficiently purified by one of these devices contains at the most 0·5 g/m³ of tar and whatever clogging of the blower may result from this can be counteracted by various means and kept down to tolerable limits; our firm has experience extending over many years in this field.

An important element of these gas blowers is the glands. The glands are of different designs according to the nature of operations and the more or less dangerous character of the gas being dealt with. For many years now, Brown Boveri have had at their disposal a series of special gland designs, from the simple labyrinth gland with or without sealing gas up to the absolute vacuum-tight or gas-tight glands with fluid sealing used for dangerous and poison gases. The experienced designer must be left the choice of gland design, from case to case.

Among blowers delivered for special purposes, Brown Boveri got an order, last year, for four big units for compressing blast-furnace gas.

4. *Charging blowers driven by exhaust-gas turbines for charging Diesel engines according to the Büchi process.*

The object of using charging blowers driven by exhaust-gas turbines — in short charging sets — in conjunction with internal combustion engines is to

increase the output of the latter by supplying them with compressed air. In the case of four-stroke engines, the engine cylinder is also scavenged, which increases its output considerably.

In most cases, charging is carried out according to the Büchi process. The Büchi Syndicate in Winterthur, of which our firm is a member, handles all technical questions in so far as they concern the charging process of the Diesel engine and the alterations which it is necessary to make to the latter in order to apply the process most advantageously.

The charging set proper, on the other hand, composed of an exhaust-gas turbine and charging blower are original Brown Boveri designs. As can be expected of an absolutely new type of machine, the design of charging sets was subjected to considerable modifications in the course of the first years of development. The first charging blower had two stages and the gas-turbine housing was not water-jacketed, in order not to reduce by cooling the energy contained in the exhaust gases.

The turbine housing was secured to the blower housing in such a manner that it could expand freely when heated, the exact centering of the housing being unimpaired.

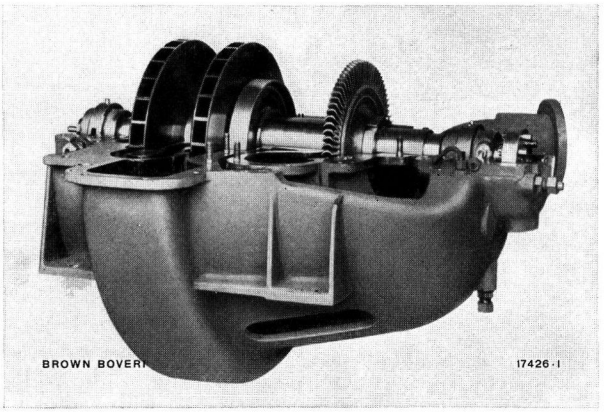


Fig. 115. — First Brown Boveri charging set, dating from 1923, for charging a Diesel engine built by the Swiss Locomotive and Machine Works, Winterthur.

The exhaust-gas turbine housing is not water-cooled. It is supported by the blower housing, and is free to expand in all directions. This charging set is now in the new machinery laboratory of the Swiss Federal Institute of Technology in Zurich.

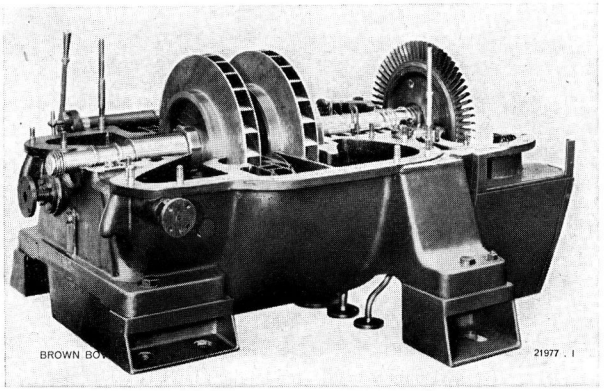


Fig. 116. — Charging set with two-stage blower and gas-turbine wheel mounted overhung, dating from 1926, for the charging of a 1200.-H.P. Diesel engine.

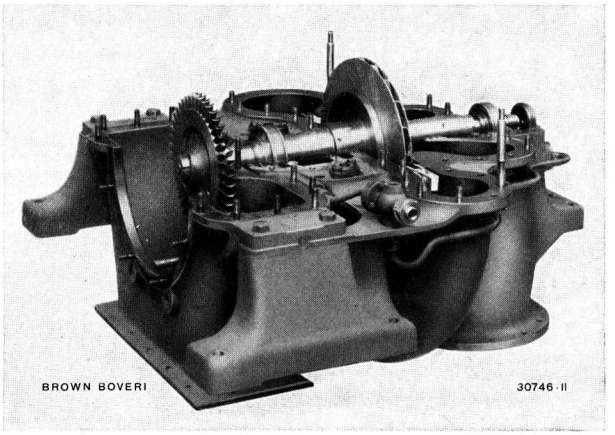


Fig. 117. — Charging set with single-stage blower and gas-turbine wheel mounted overhung, dating from the year 1930.

In order to improve the efficiency, the charging set is mounted on roller bearings.

In order to eliminate the bracket for the bearing on the turbine side, the next series of charging sets was built with turbine wheel mounted overhung on the shaft end. In order to take the critical speed into account, the shaft had to be thick, the diameter of the turbine bearing became relatively big, and roller bearings were adopted, because bearing losses in a charging set play a considerable part.

All these early charging sets had two-stage blowers, as already mentioned and they ran at relatively moderate speeds. This design gave excellent results for the

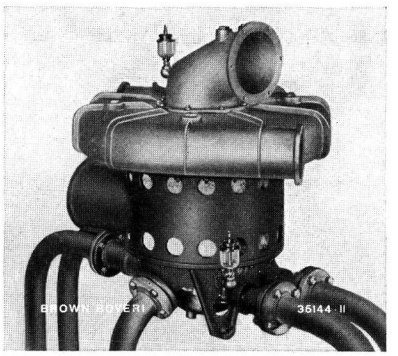


Fig. 118. — First Brown Boveri charging set for operation according to the impulse process.

The charging set serves to charge a Maybach twelve-cylinder V-motor. The first successful tests for charging this high-speed Diesel engine took place in 1930 in the shops of the Maybach Motorenbau G. m. b. H. in Friedrichshafen (the pipe lines are laid for running on the test bed).

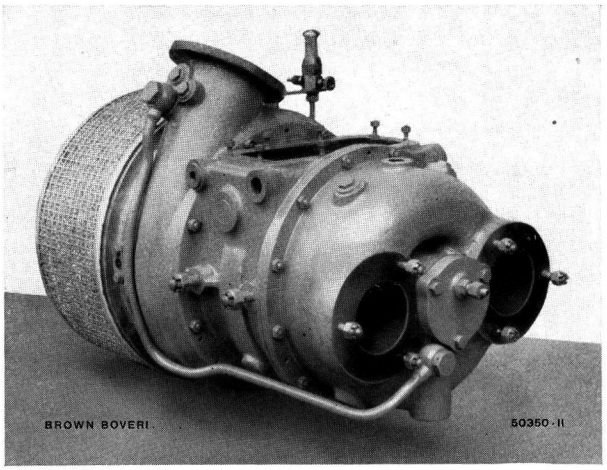


Fig. 119. — Modern water-cooled charging set Type VTx 200 for charging Diesel engines of about 225 to about 375 B.H.B. when charged.

On the left:— Suction filter and pressure branch of the blower. On the right:— the two inlet openings for the exhaust gas. The exhaust is in the middle, directed upwards.

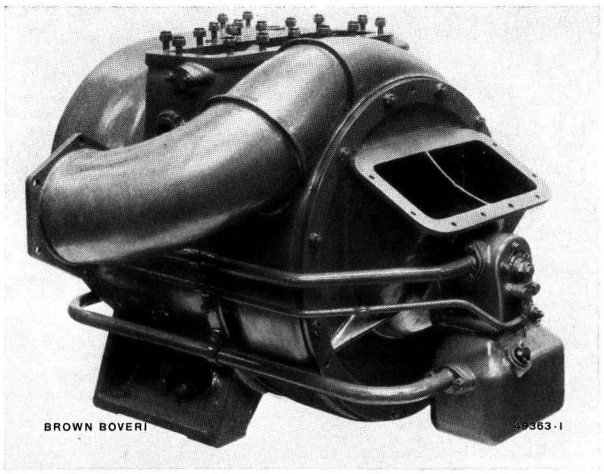


Fig. 120. — Modern water-cooled charging set Type VTx 350 spec. for the charging of Diesel engines of about 650 to about 1200 B. H. P. when charged.

Suction branches and pressure branches of the blower are arranged according to the special requirements of the engine builder. The outlet of the exhaust gases is directed upwards, the gas inlet branches are not visible. On the right, in the foreground, the lubricating pump is seen.

charging of big, slow-speed Diesel engines. However, when the charging of small high-speed Diesel engines according to the impulse process was taken up, about the year 1930[1], it was shown that charging sets built to the design current at that date, were disproportionately big as compared to the small high-speed engines they had to charge and, further, that the efficiency no longer sufficed. It was, thus, necessary to create a new and considerably smaller charging-set design of better efficiency.

As first step, the speed was increased until the necessary charging pressure could be attained with a single-stage blower wheel. The bearings were again placed outside, so that small bearings with small losses could be used. The turbine blading was improved and the sets were divided up vertically instead of horizontally as regards the axis, so that the separate parts could be mutually rotated and whatever pipe-branch layout adopted as was considered desirable, this in order to make the charging sets meet the needs of different plants. In order to prevent deformation of the sets caused by the high temperature of the exhaust gases, the turbine housing was water-jacketed like the Diesel engine itself. Thus, the present-day design of Brown Boveri charging set was developed, a design which is protected by numerous patents.

[1] The first successful tests in this field were carried out in 1930-1932 in Friedrichshafen in the shops of Maybach-Motorenbau G. m. b. H.

The first sets built still had exhaust-gas inflow pipe branches which were not cooled artificially; the object being to prevent unnecessary cooling of the exhaust gases in order to get the highest efficiency possible. The higher efficiency of the turbine and, especially, the advantageous use to which the energy contained in the ex-

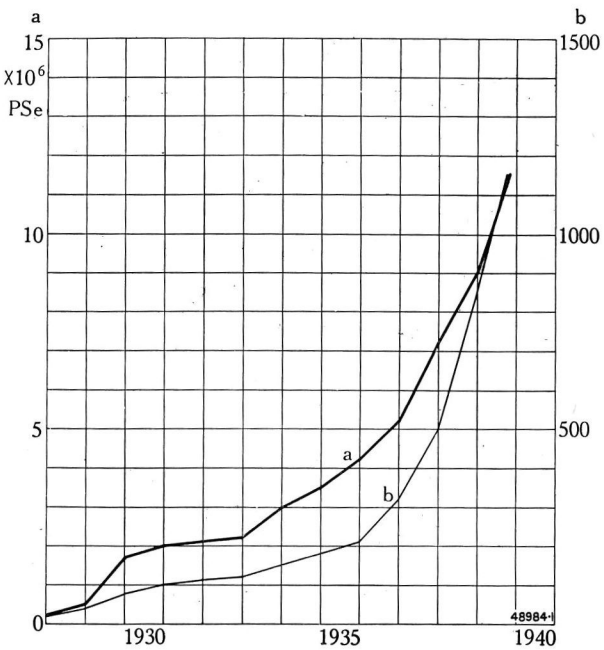


Fig. 121. — The development of the charging of Diesel engines according to the Büchi process.

a. Total output of charged engines in B. H. P.
b. Total number of charged Diesel engines.

From the character of both curves, the rapid development which has marked recent years can clearly be seen. Also that the charging of small Diesel engines (high-speed units) is always gaining more ground.

haust gases is put by the impulse process, soon made it possible to water-jacket the gas inflow branches as well.

Büchi charging for Diesel engines is strongly on the increase. At the end of 1939 there were 1200 Diesel engines representing a total output of 1,200,000 H.P., all charged by the Büchi charging process.

The percentage subdivision, according to number and output for the various fields of application is given in the following table.

	Number	*Output*
Land Diesel engines	18%	16%
Marine Diesel engines	36%	58%
Traction and road-truck engines	46%	26%
	100%	100%

As can be expected, the marine engines are chiefly big units, while the traction engines are small.

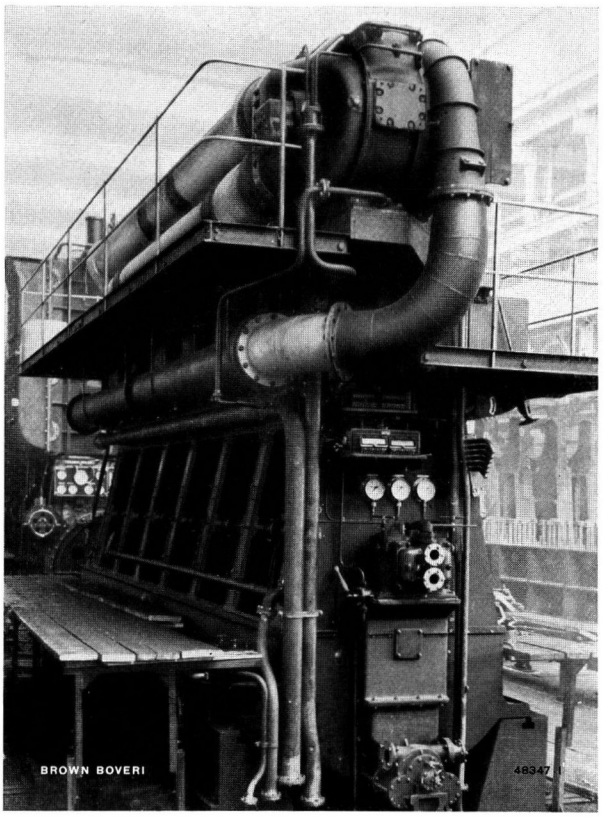


Fig. 122. — Brown Boveri charging set Type VTx 410 with six-cylinder four-stroke Diesel engine for charging according to the Büchi process. Delivered to the power station of the tin mine "Aramayo" in Bolivia; at an altitude of 3800 m, the engine still delivers 1480 B. H. P. at 187 r. p. m., thanks to charging.

(a) *Land plants.*

It is very advantageous to be able to charge Diesel engines which are located at high altitudes. The low atmospheric pressure at high altitudes lowers the output of uncharged engines considerably. Charging allows of counterbalancing this power drop. As an example of this type of plant mention may be made of the following:—

In the power house of the "Aguilar" lead mine of the St. Joseph Lead Co., located in the Argentine Andes, at 4000 m altitude, there are three uncharged engines, each of 309 H. P. Three are also:—
One Diesel engine with a Brown Boveri charging set. This engine, when charged by the Büchi process, delivers 750 B. H. P. at 300 r. p. m., but without charging the output would only be 490 B. H. P.
One Diesel engine Type FS-16; 6×16″×21″ built by Nordberg Mfg. Co. Milwaukee, with Brown Boveri charging set, Type V Ty-410. The engine charged by the Büchi process delivers 700 B.H.P. at 300 r. p. m. Uncharged, it would only give about 500 B. H. P.

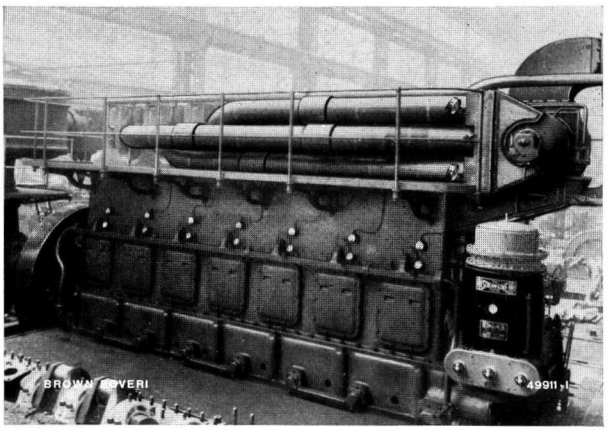


Fig. 123. — Seven-cylinder four-stroke Diesel engine Type BARU 7 of the National Gas & Oil Engine Co. Ltd. Ashton-under-Lyne (England) with Brown Boveri charging set Type VTx 410, charged according to the Büchi process.
Output 860 B. H. P. at 250 r. p. m. Delivered to the Great Boulder Mine (Australia) for operation at 500 m altitude.

In the year 1939 these clients again ordered:— A similar Nordberg engine with Brown Boveri charging set.

For the enlargement of the power house of the "Aramayo" tin mine in Bolivia, located at an altitude of 3800 m, a Diesel engine was delivered with a Brown Boveri charging set. Charged by the Büchi process, this engine delivers 1480 B. H. P. at 187 r. p. m. Uncharged, it would only give about 1000 B.H.P.

There are two Diesel engines with Brown Boveri charging sets running in the Diesel power house of the Soc. Eléctrica de Arequipa in Peru, at 2200 m altitude. Charged by the Büchi process, these units each deliver 500 B. H. P. at 428 r. p. m. Uncharged, the output would only be about 330 B. H. P.

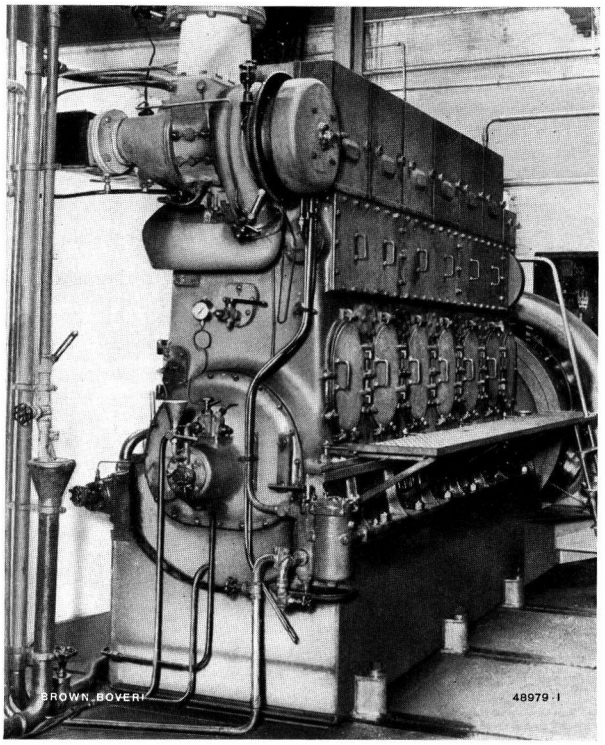


Fig. 124. — Six-cylinder four-stroke Diesel engine Type 6 VEBS, built by Ruston & Hornsby, Ltd., Lincoln (England), with Brown Boveri charging set Type VTx 260, for charging according to the Büchi process.
Output 540 B. H. P. at 500 r. p. m.

All these plants, and especially the repeat orders, go to prove that Brown Boveri charging sets are both advantageous and reliable in service in high-altitude plants.

It is becoming increasingly evident that the advantages of charging can only be fully utilized when the engine is built, from the first, to this end. For this reason there is a rapid increase in the number of firms which have developed special lines of standard-charged Diesel engines for land plants.

(b) *Marine Diesel engines.*

The motor-ship "Don Isidro" for the de La Rama Steamship Co. in Iloilo, in the Philippines, was delivered last year. This very fast motor ship is driven by two 9-cylinder Diesel engines with Brown Boveri charging set, Type VTx 590. Charged according to the Büchi process, the engines deliver each 3500 B. H. P. at 235 r. p. m. Uncharged, the output would be only about 2500 B. H. P.

Finally, mention should be made of an American plant, delivered by the Cooper Bessemer Corporation Mt. Vernon (Ohio), for the yacht "Trouper" belonging to Mr. C. A. Tilt, president of the Diamond T. Motor Car Co., Chicago. Both the Diesel engines built by

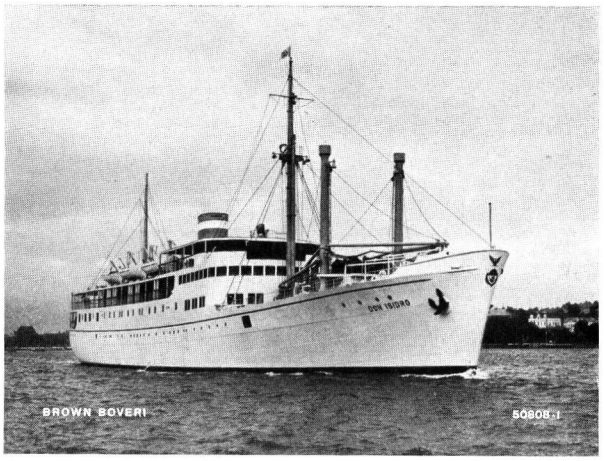


Fig. 125. — MS "Don Isidro" of the Hijos de J. de la Rama Steam Ship Co., Inc., Iloilo (Philippines).

the Cooper Bessemer Corporation are equipped with Brown Boveri charging sets.

There are also several other American Diesel engine builders who use Brown Boveri charging sets for the charging process on their marine Diesel engines.

(c) *Traction and road-truck engines.*

The percentage statistical table which we gave at the beginning of this chapter shows the importance of Büchi charging for traction and road-truck engines. Nearly half of all the charging sets delivered was for this class of engine.

In the course of last year, we delivered 63 charging sets Type VTy 410 to charge Diesel engines for

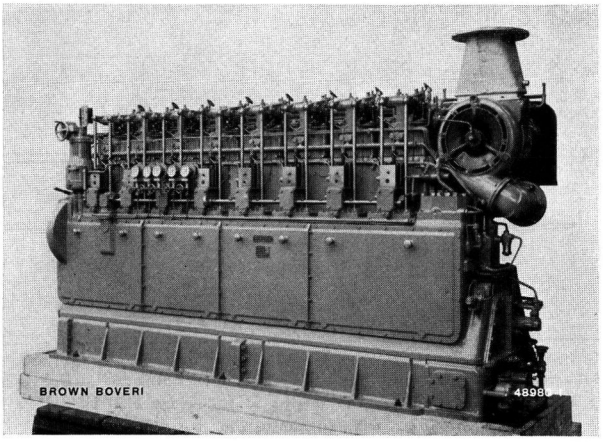


Fig. 126. — Eight-cylinder four-stroke marine Diesel engine model 8DDAH22 built by Sulzer Brothers, Winterthur (Switzerland) with Brown Boveri charging set Type VTx 260, charged according to the Büchi process.

Output 460 B. H. P. at 500 r. p. m. The Diesel-electric driven Danube paddle steamer "Stadt Wien" will be driven by two engines of this type. Messrs. Sulzer Brothers have delivered numerous engines of this series for other river and lake vessels.

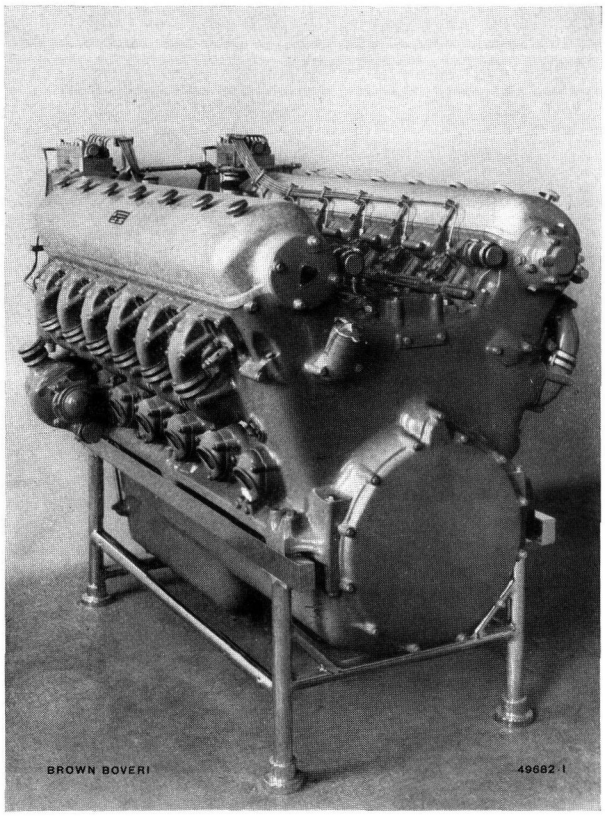


Fig. 127. — Former design without charging. Output 410 H. P. at 1400 r. p. m.

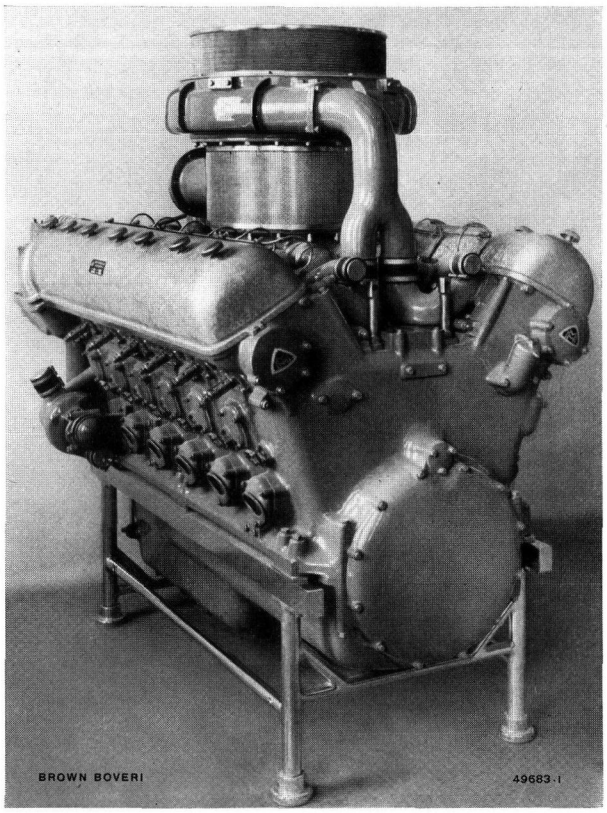
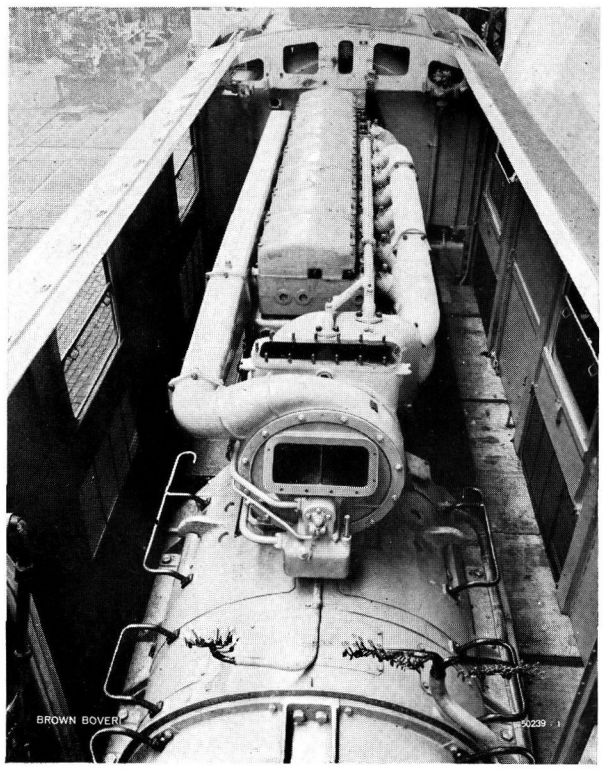


Fig. 128. — More modern design with charging according to the Büchi process by Brown Boveri charging sets VTy 410 spec. Output 600 H. P. at 1400 r. p. m.

Traction Diesel engine. It is a 12-cylinder four-stroke engine in V-design.

The exhaust gas turbine works according to the impulse process and is lodged between the two rows of cylinder. The exhaust pipes of each pair of cylinders are combined and carried by the shortest track to the turbine which is subdivided into six parts.



Diesel-electric motor-coach trains on the Dutch railways. Before this date, the Dutch Railways had more than 80 Diesel engines of the same type but *uncharged.* Charged, the new engines for the new motor-coaches will deliver 600 B.H.P. Further, 12 engines were delivered to the Belgian State Railways for six three-part motor-coaches. These engines as well, charged according to the Büchi process, and having Brown Boveri charging sets, deliver each 600 B.H.P.

For Diesel-electric locomotives for the Swiss Federal Railways, Messrs. Sulzer Brothers, Winterthur, delivered two engines Type 8 LDA 28. With Büchi charging and Brown Boveri charging sets, the one-hour rating of the engine is 1200 B.H.P. Without charging it would be about 850 B.H.P. Technical circles were much impressed with the performance of these engines.

Fig. 129. — *Eight-cylinder four-stroke traction Diesel engine Type 8LDA28, built by Sulzer Bros., Winterthur (Switzerland) with Brown Boveri charging set Type VTx 350 spec., charged according to the Büchi process.* Output 1200 H. P.

Delivered to the Swiss Federal Railways for the Diesel-electric locomotives Am 4/4 No. 1001 and 1002.

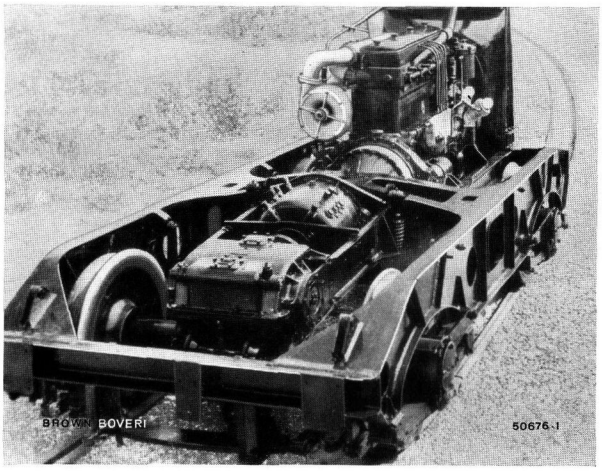


Fig. 130. — Traction Diesel engine built by Adolph Saurer A.-G., Arbon (Switzerland) with Brown Boveri charging set Type VTx 200, charged according to the Büchi process.

The Ferrocarril Central del Peru transformed a Sentinel steam motor coach to Diesel-electric drive as an experiment some time ago. After this coach had been running for six months and had covered 53,000 km without any trouble on a line section with gradients up to 5000 m altitude, the company ordered engines allowing of transforming five further coaches, and also ordered five new motor coaches. The engine delivers 200 B. H. P. at 1500 r. p. m. at sea level; at 5000 m altitude, thanks to charging, it still delivers 160 B. H. P.

Mention should also be made of the traction Diesel engine built by A.-G. Saurer in Arbon (Switzerland), Type BXD. This is a relatively small engine delivering 200 B.H.P. at 1500 r.p.m. It is no easy matter to build a charging set of sufficiently high efficiency for an engine as small as this one, and the good results attained are all the more remarkable. The engine was delivered to the railway authorities of the Ferrocarril Central del Perú, and built into a motor coach running on a difficult mountain section, which climbs to 5000 m over stiff gradients. As mentioned, the engine delivers 200 B.H.P. at sea level and, thanks to charging, is still able to deliver 160 B.H.P. at 5000 m altitude.

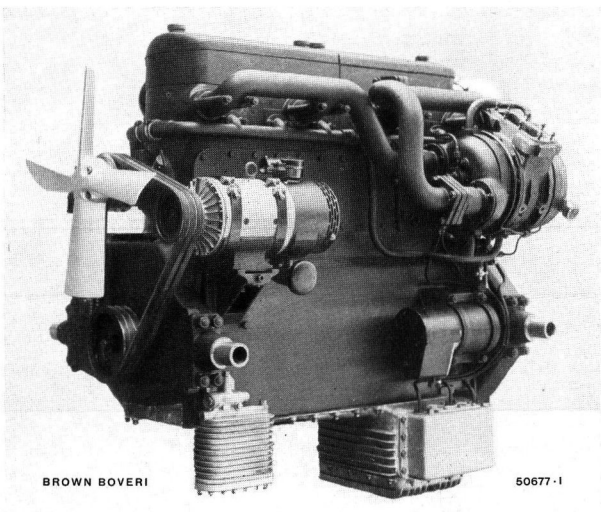


Fig. 131. — Four-cylinder traction Diesel engine Type BXD, built by Adolph Saurer A.-G. in Arbon (Switzerland) with Brown Boveri charging set Type VTx 150, for charging according to the Büchi process.

Three engines of this type are being built for the Kenya-Uganda Railway, which climbs to 2500 m altitude. At this altitude, the engine, thanks to charging, is still able to deliver 160 B. H. P. at 1500 r. p. m.

After the first transformed motor-coach had run for six months and covered 53,000 km without a breakdown, the railway management decided to make-over a further five motor-coaches and also ordered yet another five new motor coaches.

Three similar Saurer engines, but with smaller charging sets, are in hand for the Kenya-Uganda Railway.

It is very encouraging to see how the charging of Diesel engines according to the Büchi process is also meeting with increasing success in the United States. The American Locomotive Co., alone, has already ordered from us a total of 75 charging sets type VTx 350 for the charging of traction Diesel engines for shunting locomotives of each 1000 B.H.P. at 700 r. p. m.

5. *The charging process in the chemical industry.*

In the course of last year we booked different orders for compressors driven by exhaust-gas turbines for the chemical industry. Mention can be made of two compressors dealing with 20,000 and 11,000 m^3/h respectively with delivery pressures of 8·5 and 8·0 kg/cm^2 abs, respectively. Both compressors are used to charge an absorption process for the manufacture of nitric acid according to the du Pont de Nemours process. The hot exhaust gases developed during the process are led at a pressure of 7 kg/cm^2 abs and a temperature of 475—500 °C to an exhaust-gas turbine. As the gases still contain traces of nitrogen oxides, the whole exhaust-gas turbine had to be built of acid-proof chrome-nickel steel.

In this process, the exhaust-gas turbine is not able to deliver the whole power required for compression, therefore an electric motor is added which delivers the additional power required through a reduction gear. The motor is also used to start the set.

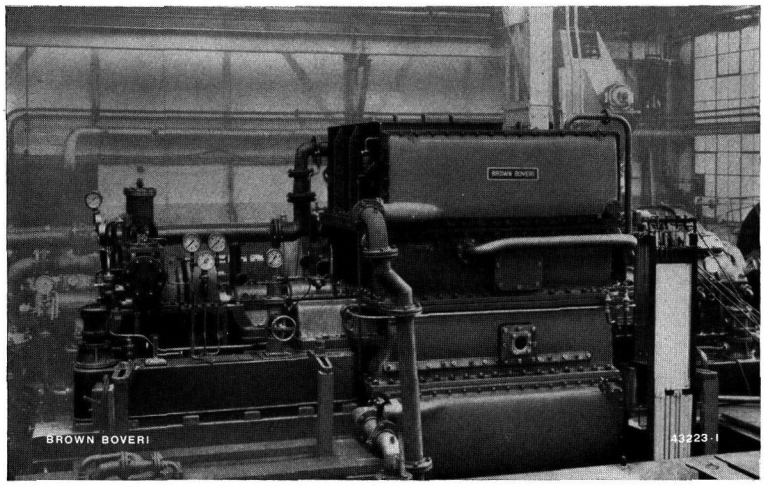


Fig. 132. — Compressor set for a charged absorption process for the manufacture of nitric acid.

The compressor compresses about 20,000 m³/h of air to 8·5 kg/cm². The power requirements on the coupling is 1780 kW. Oxygen and nitrogen are combined chemically to form nitrogen oxydes, and by absorption under pressure are elimited from the residual gas, which leaves the process under a pressure of 7·5 kg/cm² abs and 500 ° C, to be then delivered to the gas turbine on the left, which develops 1400 kW. The remaining 380 kW is covered by the driving motor, which, however, on account of having to provide power at starting, has to be dimensioned for the whole compressor output. (The motor is on the right, but not visible). As the residual gases still have traces of nitrogen-oxydes, the gas turbine has to be made of acid-proof chrome-nickel steel. The illustration shows the compressor set on the test bed in our shops.

While, in the case under consideration, it is necessary to provide some supplementary power, there are other cases in which the exhaust-gas turbine gives more power than is required for compression so that the charging set has excess power available. This happens with the numerous charging sets delivered by us to oil refineries and oil-cracking plants operating on the Houdry process.

In this cracking process, the crude oil is vaporized and the vapours led over catalysers, which results in the oil vapours being transformed into the lighter fractions, notably into benzine. The product obtained varies according to the temperature used and the nature and duration of the catalytic process. After this, the vapours are subjected to fractional distillation. The catalyzer gets gradually clogged by deposits of tar and coke and loses its efficiency; it can, however, be regenerated by combustion of the foreign matter which has clogged it.

Earlier, this combustion was carried out at atmospheric pressure simply by blowing air through the catalyzer. This proved a lengthy process, however, and meant withdrawing the catalyzer from the cracking process for long periods, which brought down the efficiency of the plant.

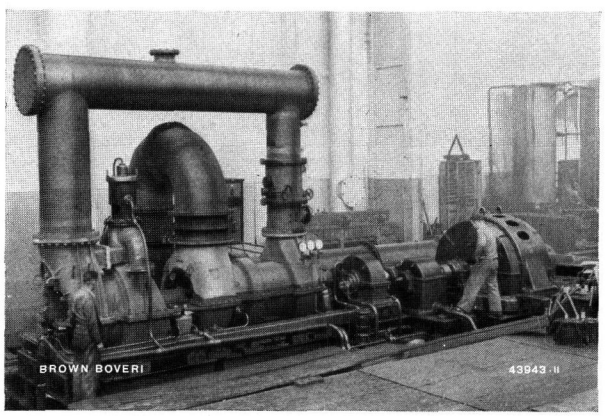


Fig. 133. — Charging set for a cracking plant according to the Houdry process.

The axial compressor compresses 70,000 m³/h of air to 4·5 kg/cm² abs, and requires 4100 kW on the coupling. The gas turbine generates about 5300 kW. The excess output of 1200 kW is delivered to the generator, which also serves to start the set. The catalizers soiled with tar and coke are burnt out under pressure in a fraction of the time it would need to do so under atmospheric pressure. Further, as already said 1200 kW of electric output is recuperated. The illustration shows the set on the test bed in our shops in Baden (Switzerland). The combustion chamber above the set serves to start and to test the set.

By using a charging set, it has now been found possible to carry out the combustion process under a pressure of several kg/cm². This accelerates considerably the combustion of the tar and coke residues. Only a fraction of the time formerly necessary is taken up by the combustion process and the usefulness of the plant is considerably increased; less catalyzing agent is needed.

Apart from this, the troublesome tar and coke residue is transformed by the charging process into useful fuels which are used to heat the exhaust gases. When no charging was used, it was necessary to drive the blower by an electric motor; now, the gas turbine driving the charging set produces more power than is required for the blower; so the set gives useful power for other purposes. The charging set is, in principle, nothing else than a combustion gas turbine in which the fuel used is formed of the desposits soiling the catalyser.

Last year Brown Boveri Baden and their concessionaries delivered a number of charging sets of this

kind. The following table gives some data on the sets in question delivered up till now.

Plant No.	Gas turbine output kW	Excess power available from the charging set kW	Comments
1	5300	1200	Running since year 1936
2	1400	200	„ „ „ 1937
3	2700	500	„ „ „ 1938
4	5300	1200	Now in process of erection
5	2700	500	„ „ „ „ „
6	2700	500	„ „ „ „ „
7	5300	1200	„ „ „ „ „
8	2700	500	„ „ „ „ „
9	2700	500	„ „ „ „ „
10	2700	500	„ „ „ „ „
11	2700	500	„ „ „ „ „
12	5300	1200	„ „ „ „ „

Plant 1 has been years in service with very few stoppages — the stoppages were due to other parts of the cracking plant — and the charging set has run for up to 8 months in continuous day-and-night operation. This gas turbine has, thus, shown its qualities for continuous service, which is testified to by the number of repeat orders which we have received.

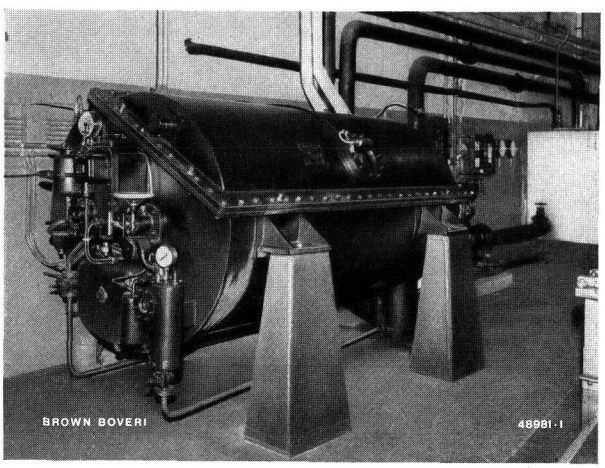


Fig. 134. — Frigibloc for cooling water from 7 to 2 ° C; refrigerating capacity 110,000 kcal/h.

Compressor with driving motor; evaporator and condenser enclosed in a common gas-tight housing. There are no external pipe connections to become leaky. Delivered to a film manufacturing plant.

F. REFRIGERATION (FRIGIBLOC).

60 % of last year's Frigibloc orders were for air-conditioning plants and the remainder for various other purposes. The circle of Frigibloc clients is constantly widening thanks to the excellent properties of this type of refrigerating machine.

We would mention the following Frigiblocs for air conditioning:—

1 Frigibloc for a refrigerating capacity of 190,000 kcal/h for the air-conditioning of a big hotel.

1 Frigibloc for a refrigerating capacity of 160,000 kcal/h for the air-conditioning of a works manufacturing physical instruments.

1 Repeat order for 2 Frigiblocs for a slaughter house with a refrigerating capacity each of 100,000 kcal/h at an evaporation temperature of — 21 ° C. One of these units was set to work in the spring of 1939.

Special interest attaches to a Frigibloc of the exceptional refrigerating capacity of 2,400,000 kcal/h with an evaporation temperature of — 12 ° C. It will be put into an artificial-silk mill. Drive is by a steam turbine mounted outside the bloc proper. Drive by steam turbine allows of varying the refrigerating capacity and brine temperature over a wide range. The compressor is of the multi-stage axial type, superior, in the present

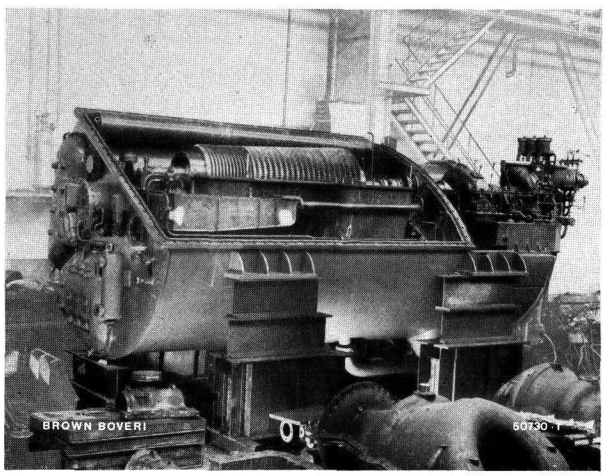


Fig. 135. — Frigibloc for cooling brine from 0 ° C to —12 ° C. Refrigerating capacity maximum 2,400,000 kcal/h. Drive by a back-pressure steam turbine of 800 kW through a reduction gear. The turbine is mounted outside the block.

The block is 8 m long and has a diameter of 3·4 m, and is just small enough to meet the railway loading gauge regulations. Delivered to an artificial silk mill.

case, to the centrifugal type as regards efficiency, weight and compactness. It may be added that, as regards railway loading gauges, this Frigibloc is the biggest that can be forwarded in one piece.

IV. TRACTION.

A. ELECTRIC LOCOMOTIVES AND COACHES.

Decimal index 621.33.

This continued to be an active field of development, last year. The *Swiss Federal Railways* ordered a number of new locomotives, the electrical equipment of which was entrusted to us, in a great number of cases.

Among these units, we would mention four *express locomotives,* Series 10,801, with 1 D_o 1 axle arrangement, which is a new one for the Swiss Federal Railways. We delivered the transformers for these locomotives, the control equipment on the high-voltage side, an arrangement which we introduced to electric locomotives a few years ago; we also delivered the current collectors and the main circuit breakers which are of the air-blast high-speed type.

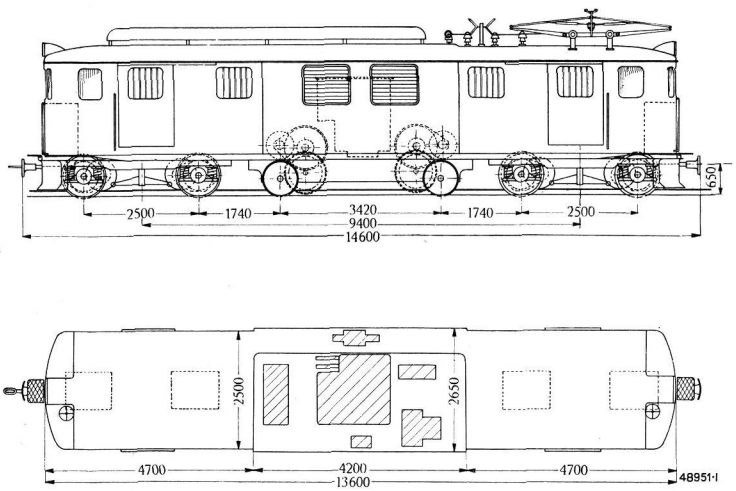


Fig. 136. — Rack-type luggage motor coach, Series Fhe 4/6 901 for the Brünig-section of the Swiss Federal Railways.

The final decision to electrify the narrow-gauge *Brünig line,* from Lucerne to Interlaken, was taken in the summer of 1939. The current is to be single-phase, 15,000 V, $16^2/_3$ cycles. This line section is of the adhesion type for 58·5 km and the rack type for 15·5 km. As the latter amounts to only about $^1/_4$ of the total length, the rack locomotives in steam service were used exclusively for the rack section located about half way between Lucerne and Interlaken while other locomotives were used for the adhesive section. This meant changing locomotives twice on one trip, which complicated running conditions. This drawback will now be eliminated as the same luggage motor coach will cover the whole run. These are six-axle motor coaches (Fig. 136), the middle section being taken up by the machinery and two compartments at the ends being reserved for luggage. The outer four adhesion axles are driven by nose-suspended motors of a total one-hour rating of 1248 H. P.; the two inner axles are for rack drive and have two motors delivering together 704 H. P. and working on the pinion wheels through double reduction gears. Electric braking is confined to the rack section of the line, the separately-excited six driving motors then work on braking resistances on the roof of the coach. We got the order for the electric equipment of 7 of the 16 motor coaches and the order for the current collectors, compressor motors, safety apparatus, lighting regulators and window-pane wipers for all 16 coaches.

The Swiss Federal Railways also ordered three more *shunting* locomotives Ee 3/3 of the same design as that built to for earlier units. Here, again, we got the order for the major part of the electrical equipments, as had been the case for all the 54 locomotives of this type.

The electrification of the *Andermatt-Disentis* line section of the *Furka-Oberalp Railway* was decided on last autumn. The system chosen is single phase, with 11,000 V trolley-wire voltage and $16^2/_3$ cycles, this having been used successfully on the Rhetian Railway and the Visp-Zermatt Railway. Further, the Schöllenen Railway (Goeschenen to Andermatt), which was put into service in 1917 and is now under the same management as the above railways, is also to be made over from 1200 V d. c. to single-phase current at 11,000 V trolley-wire voltage, $16^2/_3$ cycles.

We got the order as general contractors for the electrical equipment of three four-axle *motor coaches* for mixed adhesion and rack service, which will run, not only on the Oberalp line section from Andermatt to Disentis, but also on the Schöllenen Railway between Göschenen and Andermatt and on the Rhetian Railway line section, between Disentis and Chur. Later on these coaches will make through service, between Göschenen and Chur, possible. As Fig. 137 shows, these 1-metre gauge motor coaches, of about 32 t, will have a two-axle driving bogie with two motors giving,

together 430 kW at one-hour rating, and a runner bogie. Apart from the two driver cabs and an entrance platform in the middle, the coach body contains a second-class compartment with 6 to 8 seats, a third class compartment with about 32 seats and a luggage compartment. The apparatus is lodged in a small apparatus chamber in so far as it does not find room under the coach. 51 t is the heaviest train load allowable on the Göschenen-Andermatt line, having a maximum gradient of 179‰; 70 t is allowable for the Andermatt-Disentis line section having a maximum gradient of 110‰ and 95 t for the Disentis-Chur line section with a maximum gradient of 27‰.

The new electric equipments of the four existing locomotives of the Schöllenen Railway[1], which are to be made over from direct current to single-phase current, are identical in their chief parts to those of the Oberalp motor coaches, a considerable advantage as regards attendance and upkeep. Each locomotive is equipped with the same motors giving together 430 kW. The order for the total electric equipment of all seven vehicles was entrusted to us except the transformers and some small parts of the apparatus which we were called on to subcontract to S. A. des Ateliers de Sécheron (Geneva). The mechanical equipment of the motor coaches is built by the Swiss Locomotive and Machine Works of Winterthur (Switzerland). The total plant with the new motor coaches and transformed locomotives have to be handed over at the end of 1940.

The motor coaches for the *Schweizerische Südost Railway* mentioned in our last year's report, and for *Rhetian Railway* (Fig. 138) were put into service last autumn.

In *Italy*, our spring drive is being used on motor coaches of the *Ferrovie Nord Milano*. Nose suspension is avoided in this way, the motors are secured rigidly to the bogie frames and, thus, form part of the sprung part of the vehicle (Fig. 139).

Our French concessionaries, the Cie. Electro-Mécanique, working in collaboration with the Cie. de Fives-Lille, got an order for five more locomotives 2 D_o 2 for the south-eastern region of the S. N. C. F. The total number of locomotives of this now thoroughly approved type, including the similar units built for the eastern region is now 73.

In *Norway*, work is being actively pushed on the eight 1 D_o 1 locomotives, Series 2045, mentioned in last year's report. Here also the main breaker is designed as an air-blast high-speed circuit breaker which normally works with compressed air at 7 kg/cm², pressure being taken from the apparatus air tank. In order to make quite sure that making and breaking will be carried out, under all conditions, even when the air for the brake fails owing to the coach being at a standstill for a long time, small motor compressors are used on these locomotives, for the first time. The motors of these sets gets current from the lighting battery. Thus the breaker air tank can be charged at any time without difficulty and the current collector raised.

Last year, the *Norwegian State Railways* decided to enlarge their fleet of motor coaches. Due to the excellent results shown with the 14 units electrically equipped by *Norsk Elektrisk & Brown Boveri in Oslo*, 13 other motor coaches of the same design were ordered, with four nose-suspended motors of 116 kW one-hour rating and, at the same time, 13 control coaches and 13 wired coaches (with wires for control running through them). The A/S Skaho Jerbanevognfabrik in Skøyen near Oslo is delivering the mechanical parts of the coaches. Further, *four express motor-coach trains* were ordered, each composed of a motor coach, a control coach and an intermediary coach. The four driving motors of each motor coach, giving 4×180 kW, transmit their torque to the wheel axles through Brown Boveri spring drives, which are, thus introduced for the first time to the Norwegian railways.

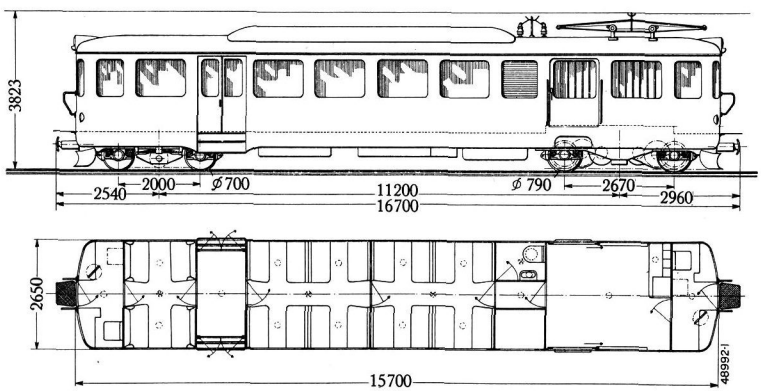


Fig. 137. — Rack-type luggage motor coach, Series BCFe 2/4 of the Furka-Oberalp railway.

In our last report, we mentioned, the first electric Micheline train, on pneumatic tires built for 650 V d. c. and it has been described, in the meantime in detail in this Review[1].

The great progress achieved in the design of autobuses and automobiles has forced the *tramway*

[1] See La Revue BBC of February 1918, page 23.

[1] See The Brown Boveri Review of September 1939, page 219.

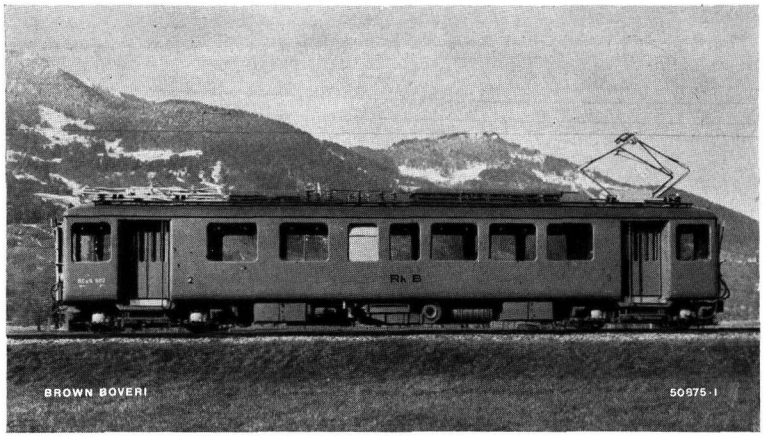


Fig. 138. — Motor coach series BCe 4/4 501 of the Rhetian railway.

companies and the manufacturers of rolling stock for these to improve both traffic service and the vehicles used in an endeavour to meet the serious competition of auto-buses and automobiles. One method of meeting competition is to acquire new modern tramway coaches, the other, to transform the existing tramway service into trolley-bus service. We have done much

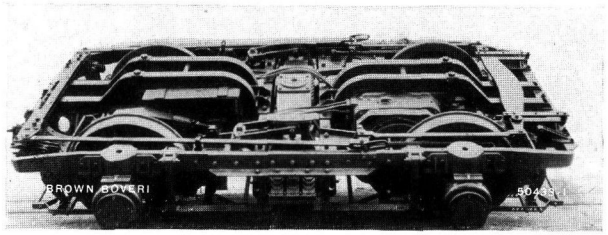


Fig. 139. — Driving bogie equipped with two motors and Brown Boveri spring drive.

development work in both these fields. We would recall, here, the *Simplex bogie* which allows of building modern four-axle roomy tramway motor coaches, which are certainly preferable to two-axle coaches with trailers and we would also refer to our *trolley-bus* material which has been still further improved.

As already reported we used a control based on the line-switch principle for the first time on the trolley-buses of the Town of Winterthur (Winterthur-Wülflingen line). This innovation proved an excellent one and, since then, it has been applied, in somewhat modified form, on the three coaches for the *Neuchâtel-Serrières line.*

In its latest design, this control allows of controlling in one single stroke of the travelling or braking pedal respectively any one of the following processes.

With the starting pedal:—

(a) Finely-graded starting of a motor with subsequent field regulation in several steps, upwards and downwards.

(b) Finely-graded starting of a double motor in series and parallel with subsequent weakening of the field in 1 to 2 steps.

With the braking pedal:—

(c) Finely-graded short-circuit braking with subsequent actuation of a compressed air and servo brake.

(d) By the addition of additional braking steps, a limit regulation of the braking current is introduced when the brake pedal is brought back.

A braking device built on to the finely-graded starter to limit the motor current at travelling and short-circuit braking in conjunction with the pedals, prevents too rapid switching in and allows semi-automatic starting and short-circuit braking.

The deciding factor which marks the superiority of our control system, the Neuchâtel design of which is shown in Fig. 140, is that the number of travelling steps is not determined by a given maximum switching capacity per switching step but can be freely determined according to the technical characteristics of the traction duty required of it. We would add here that, to-day, no doubt remains that, taking town modern requirement into account (starting smoothly with maximum acceleration and moderate current peaks), 18 to 25 starting and about as many braking steps are sufficient and an increase in the number of steps beyond this figure does not bring any noticeable improvement of technical or of travelling conditions of the vehicle.

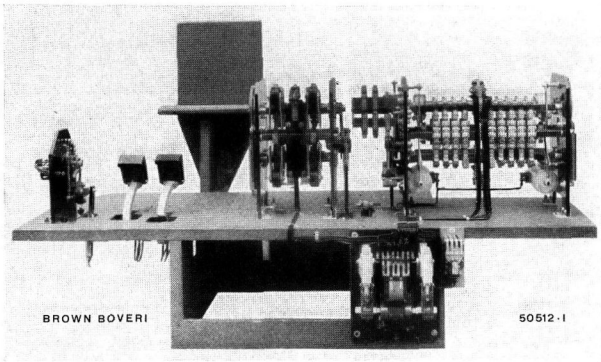


Fig. 140. — Line-switch apparatus for trolley buses.

Fig. 141 shows the trolley-bus current collector which we have developed with its sliding contact piece built into the base and its pressure diagram for a working range of 1·0 to 4·0 m measured over the lower edge of the base.

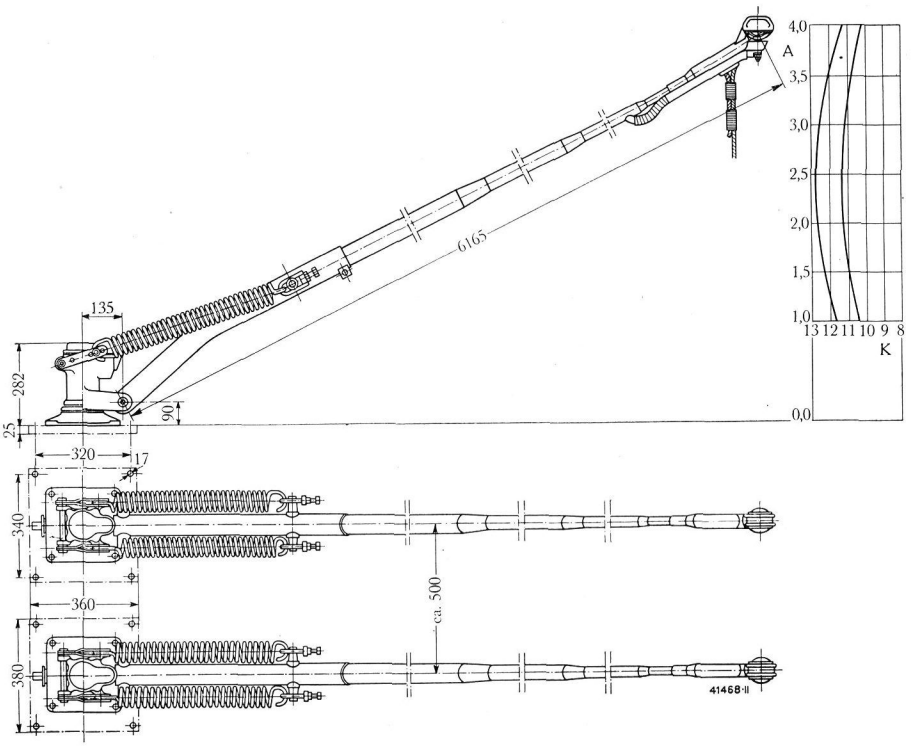


Fig. 141. — Rod-type trolley-bus current collector.
A. Working range. K. Pressure exercised in kg.

Apart from Neuchâtel, we got trolley-bus equipment orders from the *Bienne* and *Berne* tramway systems. In Bienne, the tramway line from that town to Mett, in Berne the line from the main railway station to Schosshalde are to be made over for trolley-bus service.

In all the trolley-bus plants put into service up till to-day, a welcome increase in the traffic has been noted, after a short time.

B. DIESEL VEHICLES.

The two B_o—B_o Diesel-electric locomotives, already mentioned here, having Brown Boveri-Büchi charging, of Series Am 4/4 No. 1001/02 for the Swiss Federal Railways, have been put into service. One of them was brought to Zurich (after performing some trial runs between Winterthur and Schaffhausen at the end of April) and formed a permanent exhibit of the Swiss National Exhibition. The other carried out a taking-over run from Winterthur to Geneva and back on the 17th of July, 1939. The total weight of this trial train with locomotive and dynamometer coach was 180 t. Since the middle of August 1939, the machine has been running in ordinary service.

The two *Diesel-electric buses* for *Lucerne,* mentioned here last year, have also been taken over and are running.

In conjunction with the 18 Diesel-electric five-coach trains for the Dutch Railways also mentioned in last year's report, a new type of *number-of-revolution adjuster with motor drive* has been developed for adjusting the r. p. m. or the fuel charge of the Diesel engine, in several steps; it is used for the servo field-regulator control placed on these trains. As fuel charge adjuster, the apparatus has special application to those Diesel vehicles having hydraulic power transmission. The different steps are adjusted to by cam switches which it is easy to adjust to meet service needs. The electric motor which drives the adjusting chain wheel through a *worm wheel reduction gear,* is itself controlled by a switching in and braking relay and a change-over relay. In order to shield these relays from the strong vibrations inherent to running they are not combined with the adjustment apparatus but designed for separate mounting.

The chapter on Blowers and Compressors on page 43 of this number gives information on the Brown Boveri charging blowers driven by exhaust-gas turbines, for the charging of traction Diesel engines, according to the Büchi process.

C. VELOX LOCOMOTIVES.

The first Velox locomotive has been running since the middle of 1938[1] and had covered 15,000 km up till the middle of March 1939. It is now used for hauling fast passenger and express trains on the Paris-Dijon line section.

The Velox steam generator of this locomotive is supplied with raw feed water which is treated on the

[1] The Brown Boveri Review of Jan./Febr. 1939, page 43.

locomotive itself and the sludge precipitated is eliminated by a "Dejector". It is a remarkable fact that despite these relatively unfavourable conditions for a heavily-loaded boiler, the Velox steam generator has run up till now in a most satisfactory manner.

A detailed report has been published on the service results attained with this locomotive[1] and we would refer interested parties thereto. The results attained are summarized by the French-State-Railways official, who wrote this report, as follows:—

"The question whether a Velox steam generator will work on a locomotive can be answered affirmatively to-day. The results which were expected:— Nearly instantaneous getting up of steam, flexible running and a high efficiency have been attained with satisfactory automatic operation. The future will show whether trouble as regards upkeep develops with time, this either as regards wear or scale formation. This will only be proved after comparison over a long period with ordinary locomotives performing the same service, and a considerable period will be required for this.

"From the standpoint of the railway, a Velox locomotive is certainly advantageous in cases in which getting up steam with ordinary boilers represented a relatively big part of the outlay for fuel and wages (the most pronounced case being that of the stand-by locomotive which has to be kept in the depot under steam so as to be used for any purpose), or else in continuous service where the efficiency of the boiler, its automatic operation and the less tiring duties of personel which result therefrom allow of very long daily trips. Fast-train service is of especial interest because the saving effected by the Velox steam generator is notably big at high speeds. Our observations go to show that this is due to the remarkable effect following the elimination of the blast pipe.

"It should be noted that the Velox steam generator allows of using high pressures. If the continuous service tests proposed prove satisfactory, it would be recommendable to consider the utilization of a new steam engine, either one of the design on use up till now for 30 kg/cm^2 pressure or a high-speed machine as projected by the Alsacienne-Fives-Lille-Schneider consortium for 60 kg/cm^2 pressure or, finally, a turbine.

"However this may be and without forstalling the final results which will be made known later, it can be affirmed that the results attained with the plant described are of exceptional value and do honour to the firms which built the plant".

We think this report requires no comment from us.

D. GAS-TURBINE LOCOMOTIVES.

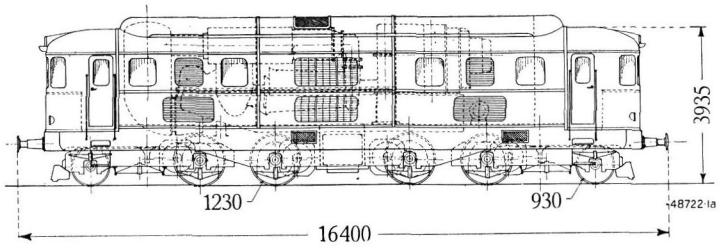
The combustion gas turbine for land plants is not yet able to compete with a steam power plant having condensing turbines, from the point of view of fuel consumption. The picture changes, however, if the steam plant runs with exhaust to atmosphere. This is generally the case for locomotives and for this reason, the gas-turbine locomotive in its present-day stage of development can already compete with the steam locomotive as regards fuel consumption.

As, up till now, the combustion gas turbine can only consume fuel oil and no solid fuel, it is necessary to take the Diesel locomotive into consideration, as well, for purposes of comparison. At a first glance, the advantage would seem to lie with the Diesel locomotive because while a good Diesel engine consumes 180 g of oil per H.P. hour the corresponding figure for a combustion gas turbine, to-day, is about 370 g.

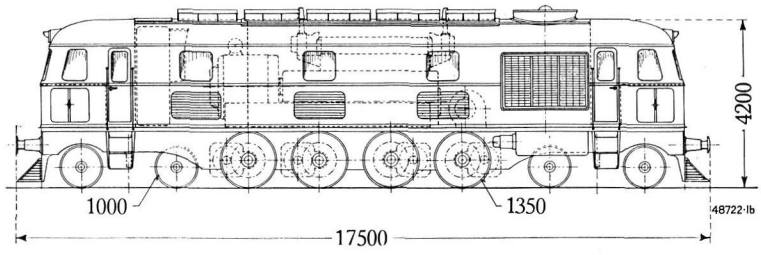
However, the fuel costs become more favourable to the gas turbine owing to the latter being able to burn cheaper oil (fuel oil). Further lubricating oil consumption has to be reckoned with and the Diesel engine requires at least 2 g of it per H.P. hour, while the consumption of the gas turbine is negligible. The cost of fuel is, however, only a part of the total running charges. If, for example, upkeep charges are considered it is seen that the Diesel engine is subjected to very considerable wear while the gas turbine, being a rotary engine, shows much less wear. The same ratio of wear may be expected here as exists between reciprocating steam engines and steam turbines.

To the above consideration must be added that of the first capital outlay which of course depends on the price of the plant. A comparison between a Diesel-engine plant and a gas-turbine plant shows

[1] "Locomotive à Chaudière Velox de la SNCF" par M. Chan. Ing. en Chef de la Division des Etudes de Locomotives à la SNCF. Revue Générale des Chemins de Fer, 1st June, 1939.



2200-H. P. gas-turbine electro-locomotive Type 1 A-B$_0$-A 1.



2200-H. P. Diesel-electric locomotive Type 2 D$_0$ 2.

Fig. 142. — Comparison of a 2200 H. P. gas-turbine electro-locomotive with a 2200-H. P. Diesel-electric locomotive.

The gas-turbine electro-locomotive is being built at the present time for the Swiss Federal Railways.

	1 A-B$_0$-A 1 *gas-turbine* electro-locomotive	2 D$_0$ 2 Diesel electric locomotive
Max. driving-axle load	16 t	16 t
Running-axle load	14 t	12 t
Max. speed	110 km/h	100 km/h
Weights		
Mechanical part	37·5 t	50 t
Thermal part	23·7 t	—
Diesel plant with accessories	—	26 t
Electric equipment	25·6 t	30·2 t
Stores and equipment	5·2 t	5·8 t
Total tare	92 t	112 t

that the latter is about 25 % lighter and that the price is reduced in a similar proportion. As, further, the gas-turbine plant is considerably shorter, the gas-turbine locomotive will also be shorter and of lighter design. These figures are obtained from the calculations carried out for the gas-turbine electro-locomotive at present in process of manufacture for the Swiss Federal Railways.

The bigger outlay for fuel consumption are more than compensated for by the lower upkeep charges and smaller capital outlay, and this is especially so when the number of annual running hours is low. If there are numerous mountainous line sections to be negotiated, as is the case in Switzerland, the lighter weight of the gas-turbine locomotive is another factor which counts in its favour.

From the technical operating point of view, the gas-turbine locomotive has the advantage of not requiring any cooling water. This means elimination of a cooler and of the numerous pumps and fans. In winter there can be no danger of freezing and the locomotive is made ready for service in a shorter time.

It is thanks to the courage and spirit of initiative of the General Management of the Swiss Federal Railways that the very first gas-turbine electro-locomotive is now being built in Switzerland, in our shops. The mechanical parts of this locomotive are being delivered by the Swiss Locomotive and Machine Works, Winterthur (Switzerland).

It will be a 2200-H. P. gas-turbine electro-locomotive for a maximum speed of 110 km/h. The tare will be 92 t. The reports on operating results obtained with this machine will certainly arouse much interest in engineering circles.

V. MARINE DRIVES.

A. VELOX STEAM GENERATORS ON SHIPS.

Decimal index 629.12.

We are, unfortunately, unable to report on any service results reached with Velox steam generators for ships which we delivered to various admiralties. We can, however, refer to the "Jahrbuch der Schiffbautechnischen Gesellschaft" for 1939, page 149 where, following Chief Eng. W. Mustelin's lecture on "Die Maschinenanlage des ersten ausschliesslich mit Velox-Kesseln ausgerüsteten Handelsschiffes", full details are given on the subject of the service results reached with the Velox plant on the test vessel "Arkona".

Both the plants on board the freight and passenger vessels "Athos II" and "Bore II" mentioned here, last year, have run regularly during 1939 under the care of the ordinary engine-room staff and valuable data has been collected for future use.

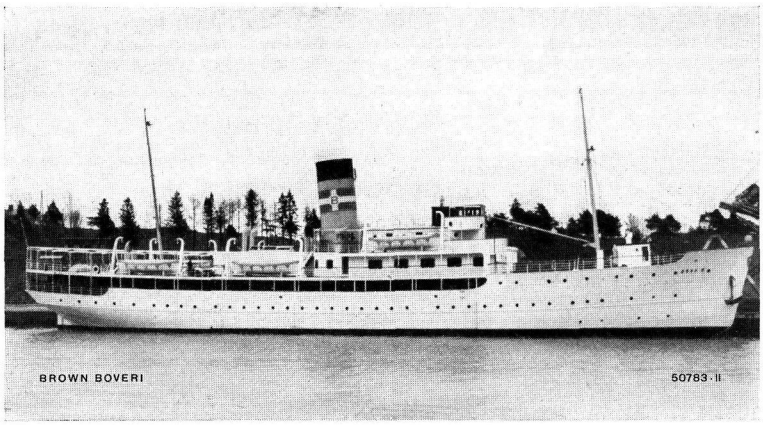


Fig. 143. — Passenger and postal steamer "Bore II" of the Reederei "Ångfartysaktiebolaget Bore" in Åbo (Finland). First steam ship exclusively equipped with Velox steam generators.

The boiler plant is composed of two Velox steam generators for a steam output of each 8 t/h at a pressure of 16 kg/cm² abs and 320° C.

On board the "Athos II", for example, the gas ducts and passages got clogged relatively quickly when poor fuel oil with a high ash and salt content was used. It was proved that the salt crust dissolved in water and for this reason water pipes were connected to the Velox to allow of swilling the boiler out, when necessary. The enclosed design of the Velox steam generator makes this an easy matter. There was no trouble on the water side of the boiler.

The latest Velox units are specially designed so as to reduce as much as possible the chances of the tubes getting clogged up.

On board the "Bore II" the main engine is of the reciprocating type so the exhaust steam carries oil and the oil must be separated from the condensate in order to get sufficiently clean feed water.

There are two oil separators provided:—

(a) A mechanical exhaust-steam oil separator between engine and condenser. It allows of bringing down the oil content of the exhaust steam to about 10—15 mg/l.

(b) A hydraffin filter with active carbon of the Lurgi design, placed after the condenser which reduces the oil content to about 5 mg/l.

Despite this high oil content, satisfactory running of the Velox boiler and the regular time-table trips of the vessel were maintained. Attempts are being made to eliminate more oil in order to improve reliability still further.

The Velox steam generator offers many advantages for marine plants on account of the small space it takes up and the fact that it can be made ready for steam delivery practically instantaneously. Experience gained on board goes to show that it satisfies all the requirements of marine service. In new Velox designs, all the experience gained in former plants is given due weight, so that we can confidently look forward to a further development of the Velox steam generator for use on board ships.

A new design of Velox steam generator was developed for warships, in the course of last year. The design is such that it is adaptable to the space available on a vessel; it takes up considerably less room than an ordinary Velox. A Velox steam generator for a steam production of 100 t/h when in service condition, but without water or oil weighs 65 t for a delivery pressure of 30 kg/cm² and about 75 t for 75 kg/cm² delivery pressure. For a steam production of 50 t/h the respective weights are about 40 and 45 t. The addition for water and oil filling comes to about 10 %.

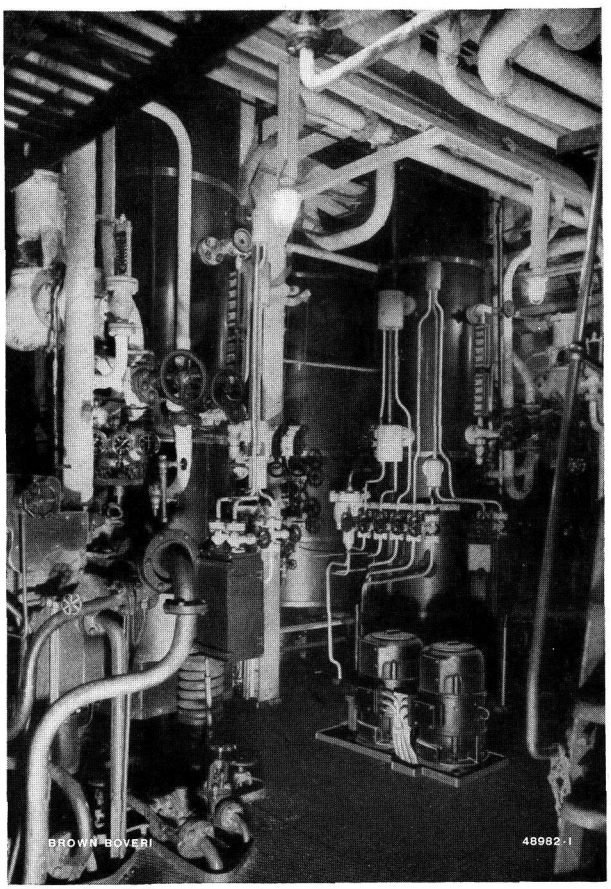


Fig. 144. — Boiler plant on board S. S. "Bore II".

In the foreground, the steam separators of the two Velox boilers. In front of them, the electric motors for the governing and lubricating oil pumps. In the background, the fuel tanks of the starboard boiler.

B. MARINE STEAM TURBINES.

Although Switzerland has no sea coast, Brown Boveri have always shown great interest in the construction of steam turbines to drive ships, recognizing that for high outputs only steam turbines can be considered, up till to-day. Thus, our firm has booked orders for marine turbines in the last years which, as regards output, are among the biggest ever built.

We also delivered, last year, a two shaft plant for a non-european navy for a special vessel, for which it was necessary to make the plant as light a possible.

Despite this requirement, we intentionally eschewed extremely light designs. Operating conditions on board ships are such that the marine turbine plant may be called *on to run* under conditions which in no way correspond to normal service. While in cases of extreme emergency, a land plant can always be shut down, it must be remembered that if the marine plant fails this may mean entire loss of the vessel and of the lives of the crew. Under these conditions, we are convinced that for marine plants only such designs can be used the reliability of which is absolutely certain and that the demand for minimum weight must take second place if its fulfilment is found to affect the reliability of the turbine plant.

The *turbine rotors* of this plant are *welded* throughout. The advantages of this Brown Boveri design were pointed out in some detail in our last year's report.[1]

[1] The Brown Boveri Review of January/February 1939, page 46.

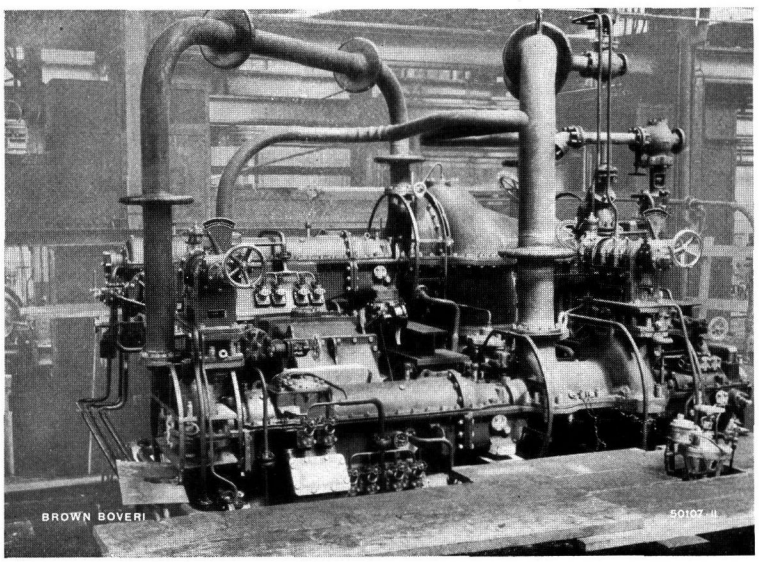


Fig. 145. — Small marine turbine plant with *double reduction gear*, built for steam of 45 kg/cm² abs and 435° C.

In the foreground, high-pressure turbine; in the background, low-pressure turbine. The illustration shows the larboard plant on the test bed in our shops in Baden (Switzerland).

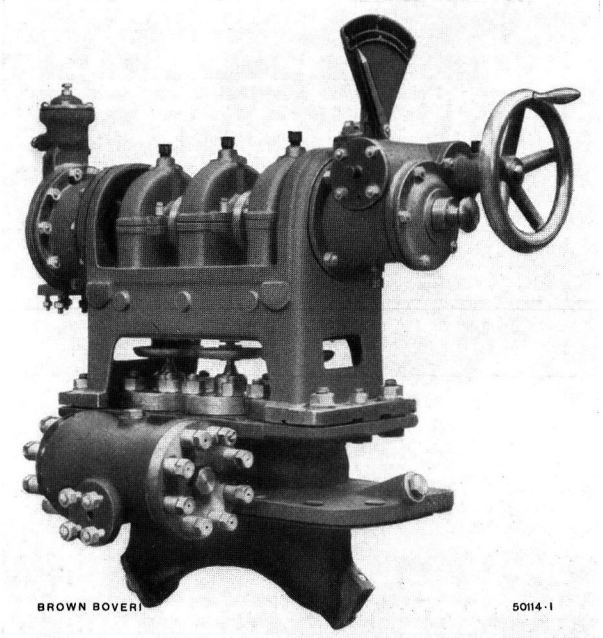


Fig. 146. — Nozzle set of the starboard high-pressure ahead turbine. Governing of the nozzle valve is through a cam shaft with hydraulic pressure servo-motor (on the left behind). By means of the knob on the right it is possible to change-over to hand control of the valves by the hand-wheel (on the right in front), this for any position of the valves. The indicator above shows the position of the valves.

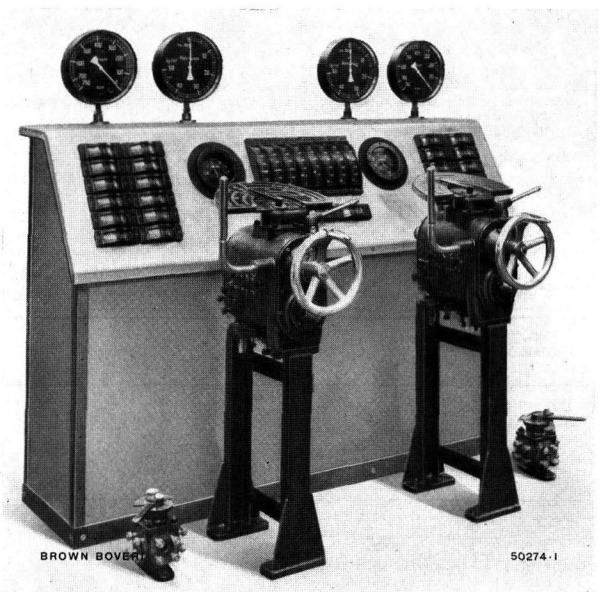


Fig. 147. — Manœuvring stand for the control of the turbine plant. By means of the manœuvring apparatus the larboard and starboard plants are set running ahead or astern. This is done by rotating the corresponding hand-wheel to the right or the left. The indicators give the sense of rotation and the position of the valves. On the switchboard there are the main instruments to supervise both plants. The turbines can be manœuvred from various positions on the vessel, as for example, from the bridge. In the engine room it is possible to go over to hand control of the valves at any moment.

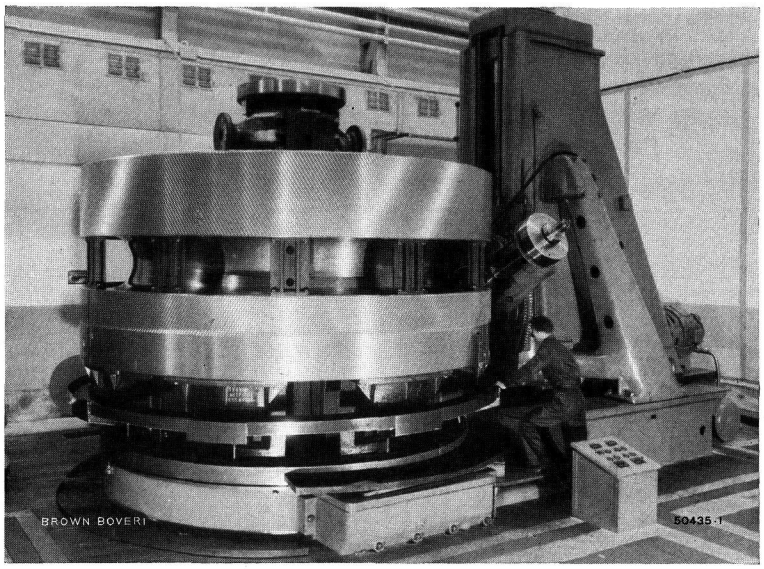


Fig. 148. — Big gear wheel for a marine turbine drive, the teeth being milled on our new milling machine.
The milling machine is built according to the most up-to-date experience and placed in an isolated chamber. The exactitude of the work is constantly supervised, so that the gear wheels produced run, at full load, practically noiselessly.

The plant has hydraulic-pressure governing gear and the governing liquid used is uninflammable. The whole plant is governed by one single handwheel by means of which all manœuvres are carried out and this from any part of the ship. Despite this arrangement, transition to manual control of all the valves can be carried out at any time, instantaneously. Every possible safeguard against too high speed of rotation, inadmissible displacement or deflexion of the shafts, too high pressure developing on any part of the turbine, want of oil etc. can easily be incorporated in the existing hydraulic pressure governing system. To do so, no rods are necessary, a pipe leading to the safety device in question is all that is required.

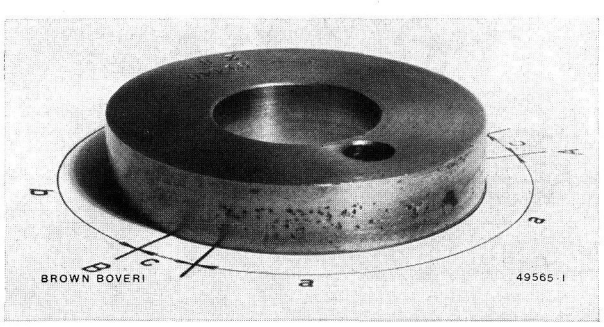


Fig. 149. — Testing pieces for investigating gear wheel material.
The outer surface of the piece being tested is stressed in a testing apparatus like the flanks of the teeth of a gear wheel. Small particles break out of the surface, so that the well known "Pitting" phenomena takes place. Detailed report on these tests was given in The Brown Boveri Review of October, 1939, page 235. See also "Engineering" of the 21st July, 1939, page 63.

In big high-pressure plants in which during manœuvring a considerable number of valves have to be actuated simultaneously or in a certain sequence, the Brown Boveri hydraulic-pressure governing system offers the greatest advantages.

The condensers of this plant are of our well-known OV type with bent shape imparted to the tubes which are expanded into the tube plates at both ends. We delivered similar condensers with tubes expanded into the tube plates at both ends to several admiralties during last year.[1]

We also delivered several reduction gears of very big dimensions during 1939. The milling machines for these big gear wheels are built according to the very latest experience acquired in this field. The precision of the work is constantly supervised and we succeeded in perfecting the manufacturing process on these gear wheels to such a point that the biggest reduction gears can now be built to run at full load, practically noiselessly.

C. MARINE GAS TURBINES.

Encouraged by the progress achieved by our firm, in recent years, in the building of gas turbines for land plants[2], we have been investigating the possibilities of the gas turbine for driving ships. Although conditions for marine plants are very different to those for land plants, the gas turbine holds interesting possibilities both for naval and merchant-marine purposes.

Warships, as is well known, very rarely navigate under full engine power[3]. Long distances are covered at about 10 % of full power and value is only attached to high efficiency at this cruising speed. At full speed efficiencies are tolerated which can be attained by a combustion gas turbine without preheater. The main characteristics demanded are that the plant be light, that it should take up little space and, if possible,

[1] The Brown Boveri Review, January/February, 1939, page 47 and October 1939, page 241.

[2] See page 13 of this number

[3] According to Charles P. Wetherbee "High Steam Pressure and Superheat Aboard Ship". Am. Soc. Nav. Arch. and Marine Eng., New York 1935, a warship travels at the most during 5 % of its useful live under more than 70 % of its full engine power and generally under less than 30 % of that power.

that it be simple, and this is where the gas turbine offers advantages even in its present stage of development.

In a gas-turbine plant there is no boiler, nor condensers with their cooling-water pumps, condensate pumps and feed-water pumps. This makes the plant astonishingly simple and easy to supervise. In order to attain a low fuel consumption at cruising speed, Diesel engines would be put in for the cruising power required and would also be used to start up the gas turbines.

A plant of this kind could be built to-day to be both lighter and smaller than a steam plant and development work along these lines will, surely, lead to further improvements.

Marine gas-turbine plants differ from land gas-turbine plants mainly in having to be reversible. They are, therefore, built with two gas turbines each. One gas turbine drives the compressor alone. As the compressor set delivers no mechanical power, this gas turbine only requires about 75 % of the compressed air from the compressor. The remaining 25 % are led to the driving turbine proper.

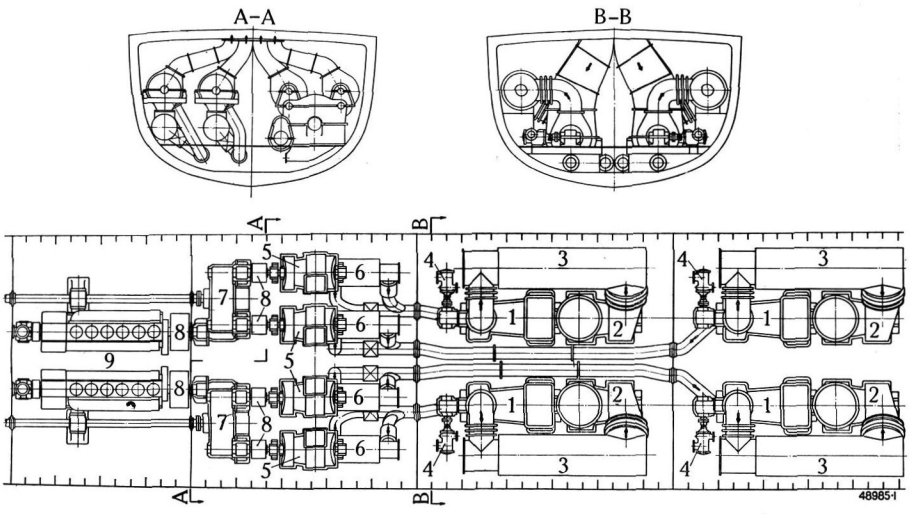


Fig. 150. — Gas-turbine plant for a torpedo boat, with two shafts, each for 11,000 H. P. at 450 r. p. m.

1. Compressor. 4. Starting motor. 7. Reduction gear.
2. Gas turbine. 5. Driving gas turbine. 8. Disengaging clutch.
3. Combustion chamber. 6. Combustion chamber. 9. Cruising Diesel engine, 1000 H. P.

1—4 form the compressor set which delivers compressed air to the driving turbine 5 with the combustion chambers 6.

In going astern and when manœuvring, only compressed air is taken from the compressor without being heated, the astern blading stages of the driving turbine consequently need not be built for high temperatures. At full-speed ahead, the air is brought up to full temperature in a combustion chamber, forming part of the driving turbine, before it is led to the ahead blading stages of the turbine. If the compressor set is placed to a separate compartment corresponding to the ordinary boiler room of steamships, this second combustion chamber is located in the engine room proper, so that no hot-gas pipes have to be led through the bulkheads.

The whole plant has hydraulic-pressure regulation such as has been described for marine steam turbines; as in the latter case, the ship can be manœuvred from any desired point.

If it is found possible to design successful propellers with adjustable blades, the astern turbine blading could be eliminated and then it would no longer be necessary to separate the compressor set from the driving turbine; this would simplify the whole plant.

Merchant ships travel for $^2/_3$ of their useful lives at over 70 % of their full engine power and a low fuel consumption is absolutely necessary here. Only gas turbine plants with a *preheater* could be considered because they attain a thermal efficiency of about 23 %. There is always room on a merchant vessel for a sufficiently big preheater. In countries in which fuel oil is considerably cheaper than Diesel oil, the gas turbine can already be considered as a competitor to the Diesel engine.

D. ELECTRIC MARINE DRIVES.

We delivered the main and auxiliary Diesel generators, last year, as well as the whole manœuvring equipment for the Diesel-electric drive for the mine layer and tug vessel "Beatrix". Thorough tests showed that the arrangement we had chosen — Ward-Leonard generators with mixed excitation and strong counter-compound winding as well as excitation controller for direct drive from the bridge — imparted excellent manœuvring qualities and flexibility to the drive, which is very important to a tug. As it is often desired to run the tug at reduced load, two Diesel-generator sets with each $^1/_2$ of the necessary total output were put in for supplying the slow-running propeller motor. Both Diesel sets are used to supply the propeller motor only when the vessel is doing heavy tug duty. For lighter loads

one Diesel-generator set suffices which gives economical running conditions at about 80 % of the full-speed of the vessel.

As was said in our last year's report, adjustment to the different towing duties is attained by making use of an automatic Brown Boveri current regulator which adjusts the excitation of the propeller motor, when the exciter controller is in the "full ahead" position, so that, both when running independently or when towing any admissible load, the tug attains the maximum admissible speed, automatically. Here, the Diesel engine and generator output available are fully utilized without any adjustment of the connections having to be made. Tests carried out on bord showed the great utility of this automaticity, because service when running with two Diesel-generator sets and with only one Diesel-generator set is made very easy indeed. This tug has been in service since October 1939 and is giving great satisfaction.

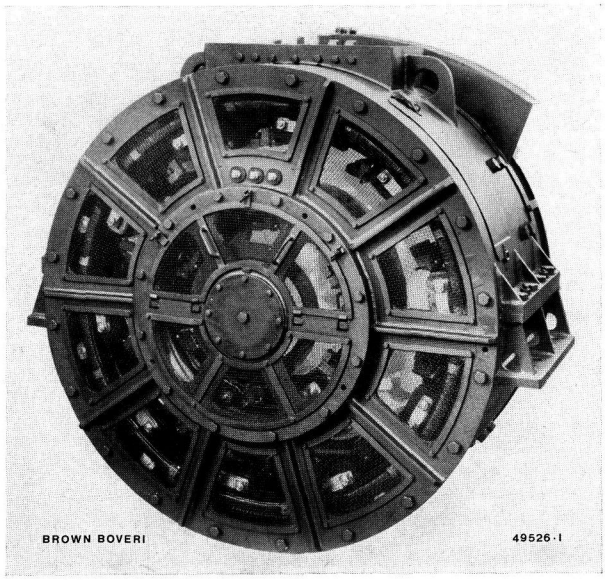


Fig. 151. — Main- and auxiliary generators in compact design delivered for the tug "Beatrix". Main generator 227 kW, 190 V, 400 r. p. m. Auxiliary generator 25 kW, 230 V. The flange on the top of the generator is for supporting the casing with the change-over switch (Fig. 152).

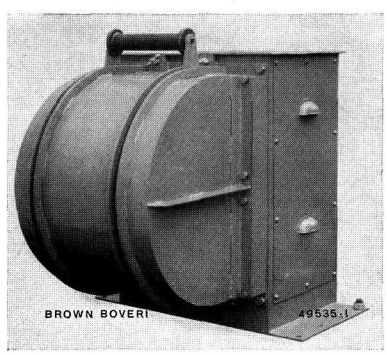


Fig. 152. — Change-over switch for allowing of connecting the main generator to the propeller motor or to the separate auxiliary network of the tug from which the motors for the fire-extinction pumps are supplied.

Fig. 151 shows one of the main generators delivered, with the built-in auxiliary generator, an arrangement which shortens considerably the length of the Diesel set as compared to the ordinary design with coupled main and auxiliary generators. The two auxiliary generators supply the auxiliary-power network and give the excitation for the main generators and the propeller motor. The main generators can, however, also be switched over to a special auxiliary power network from which power is taken for the supply of the driving motors of

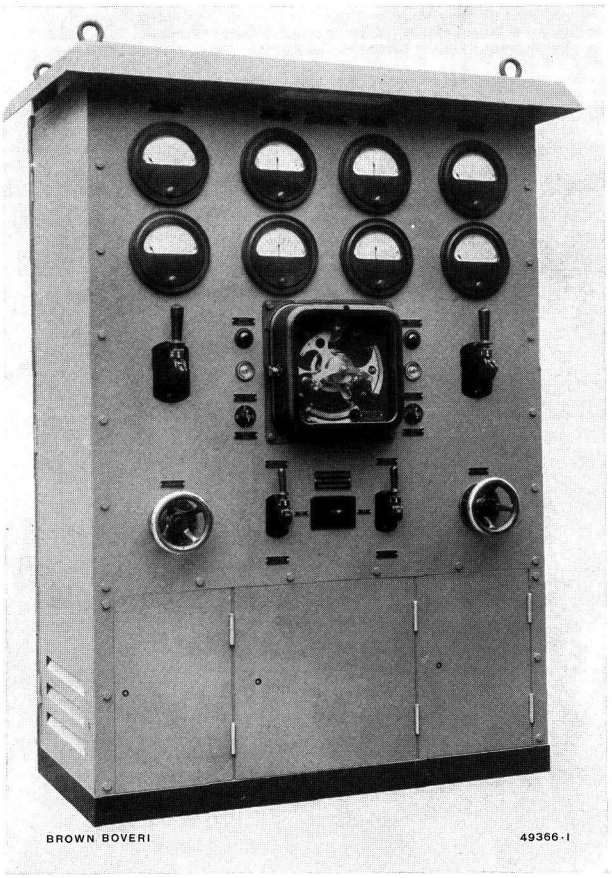


Fig. 153. — Switchboard for the Diesel-electric drive of the tug "Beatrix" with automatic Brown Boveri current regulator which adjusts automatically the excitation of the propeller motors to the momentary towing duty of the tug.

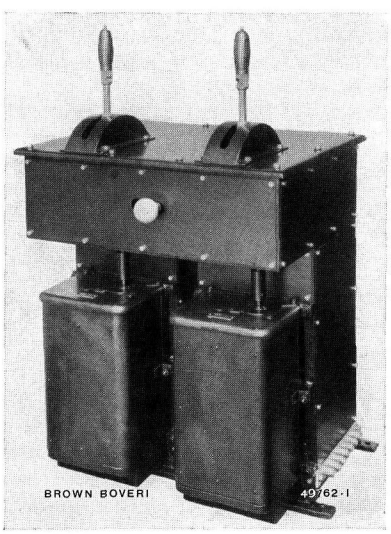


Fig. 154. — Controller for exciter for the two main generators of the tug "Beatrix".
The two excitater controllers are coupled to two Diesel-generator sets, in service.

big fire-extinguishing pumps. The change-over switches required for this (Fig. 152) are built on to the main generators.

Fig. 153 shows the switchboard of the drive which contains all the apparatus and instruments necessary for the main and auxiliary generators including the Brown Boveri current regulator which will be seen in the middle of the panel and (Fig. 154) the exciter controller.

Finally, it should be mentioned that the Finnish ice breaker "Sisu" [1] the 4000 S.H.P Diesel-electric driving plant of which was delivered by our Finnish concessionaries, O. Y. Strömberg A. B. in Helsingfors, was commissioned in the winter of 1938/39. The Diesel-electric drive has given full satisfaction.

E. MARINE AUXILIARIES.

1. *Auxiliary steam turbines.*

In turbine-driven vessels it is often advantageous to group certain pumps together and drive them from a small steam turbine. As it is not advantageous to run all these pumps at the same speed, a reduction gear with several pinions is used, so that each pump can be driven at the speed most advantageous for it. We delivered several sets of pumps of this kind, last year, both alone and along with the marine-turbine plants which have already been mentioned.

[1] For details see "Motorship", London, April number 1939, page 22.

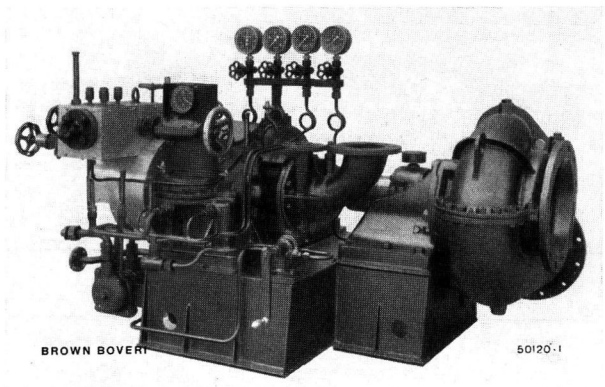


Fig. 155. — Auxiliary set for a marine turbine plant.

In order to save space, and in the interests of economical service for the auxiliaries as well, all pumps of one set are grouped together and driven by a simple common steam turbine. The set shown includes the following auxiliaries:

Cooling water pump . . . . . speed 1200 r. p. m.
(on the right in illustration)

Main lubricating pump . . . . . speed 1200 r. p. m.
(on the left, but not seen)

Condensate pump . . . . . speed 4200 r. p. m.
(seen in the middle)

The drive is by steam turbine . . . . . speed 13,000 r. p. m.
(seen on the left)

Below the turbine the oil cooler is seen, and below the condensate pump the hand oil pump, with handle, for starting the auxiliary set.

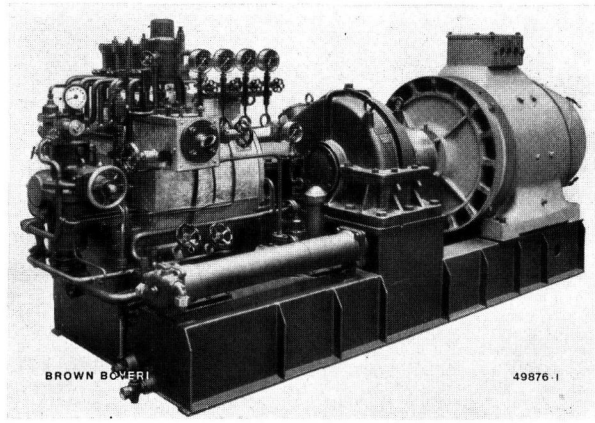


Fig. 156. — Turbo-dynamo set for use on board ship. Drive by small turbine of 160-kW output. Steam pressure 31 kg/cm² abs, 390° C, with reduction gear 10,500/1500 r. p. m.

The generator is built by another firm. The set was delivered for a fishery cruiser.

2. *Electric auxiliary-marine drives.*

(a) *Turbo-dynamo for use on board ship.* — Mention can be made of two d. c. turbo-dynamo sets, each of 150 kW, delivered for a tanker, for which we also delivered two 75-kW Helux dynamos with the automatic voltage regulators and switchgear for all the four generators. The turbo-dynamo sets are supplied from the exhaust-gas steam boilers of the motor ship. They operate in parallel with the Helux dynamos and in such a way that all the steam which is available from the exhaust-gas steam boilers is utilized automatically by the turbo-dynamo sets.

The small *d. c. turbo-lighting sets* developed by us, for outputs up to 10 kW in turbloc design have given excellent results in service. In response to frequent enquiries, we have now brought out a bigger turbo-lighting set of similar design (Fig. 157) which can be used for outputs up to about 20 kW at 110—220 V d. c., at a limit temperature rise in accordance with the specification laid down by certain marine classification societies. This new turbo-lighting set is identical to the smaller Brown Boveri d. c. turbo-lighting sets shown on page 33 of the Brown Boveri Review of 1934, with the following adjunctions:—

1. A speed adjusting device allowing of $\pm 5\,\%$ speed adjustment,
2. A manually operated nozzle valve allowing of economical running under partial load.

A large number of these sets was delivered, last year. They are characterized by moderate steam consumption, compactness, simple operation and strong construction so that attendance and supervision are reduced to a minimum.

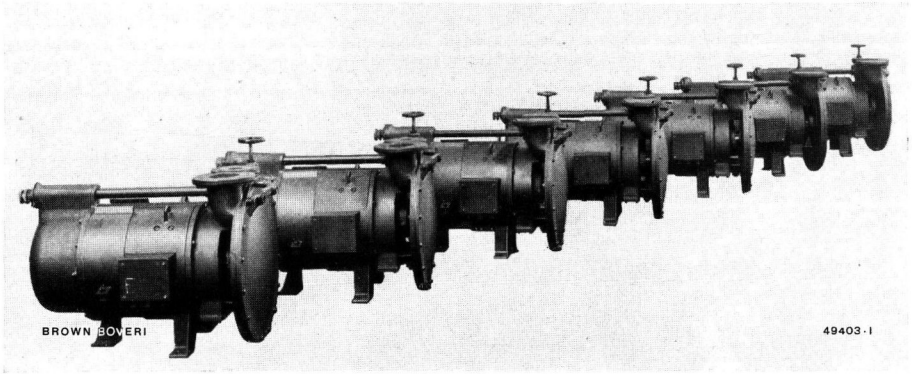


Fig. 157. — D. c. turbo-sets 10—20 kW, 3600 r. p. m., for lighting ships.

We also developed, last year, turbo-lighting sets for *three-phase current* which are very suitable as stand-by or emergency lighting sets for manufacturing plants, etc. These sets can be delivered to start up automatically, so that they take over the delivery of lighting current automatically when the voltage on the lighting system fails (Fig. 158).

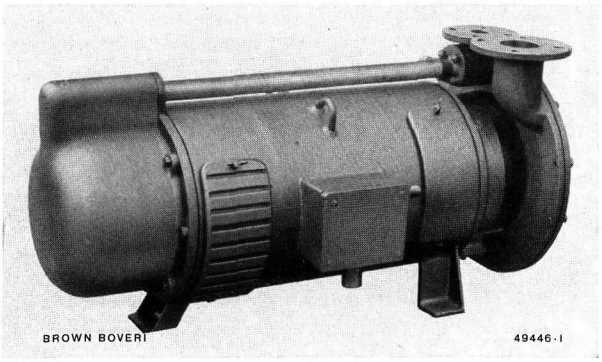


Fig. 158. — A. c. generator 10 kVA, 120/220 V, 27·8 A, 3000 r. p. m., for use on board ships.

(b) *Electrical material* for use *on board ship*, such as generators, motors to drive auxiliaries with the apparatus belonging thereto.

We would draw special attention to our generators of compact design, such as the double generators for d. c. and a.c. in which the small a.c. generator is built into the d. c. generator, with the object of shortening the length of the machine as much as possible, further, our synchronous generators with exciter built into the a. c. generator. Thanks to the special design, both the weight of the generator set and the space it takes up are much smaller than those of ordinary sets, which is a great advantage for marine machinery. As regards d. c. generators, we delivered, last year, among other units, 14 identical Diesel dynamos each for 135 kW, 220 V, 500 r. p. m., to be directly coupled to 200 B.H.P. four-stroke Sulzer Diesel engines, all to be mounted in merchant ships (Fig. 159).

There has been an increasing demand for our *automatic quick-acting regulator* and for *Helux equipments* for ship-lighting plants, the latter chiefly for small vessels on inland waters, rivers and coastal service. Thus, just as was the case for land plants, the Brown Boveri automatic quick-acting regulator with rolling contacts has now proved superior to all other regulators on the market for plants on board ship, thanks to its great reliability in service and insensitivity, both to vibrations and to inclined positions, such as characterize marine plants and especially those on war vessels. We got orders for over 150 regulators and Helux equipments for ships in the course of last year. Among these are five automatic voltage

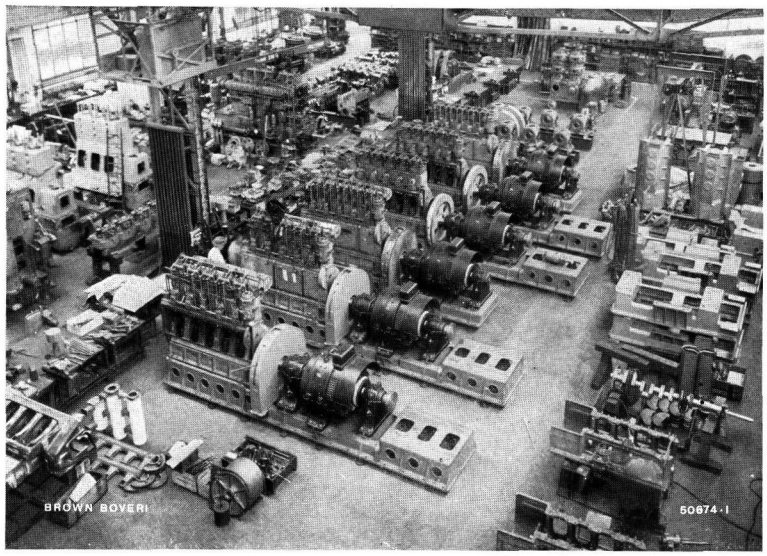


Fig. 159. — Auxiliary Diesel-generator sets for marine power stations 135 kW, 220 V, 500 r. p. m., being assembled to 200 H.P., 5-cylinder, 4-stroke Sulzer Diesel-engines.

regulators for the 220-V d. c. auxiliary power station of the new 36,000 S. H. P. passenger vessel of the Rotterdam Lloyd. This power station comprises a 530-kW and three 1000-kW Diesel generators as well as a 600-kW turbo-generator. All five generators advantage that no compensating leads are needed between the different generators and that the generators can be protected by ordinary two-pole automatic switches.

Fig. 160 shows the series of voltage regulators

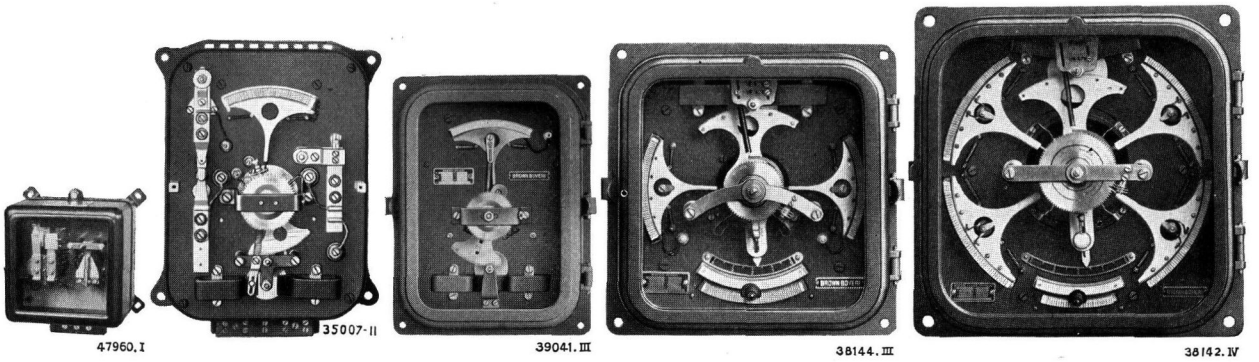


Fig. 160. — Regulators type M 1, G 1, J 1/0, AB 2/0, AB 4/0 for d. c. J 1/1, AB 2/1, AB 4/1 for a. c.

Automatic voltage regulators for d. c. and a. c., auxiliary power stations on merchant and war vessels.

M 1	For small vessels on inland waters, rivers and coastal service, with d. c. lighting plants up to a maximum of 1000 W, with or without storage battery.	In service with a storage battery these regulators are equipped with a paralleling switch by means of which the Helux dynamo is cut off from the network automatically, during manœuvring or when the propeller shaft is running too slowly. According to the service conditions and the connections chosen, the battery is loaded entirely automatically or semi-automatically.
G 1	For bigger vessels on inland waters, rivers and coastal service, for fishing vessels, tugs etc., with d. c. lighting plants up to about 10 kW, with storage battery.	
J 1/0 and J 1/1	For vessels with d. c. Helux dynamos up to 20 kW output, for d. c. or a. c., turbo- and Diesel-driven dynamos up to about 100 kW output.	
AB 2/0, AB 2/1, AB 4/0, AB 4/1	For d. c. Helux dynamos of bigger output, for d. c. or a. c., turbo- and Diesel dynamos of the auxiliary power stations of bigger vessels.	

are purely shunt wound and the automatic voltage regulators have to maintain constant voltage from no-load to full load under the speed fluctuations inherent thereto, further they have to look after proper distribution of the load among the generator sets. As compared to the compound-wound generators, chiefly used, formerly, for marine plants, the arrangement with shunt generators and automatic voltage regulators has the brought out by us for marine purposes. A suitable regulator is available for every size of machine encountered in marine plants. The four bigger regulator types have rolling contacts, exclusively, but the small regulator Type M 1 is designed as a vibration regulator; as the latter is only used for small vessels with lighting plants up to about 1000 W total load, we see no objection to putting in vibration-type contacts. We



Fig. 161. — M. S. "Oranje" of the N. V. Stoomvaart Mij. "Nederland", for which we have delivered 105 motors (a. c. and d. c.) for a total of more than 4900 H.P., further automatic voltage regulators and an automatic synchronizing apparatus.

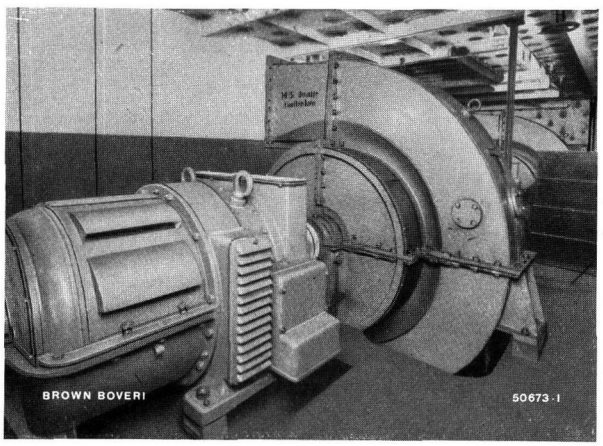


Fig. 162. — Two of three scavenging blower sets during erection on the M.S. "Oranje", each for 87,000 m³/h, 1,0/1,25 kg/cm² abs, 2300 r. p. m. each driven by two d. c. turbo-motors each of 500 kW, 220 V.

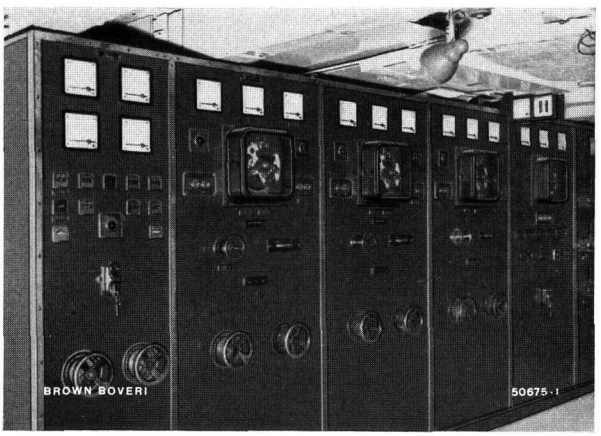


Fig. 163. — Switchboard of the three-phase auxiliary power station on the M.S. "Oranje", with 3 automatic Brown Boveri voltage regulators and a Brown Boveri synchronizing device for the three 220 kVA, 220 V, 50 cycle, three-phase generators.

desire, however, to state specifically that for bigger plants we only use rolling-contact regulators and that we have not altered our views on the utilization of vibration regulators for machines of the bigger output range.

The new motor passenger vessel "Oranje" of the N. V. Stoomvaart Mij. "Nederland" was put into service. We delivered for this vessel 105 motors (d. c. and a. c.) for a total output of over 4900 H. P., further automatic voltage regulators and an automatic synchronizing apparatus allowing of automatic synchronization of the three 220-kVA three-phase generators of the power station. All this material has given entire satisfaction. Figs. 161 to 165 show the vessel, itself, and some of our material.

Speaking quite generally, it can be asserted that the use of electric drives for marine auxiliaries is much on the increase and that the utilization of three-phase current for auxiliary purposes, on big vessels as mentioned in last year's report is meeting with favour. Therefore, it is fortunate that the International Electrotechnical Commission took decisive steps towards the standardization of the regulations governing electrical marine equipments.

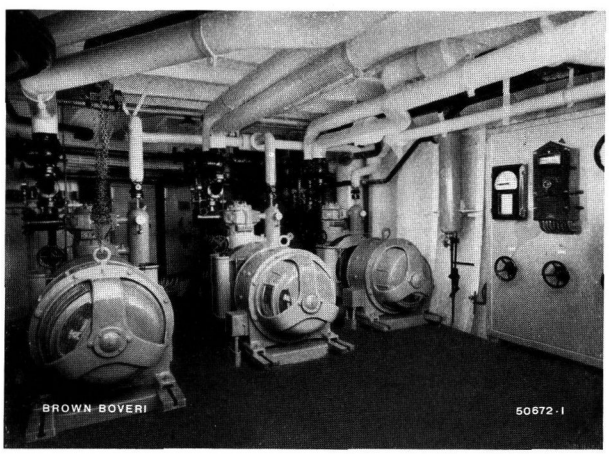


Fig. 164. — For the cooling- and air-conditioning plant of Sulzer design, placed on the M.S. "Oranje", 16 Brown Boveri d. c. and three-phase motors were delivered for the drive of compressors, pumps and ventilators.

Three d. c. compound motors, each of 65 H. P., 220 V, 580 r. p. m. for the drive of Sulzer-ammonia reciprocating compressors are to be seen. Two of these compressors are available for the air-conditioning plant and are regulated totally automatically, as to speed, between 280 and 580 r. p. m. in such a way that the cooling temperature is maintained at the desired value, with in a range of + or — 1° C.

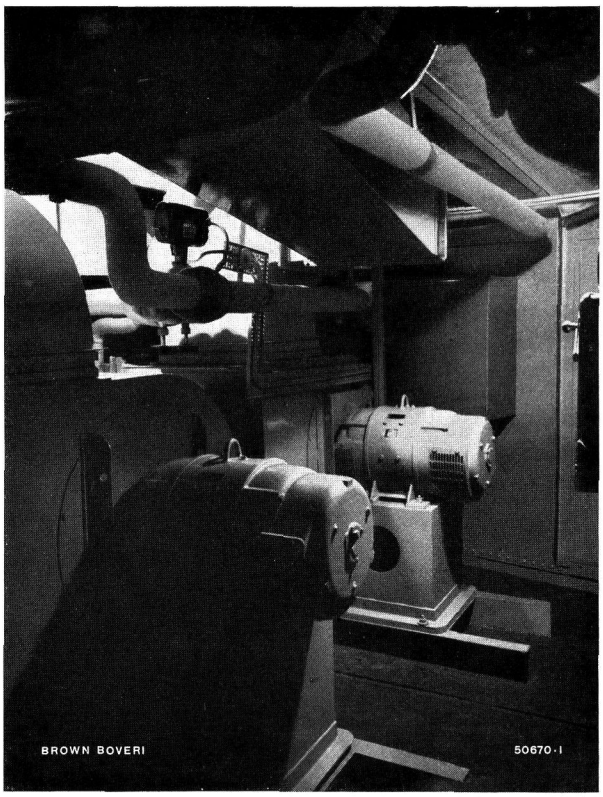


Fig. 165. — Two of 64 d. c. motors each of 3·7 to 8·8 H.P., 280 V, 900/700 r. p. m., delivered for the drive of Meidinger-ship fans on the M. S. "Oranje".

VI. HIGH-FREQUENCY TECHNOLOGY.

Decimal index 621.396.

This is the first time we mention high frequency work in this report. In the number of this house journal devoted to the Swiss National Exhibition (No. 4/5, 1939) we explained why we had entered the high-frequency field and gave some data on the first results achieved.

We have developed big *emitting tubes* which can be *dismantled* and which are permanently connected to the high-vacuum pump. These (Fig. 170) have the advantage of a, practically, unlimited life, because the cathode can be changed in *half an hour or less* and the tube put to work again. The life of the tubes sealed by melting in use up till now had a maximum of 8000 operating hours after which the whole tube was useless and had to be changed. The tubes which can be dismantled have, further, the advantage of being able to carry bigger loads and the capacitance is smaller allowing of using them for short wave lengths. Emitting tubes of this kind have been placed, for the first time, in the Swiss Broadcasting Station at Beromunster.

In conjunction with our work in the field of short and ultra short waves, mention should be made of the complete high-frequency equipment to the Swiss Federal Institute of Technology and to investigation work carried out in collaboration with the Institute on the *chamber* of the *Cyclotron*. The Cyclotron is now in the physical laboratory of the said Institute. Fig. 166 shows the chamber which is shaped like a box and composed of two parts, between which an electric field is active. The high-frequency emitter belonging thereto and delivered by us, similar to that shown in the figure, generates the voltage to be impressed on the two electrodes, in a frequency range of 13·5 to 15·8 M. Hz. corresponding to a wave length of 22 down to 19 m. The power it delivers is about 24 kW. The Cyclotron will be chiefly used for the investigation of chemical elements and to produce so-termed artificial radium rays.

Apart from high-power emitter tubes, we have studied the development of smaller tubes for ultra short wave generation; such as are used for *tele-*

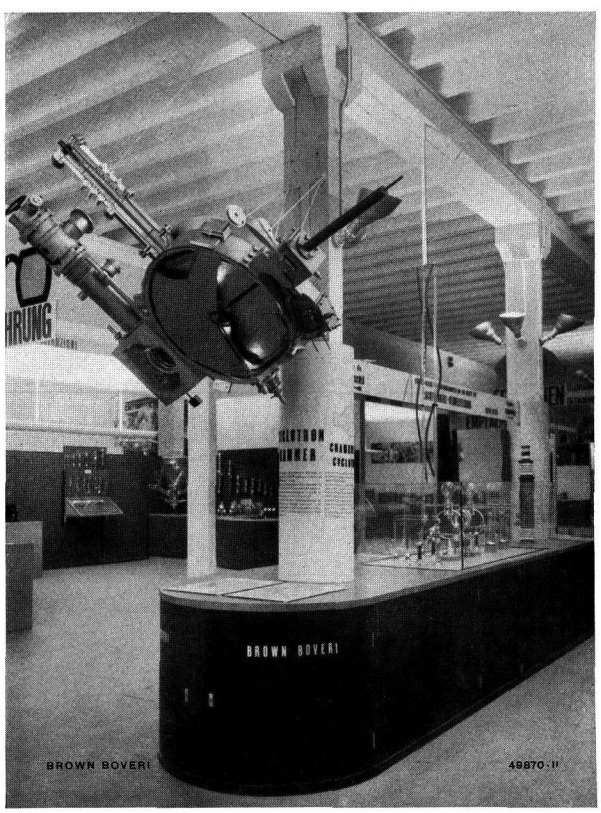


Fig. 166. — Chamber for the cyclotron of the physical laboratory of the Swiss Federal Institute of Technology, Zurich.

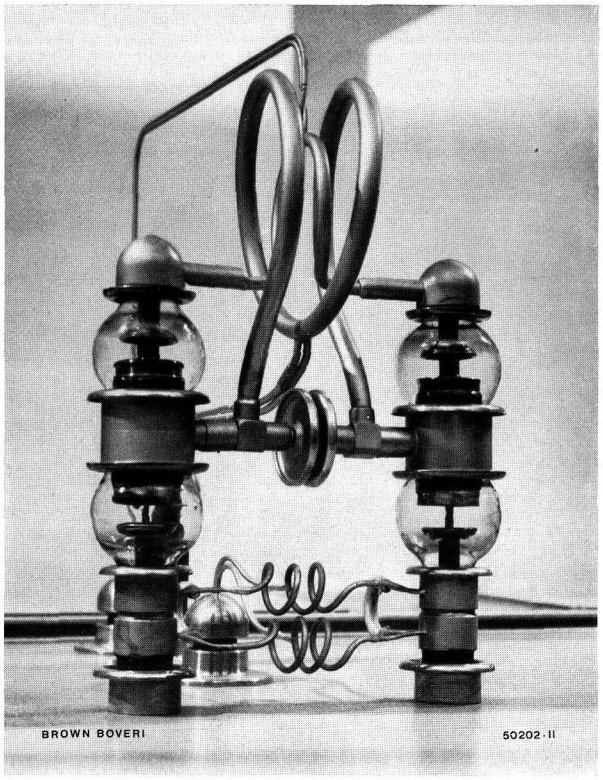


Fig. 167. — Magnetron tubes which can be dismantled.

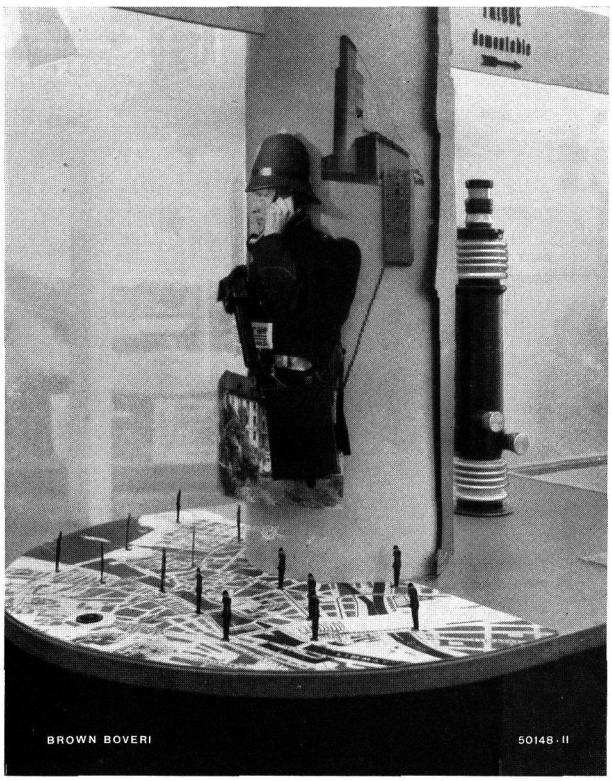


Fig. 169. — Exhibition panel showing the wireless equipment for the police of the town of Zurich.

vision and ultra short wave telephony. This led to the development of *magnetron tubes* which has now reached the stage of standard production (Fig. 167).

Development work has also been carried out in the field of wireless installations in a relatively small area, which is of great importance for police purposes. We had an opportunity of perfecting apparatus of this kind for the police wireless organisation on

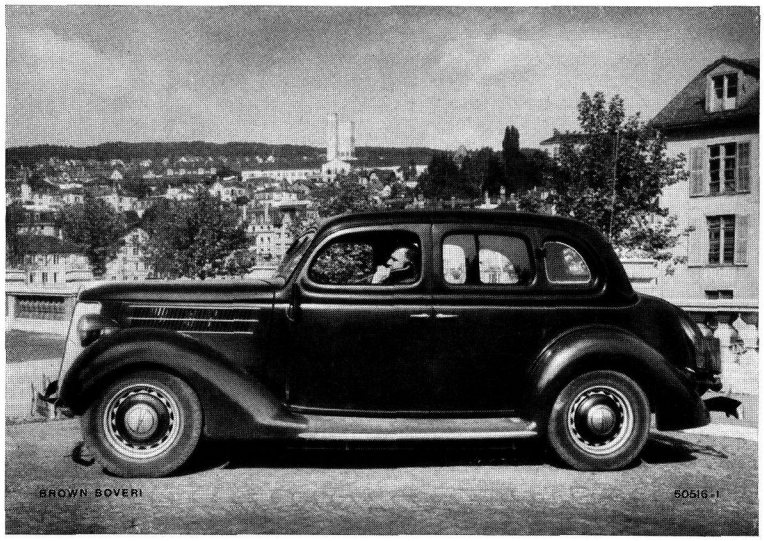


Fig. 168. — Patrol wagon of the police of the town of Zurich, equipped with a Brown Boveri broadcasting plant.

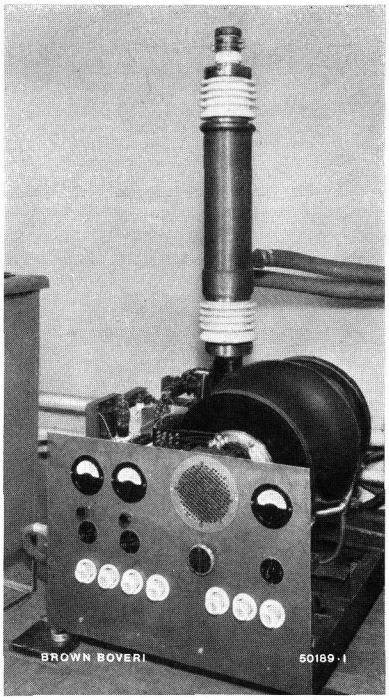


Fig. 170. — Emitting tube which can be dismantled, mounted on a molecular pump.

the occasion of the Swiss National Exhibition in Zurich. The wireless transmission is on a 128 m wave length and is used to transmit orders from a central police station to officials properly equipped to receive them, in different parts of the town. The transmission is effected by emitters and receivers delivered by us. The receiving apparatus can be carried in a pocket and have call relays and bells. Further the officials thus equipped can call up the central police station on an ultra-short wave length of about 5 m (Figs. 168 and 169). The decision to use such short waves for this purpose was reached on the basis of experience gained when we were carrying out very extensive tests on short waves for transmission purposes.

K. Sachs. A. Meldahl. (Mo.)

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