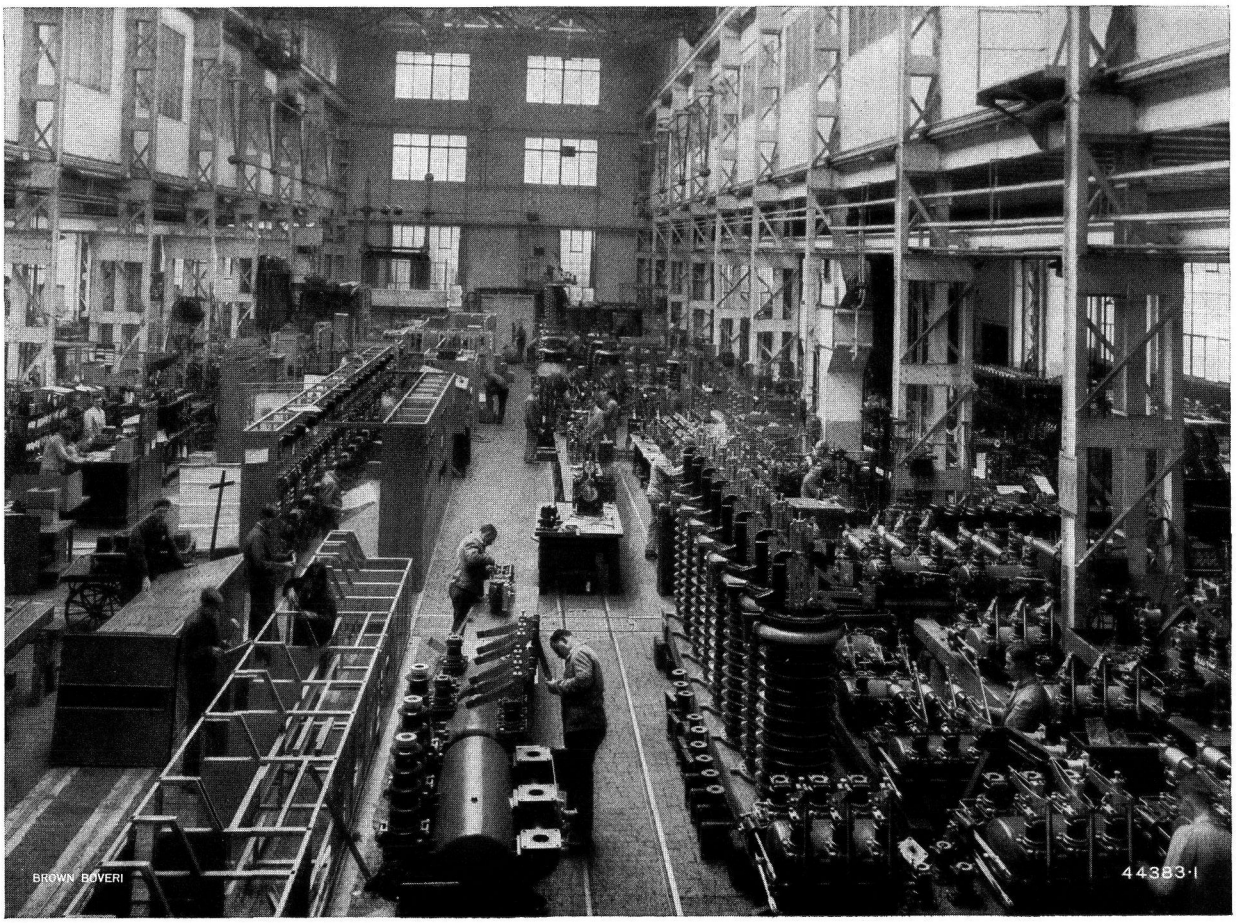
VOL. XXIV JANUARY/FEBRUARY, 1937 (DOUBLE NUMBER) No. 1/2

THE BROWN BOVERI REVIEW

EDITED BY BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)



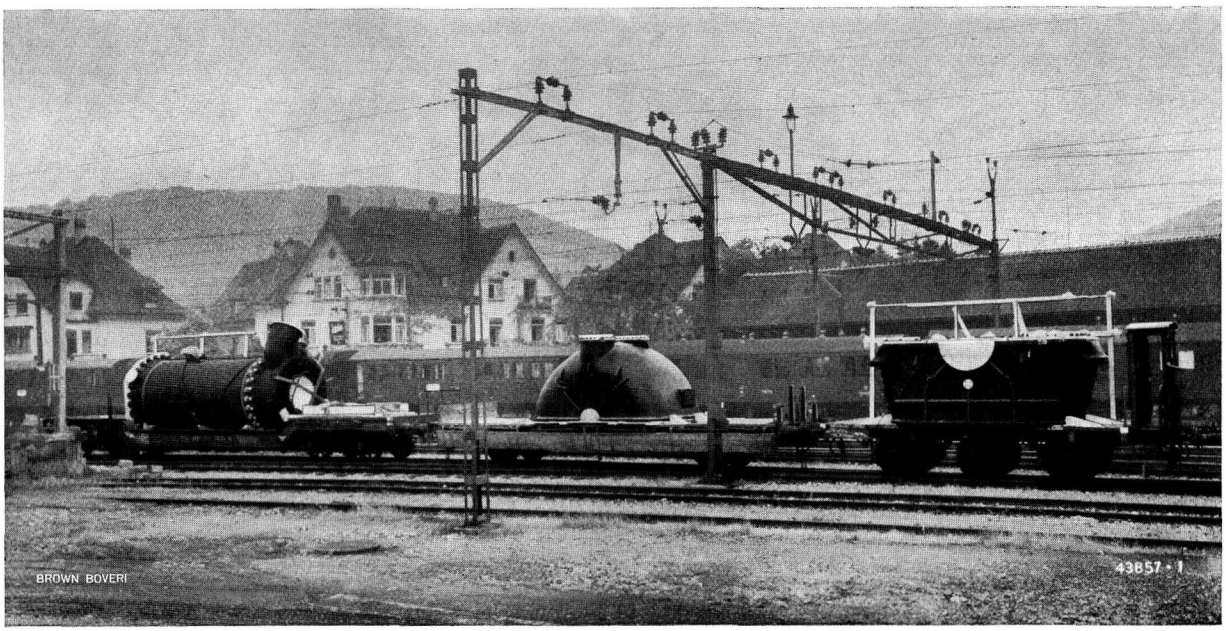
INTERIOR OF SWITCHGEAR SHOP OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND).
(Taken at end of 1936.)

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PROGRESS IN BROWN BOVERI DESIGN DURING 1936.

A.G. BROWN, BOVERI & CIE
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The main equipment of the Velox Power Station of Oslo: a Velox steam generator and a 32,000-kW turbine ready for despatch in the Baden railway station.

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THE BROWN BOVERI REVIEW

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PROGRESS IN BROWN BOVERI DESIGN DURING 1936.

INTRODUCTION.

Decimal index 621.3.

A retrospect of the work of development accomplished from one year to the next brings a realization of the amount of effort and expense which go to the evolving of a complete machine, from its first technical conception. A whole series of preliminary tests must be carried out before even a basis for the calculation of the main dimensions is laid and it is only after numerous draft plans have been drawn up that a really definite design and the workshop drawings belonging thereto can be made. Then comes the practical building of the new machine which sets the builder problems to solve as, not infrequently, new methods and new machine tools are required. The machine, once completed, is ready for the test bed and every experienced engineer is aware that, whatever care may have been devoted to calculations, design and construction, weaknesses are likely to crop up at this stage, all of which must be remedied. Clients who are far seeing enough to grasp the possibilities of a quite new product and are, also, confident enough to give it a trial, must now be looked for. We owe much to a number of far-sighted men who have been ready to take the responsibility inherent to putting a quite new type of machine into their own plant. We have been fortunate to find such friends in the fields of the steam turbine, turbo-compressor, high-pressure steam generating plant as well as in that of Diesel-charging and of the Velox steam generator; the same applies to the mutator, the circuit breaker and distribution system protection. Such clients are, of course, not easy to find and the field of technical development in many branches owes a debt of gratitude to their far-seeing and pioneering spirit.

We would recall that the development of the steam engine took several generations to complete, as every step forward had to be based on new experience and painstaking tests. To-day, the scientifically equipped engineer has thoroughly-developed methods of calculation and of testing to help him and he is backed up by well-equipped laboratories, so that any idea considered worthy of practical evolution can be perfected in a far shorter time than in earlier days. It is this accelerated pulse of technical progress which justifies us in presenting a yearly summary of the development work we have accomplished in the preceding twelve months.

I. POWER PRODUCTION

A. STEAM POWER PLANTS.

1. *Velox power stations.*

A big *Velox power station*, entirely designed by our power-plant department with the collaboration of Norsk Elektrisk Brown Boveri, Oslo, was put into service towards the end of last year. This station is an enlargement of the older 12,000-kW "Rosenkrantzgate" power house and it is located in the centre of the town of Oslo. The new station contains two Velox steam generators each producing 75 t/h of steam, a 32,000-kW steam turbine with its condenser and generator and all auxiliaries, transformers and switchgear plant. It is, really, a peak-load and stand-by power station to complete and assure the power supply to the town of Oslo, which, under ordinary conditions, is supplied from hydraulic power stations. A Velox plant was chosen, here, because of the rapidity with which it can be started up, because it produces no smoke and, also, because it takes up very little space, all qualities in which the Velox is superior to any other type of steam generating plant. There was

less space available for the whole new plant (including sufficient room for a third similar Velox and a 20,000-kW electric boiler) than that which was taken up by the old boiler house, alone. To-day 42 kW per square metre floor surface are produced as against 10 kW in the old power house, which was, itself, far from being amply dimensioned.

The Oslo Velox Power Station was built in a remarkably short space of time. Work on dismantling the old boiler house began at the beginning of 1936. The new foundations were in place by May and June, part of which foundations are carried on a framework of piles and part on rock. At the same time, the crane-rail tracks and their supporting columns were strengthened and bigger cranes put in. Erection work on the Velox units and the turbine was begun in July and the plant was set to work as early as the middle of November.

Fig. 1 shows an interesting view of both the 75-t Velox steam generators and of the 32,000-kW turbine of the Oslo plant, while it was still on our test bed. This is certainly the first occasion in the whole history of technical development in which a complete power plant of such considerable output, consisting of steam generator, turbine with apparatus, piping, etc. has been mounted complete and tested

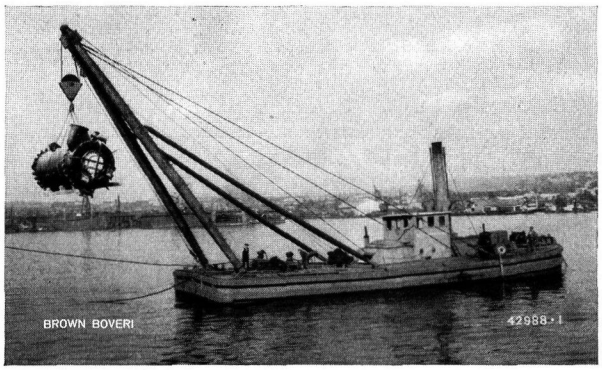


Fig. 2. — A Velox steam generator for 75 t/h of steam for the Oslo power station being landed by means of a floating crane.

on the manufacturer's test bed. Every engineer familiar with power station building will appreciate the value of this possibility offered by the Velox of having the whole plant tested complete before it is despatched. The transport conditions of the Velox plant in question, which was sent away after dismantling into a few main parts, only, offered some interesting points. Fig. 2 shows the combustion chamber which is the biggest part of the Velox being landed in Oslo harbour with the help of a floating crane. Finally Figs. 3 and 4 show two interior views of the new Rosenkrantzgate Power Station. The Velox units and

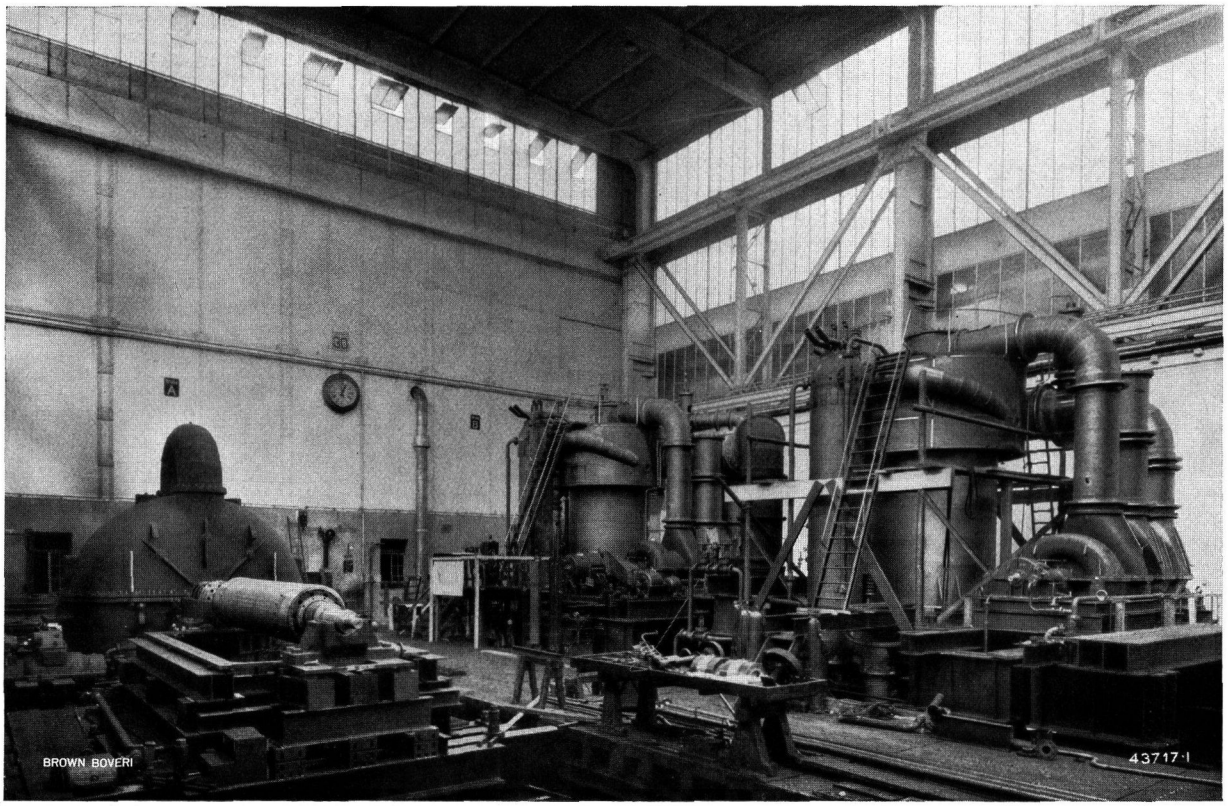


Fig. 1. — The power-generating plant of the Velox power station of Oslo, on the Baden test bed. It is composed of two Velox steam generators each for 75 t/h of steam and of a 32,000-kW steam turbine with generator.

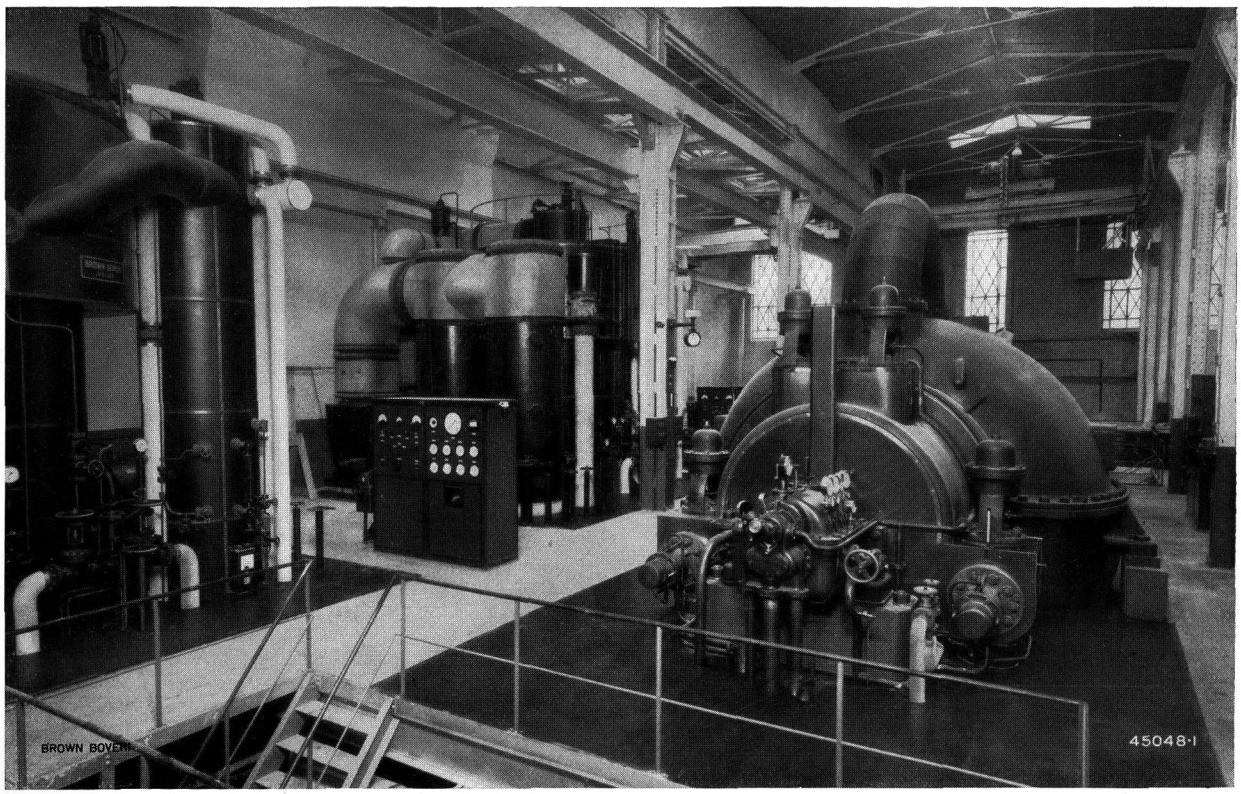


Fig. 3. — Velox steam power station of Oslo. Two Velox steam generators each for 75 t/h of steam and a 32,000-kW single-cylinder steam turbine.

the turbine are seen and it will be noted that they are not crowded together in an undesirable way, despite the restricted space available.

No power plant, whatever the source of its power may be, takes up as little room, for a given output, as does the Velox with its steam turbine. The Velox has a considerable future in the design of *bomb-proof power stations* which are, unfortunately, a problem with us, to-day. Such plants are covered in by massive concrete arches or else hollowed out of the rock. Space saving is, thus, of primary importance in order to keep cost low and reduce target surface for bombs and shells. Fig. 5 is a typical example of the design of a bomb-proof Velox power station for 20,000-kW output. It is designed to be lodged in a tunnel excavated in the rock and having a section similar to that of a two-track railway tunnel. This plant comprises a Velox steam generator to produce 80 t/h of steam, a steam turbine with its condenser, a 20,000-kW generator, all accessories and the switchgear plant. There are oil tanks in this bomb-proof chamber and the capacity of the said tanks allows of generating two million kWh which is sufficient for 6—7 days service.

Fig. 6 is a suggestion for an underground bomb-proof Velox steam generating plant for producing 12,000 kg/h of steam. This would be a stand-by boiler plant for an industrial works, which would be dangerously situated in case of hostilities.

The following chapter gives test results from which it will be seen that a 45-t Velox steam generator was got under full head of steam in $3^1/_2$ minutes, starting from the stationary cold state. This extremely short starting-up time opens up interesting possibilities for the layout of *stand-by steam power stations* combined with Velox steam generators. The following two cases may be examined here:—

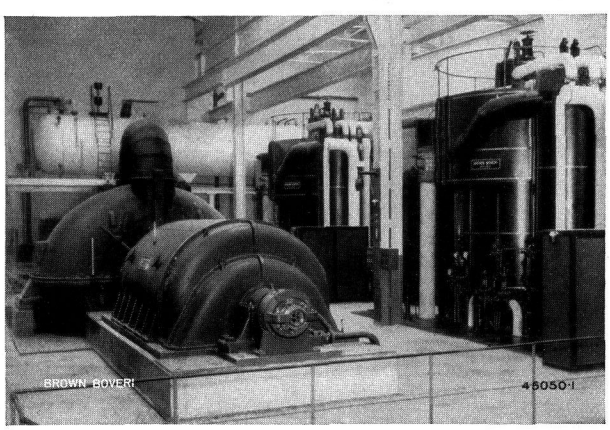


Fig. 4. — Velox power station of Oslo, seen from the generator side.

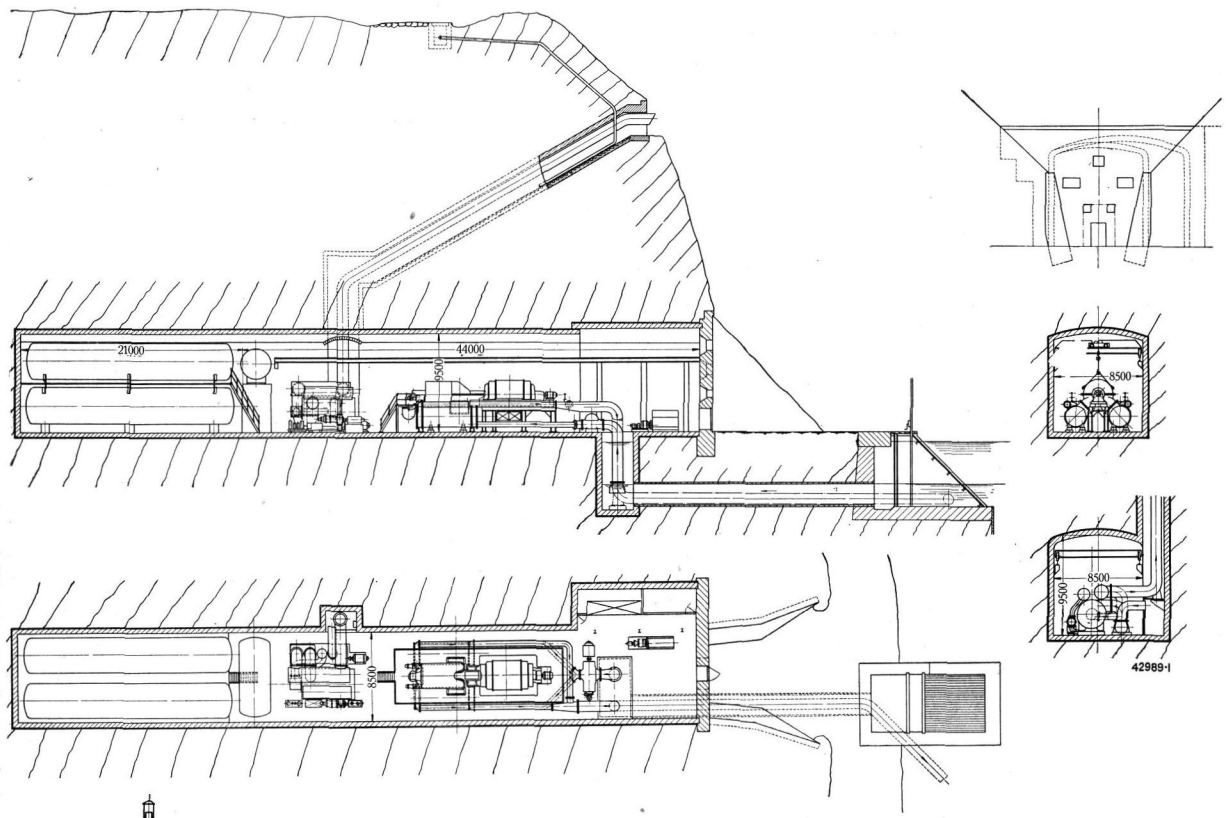


Fig. 5. — Bomb-proof Velox power station to produce 20,000 kW.

It has sufficient fuel for about a week. It is located in a tunnel in the rock having the section of a double-track railway tunnel. The small space requirements of the Velox make it very suitable to bomb-proof stations, as building costs are lower and the station offers a smaller target to enemy projectiles.

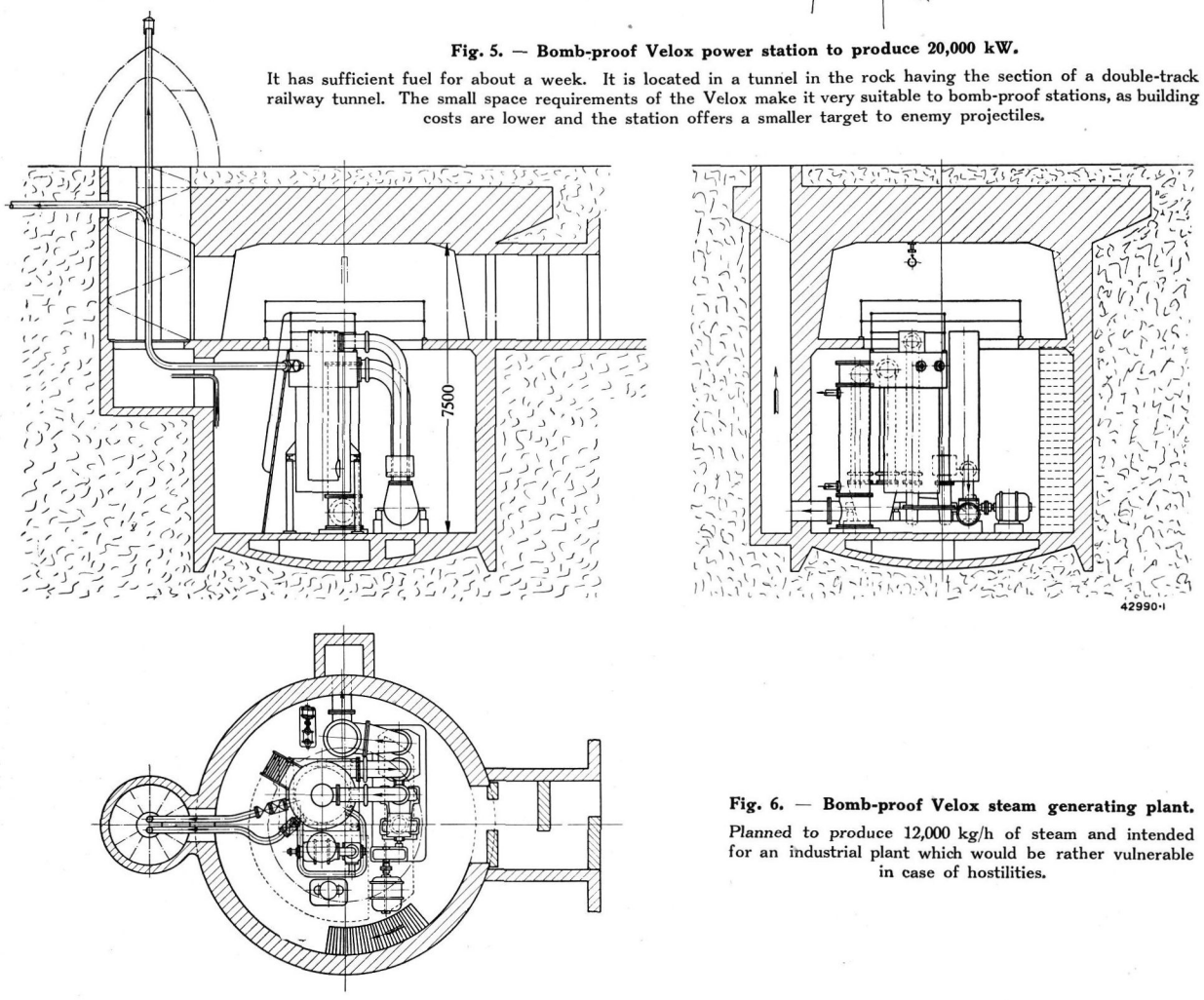


Fig. 6. — Bomb-proof Velox steam generating plant.

Planned to produce 12,000 kg/h of steam and intended for an industrial plant which would be rather vulnerable in case of hostilities.

1. The stand-by power station to act as a *quick-acting stand-by plant* and be started up after the disturbance of ordinary service has occurred; it must be able to take over load within a few minutes.

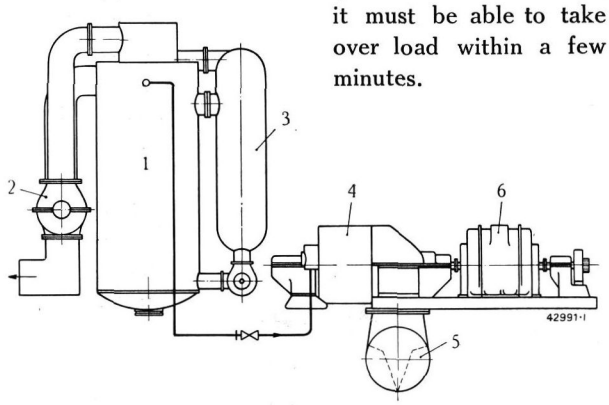


Fig. 7. — Diagram of a quick-acting stand-by power plant with Velox steam generator, which can be started very quickly and even automatically, if so desired, when trouble occurs on the distribution system. It can take over full load in 5—8 minutes.

1. Combustion chamber of Velox.
2. Charging set.
3. Steam separator.
4. Steam turbine.
5. Condenser.
6. Generator.

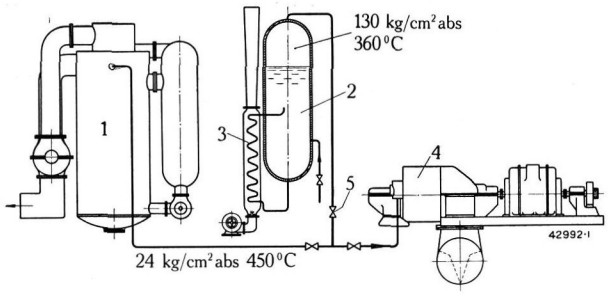


Fig. 8. — Diagram of an instantaneous-action stand-by power plant with Velox steam generator and high-pressure bridging accumulator which takes over load, immediately, when trouble occurs on the distribution system and prevents any interruption in current distribution.

The turbo-set runs continuously as phase advancer. In case of trouble it is fed from the steam accumulator, until the automatically-started Velox takes over load.

1. Velox steam generator.
2. Bridging accumulator.
3. Oil-heating to charge accumulator.
4. Turbo-generator.
5. Throttle valve.

2. The stand-by power station to act as an *instantaneous-action stand-by plant* and prevent any interruption of power delivery at all.

Generally, the first type of stand-by plant should suffice for industrial services, railway power stations, small communities, etc., while the second type is desirable for big towns.

A diagrammatic illustration of the quick-acting reserve plant is shown in Fig. 7. This is a standard Velox and turbo-set plant which is started up very rapidly and, if so desired, automatically. It can take over full load in about 6 to 8 minutes.

Fig. 8 shows the instantaneous-action reserve plant, composed of a Velox, a turbo-set and a so-termed *bridging high-pressure steam accumulator*. Velox and turbine are built for 25 kg/cm². The accumulator is charged up to 130 kg/cm² by means of a small oil-firing equipment or similar gear and delivers steam through a throttle valve to the 25-kg/cm² steam system. During the waiting period the turbine runs at full speed with open admission valve but closed governing valves it being driven by the generator running as a phase advancer. The condenser is working (with reduced cooling water volume) so that the turbine can run on vacuum, with lower losses. As soon as the failure of other sources of power cause the generator to take over power delivery, the governing valves of the turbine open, according to the action of the turbine governing system, and the turbine delivers power. The accumulator supplies steam until the Velox steam generator takes over from it. The Velox is started automatically by making the valves of the gas turbine of the Velox open at the same time as the governing valves of the main turbine, and by making the charging and pump set run on steam from the accumulator. In this way the Velox can be brought to full delivery in about 3 to 4 minutes, especially when the accumulator keeps it under pressure; thus the high-pressure steam accumulator can be of small dimensions and inexpensive.

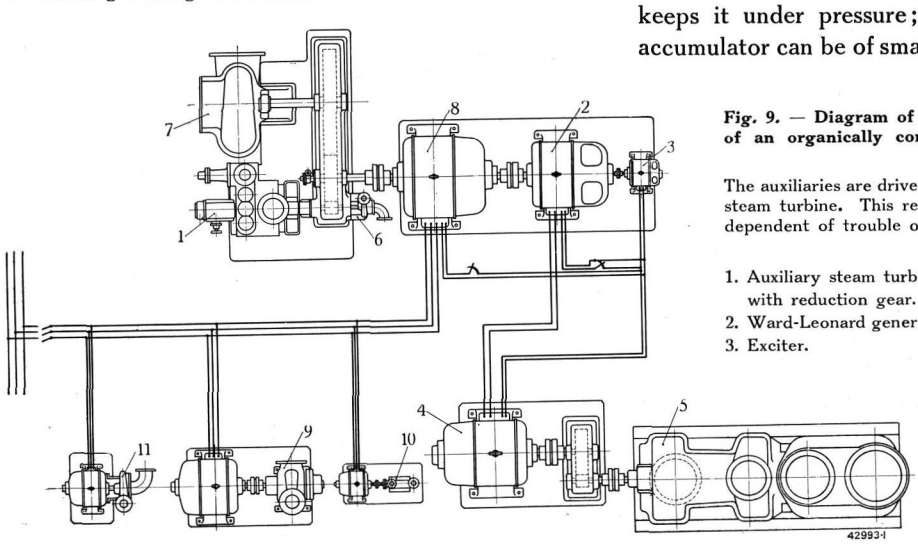


Fig. 9. — Diagram of auxiliaries of a Velox motor, i. e. of an organically combined Velox steam generator and turbine.

The auxiliaries are driven, directly or indirectly, by an auxiliary steam turbine. This renders the drive of the auxiliaries independent of trouble on the system, in the power house or on other sets.

1. Auxiliary steam turbine with reduction gear.
2. Ward-Leonard generator.
3. Exciter.
4. Ward-Leonard motor.
5. Charging set.
6. Feed pump.
7. Cooling-water pump of condenser of main turbine.
8. Three-phase generator which is, also, a starting motor.
9. Circulation pump.
10. Fuel pump.
11. Condensate pump.

When on this subject, the *problem of auxiliaries for the boiler and turbine plant* can be treated briefly here, as well. The reliability of these auxiliaries and their drives are of primary importance to the reliable operation of the whole power station. Above all, measures must be taken that trouble on the electric system does not cause the driving motors of the said auxiliaries to fail and thus shut down the whole plant. According to old Brown Boveri practice, the motor-driven pumps of the condensing plant are provided with a spare turbine, this in the case of plants having big main steam turbine sets; the spare turbine starts up automatically, if current fails, and takes over the auxiliary drive. The drive of the auxiliaries of the Velox plant must be assured similarly, if it is desired to keep up the service of the power station when current fails. In order to avoid having such a large number of small auxiliary turbines, we have, recently, created an arrangement such as the one shown in Fig. 9 which is intended for a plant containing a Velox and main steam turbine with condenser. The auxiliaries are driven from *one* auxiliary turbine instead of from the electric supply system. The exhaust of this turbine is carried to an intermediate stage of the main turbine, in small stations, in order to increase the economic qualities of the plant; in big plants the exhaust of the auxiliary turbine goes to the condenser. The auxiliary turbine drives the following units directly:— the Ward-Leonard generator and its exciter for the drive and regulation of the Velox charging set, the Velox feed pump, the circulating water pump of the condenser as well as a small three-phase generator. The latter drives auxiliary turbine to some stage to a main turbine or to a condenser, or to utilize it in any other way. The arrangement of the auxiliaries given in Fig. 10 shows that it is, nevertheless, possible to make the drive independent of trouble on the electric system. The Ward-Leonard generator, its exciter, the Velox feed pump and the governing-oil pump are driven in common from the electric system by a three-phase synchronous motor, while the circulation pump and the fuel pump are also electrically and separately the circulation pump of the Velox, the fuel pump and the condensate pump of the condensing plant, because these apparatuses have to be located in definite parts of the plant. The auxiliary generator works as a motor at starting, getting current from the electric system or, if the latter is dead, from an auxiliary Diesel set or a petrol-engine generator set. All auxiliaries of the power station are, thus, entirely independent and trouble on the electric system, or caused by other machines, does not disturb their working.

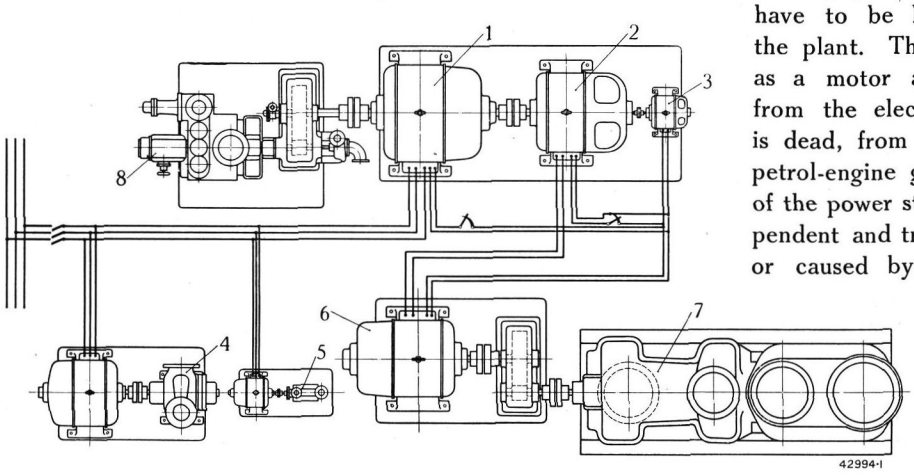


Fig. 10. — Diagram of the auxiliaries of a Velox steam generator.

The auxiliaries are driven electrically from the system because there is no way in which the exhaust from an auxiliary turbine could be used. A stand-by steam turbine takes over the load automatically if trouble occurs on the electric supply system. The synchronous motor of the Ward-Leonard set cuts itself out automatically from the system and runs as a generator supplying the other auxiliaries with current. Trouble on the electric system or in the station cannot affect the working of the Velox.

1. Three-phase synchronous motor. 3. Exciter. 5. Fuel pump. 7. Charging set.
2. Ward-Leonard generator. 4. Circulating pump. 6. Ward-Leonard motor. 8. Stand-by steam turbine.

The drive of the auxiliaries of a Velox which has no steam turbine with it, is carried out differently. The auxiliaries of the condensing plant are of course eliminated. The drive of the auxiliaries of the Velox proper must be by electricity, under usual conditions, because their is no possibility of leading the exhaust from an

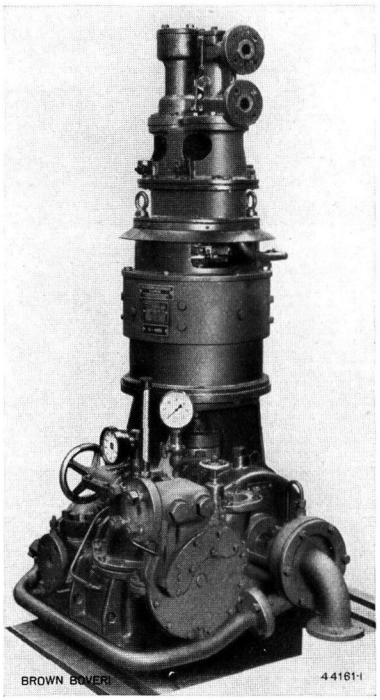


Fig. 11. — Pump set of a Velox steam generator for a locomotive.

A steam turbine drives the following auxiliaries:— Velox feed-water pump, circulation pump, fuel pump, governing and lubricating oil pump, a D. C. generator for the starting of the pump set. This generator also serves to light the locomotive when running.

driven from this source, but separately by induction motors. A spare steam turbine is also built on to the Ward-Leonard set which takes over duty automatically if a disturbance occurs on the electric supply. This turbine is allowed to exhaust to atmosphere or to the feed-water tank during the usually short time it runs.

The synchronous motor cuts itself out, automatically when voltage fails; however, it goes on running as a generator and drives the motors of the circulation and fuel pumps. Thus, in this case as well, trouble on the electric supply or in the power house does not influence the working of the Velox.

Fig. 11 shows the pump set of a Velox plant designed for a locomotive. The driving steam turbines, the Velox feed pump and the low-placed circulating pump, the governing-oil and fuel pumps as well as a D. C. generator and reduction gear are all exceptionally compact in design but, nevertheless, very accessible. The D. C. dynamo is used as a motor to start the pump set and operates, in running service, as a generator to supply the lighting and to drive various auxiliaries.

2. *The Velox steam generator.*

Up to date, Brown Boveri and their concessionary companies have built, or have in hand, 46 Velox steam generators. All these units were tested before despatch and many have been in continuous service now for a period of several years. Much valuable experience has been collected in a relatively short time and put to good use, and we are, thus, able—after a period of development of hardly four years duration—to assert that the Velox is just as reliable in service as the best boilers of older types. Observations made, up till now, show that, if the Velox is properly handled, no recurring service stoppages and repair work — apart from the standard overhauling and cleaning operations — are called for, which makes the Velox superior to the former bricked-in boilers.

The Velox has, really, the characteristics of a machine and it can be expected to work just as reliably as the steam turbine it supplies.

Naturally, this quite novel type of machine, with no antecedents, passed through a period of growing pains. We are happy to be able to state here, however, that there have been no difficulties, whatsoever, encountered which may be imputed to the working principle proper on which the Velox is based. All the following characteristics of the Velox have given brilliant proof of their qualities:— Combustion under pressure and in a small space with a calorific production per cubic metre of combustion chamber about 20 times greater than in other boilers, high gas velocities giving a 15 times better heat transmission through the heating surfaces of the gas tubes, much better evaporation with a minimum of water chamber volume, separation of the big volumes of steam produced from the circulating boiler water, the gas turbine, the axial compressor, the regulating principle of firing and air delivery, the pressure regulation, the feed-water supply, etc. The first plants delivered showed that the Velox principle was a really new factor to be reckoned with in the technique of steam generation. The Velox designers have been quick to recognize and remedy those difficulties of other natures which only became apparent once Velox plants were running in practical service.

We wish to express, here, our grateful appreciation to our clients and to their service engineers for their most efficient collaboration with us, which contributed in no small degree to the elimination of imperfections in the first Velox plants and, thus, generally speaking, helped to increase existing knowledge in the field of practical steam generation.

Now that the Velox has become a very reliable steam generator, it will interest our readers to learn something of the practical experience gained in Velox plants. We will not hesitate to speak openly of the difficulties encountered and how they were surmounted, because we feel that the confidence placed by readers in our technical achievements and general reliability of our products can only be strengthened by a clear statement of facts.

One of the conditions of economic operation and general success of the Velox is a high efficiency of the charging blower with its gas turbine, because the blower output necessary for the high combustion pressure generated amounts to as much as 25—30 % of the effective power to be obtained from the steam generated in the Velox. Fortunately, all the elements requisite to efficient *gas-turbine design* were already available, the Brown Boveri reaction blading with its very high efficiency, as used in our turbines, could be utilized, here. The *charging blower,* however, had to be created in accordance with the latest data available in the field of aerodynamics, and after many tests. The quite new machine developed, the axial compressor, with its inherent sensitiveness of air flow along the wing profile were the cause of the compressor characteristic not coinciding as exactly as was desirable with the resistance characteristic of the gas cycle of the Velox, which was, itself, a rather undetermined quantity, at that time. Thus, there were certain zones of service output where instability in charging was met with. The fault was soon corrected by modification of the compressor blading and it was found possible to so increase the efficiency of the compressor that, to-day, there are certain plants where the charging set not only does not consume power but, actually, gives power back to the electric supply system.

We have been granted patents in most countries covering the use of the axial blower in conjunction with combustion processes under pressure. These were based on our knowledge of the characteristics of the said blower and its particular adaptation to the different organs of which a Velox is composed.

The *Velox-burner* was one of the most difficult problems of all to solve. Up to ten times the usual amount of oil had to be burnt by a *single* burner, in a very small chamber. Further, the oil supply had to be regulated, automatically, from full to no

load, a duty impossible to an ordinary burner. The desired conditions were met thanks to the investigations carried out on the first test Velox we built. There was, sometimes, a very little smoke emitted by the Velox which fault was immediately remedied by slight adjustments of the supply of fuel oil and charging-air volume.

To-day, under rapid fluctuations of load, the Velox run without any production of smoke, a valuable quality for urban plants and for naval vessels.

Those ignorant of the subject have been inclined to consider the *evaporating elements* of the Velox as being a weak point in the design because heat transmission through the walls of these tubes is 15 greater than in former boilers. However, thanks to the forced circulation of the boiler water, the temperature of the walls of these tubes is not higher than that of the walls of ordinary fire tubes and they have shown that they can stand up to years of service, without a weakness developing. This, of course, assumes that the *Velox feed water* has the usual qualities of good water for all high-capacity boilers. Experience has brought to light the interesting fact that the strong flow in the Velox, the energetic movement of the water itself due to great evaporation are factors which prevent, to a considerable degree, the formation and crystalisation of hard scale on the heating surfaces.

Some of the first Velox boilers, which were fed with improperly treated feed water, showed that the wall surfaces subjected to vigorous flow remained clean and that only a few dead ends suffered from scale formation and hot zones. If the feed water is properly treated this kind of trouble is eliminated. Further, improved water circulation caused dead ends to be efficiently scoured and this made the Velox all the more insensitive to feed water which, for any reason, has not been perfectly treated. An interesting fact noted was that tube bursts occurring in one of the first Velox by improper water being used proved harmless in the closed combustion chamber and were hardly noticed, a clear proof of the quality of the pressure-fired steam generator.

A Velox working in the power station of a chemical works showed how adaptable this steam generator can be made to undesirable feedwater conditions. In this plant, all the steam generated is used for chemical purposes, and the feed water has to be constantly renewed from treated raw water, which contains silica and is also a soft river water which sometimes holds in suspension a very fine clay sludge. The water is treated with a solution of caustic soda and magnesium sulphate to soften it; it is then treated with trisodium phosphate. This latter treatment protects the boiler tubes from

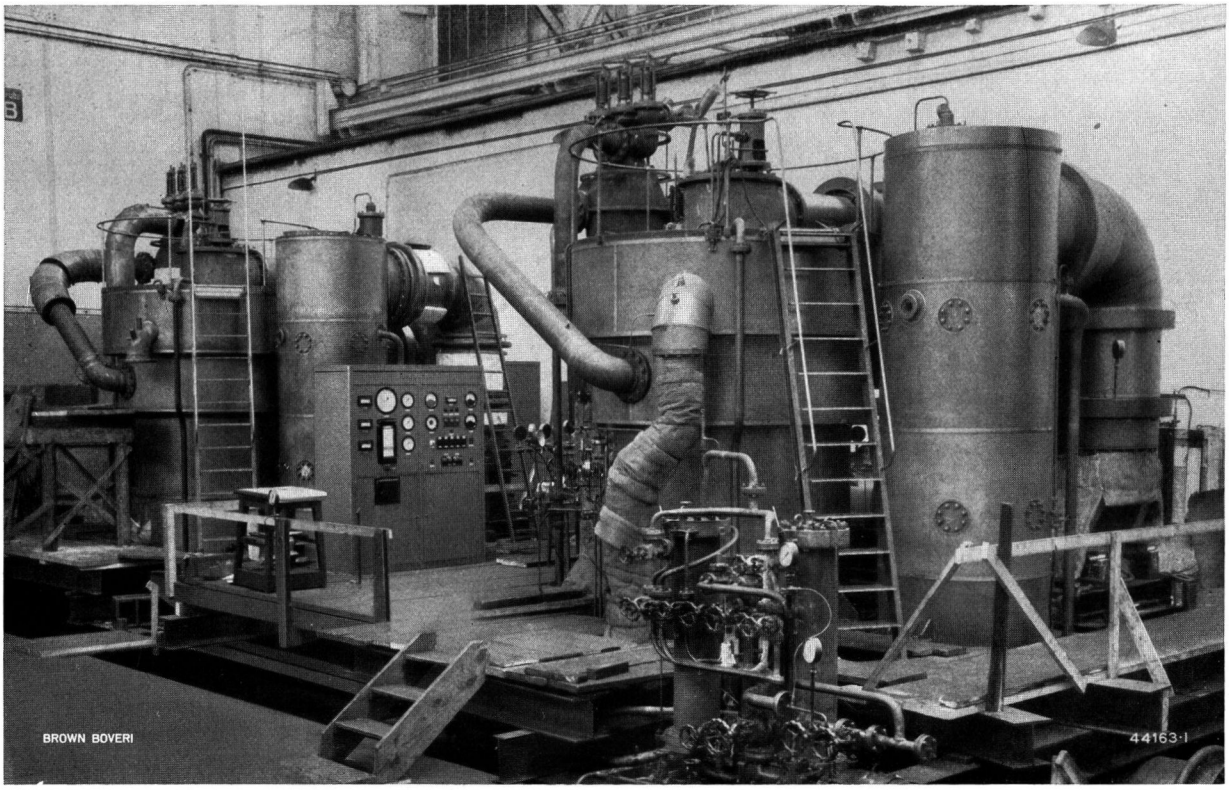


Fig. 12. — Two Velox steam generators, for 45 t/h of steam at 30 kg/cm² and 420° C, for the Wellington Power Station, New Zealand, mounted on the Baden test bed.

The Velox units are mounted with all their instruments and apparatus. They were tested up to overload. Between the boilers, the switchboard is seen, from which all motors and apparatus are remote-controlled by push buttons. A filtering, preheating and circulating equipment for the fuel oil is seen in the foreground.

TABLE I.
Tests on a 45-t/h Velox steam generator for Wellington (New Zealand)
(17th November 1936).

Test	No. 4	1	5	2	3
Load . . . . %	118	105	78	54	31
Steam					
Quantity . . kg/h	48,252	43,119	31,941	22,209	12,922
Pressure . kg/cm² abs	18·0	17·4	16·8	17·3	16·8
Temperature . °C	336	332	313	313·6	298·4
Feed water inlet temperature . °C	50·6	50	50·6	48·5	52
Fuel	Shell fuel oil				
Calorific value Hu . . . kcal/kg	—	—	9735	—	—
Temperature before burner . °C	97	103	104	102	103
Quantity of fuel used . . . . kg/h	3595	3215	2340	1638	940
Quantity of air used . . . . kg/h	57,665	50,085	37,450	27,537	18,040
Excess of air kg/h	1·12	1·085	1·12	1·175	1·34
Quantity of hot gases . . . kg/h	61,260	53,300	39,800	29,175	18,980
Auxiliaries					
Ward-Leonard set . . . . kW	−96·2	−126·2	−72·5	−19·7	+18·6
Circulation pump . . . kW	62·9	63·5	65·1	67·8	69·5
Fuel pump . kW	7·5	7·0	7·8	7·8	8·0
Total power input to auxiliaries . . .	—	—	0·4	55·9	96·2
Power restitution to system in . . kW	25·8	55·6	—	—	—
Temperature of exhaust gases °C	107	104	93	88·6	81·6
Plant efficiency:– η of plant =	Heat in steam-preheating of fuel $-\frac{4000 \times \Sigma \text{ auxiliary output}}{\text{quantity of fuel} \times \text{lowest cal. value}}$				
Heat in steam 10^3 kcal/h	33,400	29,800	27,780	15,180	8675
Preheating of fuel 10^3 kcal/h	141	134	124	67	41
Heat value of auxiliary output 10^3kcal/h	−103	−222	15	224	385
Useful heat 10^3kcal/h	33,362	29,887	21,655	14,889	8250
Brought in in the fuel . . 10^3 kcal/h	35,000	31,280	22,820	15,945	9150
η of plant . . %	95·2	95·6	95·0	93·4	90·2
Humidity of saturated steam . %	0·43	0·43	0·4	0·45	—

the formation of a silica scale. This Velox has been in satisfactory operation for about a year under these exceptionally difficult conditions of feed-water supply. A second unit has now been ordered by the same clients.

We lay down no special specification as regards the *fuel* used, when we deliver our Velox plants, because we think every oil on the market can be used. However, we were informed of certain difficulties which arose, in different plants, and which are imputable to the quality of the fuel oil used.

Thus, in one case, the feed-water preheater was getting choked up after a new kind of fuel oil had been introduced, and this meant a weekly cleaning of the preheater. The cause was found to be too much sulphur in the oil which was precipitated as a sulphurous acid at low feed-water temperatures and which was then deposited in the gas tubes along with the water vapour and exhaust gas ashes. By slightly increasing the temperature of the feed water, this deposit no longer took place. Further, it was found that the preheaters could be perfectly cleaned simply by rinsing them with water, an easy and brief operation. This led to a layout of the preheaters such as shown in Fig. 12 which allows of simply taking off a cover to get at and clean them.

If the fuel oil has much sulphur, it may happen that the rolled and welded joints of the preheater are attacked by the sulphur. This is prevented by some slight alterations in the design.

The *circulation pump* was a new element of Velox design, the glands of which, contrary to those

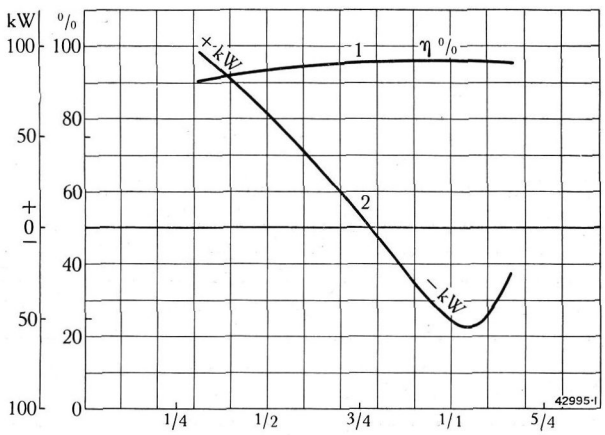


Fig. 13. — Efficiency curve in function of load of the Wellington Velox steam generator, all auxiliaries included, without feed-water pump.

The efficiency is exceptionally good down to 1/4 load which compensates greatly for the higher cost of fuel oil as compared to that of coal.

1. Efficiency.
2. Output of the auxiliaries (without feed-water pump) either taken from or restituted to the electric supply system.

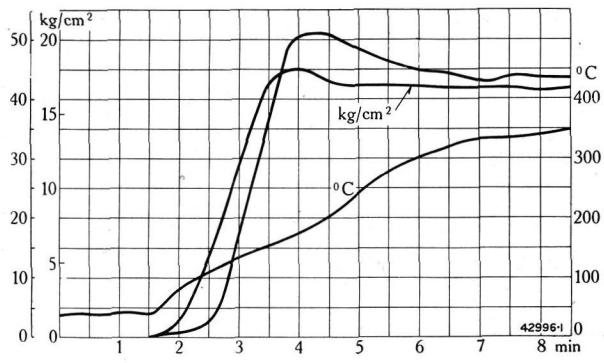


Fig. 14. — Starting test on the Wellington Velox steam generator.
From standstill and cold state up to full load of steam in 3 1/2 min. The slow rise of steam temperature is beneficial to the turbine.

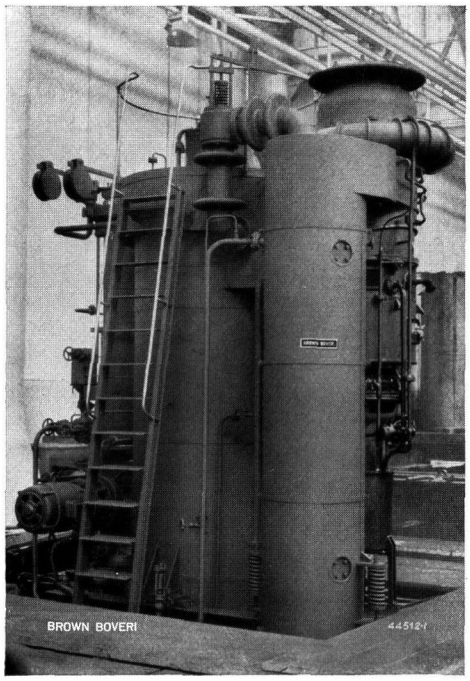


Fig. 15. — Velox steam generator for 9 t/h of steam, 25 kg/cm² abs for Dombowita.

The charging set is vertically mounted in close proximity to the combustion chamber.

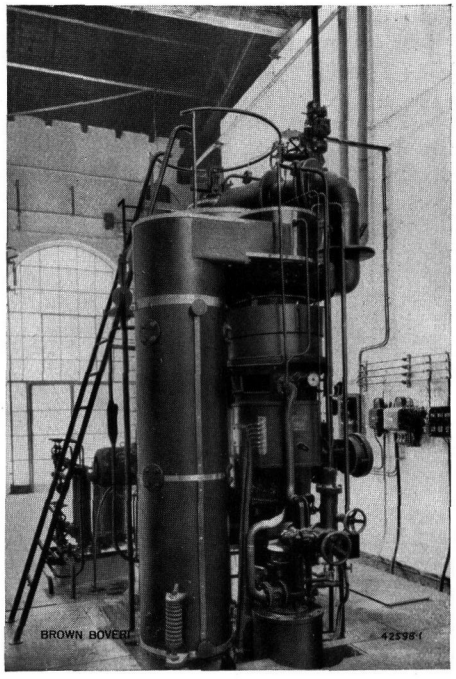


Fig. 16. — High-pressure Velox steam generator for 5 t/h of steam at 80 kg/cm² and 470° C.

We will show in the following pages some illustrations of Velox plants built.

Fig. 12 shows two Velox steam generators on the test bed. These units are for the town of Wellington (New Zealand). They each generate 45 t/h of steam at 30 kg/cm² and 420° C. These Velox were tested and passed by Lloyd and by the Swiss Boiler Association. Table I gives the test results. The remarkably-high efficiency of 95·6% at full load was attained and this includes the power required for all auxiliaries (without the feed pump). Fig. 13 gives the curve of the efficiency in function of the load and shows that, down to quite low loads, the efficiency is far higher than any figures previously reached. This economic quality of the Velox is the more valuable for plant in continual operation under fluctuating loads; this is also so for peak-load plants and heating plants which must work with oil in order not to produce smoke or because there is little space available. The starting up tests on these two Velox also gave astonishing results which are shown in Fig. 14. From stationary cold state, the Velox was brought up to full-load delivery

of a feed pump, have to stand up to the full boiler pressure and full temperature. Despite careful preliminary investigation, this element was the seat of various kinds of trouble, at first. We brought out a new sealing material and modified the pump design proper and the glands, while introducing intensive cooling of the latter; these measures were successful in eliminating the trouble and we have built sealing glands to this new design for pressures up to 80 kg/cm² and 300° C.

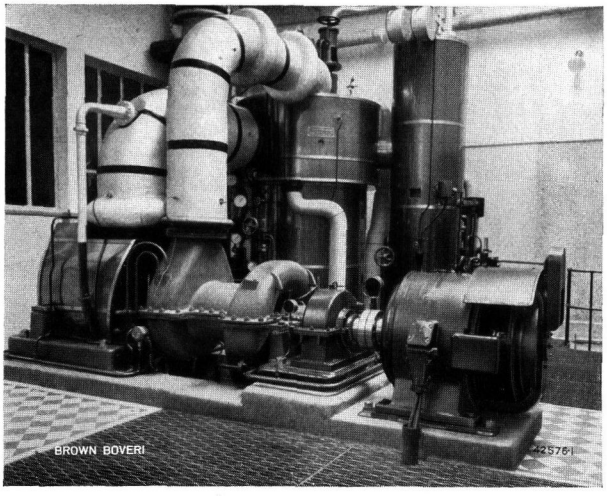


Fig. 17. — Velox steam generator for Blin and Blin, for 16 t/h of steam, 25 kg/cm² abs and 375° C.

All apparatus is governed from the switchboard seen beside the Velox.

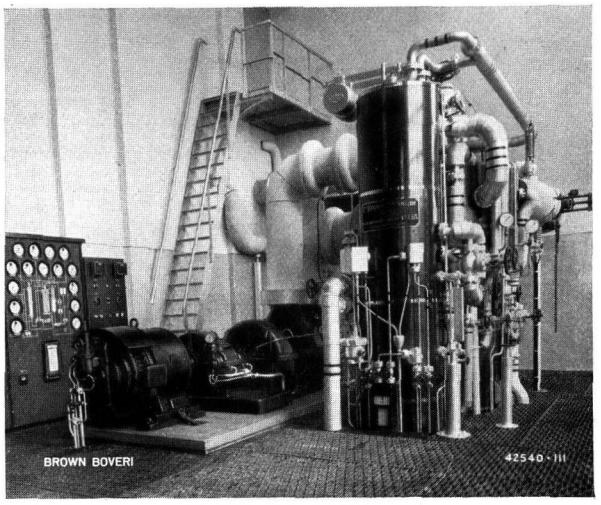


Fig. 18. — Remy plant at Gaillon. A 12-t/h Velox steam generator.

The switchboard, from which all the apparatus can be controlled, is seen beside the Velox.

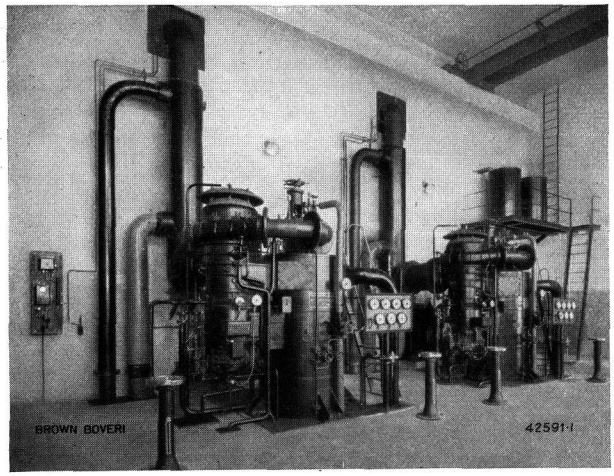


Fig. 19. — Velox remote-heating plant of the Rome Città Universitaria.
Two Velox for hot-water generation and mazout firing, each for 4,000,000 kcal/h, temperature of hot water 80—100° C.

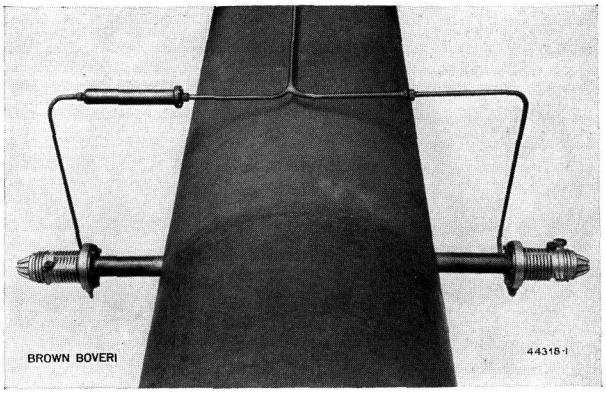


Fig. 21. — Smoke detector to supervise the smoke-free operation of the Velox.
The transparency of the smoke column is measured by an electric lamp and a photographic cell and can be read off an instrument on the switchboard panel. This apparatus can also be delivered for other types of firing, for Diesel engines, etc.

in $3\,^1/_2$ minutes. This proves how suitable the Velox is for peak and for stand-by plants, which must intervene at short notice.

Figs. 15 shows a small Velox with vertical-shaft charging set (charging blower, gas turbine, auxiliary motor). This vertical set is located close to the combustion chamber. The design, built up to 10 t/h output, has the advantage of being rapidly erected.

Figs. 16 to 19 illustrate some new Velox equipments, showing the compact and pleasing design characteristic of these plants.

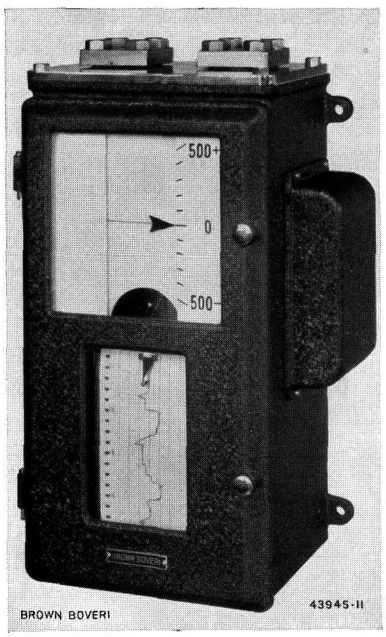


Fig. 20. — Brown Boveri Nivometer.
This boiler water-level indicator can be placed anywhere convenient below the water level. It has end travel contacts actuating an alarm or feed device. The Nivometer is delivered as a second water-level indicator with all Velox plants.

To conclude our report on the Velox steam generator, we desire to mention two interesting apparatuses which can be used on other types of boiler. Fig. 20 shows the *Brown Boveri Nivometer* used on all Velox plants as a second water gauge. It can be placed anywhere below the level of the water in the boiler.

Indications and recording devices are on a large easily-read scale. Electric contacts close in the extreme positions, i. e. when there is too much or too little water. These contacts energize an alarm device or cut out the Velox. The Brown Boveri Nivometer makes use of a mercury column measuring the difference in pressure between a fixed tube connection above the level of the water and the level of the water itself. There are iron balls carried on the mercury which transmit magnetically the displacement of the mercury columns to the indicating device, without any sealing glands being required. This nivometer suits all known types of boiler and, with its alarm device is a welcome addition to the safety appliances.

The *Brown Boveri smoke detector*, Fig. 21, is another interesting apparatus. It is composed of an electric lamp and of a photographic cell placed each on one side of the smoke flue. Both elements are protected from dirt and heat by a current of air from the air compressor. The thickness of smoke is measured by the current of the photo cell and shown on a scale on the switchboard panel. This device allows of supervising the behaviour of the boiler, independently of the light and time of day.

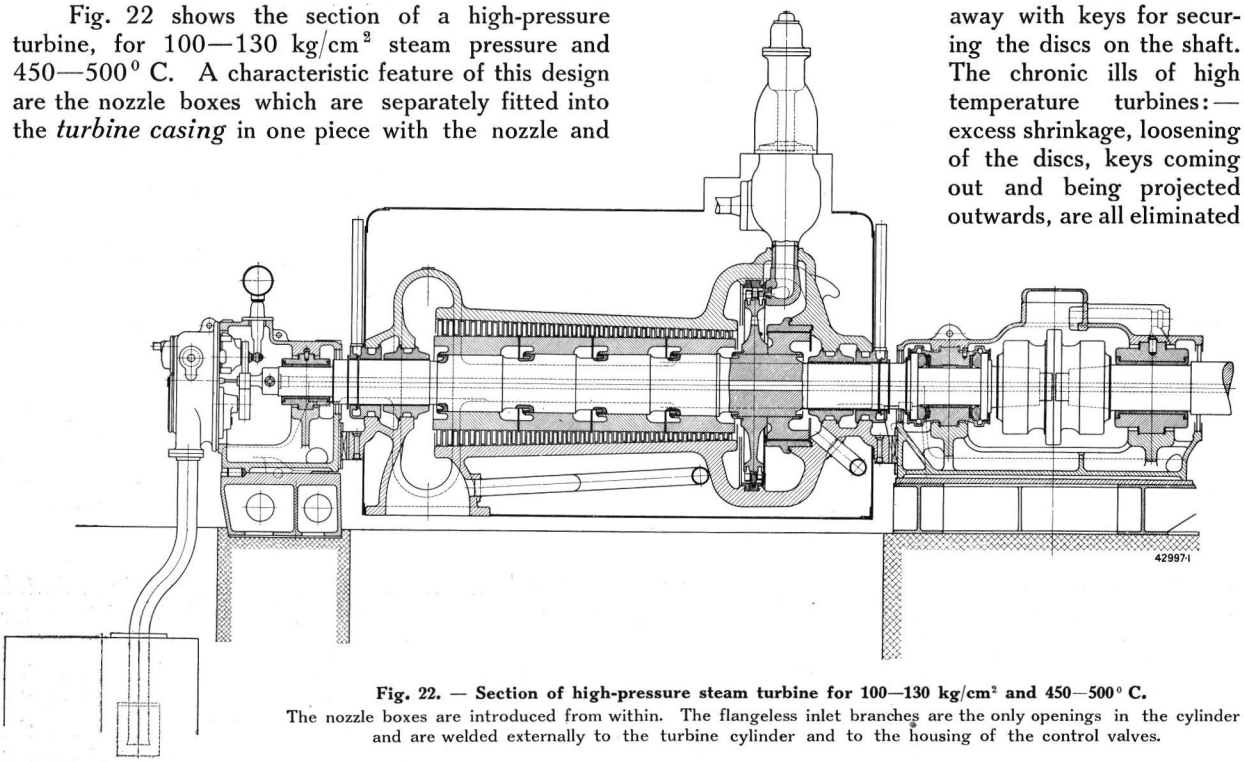
3. *Steam turbines.*

Our firm has done pioneer work in the field of high-pressure steam-turbine development and has created a super *high-pressure high-temperature turbine*, this by a suitable design of the turbine proper and special construction of various important details. As the following Table shows, we have built a large number of high-pressure and high steam temperature turbines and, in so doing, have collected much valuable experience in this field.

TABLE II.

Turbines for	Number	kW
Steam pressure 50— 99 kg/cm² abs	29	341,000
„ „ 100—200 „ „	14	178,000
Steam temperature 400—500° C	300	2,800,000

Fig. 22 shows the section of a high-pressure turbine, for 100—130 kg/cm² steam pressure and 450—500° C. A characteristic feature of this design are the nozzle boxes which are separately fitted into the *turbine casing* in one piece with the nozzle and



away with keys for securing the discs on the shaft. The chronic ills of high temperature turbines: — excess shrinkage, loosening of the discs, keys coming out and being projected outwards, are all eliminated

Fig. 22. — Section of high-pressure steam turbine for 100—130 kg/cm² and 450—500° C.
The nozzle boxes are introduced from within. The flangeless inlet branches are the only openings in the cylinder and are welded externally to the turbine cylinder and to the housing of the control valves.

welded by a patented process to the turbine housing and also to the adjacent housing of the control valves. The awkward high-pressure flanges, bolts and sealings of the nozzle chests and steam inlet connections are eliminated by this welding, as Fig. 23 shows clearly.

The nozzle chests, built of high-temperature proof material, are alone subjected to the superheated steam, while the housing of the turbine with its separating flange has lower temperatures and pressures to stand up to. The wall of the cylinder of the high-pressure part is only pierced by the small, flangeless apertures to take the nozzle chests; it is thus, practically, whole as compared to the usual design in which the high-pressure cylinder is cut to allow the lodging of the nozzle chests. On account of the high temperatures of the housing, the turbine rests, quite free, on low and strongly-built feet or paws on the cold bearing pedestals. There are cross keys in the paws at the high-pressure end and guiding keys in the middle plane, which maintain it rigidly in axial sense but allow it to expand or retract freely in both lateral senses and longitudinally. The feet or paws are very low which excludes a displacement of the axis of the housing in the vertical sense.

The *turbine rotor* is specially designed for high temperatures. It is small, and not too massive in any part so that it heats up rapidly and uniformly at the starting up of the turbine and can follow, immediately, the temperature changes inherent to load fluctuations. The discs and balancing pistons of the high-temperature zone are welded to the shaft by means of flexible cylindrical prolongations on the said discs, this being a patented process which does in the welded Brown Boveri rotor. The welded rotor design has, already, been used on about 80 steam turbines and about 300 gas turbines and has given most satisfying results.

The *governing gear* calls for very careful study in turbines of this class. There are considerable forces set up by the high steam pressures, which are incompletely balanced and which act on the valves and there are also considerable heat expansions resulting from the high temperatures as well as undesirable friction conditions in the spindle guides to be reckoned with. Gripping and friction can be

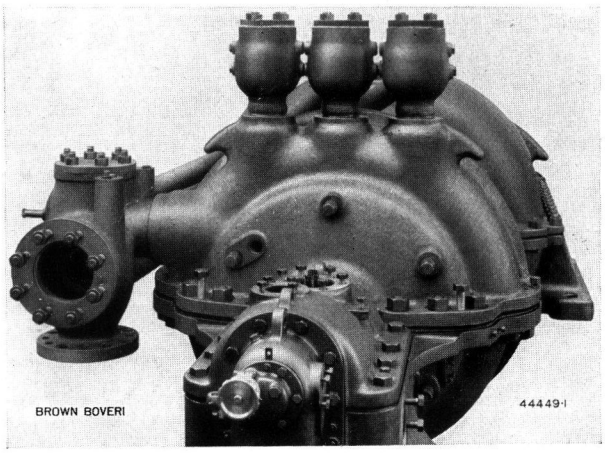


Fig. 23. — Superheated steam turbine for 450—500° C.
The nozzle chests and governing-valve housing belonging thereto are welded to the turbine cylinder, by a patented process. There are no flanges, bolts, glands on the nozzle chests or on their steam inlet pipes. This is very advantageous for high pressures.

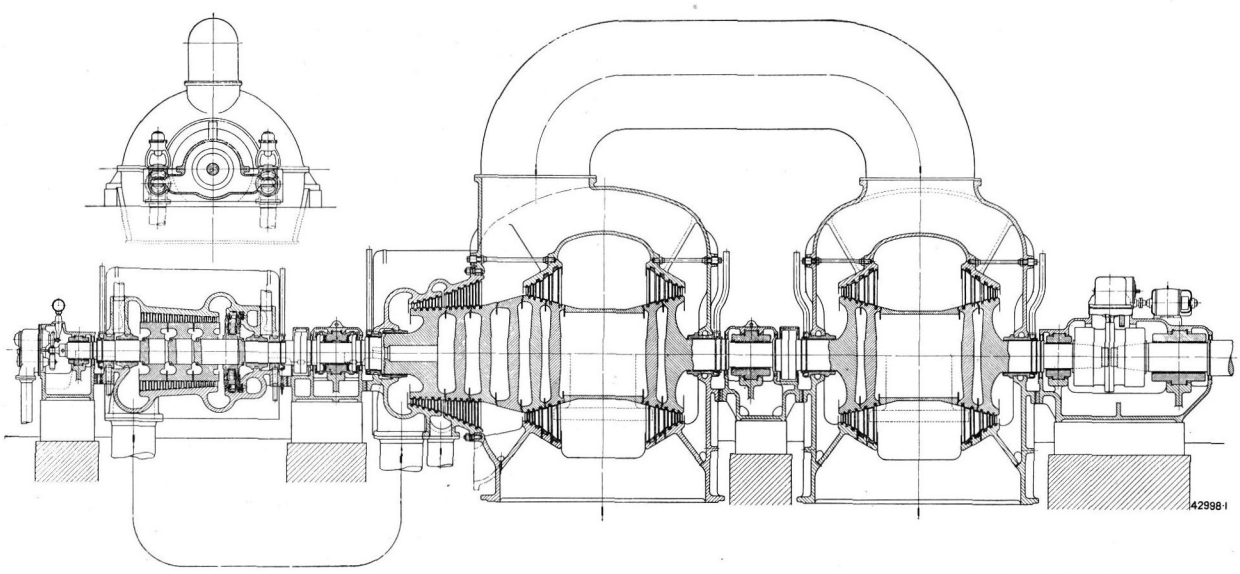


Fig. 24. — Brown Boveri big turbine for outputs up to 100,000 kW and pressures up to 80 kg/cm² and 450° C.
The rotors are welded and adapt themselves flexibly and rapidly to all temperature fluctuations at starting and in service. The big volume of steam requires four parallel steam exhaust channels.

dealt with by using special valve designs and suitable material. Further, the high-pressure high steam-temperature turbines have auxiliary servo-motor governing (turbine governor regulating small oil-pressure servo-motor which governs in its turn the powerful servo-motor for the valves). Big forces are, thus, generated to move the valves and reliable governing movements are assured even at 500° C.

These turbines allow of utilizing the highest steam temperatures in absolute safety and thus meet the Carnot requirement:— introduction of heat to the cycle at highest possible temperature. We have, therefore, called this type of turbine the "Carnot turbine".

High-pressure steam at a high temperature is used in order to attain high efficiency in the cycle process and thus to reach a low fuel-consumption figure for the steam plant. It is, therefore, natural that the designer should also strive to attain the *highest possible turbine efficiency*. Brown Boveri uses, to this end, *impulse blading* for the first stages, because, even at partial loads, it gives good efficiencies, by partial nozzle admission. In all the remaining part of the turbine, however, the patented Brown Boveri *reaction blading* is used, the efficiency of which is 95 % and which allows of attaining the highest possible economy of the plant.

A turbine of high efficiency for a big heat drop requires a relatively large number of blade stages and this makes a subdivision into several cylinders necessary. This subdivision has the great advantage that, at starting and when sudden load changes occur, the high-temperature part is absolutely separated, in a small high-pressure cylinder, from the rest of the turbine, which is colder. Further this design has the advantage that the axial thrusts of the shafts can be compensated by counter action of different sections of the blading which allows of eliminating balancing pistons with the losses inherent thereto.

Fig. 24 gives the section of a big turbine, which is suitable for outputs up to 100,000 kW and pres-

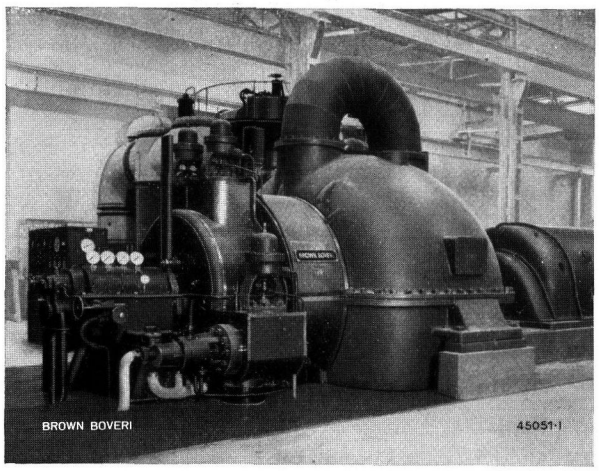


Fig. 25. — View of 32,000-kW single-cylinder/steam turbine, 3000 r.p.m. for the Oslo Power Station, having two, parallel steam exhausts.

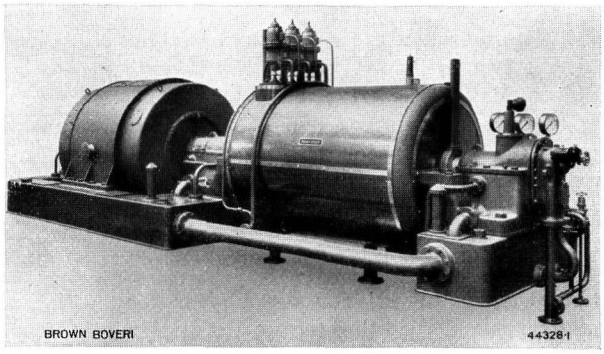


Fig. 26. — Back pressure turbine, 1250 kW, 46 kg/cm² abs, 450° C. and 7·5 kg/cm² abs back pressure.
The steam for heating is first used to generate electricity. The unit runs in parallel with an electricity distribution system.

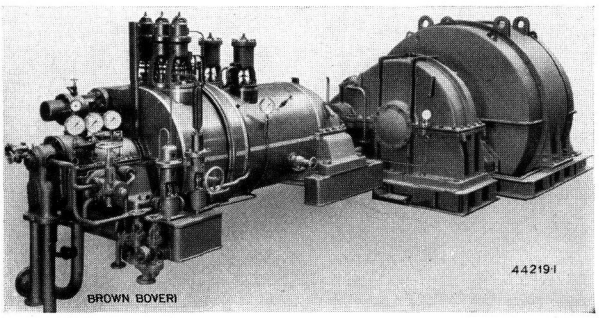


Fig. 27. — Extraction turbine for 3320 kW, 6000 r. p. m.

The set supplies a British cardboard factory with electricity and hot steam which, however, first does work in the high-pressure section of the turbine before being utilized. Both high and low pressure sections of the turbine are governed by nozzles.

sures up to 80 kg/cm^2. We chose a speed of 3000 r. p. m. for this big output, because experience shows clearly that these high-speed units at high steam pressures and temperatures are not only cheaper and smaller but are less sensitive to changes in temperature, owing to their smaller size, and are, thus, more reliable in service. Fig. 24 shows that the rotors are welded and material saved in this way. The big volume of exhaust steam calls for four low-pressure blading sections in parallel. The three bearing pedestals rest, directly, on the foundations and also carry the cylinder with its supporting paws. The axial displacement of the blading is equalized through the supporting paws and the coupling, by a patented process.

In stand-by plants, only running for a short time, efficiency plays a less important part while low first costs come to the fore. For this reason, we have often used single-cylinder turbines, which are cheaper and call for lower building costs for the engine house as they take up less room than multi-cylinder units. Fig. 25 shows the 32,000-kW single-cylinder unit at 3000 r. p. m. for the Oslo Electricity Works, chosen here, chiefly, because of the restricted space available.

Fig. 26 shows an industrial turbine of the back-pressure type and Fig. 27 an extraction turbine with nozzle-valve governing both on the high and low-pressure ends.

New demands have been made on steam-turbine *governing* owing to the linking up of big power stations to extensive distribution systems. A generator unit, alone on a consumer system, always gives the output required of it, its speed and frequency varying slightly according to the governor characteristic (speed n in function of output L). If the said curve is a straight line, i. e. if $\frac{dn}{dL} = \text{constant}$, the speed variation for a given load variation, at every load, will be the same. If the said curve deviates from the straight, the change in frequency for a given change in the load will differ according to the inclination of the curve. If, now, there are several machines of the same power house, or on the same system, connected in parallel, the speeds of all the machines will change, when the load on the system varies, according to the sum of all the regulating characteristics. If all regulating curves were the same inclined straight lines, the load ratios of all the machines would be the same. If the curves deviate from one another the load repartitions change according to the value $\frac{dn}{dL}$.

This shifting of load between the respective turbines is without importance as long as the units are in the same station, as the station operator can intervene and make suitable adjustments. It is a much more difficult problem when, in the place of several machines in one station, there are several power stations or, even, several independent electricity companies with interconnected power stations. In such cases the load is devided up between them according to contracts in accordance with their power and the price of the electrical unit. For instance, it may be agreed that all stations share equally in current delivery or else there may be hydraulic plants with peak-load storage plants or steam power stations the current of which is expensive and which should, thus, only be called on when the ordinary hydraulic power stations are fully loaded.

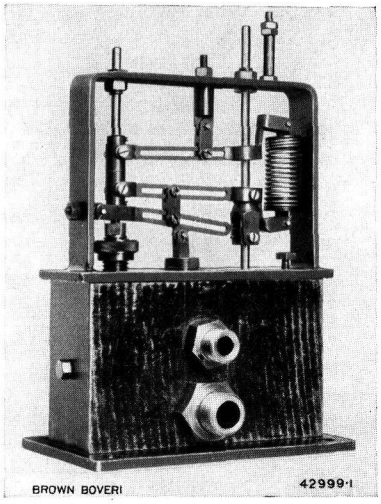


Fig. 28. — Load-carrying apparatus for Brown Boveri steam turbines.

This apparatus allows of altering the governor characteristic curve of the turbine, during operation, from a rising to a falling curve, passing through the isodrome characteristic. The capacity of the turbine to take over load can, thus, be made to obey the load program desired, over a wide range.

The carrying out of a determined loading program or chart is much simplified if a simple means can be found to alter the inclination of the governor characteristic and, therewith, the capacity of the machines to take over load. To meet these requirements, Brown Boveri has brought out a *load-carrying apparatus* which can be built on to standard Brown Boveri steam-turbine governing gear, at little cost. It is shown (cover removed) in Fig. 28. The apparatus allows of altering the speed/load characteristic of the turbine over a wide range, from a rising governor characteristic through the isodrome characteristic to a falling governor characteristic, this when the unit is operating, and thus of varying the capacity of the said unit to take load, in such a way that it meets the loading programme or chart laid down.

The device also allows of varying the momentary and passing irregularities of the governing system and thus of avoiding hunting.

4. *Condensing plants.*

The Brown Boveri condenser, in its latest design, can be said to have reached a development stage

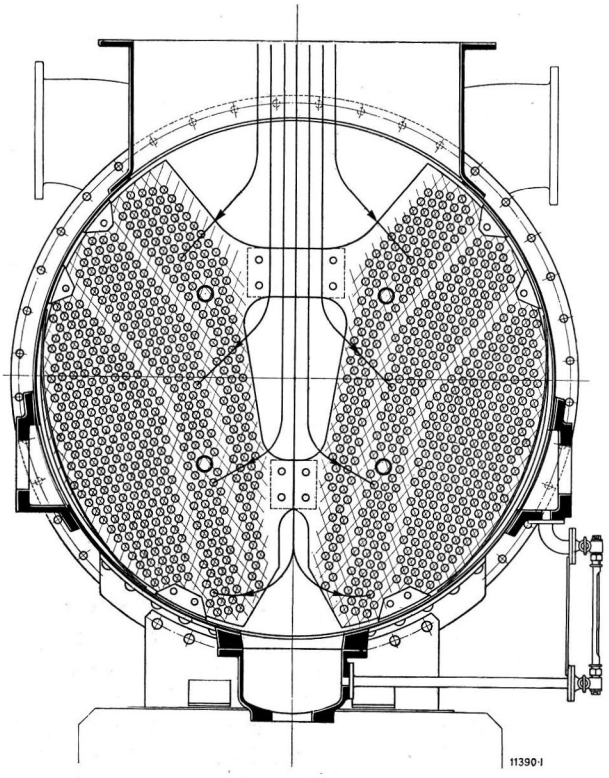


Fig. 29. — The OV-type of condenser which Brown Boveri has been building for 25 years.

The steam flows from a wide central passage to two lateral stacks of water tubes, the section for steam inlet being big and the depth of the stacks small.

which makes it an apparatus offering every guarantee of reliability. We would recall, here, that the condenser tubes are arranged in the shell in the so-termed OV form (Fig. 29), in which the steam flows to the two lateral sheaves of condenser tubes through a V-shaped inlet channel extending the whole length of the shell which offers big open surfaces to the lateral flow of steam between the tubes and little depth, therefore little resistance, of the tube stacks. This design, created by us in 1911, is so suitable to condenser operation that, as soon as our patent rights on it had lapsed, a number of other firms took it up. Thus, it will be found on the new Cunarder-White Star liner "Queen Mary". Our design of condenser with double water chamber, allowing of cleaning in service, has also become common property, to-day. The design proper to the new Brown Boveri condenser is shown in Fig. 30. The tubes are expanded at both ends into the tube plates. According to a patented process, they are first given a wavy shape, and, at the points of contraflexion, they are supported by stiffening plates, in order to prevent deleterious stressing between the tubes and the shell or between tubes in different positions, when temperature differences arise. The tightness of the tube

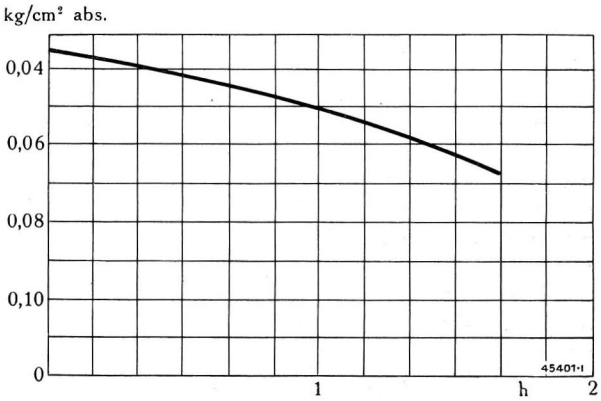


Fig. 31. — Vacuum characteristic of a 16,000-kW Brown Boveri steam turbine plant with vacuum pump shut down.

The plant can work for hours without the vacuum pump, without endangering service.

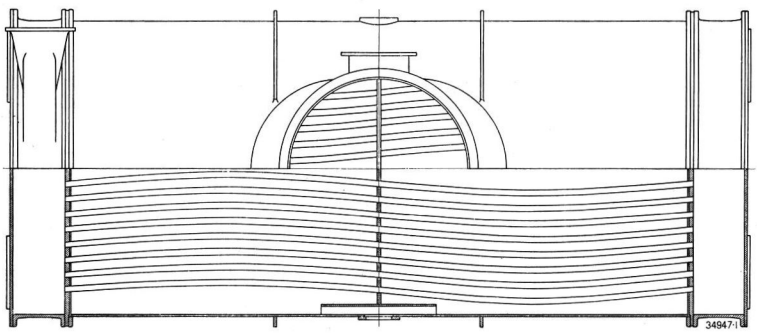


Fig. 30. — Brown Boveri condenser with wave-shaped tubes.

The cooling tubes are expanded into the shell end plates at both ends but are given a wavy shape before being put in, to prevent undesirable stressed due to temperature inequalities between tubes and between tubes and shell (patented). The tubes are supported at the point of contraflexion. The elimination of sealing glands makes the condenser very tight. The tubes can be of soft brass and are, thus, less susceptible to corrosion.

fittings is no longer dependent on hundreds of glands which sooner or later become loose, especially when there is an insufficiency of water. Further, the brass of the tubes no longer requires to be hard, in order to prevent the tubes being squeezed into the glands, as used to be the case. Soft brass tubes are, now, used with this expanded process and these have the great advantage of being subjected to hardly any corrosion and of bursting very rarely indeed.

The Brown Boveri condensers with wave-shaped tubes are being built to-day, under licence, by several other firms, for stationary plants as well as for merchant and naval vessels.

The vacuum chamber of the condenser has no flange towards the outside, through which air could filter in, apart from the unavoidable pipe connections

for steam inlet and the air and condensate-suction outlets. Our condenser plants are, really, so tight, on this account, that service can be kept up for hours without running the air ejector pump. Fig. 31 gives the results of a test on a 16,000-kW steam-turbine plant which ran for two hours with the air ejector pump cut out, without any trouble-some deterior-ation of the vacuum oc-curring.

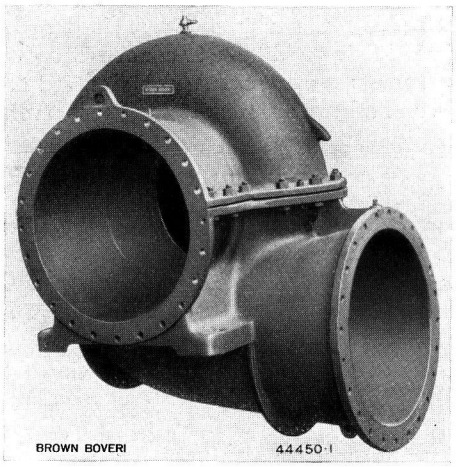


Fig. 32. — Housing of the new cooling-water pump for condensing plants with high-speed motor; for large quantities of water under low heads.
For cleaning purposes, it is easy to remove the cover.

Fig. 32 shows the latest cooling-water pump design for relatively big volumes of water and low heads. The pump is very compact. The branches are so laid out that the big cooling water pipes can be arranged simply and suitably. The cover of the pump is easily removed without preliminary dismantling of the said pipes. This requirement is generally specified by steam-power house operating engineers, because the cooling-water pump often has to handle very dirty water and provision has to be made for cleaning it with as little difficulty as possible.

5. *Turbo-generators.*

The demand for electric power, which increased by leaps and bounds in the years just after the War, obliged power-generating stations to make exceptional demands on the resources of manufacturers and this, particularly, as regards the two-pole type of turbo-generator, by the forcing up of the individual outputs of these machines. It is only just to say, here, that these requirements met with a courageous response both from electrical and the metallurgical firms concerned.

If, on the one hand, the increase in output of generating units was met by an increase in the dimensions of the said units, on the other hand, the requirements of economy, which characterized technical developments in recent years, naturally led to the endeavour to attain better utilization of material and introduce simplifications in design.

This better utilization of material was attained by decreasing losses, by introducing better cooling methods combined with considerably lower volumes of cooling air. The superior efficiency, which went hand in hand with these improvements in design, is a factor which is being more appreciated, in recent times, than it was a few years ago, when there was a tendency to assume that capitalization of losses should be disregarded if only low first costs of the plant were achieved.

This progress in design was carried out by careful avoidance of all these constructive factors which experience proved to be the source of losses and also by the introduction of some quite new principles in the elimination of the unavoidable quantity of heat generated in the machine.

As the following Table shows, efficiencies were attained on two 37,500-kVA generators which, up till quite recently, would only have been possible by resorting to artifices such as oil and water cooling or by making some undesirable concessions in the field of the operating reliability of the machines. The results attained approach, in fact, those figures generally associated with oxygen cooling, a design we have never given our approbation to, on account of the complications it means in design and operation and the increased supervision it demands.

TABLE III.

	kW	kW	kW	kW	kW
Output	37,500	30,000	22,500	15,000	7500
Efficiency	%	%	%	%	%
at:— p. f. = 1	98·5	98·4	98·1	97·5	95·6
p. f. = 0·8	—	98·0	97·8	97·3	95·4

A considerable simplification has been introduced in the design of turbo-generators up to 3125 kVA by putting in a single fan wheel, instead of two, on the rotor, this while leaving our well-known cooling system unaltered and, even, improving it to the point that all appreciable differences in temperature in the machine due to differences in the flow of cooling air are entirely eliminated. The new design also offered attractive possibilities to combine the cooler and the generator so that they took up less space, this, however, without lodging the cooler proper in the generator housing, which is not a desirable arrangement.

Turbines for industrial requirements were built for speeds exceeding 3000 r. p. m., in order to enjoy better steam consumption figures, this for low outputs, the generator being driven through a reduction gear. Thus, we built two generators for 1000 r.p.m. each to deliver 3900 kVA and driven by turbines at 6000 r. p. m. These are high-pressure extraction-type turbines for the Warrington Paper Mill, England.

B. DIESEL POWER STATIONS.

The *charging process for Diesel engines, according to the Brown Boveri-Büchi system* is being used, to-day by 42 different firms. Eleven of these, among them Sulzer, MAN, Deutz, Harland & Wolff, hold general licence agreements for themselves and their own licensees. The number of charged Diesel engines had risen to 350 at the end of 1936 (Fig. 33) and the total output of charged engines to 600,000 brake H.P.

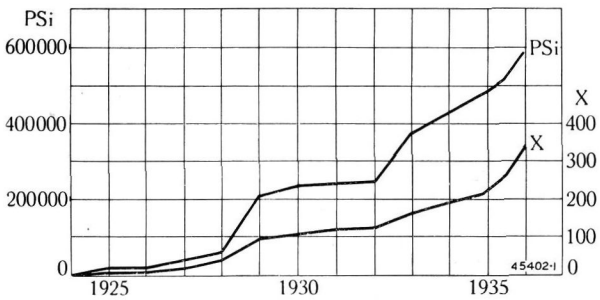


Fig. 33. — Number and output of Brown Boveri Büchi charged Diesel engines.

There was a hold-up of development during the severe industrial crisis which, however, was quickly recovered.

PSi. Total output of charged Diesel engines.
X. Number of charged Diesel engines.

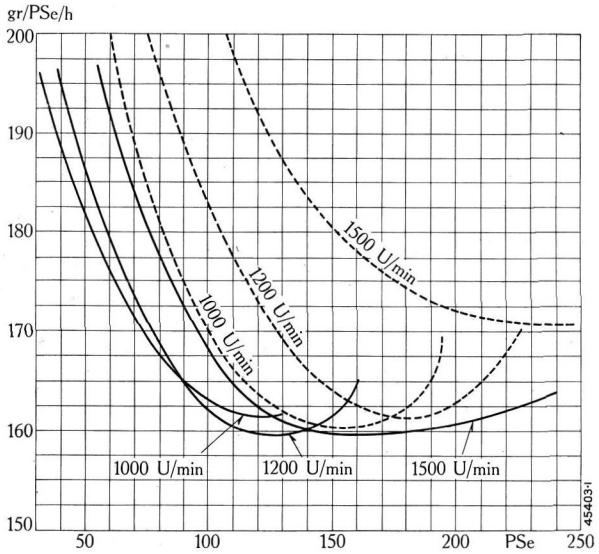


Fig. 34. — Fuel consumption of two Saurer-Diesel engines, 225 H.P., one (dotted line) uncharged, the other (full line) charged.

The great improvement in fuel consumption at high speeds and especially at partial loads will be noted.

We desire to refer, shortly, to the advantages to which, alone, must be attributed the exceptional development of the field of application of the charging process. This is best done in connection with the test results of a charged Diesel engine, reproduced in Fig. 34, and which Messrs. Ad. Saurer A.-G., Arbon (Switzerland) have placed at our disposal. Generally speaking, by means of charging, the output of the Diesel engine can be increased by 50—60 % continuous-load rating this without any major alterations to the said engine except the adding of the charging set. The specific fuel consumption of a low-speed engine at full load is improved by about 5 % and that of a high-speed engine by 10 % as compared to the specific consumptions when there is no charging. At half-load the saving in fuel is 10—20 %. The consumption

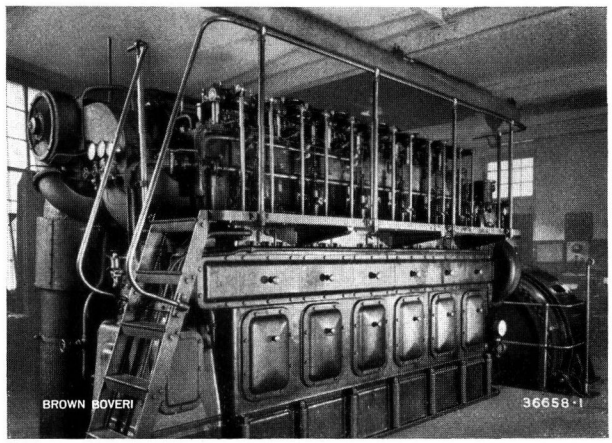


Fig. 36. — Sulzer-Diesel engine at 375 r. p. m. dating from thea yer 1932 and placed in the Jakob Rieter Maschinenfabrik in Winterthur (Switzerland). By adding a Brown Boveri-Buchi charging set its output was raised from 390 H.P. to 550 H.P. and its specific fuel consumption lowered to 163·5 g/H.P.

of lubricating oil remains the same, despite the addition of charging; it, therefore, diminishes as measured per H. P. delivered. The space taken up is hardly any greater as is clearly shown by Fig. 35 of a MAN charged engine; the weight is only very slightly greater. The running of the charged engine is smoother, because the combustion is less violent due to the scavenging and because the exhaust gases of the engine flow to the gas turbine and give up to the said turbine the power they contain. Regulation is very good as the charging set adapts itself, rapidly, to all variations in load.

An interesting field, full of possibilities, is that of the *placing of charging sets* on existing Diesel engines, so as to increase their output and bring down their specific fuel consumption. Fig. 36 shows a four-stroke Diesel engine in the Jakob Rieter Machine Works in Winterthur (Switzerland), built in 1932, the output of which has been increased by the addition of a Brown Boveri charging set built by Messrs. Sulzer Bros., from 390 H. P. to 550 H. P.

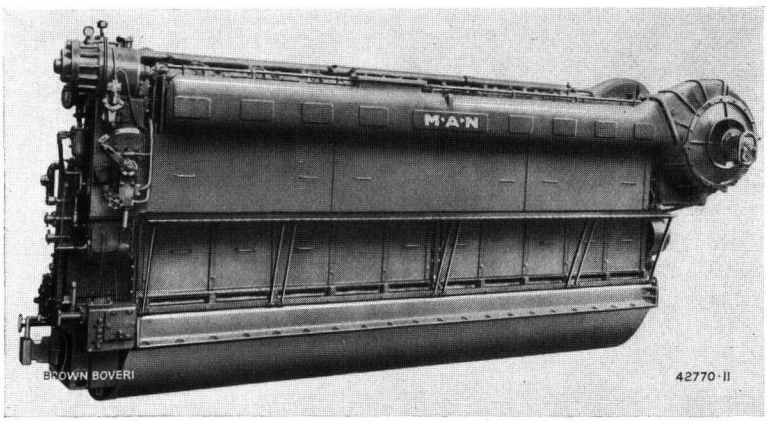


Fig. 35. — MAN Diesel engine charged to 1750 H.P.

The charging blower is incorporated in the design of the engine. It increases its output by 50 % but does not take up any additional space.

In this field, a three-phase generator of 875 kVA at 300 r.p.m., 6000 V, 50 cycles, ordered from us, is worthy of note. This unit is driven by a Diesel engine through a magnetic coupling combined with the flywheel. When disengaged, the coupling allows of using the generator as a phase advancer.

C. HYDRAULIC POWER STATIONS.

Since our last year's report, there have been no essential changes to record, in this field. We are expecting a period of inactivity of some duration as regards the building of new hydraulic stations in Switzerland, after the starting-up of the Etzel Power Station, at a near date, to which we delivered both single-phase generators and 150-kV switchgear material. The reason for this is that the demands for power are now amply covered, including all possible requirements for traction, this even if the requirements of industry should show considerable increase in the next few years.

On the other hand, replacement of obsolete turbines in local plants and on small power-transmitting systems offered an opportunity for the replacement of the generators belonging thereto by modern units.

In other countries, where the development of hydraulic power has not nearly attained the degree of completion characteristic of Switzerland, and where big hydraulic developments are still possible, we, as well as our concessionary companies, have been able to participate, most successfully, in the equipment of electric power stations of big and small outputs. The wide experience gathered, in the design of generators for big Swiss power stations, as well as in that of transformers and switchgear, came in usefully here, both for us and our concessionary companies.

1. *Generators.*

A three-phase vertical-shaft generator, for 475 kVA, 750 r.p.m. was built, recently, for the Brugg Power Station (Switzerland). This unit is driven by the turbine through a reduction gear with helical-gear teeth, at a ratio of 1 : 12·7. The same arrangement was carried out for the Aarau Power Station (Switzerland) where a Kaplan-type turbine was put in to replace a former Francis-type unit. This former set was of vertical-shaft design for two-phase current, 1600 kVA, 107 r.p.m., 4200 V, 50 cycles and the new set, also of vertical shaft design, is for three-phase current, 2000 kVA, 107 r.p.m., 8600 V, 50 cycles. The transformation involved replacing the shaft, pole-wheel, exciter, stator winding and upper carrying spider as well as the guiding and carrying bearing. All other parts could be left unchanged despite the increased output and rise in run-away speed from 170 to 275 r.p.m. A three-phase vertical-shaft generator of standard design, built for 1500 kVA, 9500 V, 50 cycles, 125 r.p.m. was built for coupling to a propeller-type turbine in the old Wynau Power Station belonging at the Wynau-Langenthal Electricity Works (Switzerland).

Our concessionary companies have built bigger units than these. Tecnomasio Italiano Brown Boveri

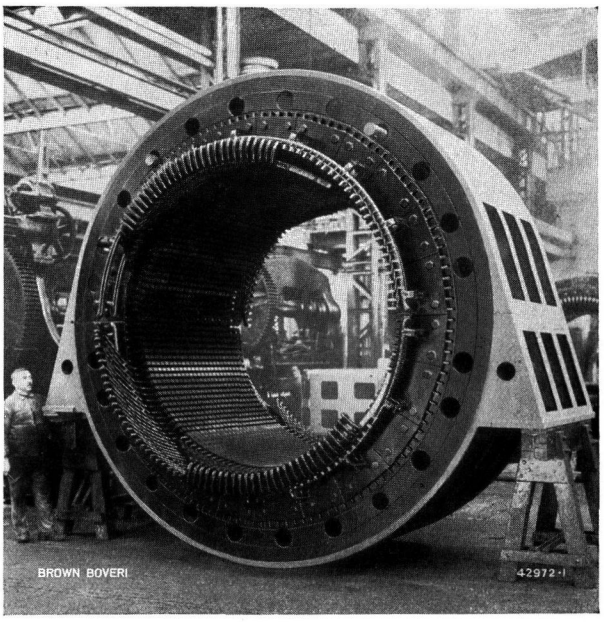


Fig. 37. — Wound stator of the 20,000-kVA generator for the Goglio Power Station of the Società Edison, Milan.

built a horizontal-shaft generator for the S.A. Ovesticina-Novara, of 10,000 kVA, 630/750 r.p.m., 10,000 V, 42/50 cycles. This generator is coupled to heavy flywheels (36·2 tm^2) which are enclosed in the generator outer casing. They also built two vertical-shaft three-phase generators 11,500 kVA, 675 r.p.m., 10,500 V, 45 cycles with main and auxiliary exciters and an auxiliary generator, for the San Mango sul Calore plant of the Società Meridionale di Elettricità. The said auxiliary generator is used, solely, to supply the motor which drives the governor pendulum of the turbine. Fig. 37

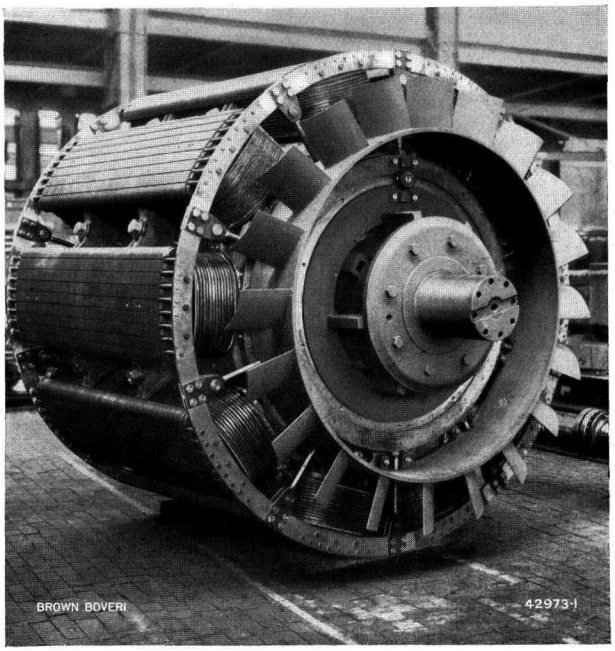


Fig. 38. — Pole wheel of the 20,000-kVA generator for the Goglio Power Station of the Società Edison, Milan.

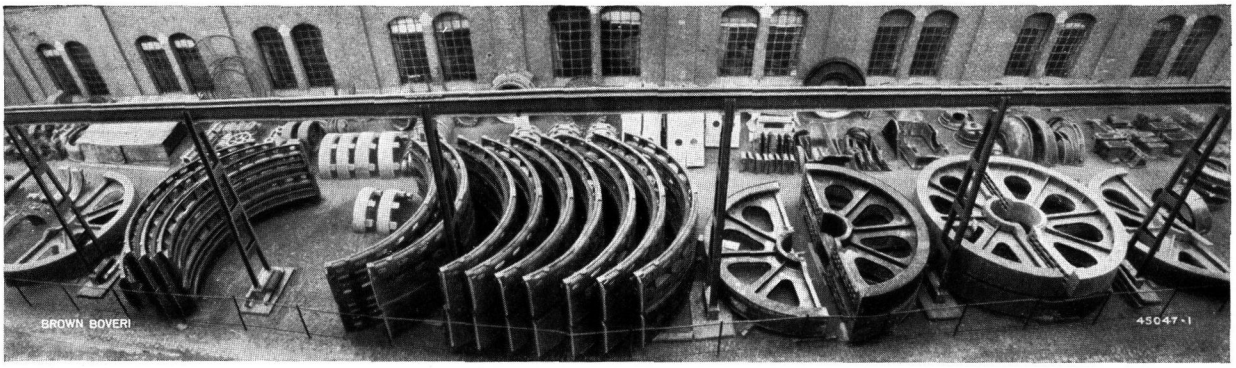


Fig. 39. — Parts of vertical-shaft outdoor generators, 5000 kVA, 115 r. p. m., 6300 V, 50 cycles.

shows the partly-wound stator of the horizontal-shaft generators, 20,000 kVA, mentioned in our last-year's report and built for the Goglio Power Station of the Societa Edison, Milan. Fig. 38 shows the pole-wheel of the same machine; Fig. 39 parts of the 15 generators, each of 5000 kVA, 115 r. p. m., 6300 V, 50 cycles, also mentioned in last year's report as having been built for an outdoor power station[1].

We got an order, in the spring of 1936, for the complete electrical equipment of the big hydro-electric power station of *Barbablanca* in Peru belonging to

[1] In our last report, these generators were said to be for the first generators for an outdoor power station built in Europe. This was an error and we desire to state, here, that two older stations of this type, by two different firms, have already been built in Europe.

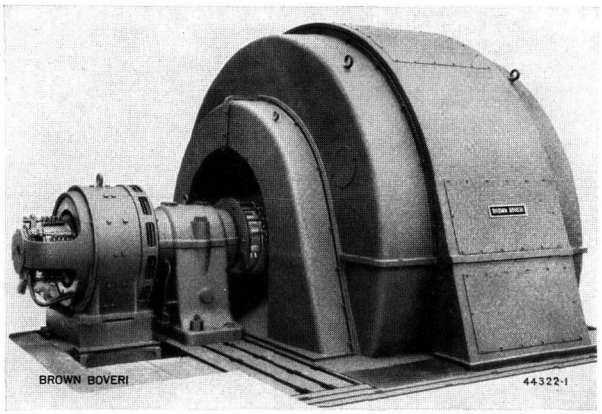


Fig. 40. — Barbablanca, Peru, Empresas Eléctricas Asociadas, Lima. Three-phase generator 17,500 kVA, 6000—6500 V, p. f. = 0·7, 514 r. p. m., 60 cycles.

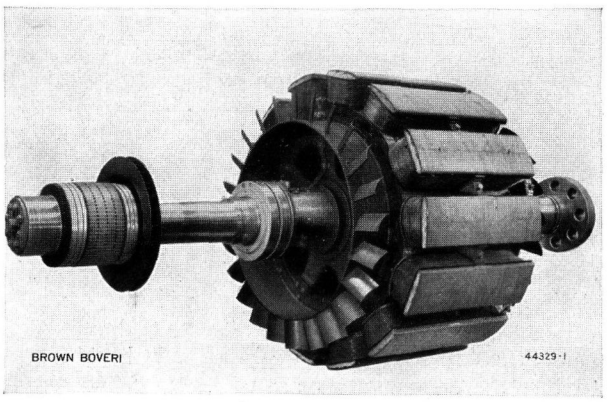


Fig. 42. — Barbablanca, Peru, Empresas Eléctricas Asociadas, Lima. Pole wheel of three-phase generator 17,500 kVA, 6000—6500 V p. f. = 0·7, 514 r. p. m., 60 cycles.

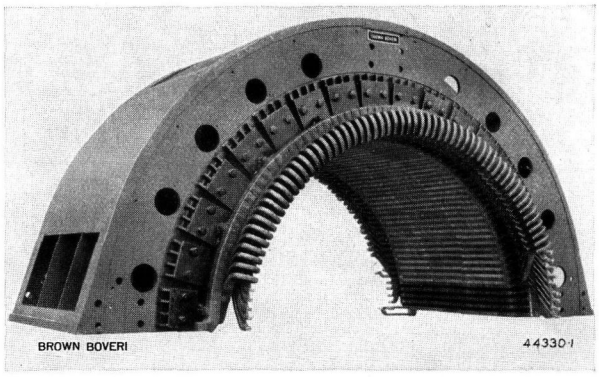


Fig. 41. — Barbablanca, Peru, Empresas Eléctricas Asociadas, Lima. Stator half of three-phase generator 17,500 kVA, 6000—6500 V, p. f. = 0·7, 514 r. p. m., 60 cycles.

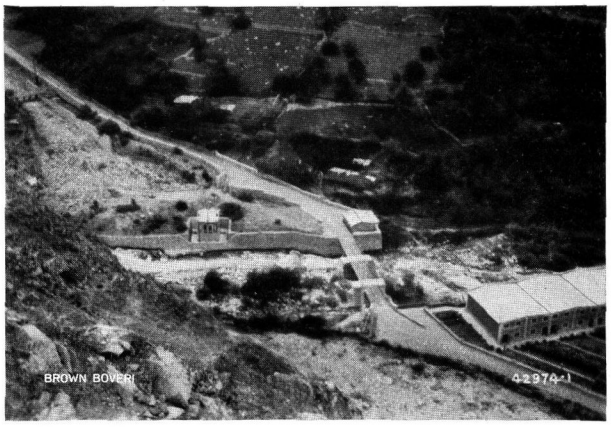


Fig. 43. — Building site of the power station for Barbablanca, Peru. Empresas Eléctricas Asociadas, Lima.

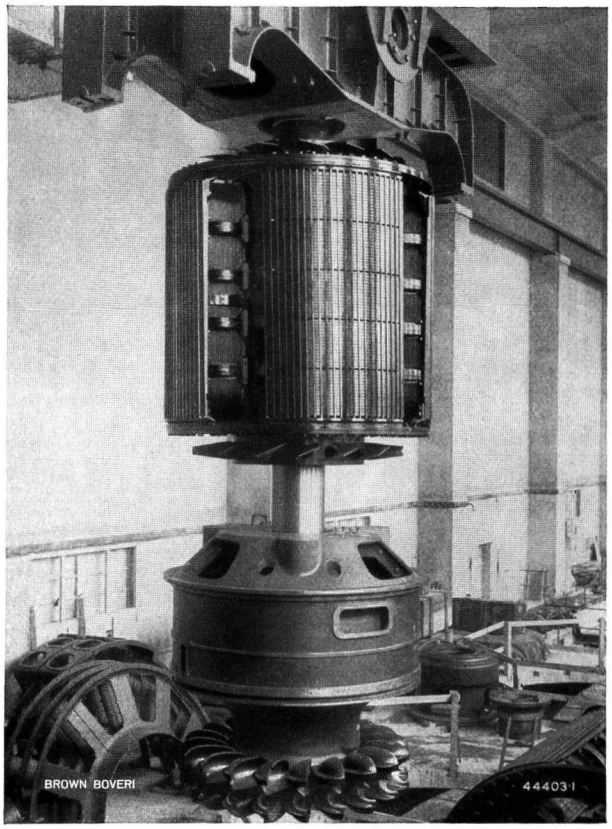


Fig. 44. — Etzel Electricity Works. Altendorf Power Station.
Rotor with crane girder for the single-phase generator 18,000 kVA, 11 kV, 500 r. p. m., $16^2/_3$ cycles with lower guide bearing and flanged-on turbine runner. Erection weight with crane girder about 100 t.

the *Empresas Eléctricas Asociadas* in Lima. This station is 54 km from Lima and will be equipped with two generating sets, in its first development stage, a number which will subsequently be increased to three. The generators are of horizontal-shaft type for direct coupling to 17,150 H. P. Pelton-wheel turbines, each is of 17,500 kVA continuous rated load, 6500 V, 514 r.p.m., 60 cycles. Fig. 40 shows a complete generator on our test bed, before freighting. Figs. 41 and 42 show the half of a stator and a pole-wheel, respectively. Fig. 43 shows the site of the power station. The switchgear plant of the station is mentioned elsewhere.

Fig. 44 is a view of the erection of the single-phase generators in the Altendorf Power Station of the Etzelwerk Co. (Switzerland).

Finally, we would record the order of four three-phase generators, each of 15,600 kVA, 214 r.p.m., 6300 V, 50 cycles which was placed, at the end of 1936, for the Roznow Power Station in Poland. These units will be built by Brown, Boveri & Cie. A.-G., Mannheim-Käfertal.

2. *Big transformers.*

These have continued to be built to designs already laid down and which have given such excellent results in practice. A great number have been built with tap switches the latest designs of which, as described in our last report, have given great satisfaction. Both we and our concessionaries have had a large number of transformers to deliver, of which the great majority was for natural cooling of the oil filling.

Mention should be made of two three-phase regulating transformers, each of 12,000 kVA, 25,000 + 20 × 180 V/7150—7000 V for the Superusina de Puerto Nuevo of the Cia. Italo-Argentina de Electricidad, in Buenos Aires, two three-phase regulating transformers, each of 12,000 kVA, 6300/171,000—150,600 V for the Zjednoczenie Elektrowni Okregu Radomsko-Kieleckiego (ZEORK), further, for the same plant, two three-phase three-winding transformers for 11,000/11,000/6666 kVA and 164/38·7/7·25 kV, all windings having taps which can be operated, the transformer being dead, by means of tap-changing switches. Further, we would mention a three-phase regulating transformer for 15,000 kVA, 6000 + 23 × 73 V/7170 V for the Laufenburg Power Station (Switzerland) and a 15,000 kVA unit, 6760/50,600 V for the same station and, finally, two three-phase transformers each 17,150 kVA, 6500/64,740 V for the Barbablanca Power Station, Peru, already mentioned (Fig. 45). The latter station operates in parallel with Santa Rosa Substation which will contain three single-phase transformers for 3 × 1563 kVA, 32,500/29,250 V/10,000 V, connected delta/delta and also built by us.

A three-phase regulating transformer was delivered to the Faal Power Station in Jugoslavia; it is of 1600, 3200, 4800 kVA primary, secondary

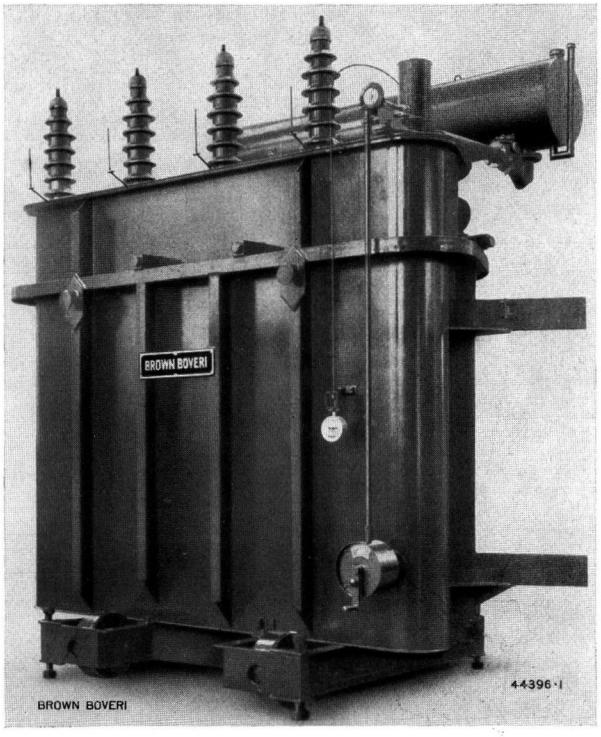


Fig. 45. — Three-phase oil-immersed transformer 17,150 kVA, 6500/64,740 V, 60 cycles, belonging to Barbablanca Power Station, Peru, Empreas Eléctricas Asociadas, Lima.

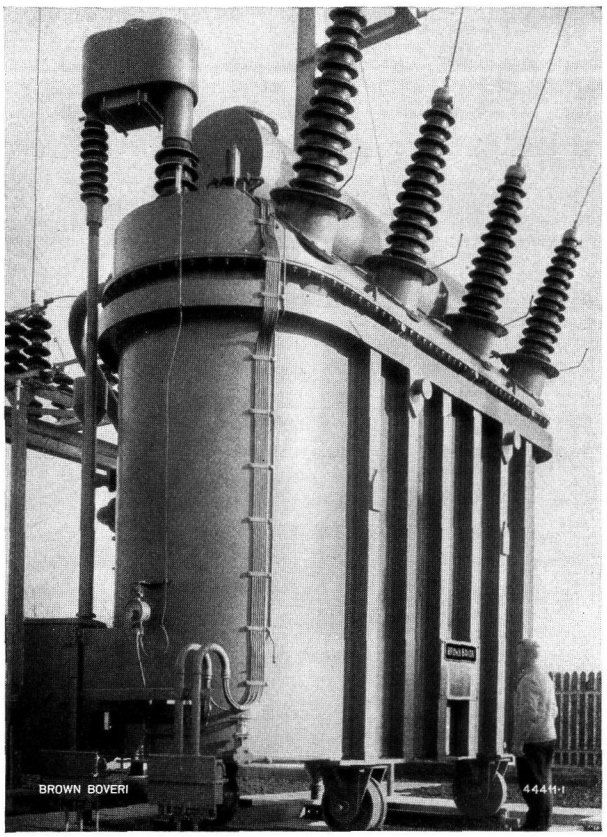


Fig. 46. — Three-phase outdoor regulating transformer, 32,500 kVA, 167,000/48,490 + (23 × 822) V for the outdoor station of the Olten-Gösgen Power Station of the Aare-Tessin Co., Olten.

and tertiary output and designed for a voltage ratio of 11,200/27,500/37,500 V ± 15 %. Secondary and tertiary windings are in auto-connection together. With this design it was possible to eliminate a two-winding transformer of 1600 kVA and a regulating transformer of 4800 kVA, as both units are now combined in one. This means lower first cost, lower installation costs and smaller losses.

The 32,500-kVA transformer for the outdoor station of the Olten-Goesgen plant (Switzerland) is shown, on site, in Fig. 46.

At the end of 1936, the Bernische Kraftwerke (Switzerland) ordered a three-phase transformer for their Mühleberg Power Station. This transformer is to be built to be regulated under load in such a manner that the 20,000-kVA output can be delivered at all voltages within the following limits, namely: — high voltage 137—143 kV; low voltage, service I, 15·66—17·5 kV, or, service II, 31·3—35 kV, or, service III, 47—52·5 kV. The low-voltage winding can be switched over to any one of the three services, the transformer being dead, by means of a built-in change-over switch, while, on the high-voltage side, the voltage is set by on-load tap switches.

One of our concessionary companies got an order for two 30,000-kVA transformers, for 4 × 5·85 kV low voltage, the high voltage of which can be regulated, by means of a tap switch inserted at the star point, by ± 20 % in ± 12 taps. These units are so designed that they can be freighted complete, with their terminals and tap switches, on a low-swung railway truck.

3. *Circuit breakers.*

The air-blast high-speed circuit breaker has been gaining ground, during the past year. It would appear to be the breaker of the future, as far as can be seen to-day, this, at least, up to that range of voltage at which the oil-circuit breaker of small oil capacity (convector circuit breaker) becomes the most suitable type.

For this reason, the series of our standard *air-blast high-speed circuit-breakers* has been extended, systematically. We had the opportunity of building a large number of these breakers to our type 64 kV (Fig. 47) which had already been designed at the end of 1935. Among these there are 13 units for the Barbablanca plant, already mentioned and for its Santa Rosa substation, five units for the Town of Zürich Electricity Works (Switzerland). The series of air-blast high-speed circuit breakers for 11 kV was increased by a bigger type for 650 MVA rupturing capacity (Fig. 48) up till then, the types built were for 100, 250 and 400 MVA. The same series for 11 kV rated voltage was completed by breakers for currents over 1000 A, namely for 1600, 2500 and 4000 A (Figs. 49 and 50).

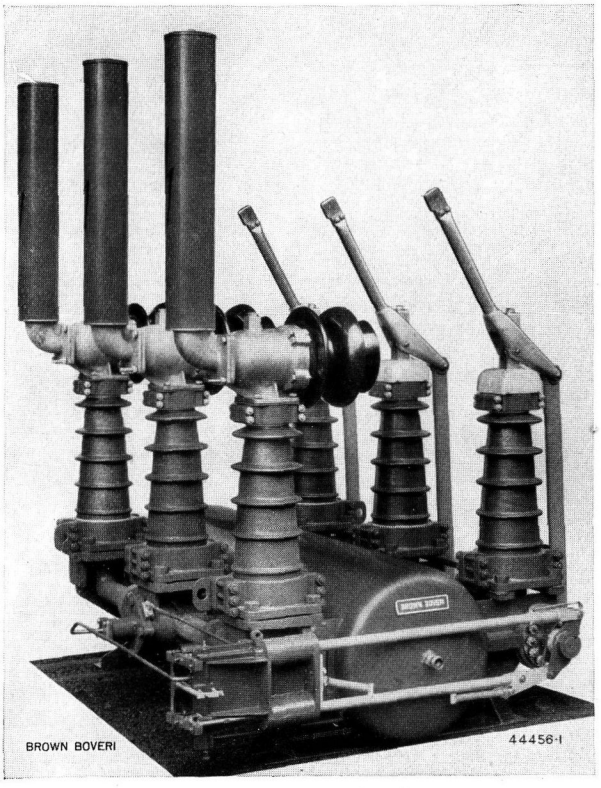


Fig. 47. — Air-blast high-speed circuit breaker of 64 kV rated voltage, 640 A rated current, 800 MVA rated rupturing capacity.

In order to gain information as to the readiness for service of the air-blast high-speed circuit breakers, we carried out a series of interesting duration tests in our shops to determine the behaviour of the breakers, in the open air and under different conditions of temperature. These tests extended over a considerable length of time, and were, partly, without and partly with switching operations at determined intervals. The results proved the great reliability of the valves fitted on the said breakers.

For high and for the highest voltages, our *convector circuit breaker* has given further proofs of its qualities in practice. Among other breakers of this type built, mention may be made of a three-pole set delivered to the Goesgen Power Station of the Aare-Tessin Co. (Switzerland), which is for 150 kV rated voltage (Fig. 51), while, for the Altendorf Power Station of the Etzel Electricity Works Co. (Switzerland), four similar sets were ordered each for 1950 MVA rupturing capacity.

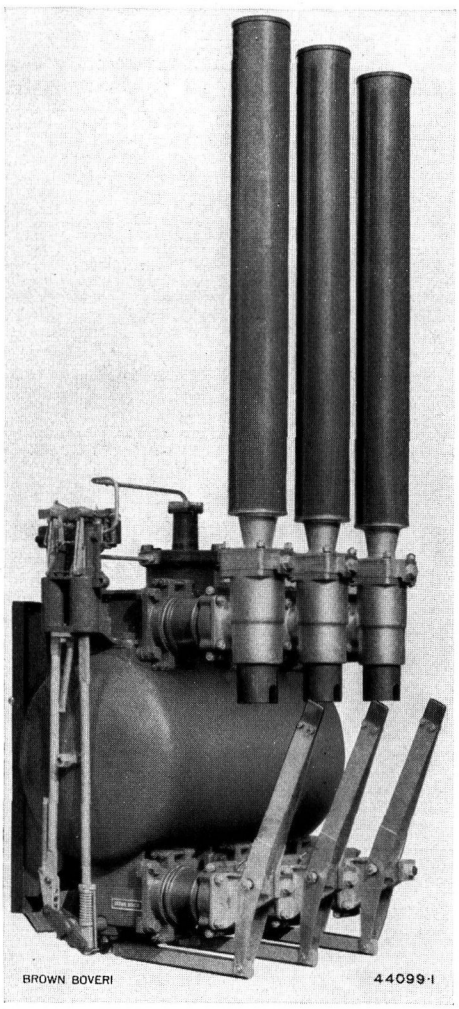


Fig. 48. — High-capacity air-blast high-speed circuit breaker.
11 kV rated voltage, 1000 A rated current, 650 MVA rated rupturing capacity.

Fig. 52 shows one "pole" of a convector circuit breaker built for 220 kV rated voltage and 2000 MVA rupturing capacity. The total oil filling of a three-pole set, for 220 kV is only about 850 litres as compared to about 65,000 litres which would be necessary for a triple-tank oil circuit breaker of the earlier design.

We described our new *power-storage drive* for a torque of 7·5 mkg in our last

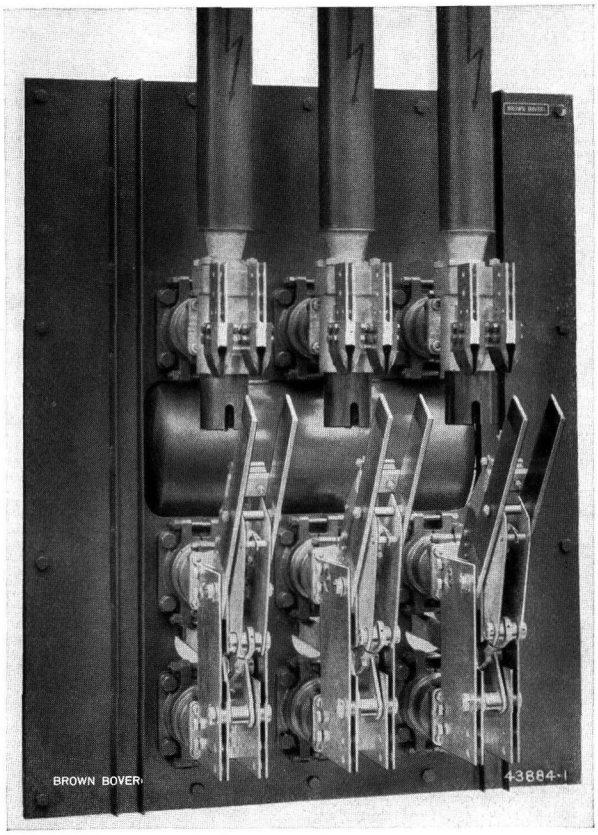


Fig. 49. — Air-blast high-speed circuit breaker.
11 kV rated voltage, 2500 A rated current, 400 MVA rated rupturing capacity.

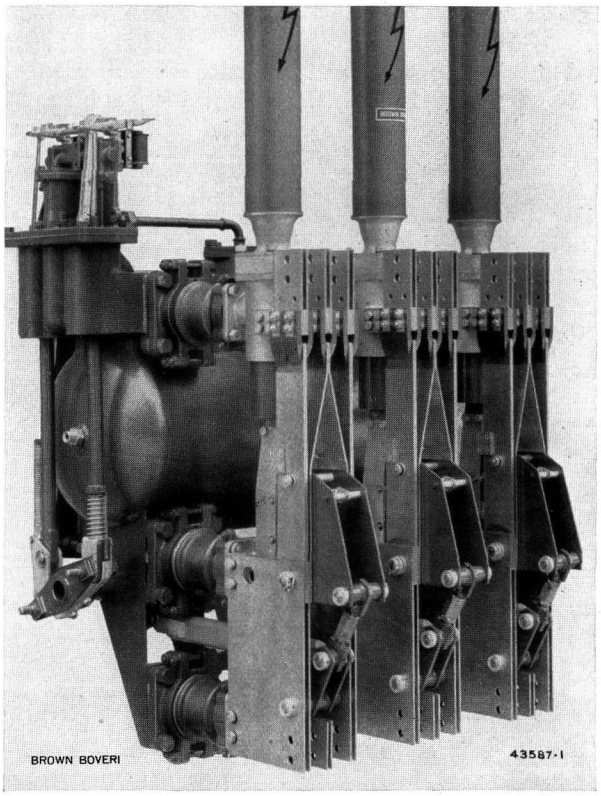


Fig. 50. — Air-blast high-speed circuit breaker.
11 kV rated voltage, 4000 A rated current, 400 MVA rated rupturing capacity.

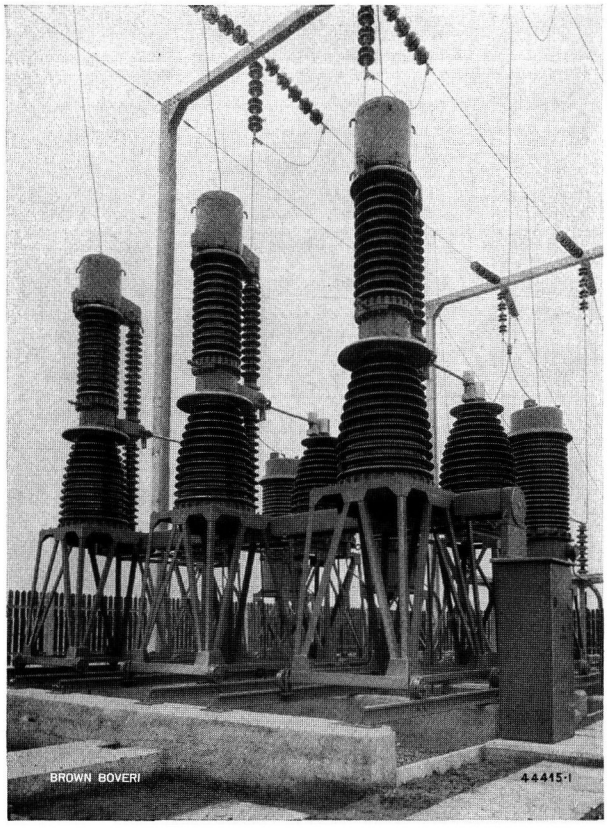


Fig. 51. — Convector circuit-breaker set of the outdoor station belonging to the Olten-Gösgen Power Station of the Aare-Tessin Co., Olten. With separate current and voltage transformers, for connecting the power station to the big Gotthard transmission line.

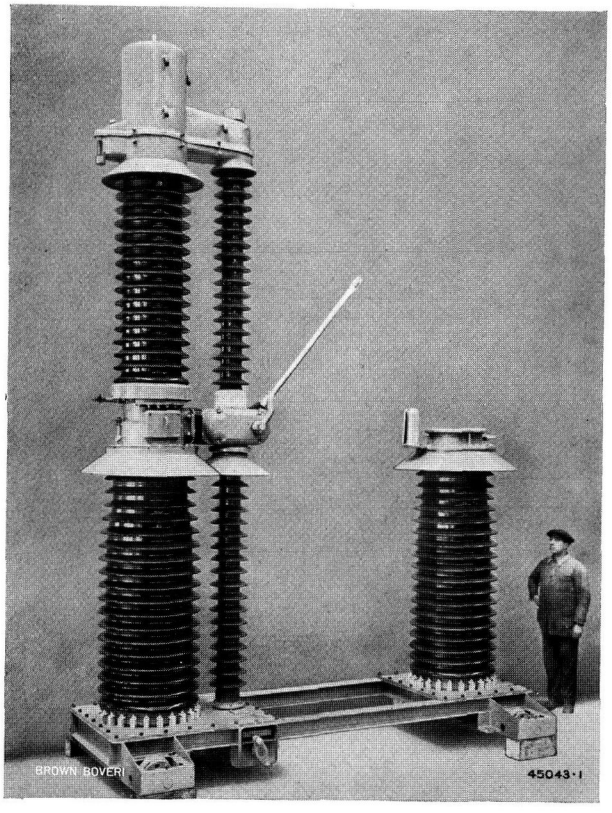


Fig. 52. — "Pole" of a convector circuit breaker for 220 kV rated voltage and 2000 MVA rated rupturing capacity.

year's report. This drive can be combined in most happy manner with a reclosing device which had, always, to be installed separately up till now as it comprised, at least, two pieces of apparatus. Now that it has been combined in a single one it can be built on to the power-storage drive (Fig. 53).

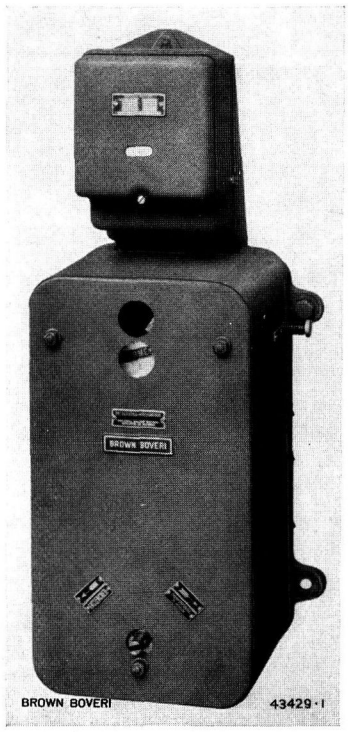


Fig. 53. — Power-storage drive with built-on reclosing device.

Our *disconnecting switches* and *change-over disconnecting switches* for voltages up to 37 kV have been entirely redesigned. They are characterized by the ease with which they can be installed and by clamped insulators in the place of cemented ones. The compressed-air drive used is their most interesting feature. Fig. 54 shows one of the new type of switches for 11 kV rated voltage and 400 A rated current, actuated by a compressed-air drive with governing valve.

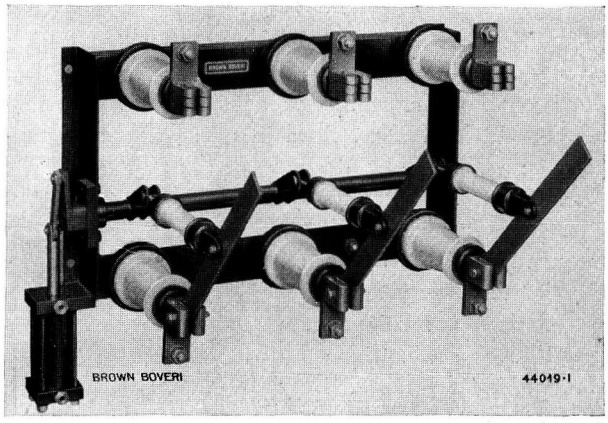


Fig. 54. — Three-pole disconnecting switch with compressed-air drive. 11 kV rated voltage, 400 A rated current.

The need to be able to switch disconnecting switches while under load, under certain circumstances, has been becoming increasingly evident of late. We have met this requirement for *on-load disconnecting switches* by a new design according to Fig. 55. It is intended to bring out a series of these switches for the range of 6·4 to 37 kV, 400 to 640 A and

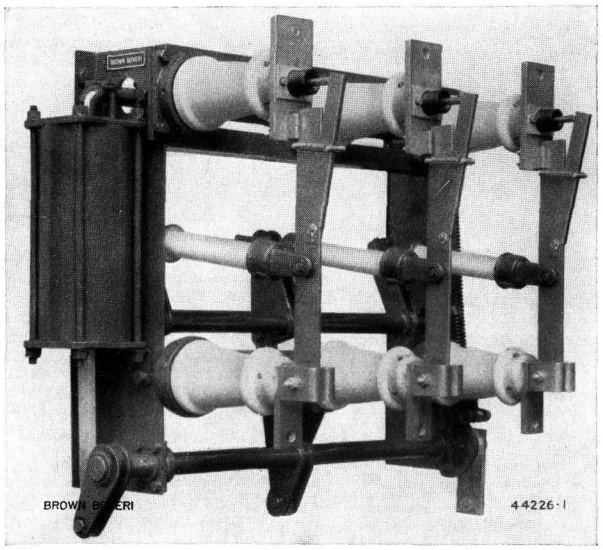


Fig. 55. — On-load disconnecting switch.
11 kV rated voltage, 400 A rated current, 10 MVA rated rupturing capacity.

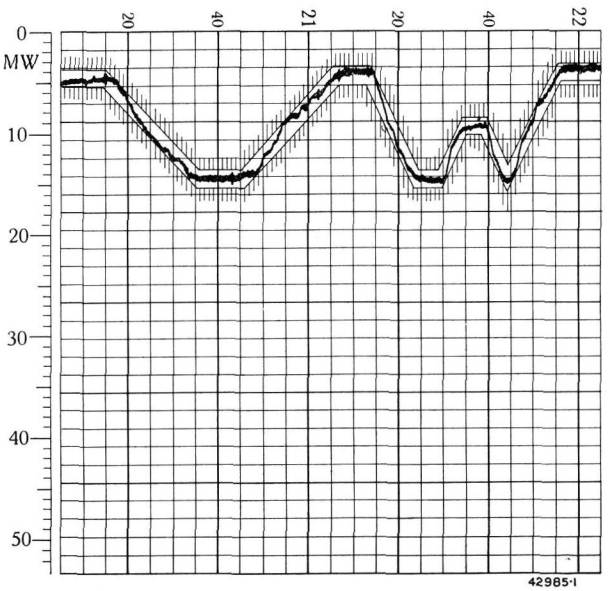


Fig. 56. — Output-regulating record chart, according to programme, in the Kembs Power Station of the "Energie Electrique du Haut-Rhin".

5 MVA rupturing capacity. Being convinced partisans of compressed air as an extinguishing medium, we have designed the new on-load disconnecting switches as compressed-air switches. Extinction of the arc takes place in the head of the upper insulator. The compressed air is generated by the switch, itself, by its own action. In some cases the switches are combined with our high-voltage fuses which are reported on elsewhere in this number.

4. *System regulation.*

It is becoming more and more important to big power stations to be able to regulate automatically the output of the station in accordance with a programme or load chart fixed in advance and in conjunction with the maintenance of the frequency. We have devoted careful study to this problem of the automatic regulation of the frequency and the output on big distribution systems.

An order received from the "Energie Electrique du Haut-Rhin" for the delivery of a complete frequency and output regulating equipment for Kembs Power Station gave us a welcome opportunity of investigating the manifold requirements of a big distributing system. The equipment delivered is based on the latest knowledge acquired and shows a high degree of adaptability chiefly as regards working with hydraulic or steam turbines. The results attained have given entire satisfaction.

Fig. 56 shows in diagrammatic form with what a remarkable degree of exactitude an output programme laid down in advance can be held to, in practice, with the help of our frequency regulator and output-programme regulator. The curve really attained or "actual curve" is seen to be between the two straight lines representing the limits of the desired or "specified line". Figs. 57 and 58 shows other output and frequency curves with hand regulation of these values and Figs. 59 and 60 the same for automatic regulation.

Apart from the frequency regulation in the Kembs station, carried out for the first time, we would say that our frequency regulator and output-programme regulator allow of solving a whole series

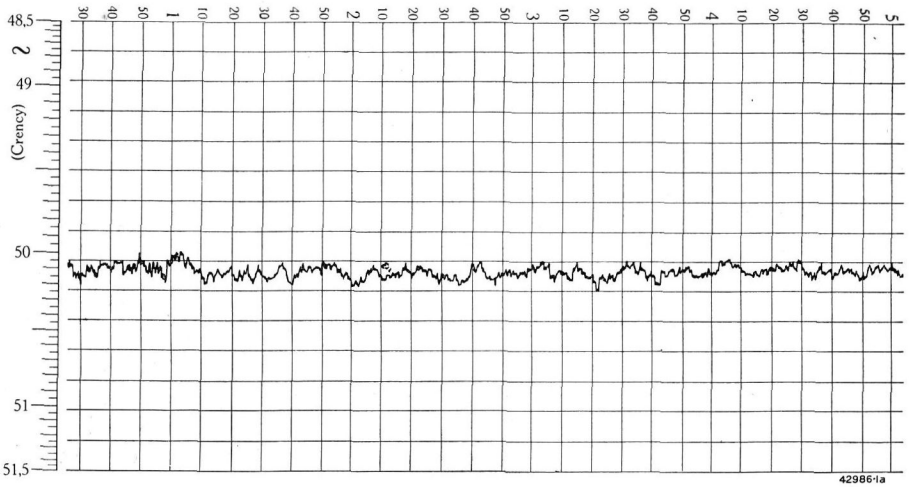


Fig. 58. — Frequency curve with hand regulation, in the Kembs Power Station of the "Energie Electrique du Haut-Rhin".

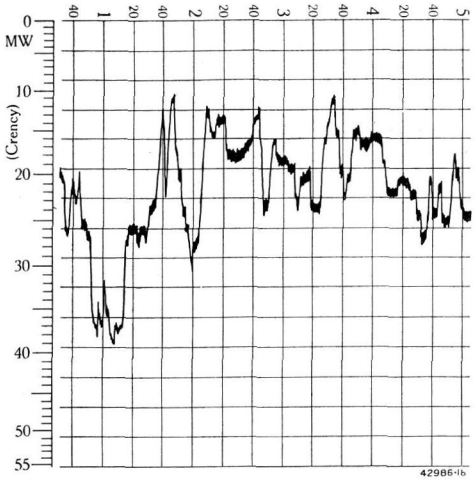


Fig. 57. — Output-curve with hand regulation in the Kembs Power Station of the "Energie Electrique du Haut-Rhin".

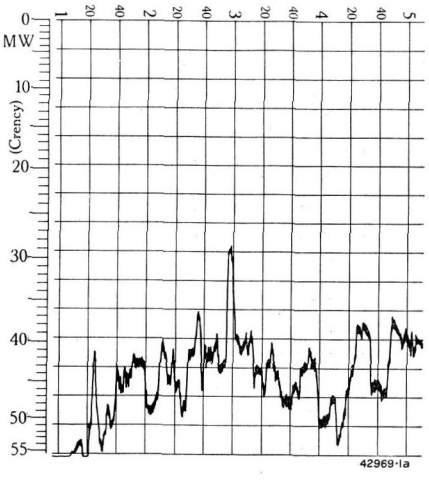


Fig. 59. — Output curve with automatic regulation in the Kembs Power Station of the "Energie Electrique du Haut-Rhin".

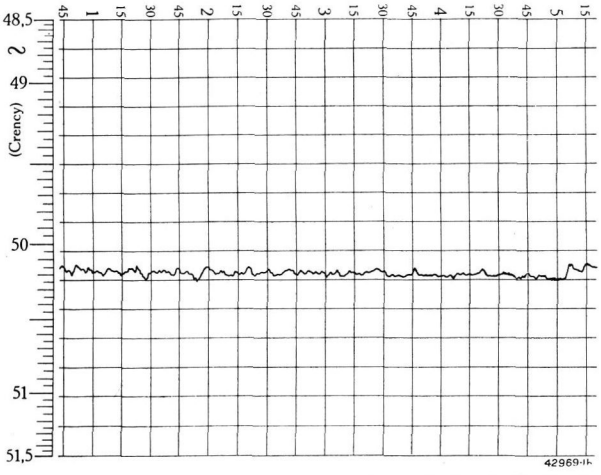


Fig. 60. — Frequency curve with automatic regulation in the Kembs Power Station of the "Energie Electrique du Haut-Rhin".

of regulating problems. Thus, it may happen on systems which are not in parallel with other systems and, themselves, supplied from hydraulic plants without sufficient storage accommodation, that the superfluous power available at given periods should be taken over by some big power consumer (electric furnaces for example); or else it happens that a large number of small plants having their own power supply also work in parallel with a big system, the duty of which is to cover their peak-load requirements; or, yet again, D. C. motors have to be regulated which are used to drive three-phase generators or industrial machinery. All such problems can be solved, simply and precisely, by our apparatus which can be added to any power station and has the advantage of improving the operating qualities of old turbine governing equipments so as to make them more capable of meeting modern requirements.

5. *Relays.*

In our last year's report, we gave some information on our new *current-indicating secondary relay Type S,* which has had a most encouraging reception, in practice, thanks to its excellent service properties. Figs. 61, 62 and 63 show different ways of installing the relay which have been developed, in the mean time, namely for mounting and connecting on the front of the switchboard panel, for countersunk installation and for mounting on the panel but with connections from the rear. Fig. 64 shows a further development of this relay in the form of a voltage relay.

Further, we have developed an *auxiliary* relay for D. C. and A. C. (Fig. 65) for 380 V rated voltage and 6·3 A which can be used as a signal relay or as a contact relay. In the former case, it is equipped with a signal drop disc and, in the latter, with two closing and two change-over contacts, or a device for contact retardation and two closing contacts.

Finally, in this connection, mention should be made of a new kind of signalling apparatus (Fig. 66).

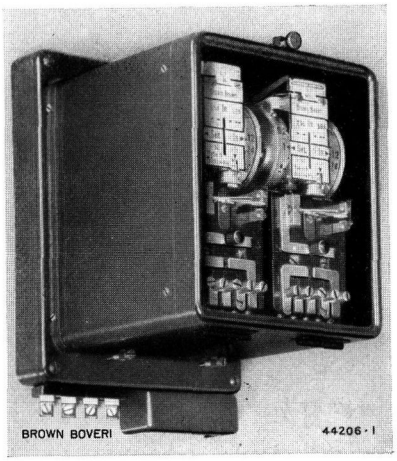


Fig. 61. — Secondary relay, in case, for connection in front (mounting in front of panel).

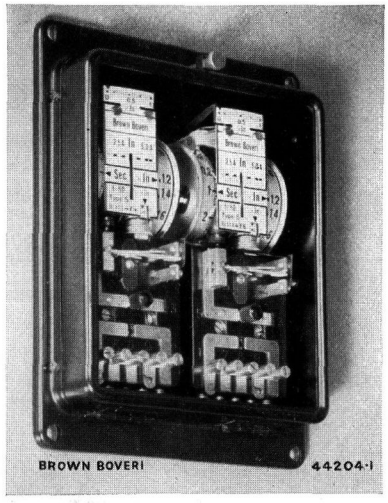


Fig. 62. — Secondary relay, in case, for counter-sunk mounting.

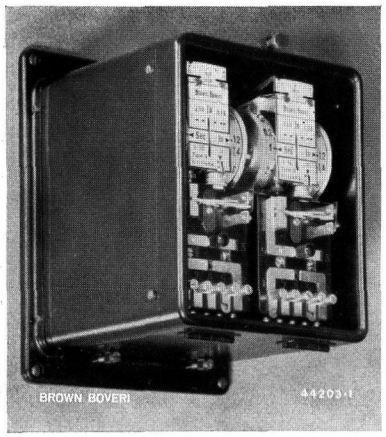


Fig. 63. — Secondary relay, in case, ready to be mounted.

In order to allow of testing different designs of relays, which may be built for very different current strengths, both quickly and with a minimum of trouble, we have developed a portable *relay-testing apparatus* (Fig. 67) for primary-system connection and composed, in essential, of a transformer without oil filling in a sheet-metal housing. The secondary winding thereof has taps to be connected to the relays being tested. The taps correspond to the big steps 5—21 A, 22 to 75 A, 76—225 A, 226—670 A, 671 to 2000 A, while the close setting of the testing-current strength, between the big-step limits, is effected by the displacement of a magnetic leg or column on the transformer by means of a handwheel, after the method used in our welding transformers.

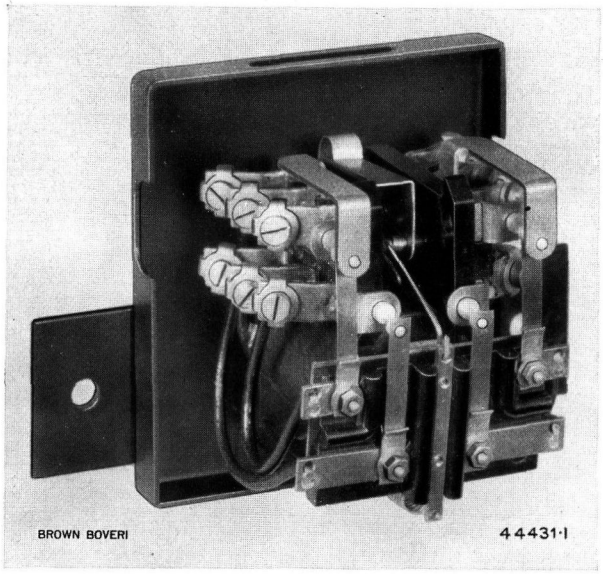


Fig. 65. — Auxiliary relay for D. C. and A. C. for 380 V rated voltage.

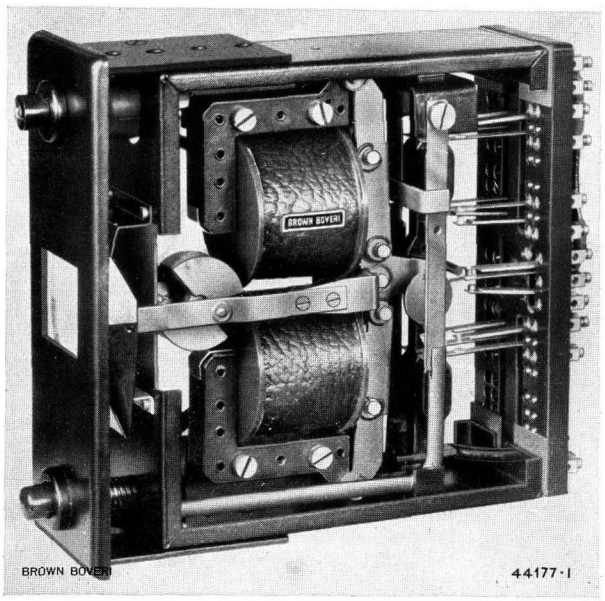


Fig. 66. — Signalling apparatus.

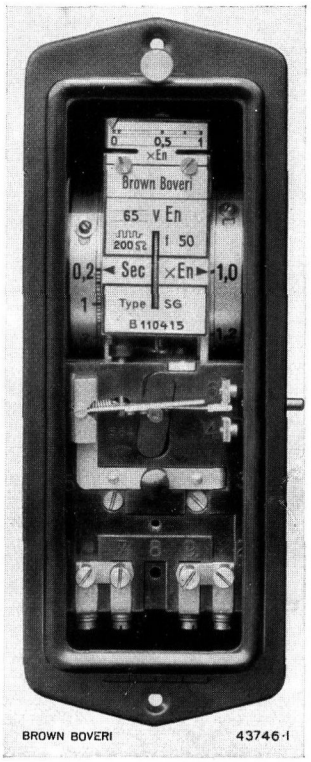


Fig. 64. — Maximum voltage relay.

6. *Switchgear plants.*

The new *air-blast high-speed circuit breaker designs* allowed of introducing some new features to medium-voltage switchgear plants. Mention should be made of the 13-kV switchgear plant delivered

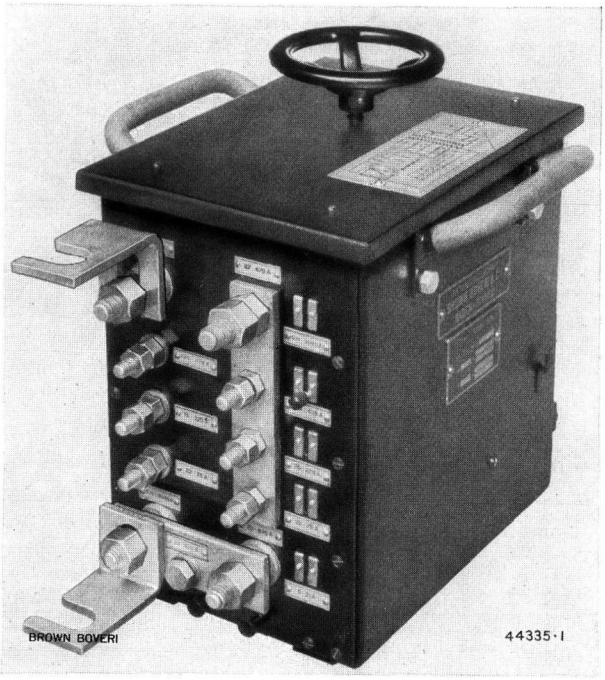


Fig. 67. — Relay-testing apparatus.

to the Cie Vaudoise des Forces Motrices des Lacs de Joux et de l'Orbe in Cossonay (Switzerland) which is shown in Figs. 68 and 69. These illustrations show up, clearly, the sharp separation of the compressed-air mechanism and low-voltage equipment from the high-voltage parts of the breaker. This makes it possible to supervise the low-voltage and compressed-air parts such as auxiliary contacts for signals, control-electro-magnets, compressed-air cylinder, valves etc., and even to do work on these parts, while the breakers are under voltage or in service.

It is possible to achieve simple, compact and safe switchboard layouts, with the help of air-blast high-speed circuit breakers, which it is not possible to attain when other types of circuit breakers are used.

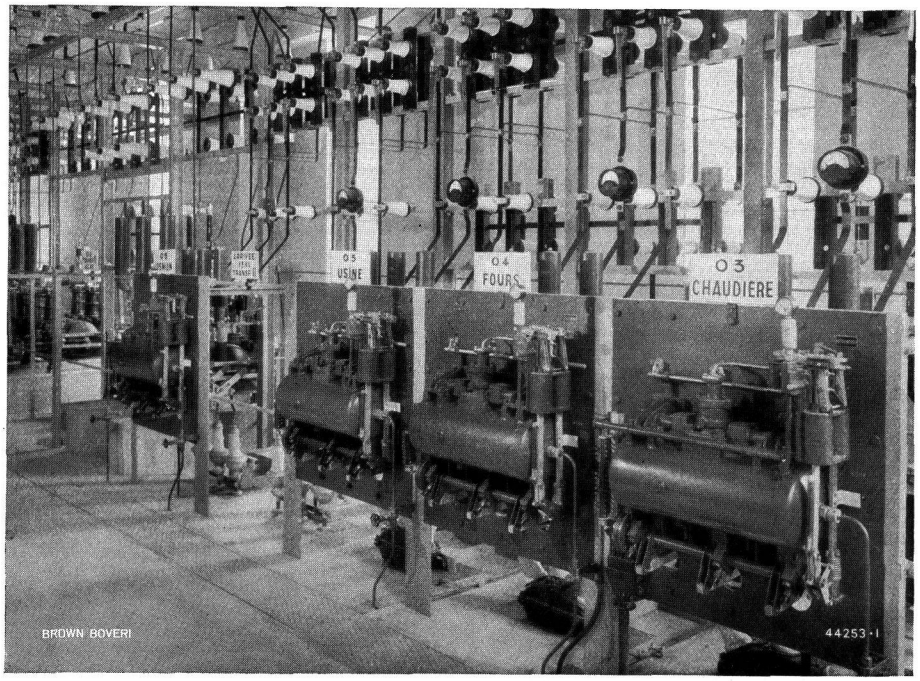


Fig. 68. — 13-kV switchgear plant with air-blast high-speed circuit breakers, belonging to the Cie Vaudoise des Forces Motrices des Lacs de Joux et de l'Orbe, Lausanne; Cossonay Station.

Low-voltage side.

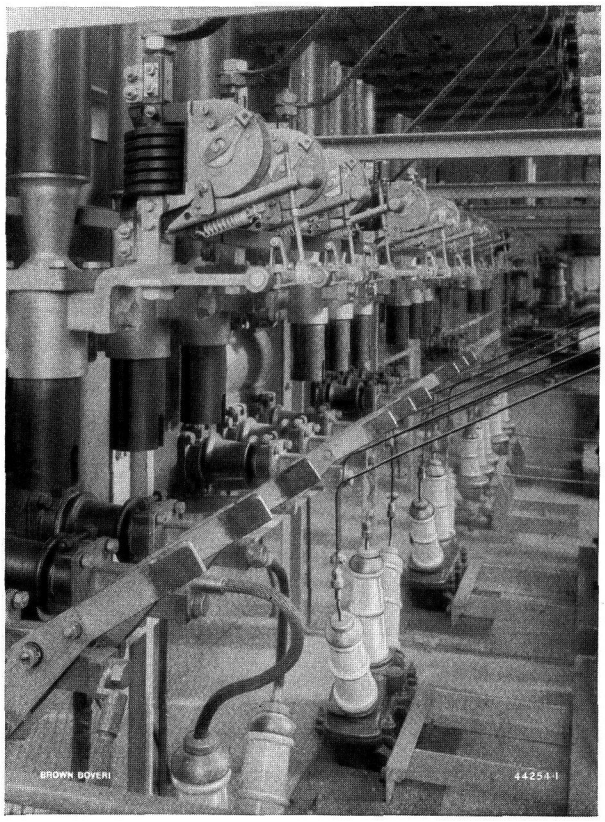


Fig. 69. — 13-kV switchgear plant with air-blast high-speed circuit breakers, belonging to the Cie Vaudoise des Forces Motrices des Lacs de Joux et de l'Orbe, Lausanne; Cossonay Station.

High-voltage side.

The compressed-air generating and distributing plants belonging to these breakers have given full proof of their reliability and are not to be considered as troublesome auxiliaries to the switchgear plant, at all; all operators agree that their availability allows of solving, elegantly, a whole series of other secondary problems. By using suitable designs, the loss of air pressure has been so much reduced that the compressed-air generator only has to run once or twice a week, if no switching of the breakers takes place, in the meantime.

The arrangement of control and recording apparatus and, as necessary, of instruments and other apparatus in the diagrams of connection of mimic switchboards is much appreciated by the personel of

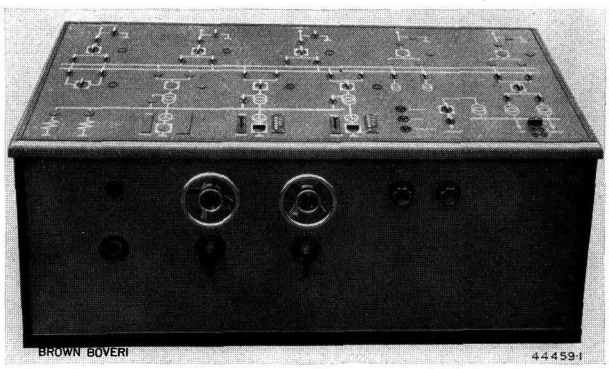


Fig. 70. — Control desk board of the Barbablanca Power Station, Peru.

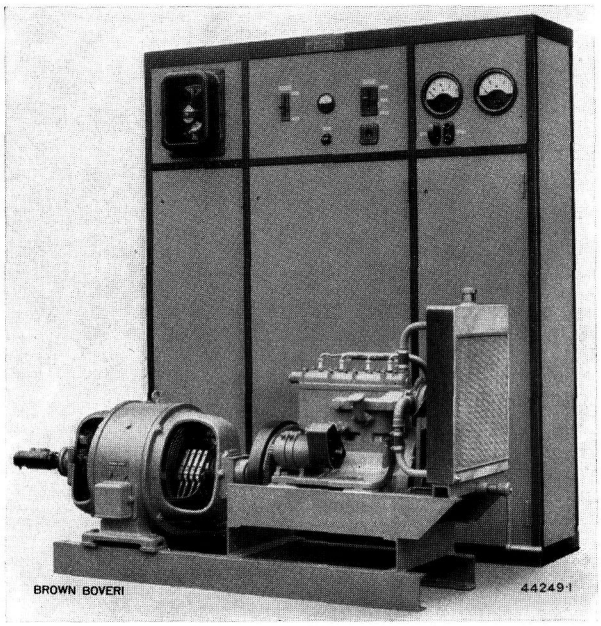


Fig. 71. — Petrol-electric emergency set. Three-phase 15 kVA, 380/220 V, 50 cycles.

stations. A desk board of this type is shown in Fig. 70, it is that of the Barbablanca Power Station, Peru. This plant, as said before, has two generators of 17,500 kVA, 6 kV and two transformers of 17,150 kVA, 6/64 kV, as first development stage and, along with the making over of the Santa Rosa Substation belonging to it, for the supply of the capital city of Lima, forms one of the most interesting orders booked in 1936. According to modern principles, both stations will be fitted with air-blast high-speed circuit breakers. Brown Boveri delivered the complete electrical equipment of the said stations.

Emergency sets have often been used, recently, to assure power supply to services which must be kept up at all costs. In collaboration with engine builders, we have developed completely-automatic sets for this purpose, with which the time elapsing between the failure of the usual source of power and the beginning of power supply from the emergency set is reduced to few seconds.

Fig. 71 shows a type of wall switchboard which swings out to allow of making both front and back accessible.

The *starting (ignition and excitation) set* for mutator plants has been newly designed. Fig. 73 shows, very clearly, how it is possible to design a pleasing apparatus taking up little room, by well thought-out combination of transformers, relays, resistances and terminals.

In the field of *high-voltage testing plants*, new and interesting designs have been brought out. The Sté d'Exploitation des Câbles électriques in Cortaillod (Switzerland) ordered a complete high-voltage testing plant from us, to generate 800 kV (r. m. s. value) and a D. C. voltage of 1000 kV. Special mention should be made, here, of the needle-type rectifier combined with the testing transformer (Fig. 79).

The following new designs of apparatus, which belong to switchgear plants proper, are worthy of note.

We have replaced the former design of *high-capacity fuse* by a new one as we found that the types used up till now did not fulfil all modern requirements. As will be recalled, extinction of the arc, in the former type of fuse, was effected by the sudden generation of gas when

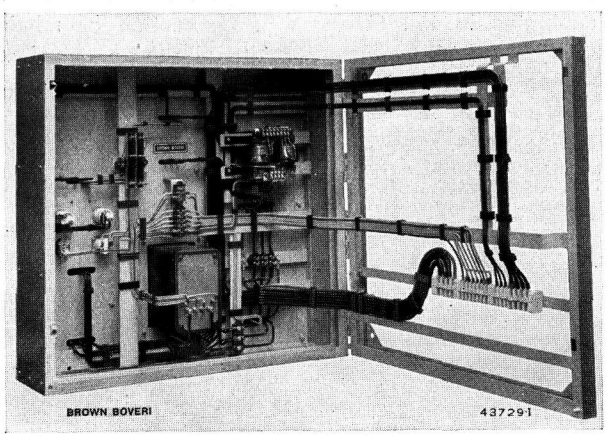


Fig. 72. — Wall-switchboard for pumping station. Back view, board swung out.

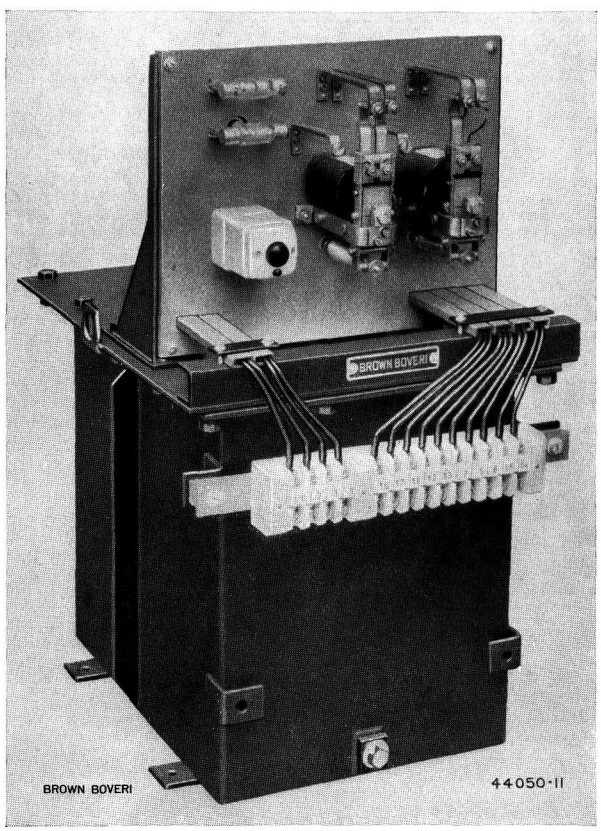


Fig. 73. — Ignition and excitation set for mutators with ignition by dipping. Front view.

the fuse wire proper melted, which produced a powerful extinguishing blast passing from the inside of the tube towards both ends. This self-producing extinction limited the rupturing capacity of fuses, in many cases, notably when the ruptured current was weak, on account of the correspondingly small amount of power in the arc. Under unfavourable conditions on the system, continuous arcs were set up in this way. In the case of heavy currents ruptured, on the contrary, the pressures generated were apt to be excessive and often caused the fuse-tubes to burst. Only average-strength currents could be ruptured with relative certainty and, in any case, when putting in these fuses the possibility of the metallic vapour ejected causing flash overs in the switchgear had to be kept in mind.

It is also possible to use liquids to extinguish the arc. Oil fuses rupturing very high currents are the seat of extremely high pressures and can explode and cause fires. In the well-known type of fuse working with tetra-chloride filling the danger of fire is eliminated but not that of the fuse bursting, further, the operation of the fuses causes the generation of poisonous gases and these attack the surrounding gear chemically.

Our investigations have led us to develop a fuse principle which eliminates the defects just enumerated. Investigations in our high-power testing plant proved to us that careful dimensioning and design of the fuse wire is essential to reliable operation of the fuse and that great importance attaches to using, for fuse wire and filling, materials which are chemically suitable to one another. The fuse wire in the tube is embedded in a special filling material. The gases generated, when the wire fuses, diffuse in the said filling and the arc is ruptured owing to the great amount of heat subtracted from it. Extinction is so intensive and so rapid that a short-circuit current cannot develop completely at all but is limited and cut out in its initiation period (Fig. 74). Thus, both fuses and plant are protected from electro-dynamical repercussions. When a fuse of this type melts, there is no inner pressure rise or outside phenomena such as flames, vapour production, detonation. The current does not fall suddenly after the rupture but goes back to zero after a certain, if very short, period. The fuse is very reliable in its extinction action, it is independent of the strength of the current and of any blow-out effect. No continuous-arc formation is possible. The fuse-tubes of the new design are of ceramic material which cannot be affected either by an overload or by the extinction process and does not carbonize like paper or paper preparations. Thus, high fuse-wire temperatures can be allowed which means short fusing time and, therefore, closer selectivity. Our new fuses have no cemented parts, can, thus, be used in the tropics and are also unaffected by salt or acid in the surrounding air. Fig. 75 shows one of the new high-capacity fuses.

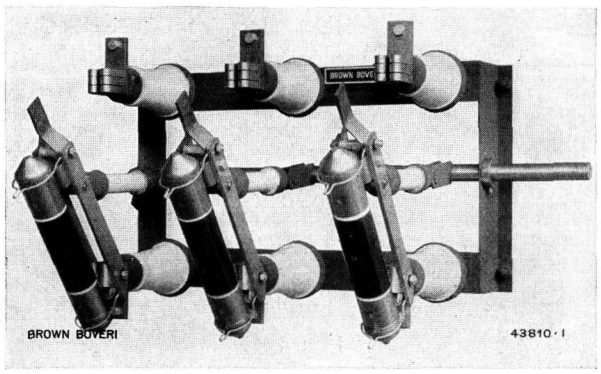


Fig. 75. — Three-pole high-capacity isolating fuse, 11-kV rated voltage.

The increase in short-circuit outputs to be dealt with, which is encountered everywhere, gives enhanced significance to the design of very high short-circuit current proof current and voltage transformers. This is especially the case for *bushing-type current transformers.* These are absolutely short-circuit proof if they are properly designed; it is easier to dimension them so that they are satisfactory from the

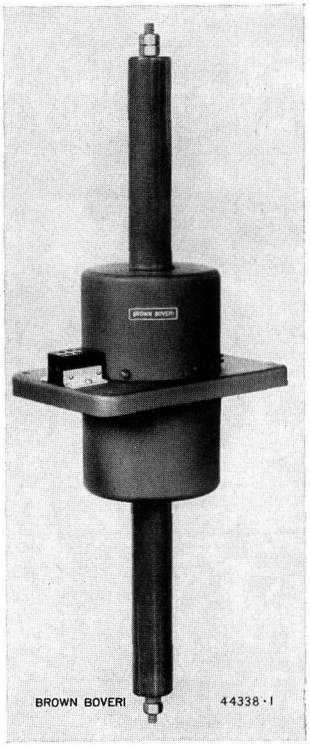


Fig. 76. — Bushing-type current transformer, 37 kV rated voltage, 250 A rated current.

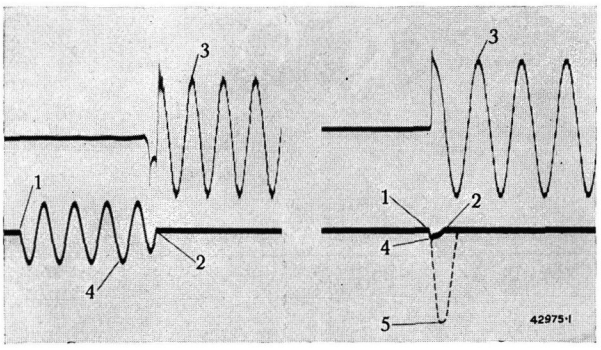


Fig. 74. — Rupturing oscillogram produced with 11 kV, 10 A, high-capacity fuse.

Left	Right
1. Beginning of overload.	1. Beginning of short circuit.
2. End of rupture.	2. End of rupture.
3. Recovery voltage.	3. Recovery voltage.
4. Current load 95 A.	4. Highest current peak attained 150 A.
	5. Short-circuit current set for 15,200 A.

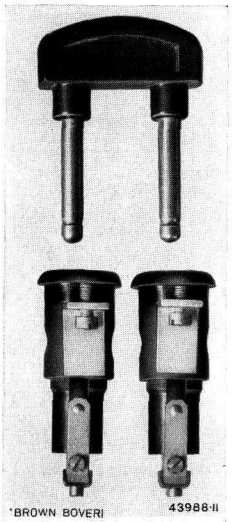


Fig. 77. — Plug contact.

thermal point of view. This makes them superior to all other current-transformer types to such a point that it must be considered a fault to put in anything else than bushing-type transformers if a suitable design thereof is really available and can be lodged in the space available.

This fact and the recognition that bushing-type transformers of the kind in use up till now, for the current ranges of 100 to 200 A and below, were much too expensive, caused us to remodel existing designs. We have been successful in bringing out a new series (Fig. 76) in which the amount of material used is brought down to a minimum without affecting quality, in any respect. The field of utilization includes voltages of 1·5 to 110 kV and primary-current strengths of 5 to 2500 A. This range of transformers is characterized by its great adaptability to all possible conditions of service.

By making efficient use of all the material used in the construction of the new apparatus, a series of *loop-type current transformers* was brought out. These are built for a voltage range of 11 to 110 kV; the range of primary current is limited to 5—250 A. Owing to the considerable length of primary winding which is cradled in the bushings, the loop-type of transformer is, dynamically, very strong against short circuits. As regards heating, it can stand a current 100 times the standard rating for a period of one second.

Mention should also be made of a new design of *plug contact* we have brought out (Fig. 77).

We would like to say here again, that, whenever it has been possible to do so, we have eliminated cemented points in favour of clamped connections in the armatures of the supporting insulators used in switchgear plants and in our apparatus.

An important *outdoor switchgear plant* was built, last year; this was beside the *Olten-Goesgen Power Station* and was put up by the Aare-Tessin Co. (Switzerland). It contains the regulating transformer for 32,500 kVA and convector circuit breakers. Despite its size, the plant, equipped with our material, is characterized by great simplicity and ease of supervision (Fig. 78).

II. POWER DISTRIBUTION AND CONVERSION.

A. TRANSFORMERS.

On-load tap-changing switches are being increasingly used in transformers, particularly in those put into substations. In our last year's report we mentioned our new type of on-load tap-changing switch with coarse and finely-graded selector, and we may say that it has given an excellent account of itself, in practice.

Mention can be made, here, of a three-phase tap transformer for the Breitenbach Substation of the Elektra Birseck in Munchenstein (Switzerland) which unit is of indoor design, with natural cooling, for 4000 kVA and 50,000 V on the high-voltage side. The low-voltage winding is for 12,600 V no-load voltage and can be regulated upwards by an on-load tap-changing switch in 15 steps each of 154 V. A three-phase tap-changing transformer in auto-connection was, also, delivered to the Schüpfheim Sub-

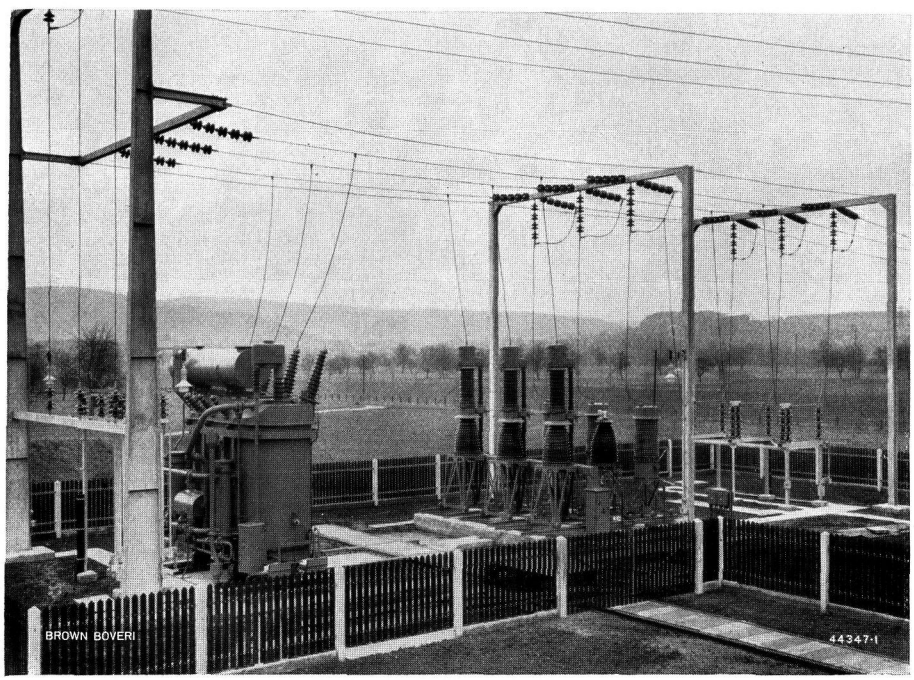


Fig. 78. — Outdoor station of the Olten-Gösgen Power Station of the Aare-Tessin A.-G., Olten, with three-phase regulating transformer for 32,500 kVA, 167,000/48,490 + (23 × 822) V, convector circuit breakers, voltage transformers and disconnecting switches.

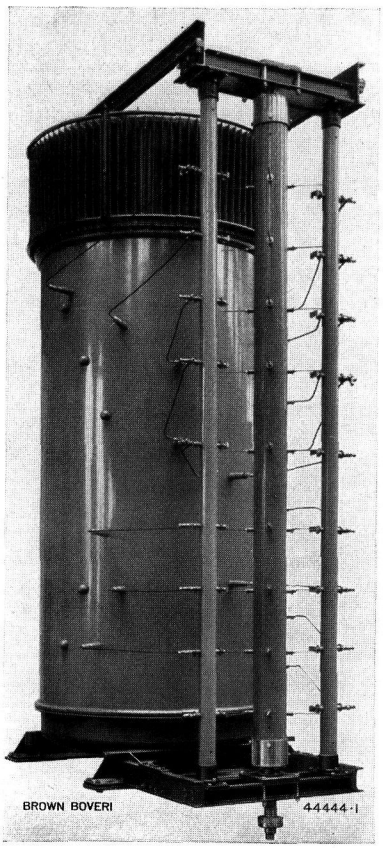


Fig. 79. — Cortaillod Cable Works. Testing transformer for A. C. 400 kVA. 400 kV (r. m. s.) 50 cycles and for D. C. 500 kV.

Lima (Peru), two three-phase transformers with internal water cooling of the oil filling, each for 17,200 kVA, 51,000 + 23 × 575 V/10,700—10,350—10,000 V, the taps on the high-voltage side being brought to an on-load tap-changing switch while, on the low-voltage side, the taps are connected to a tap switch to be operated when the transformer is cut out.

Mention should also be made of the order received from the Société d'Exploitation des Câbles électriques système Berthoud Borel & Cie in Cortaillod (Switzerland) for two *testing transformers* each of 400 kVA, 1000/400,000 V, 50 cycles to be cascade-connected for 1000/800,000 V, 800 kVA. These units are combined with a mechanical needle-type of rectifier so as to supply an impulse-generating plant at 2000 kV and station of the Centralschweizerische Kraftwerke (Switzerland). This unit is, also, for indoor use and is built for 1200 kVA continuous output, 11,250 ± 10 × 95 V/12,200 V with automatic regulation of the tap-changing switch. Further, we supplied, for the Santa Rosa Substation of the Empresas Eléctricas Asociadas, in to allow of D. C. tests at 1000 kV. The formation of the cascade set and the combination with the rectifier along with the leading-out of the taps to be served by the rectifier made it necessary to create a quite new design of testing transformer. Fig. 79 shows the transformer completed, which has already been mentioned in the preceding pages.

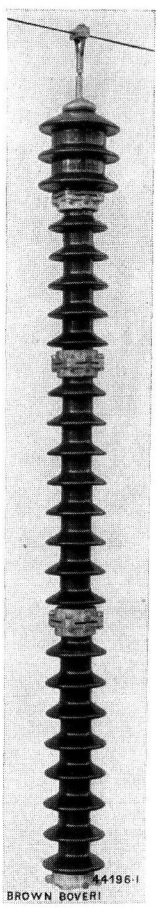


Fig. 81. — Lightning arrestor Type HF 57 and HF 64 respectively 57 kV and 64 kV rated voltage respectively.

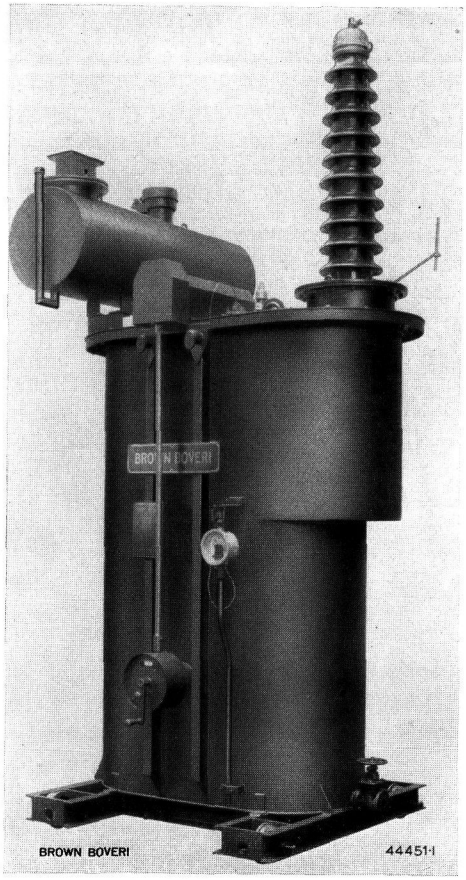


Fig. 80. — Single-phase, oil-immersed dissonance extinguishing coil, 2860 kVA (two-hours rating), 127,000/190 V, 50 cycles, 39—30 A.

B. DISTRIBUTION-SYSTEM PROTECTION.

In last year's report, we mentioned the large number of our *dissonance extinguishing coils* which had been ordered. In 1936, the *Kungl. Vattenfallstyrelsen in Stockholm* ordered from us five of these coils for the Porjus, Lulea, Vannäs, Oernsköldsvik and Bispgarden plants, these being for 7500, 2860, 8900 and 4200 kVA two-hour rating. The unit for the Porjus Power Station, of 8900 kVA, is one of the biggest extinguishing coils ever built. The coil has 15 taps, led to a tap switch in an oil tank and which is of the on-load type. The operator can determine, by means of the on-load tap-changing switch, the symmetry point (resonance point) at any time.

The coil in the Lulea plant is shown in Fig. 80.

The *Resorbit lightning arrestor* of our well-known type has been further developed for voltages between 37 and 64 kV with an absorption capacity corresponding to the increased requirements. Further,

in parallel with the existing series of from 3·7 to 37 kV, we have brought out a new series of arrestors with increased conductive capacity. Fig. 81 shows one of the new 64-kV arrestors, for suspended mounting.

C. THE COUPLING OF SYSTEMS.

The outstanding service results attained with the eleven system-coupling converter sets with commutator cascade connections on the induction side, which, incidentally, led the Swiss Federal Railways, against their first intention, to leave in service the set delivered to the Seebach Substation instead of stopping it, after the starting-up of the new Etzel Power Station, was the reason for the ordering of two further similar converter sets in the course of 1936.

One of the new sets will be placed in the plant of *Spigno-Monferrato of the Acciaierie e Ferriere Lombarde Falck-Milano* (Italy) and will be built by Tecnomasio Italiano Brown Boveri, Milan. It is remarkable both from its layout and the conditions under which it is to work. The vertical-shaft synchronous machine, connected to the three-phase system of the Italian State Railways, is built for 9000 kVA, 500 r. p. m., 3500—4000 V, 16 $^2/_3$ cycles and is coupled, on one side, to a hydraulic turbine and, on the other, to an induction machine to allow, alternatively, of connecting up to the industrial systems, 6300 V, 50 cycles, and 5100 V, 42 cycles. The frequency changer for the separately-placed Scherbius regulating machine is on the same shaft above the induction machine and over the supporting bearing, quite at the top and on the same shaft there is, also, a small auxiliary generator.

Apart from the arbitrary and alternative exchange of power between the two systems, independently of the frequency fluctuations of the said systems, or solely dependent on the frequency oscillations on the railway system, the following kinds of operation are possible:— Connected to the Scherbius regulating motor, the induction machine can run as a pure phase advancer, its reactive output being 5000 kVA at 6300 V, 50 cycles and 4000 kVA at 5300 V, 42 cycles; it can run as an induction generator and as a phase advancer, as well, the commutator machine regulating the reactive load so that the generator delivers between 6500 kW at p. f. = 1 and 7500 kVA at p. f. = 0·86, when connected up to 6300 V and 50 cycles. When connected up to 5300 V and 42 cycles it can give 5400 kW at p. f. = 1 and 6300 kVA at p. f. = 0·86. The active power delivered by the generator is covered by the hydraulic turbine. The induction machine can, however, also work, unconnected to the Scherbius unit, as an uncompensated induction generator giving 6500 or 5400 kW at p. f. = 0·86 to the 50 or 42-cycle industrial systems, respectively. The double-type Scherbius regulating machine is built for 750 r. p. m. and is coupled to a starting three-phase motor with wound armature. The excitation power required for the synchronous machine connected to the railway system is furnished by a special exciter set composed of a three-phase driving motor and a main and auxiliary exciter. A further exciter set composed of a driving motor and three-phase commutator machine, designed as a double unit, delivers the excitation for the Scherbius regulating machine.

Together with a British firm, we got an order for a 25,000-kVA system-coupling converter set, towards the close of last year. This is the most powerful set of its kind built, so far, and is for the *New South Wales Government Railways.*

The duty of the set is the flexible coupling of two three-phase systems of 25 and 50 cycles, respectively. Power exchange is to be in both senses. The induction machine must, also, be able to run as an independent generator. The synchronous machine is connected up to the 50-cycle system and, as a generator, has an output of 25,000 kVA at p. f. = 0·85, overexcited and 11,000 V terminal voltage. The induction machine has the same output and is wound for 6600 V. The frequency on the 50-cycle system fluctuates between 49·5 and 50·5 cycles that on the 25-cycle system between 24·5 and 25·5 cycles. The starting up of the set must be automatic, by push-button control and either from the 50-cycle side or the 25-cycle side. A change-over pole starting motor is used, to this end, which is coupled to the set.

The plant mentioned in our last year's report for the flexible coupling of a 50-cycle industrial system and a 16 $^2/_3$-cycle railway system by means of a single mutator has been completed and tests begun thereon.

D. MUTATORS.

In this field, which is still rich in development possibilities, there are some interesting innovations to record. For the *Soc. pour l'Industrie Chimique, Monthey* (Switzerland) we built a small mutator without water cooling and of the type mentioned in our last year's report. This unit is built for 6000 V and 5 A to supply *an arc-flame furnace* which, it is hoped, will produce more than the single-phase arc furnaces used up till the present. Further, a 300-kW mutator is in course of manufacture for *Soc. Metallurgica Italiana,* the controlled grids of which are to convert 50-cycle three-phase current into single-phase, 1000-cycle current, in order to supply a single phase induction melting furnace.

As a result of further investigations in our laboratories, all mutator types were subjected to certain constructive modifications. Above all, the anode valve was redesigned to meet the latest knowledge available on this subject. The vacuum-pump

set is, now, invariably, built on to the cooling sleeve of the main cylinder. Four supporting feet in the place of three are now delivered and these can be equipped, on request, with insulated rollers (see Figs. 82 and 83).

At the top of the list of mutator equipments ordered last year, comes the order for 27 sets each of 2500 kW output, for 660 V D.C. for the *Southern Railway* which are intended for the various substations on the Portsmouth line, to be electrified shortly. The mutators and their transformers are being built by our concessionaries Bruce Peebles, Edinburgh, the switchgear in the Baden shops. The total number of mutators delivered by us or our concessionaries to the Southern Railway amounts to 68 units, with a total output capacity of 170,000 kW.

Of hardly less importance, is the order for 16 mutator sets each of 1000 kW at 1530 V D.C. for the substations of the Arnhem-Utrecht-Amsterdam-Utrecht-Eindhoven, the Utrecht-Gouda-Rotterdam and the Gouda-Haag lines which the *Dutch State Railways* intend to electrify. This order is all the more worthy of note, because thanks to the excellent results attained with our earlier mutators we were the only European firm to get by far the major part of the order (26 sets) while what remained — 10 sets — went to an American firm. All these new mutators have controlled grids as a protection against back-fires and short circuits. The total number of mutators delivered to the Dutch State Railways amounts to 63 units with a total output capacity of 44,500 kW.

The Pilatus Railway, one of the oldest of our mountain railways has, finally, gone over to electric traction and we were favoured with the order for the substation equipment to supply this line. This comprises two mutator sets each of 600 kW, 1500 V full-load voltage. The primary side is linked up to the 50-kV ring system of the Centralschweizerische Kraftwerke. The two mutator sets are so dimensioned that they can be overloaded by 25% for the duration of the up-grade trip. As is the case of most of the recent railway substations, this one is equipped for fully-automatic operation, the putting in and cutting out of the sets can be carried out from the office for

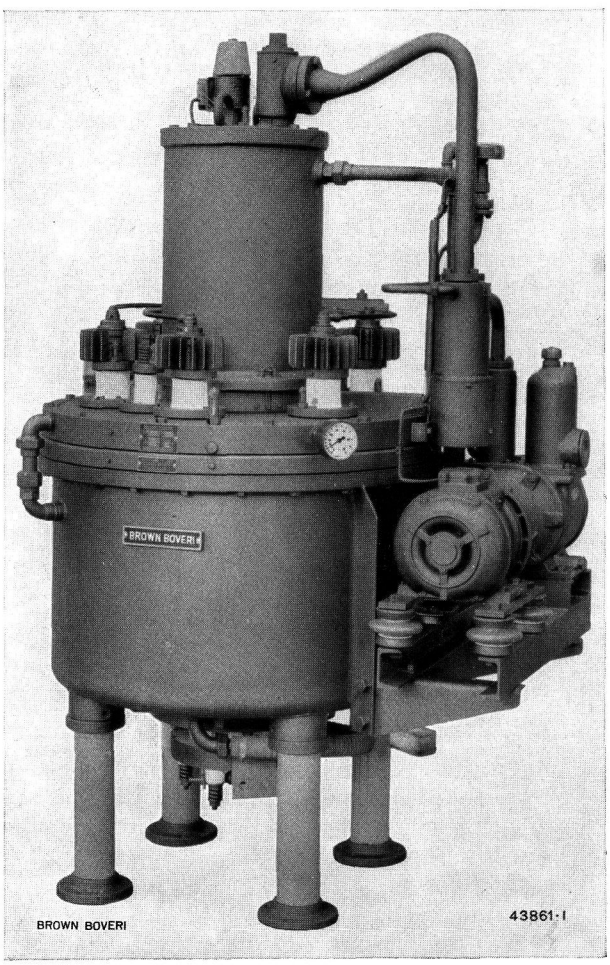


Fig. 82. — Mutator set with built-on vacuum-pump set, 184 kW, 230 V, 800 A.

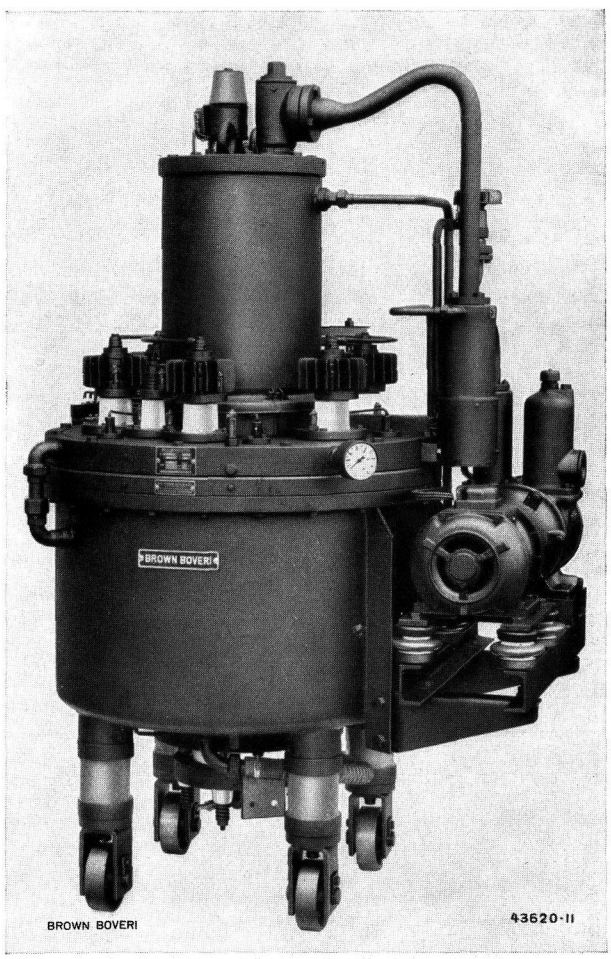


Fig. 83. — Mutator with built-on vacuum-pump set and supports with insulated rollers, 480 kW, 600 V, 800 A.

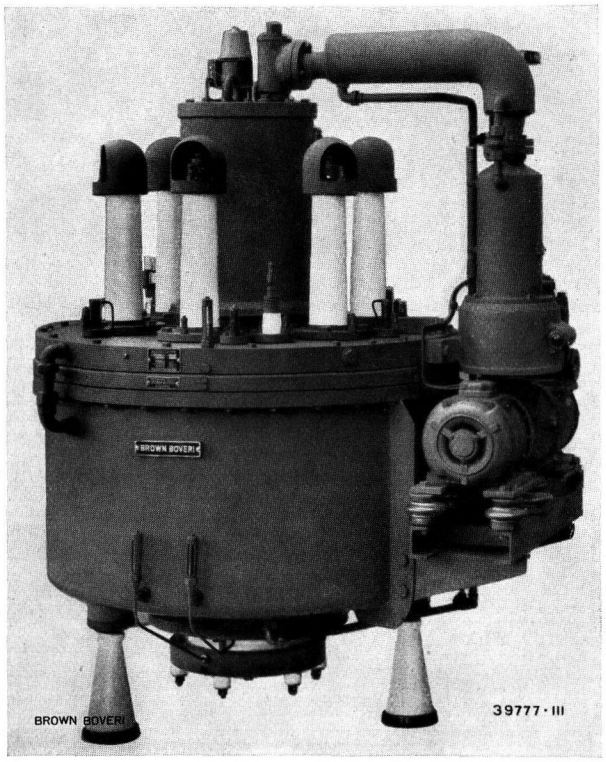


Fig. 84. — Mutator with built-on vacuum-pump set for the broadcasting station, Rome.

service supervision and all trouble messages are reported here by optical and acoustical signals.

The *Letten Substation of the Town of Zurich Electricity Works* was equipped with two mutators, 1100 kW, 620 V for tramway-line supply and the Cie Electro-Mécanique, Paris our French concessionaries got an order for 8 mutators each of 2000 kW, 1560 V D.C. for Courtillère, Bessanges, Polerol and Moulinette Substations which are on the Tours - Bordeaux line, which the *Paris - Orléans-Midi Railway* are, now, electrifying.



Fig. 86. — Mutator plants Warfield I and II of Consolidated Mining and Smelting Co. of Canada.

Our last year's report mentioned mutators each of 1000 kW and 20 kV for the Rome-S. Palomba broadcasting station, these have now been put to work (Fig. 84). There are three 1200-kW

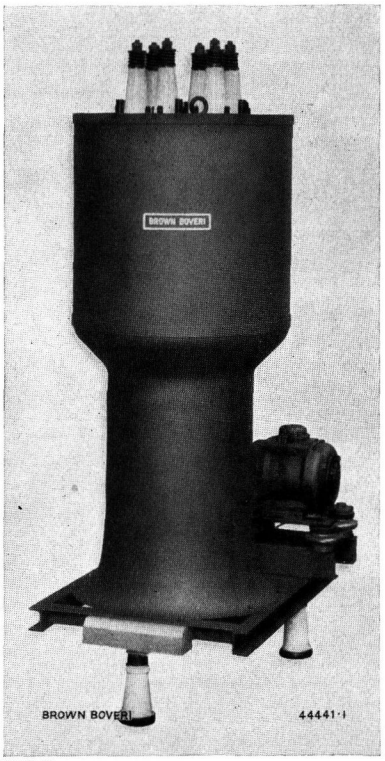


Fig. 85. — Mutator set for broadcasting station, China, with cooling by artificial air draught for both mutator and high-vacuum pump, 140 kW, 10,000 V, 14 A.

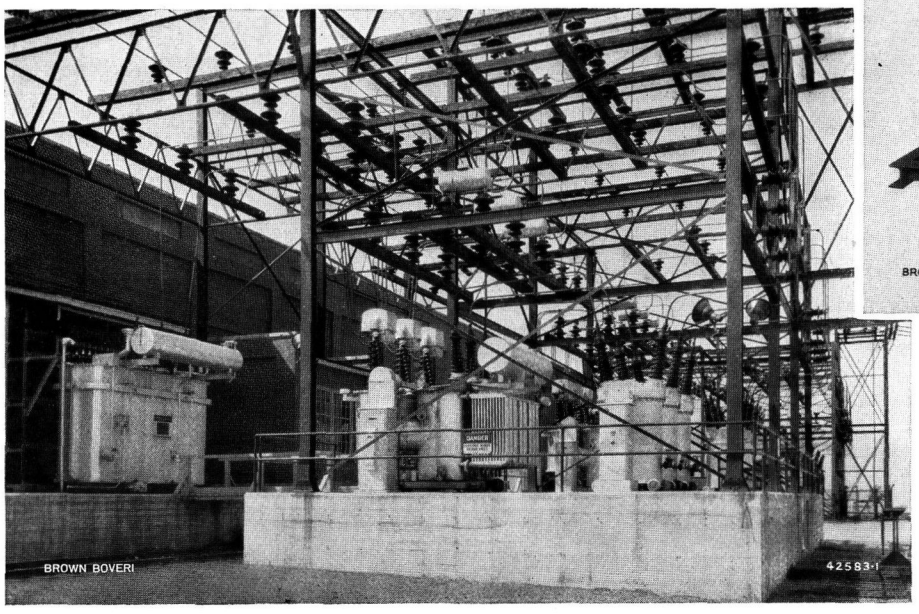


Fig. 87. — Outdoor station Warfield II of Consolidated Mining and Smelting Co. of Canada.
Each set has an oil circuit breaker, regulating transformer and a mutator transformer.

sets, 20 kV D. C. ready for starting service for the Sté Française Radio-Electrique in Paris and there are two units building each of 1500 kW at 12 kV for the broadcasting station of the U. S. S. R. the biggest built by us for this purpose, so far. Further the new, small air-cooled mutator (Fig. 85) which has met with such a welcome, in practice, has already been sold for broadcasting up to 12 kV in a plant in the Far East.

A big plant for aluminium electrolysis to which we already supplied eight mutators to give a total output of 27,500 A, is now being enlarged to take four of our mutators to produce, together, 20,000 A.

Fig. 86 shows the mutator plant of Consolidated Mining and Smelting Company of Canada, which already has 14 mutators of ours to deliver a total of 70,000 A. Fig. 87 shows the outdoor switchgear plant. Two big mutator plants for electro-chemical purposes, ordered last year from one of our concessionary companies are worthy of note. In one case, there are four mutators for a total of about 10,000 kW and 14,000 A on the D. C. side. A new kind of connection and design of the primary-side transformers had to be developed for this plant. The second plant has eight sets for a total of 80,000 A at 800 V D. C., three units working on a furnace system of 30,000 A. In all, there are two such systems, one being a stand-by. The plant is supplied at 6150 V. The mutator transformers have special connections.

III. OUR PRODUCTS IN INDUSTRY, TRADE AND AGRICULTURE.

A. DRIVES BY ELECTRIC MOTORS.

As the evolution in the design of our three-phase motors had reached a certain point of completion, at least as far as the units of low and average output are concerned, it was the turn of the *D. C. machines* to undergo a revision of design, the partial aim of which was to reach as close a degree of constructive similarity as possible with the three-phase motors of the same outputs and speeds and to make them as adaptable to the machines they are called on to drive as the latter have become in recent years.

The first D. C. machines to be revised were those of the 0·6 to 70 kW output range in which the standard design is also drip-water proof. There is a big opening on the commutator side, downwards, which gives access to the commutator and brushes. Further the brush rocker is designed to allow of rotating it, to make the changing of brushes easy. All these machines have both ample and strong ball bearings, constantly lubricated by grease, as is the case of the three-phase motors, so that the machines can remain for years in service without supervision.

Apart from the standard design with supporting foot and horizontal shaft (Fig. 88) the same motors

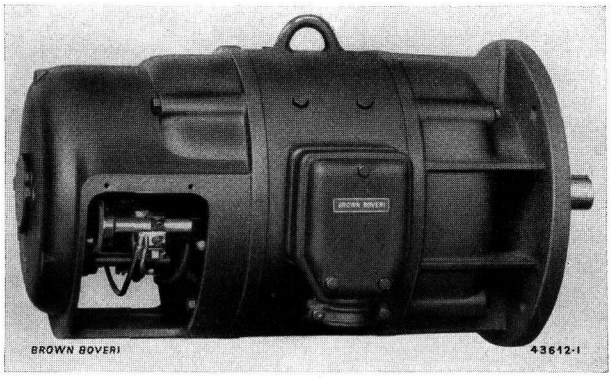


Fig. 89. — D. C. machine, 220 V, 6·6 kW, 1430 r. p. m.
Design with flange and feet, drip-water proof.

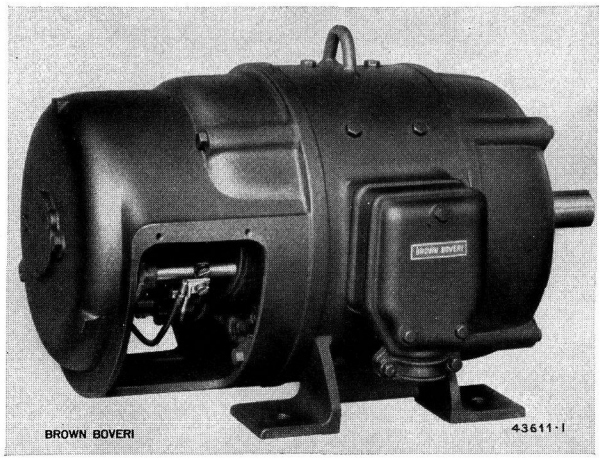


Fig. 88. — D. C. machine, 220 V, 6·6 kW, 1430 r. p. m.
With feet and in drip-water proof design.

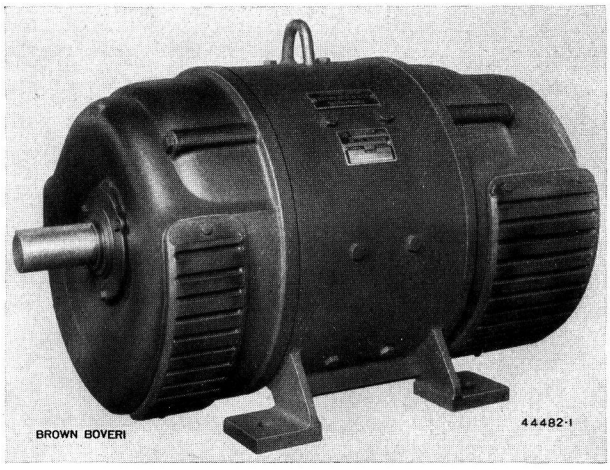


Fig. 90. — D. C. machine.
Wave-wash proof design.

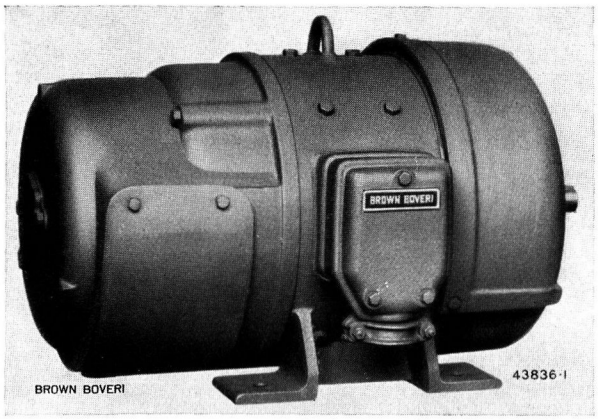


Fig. 91. — D. C. machine.
Totally enclosed, external fan and with foot, shaft horizontal.

are built with flange for close combination to industrial machines (Fig. 89) or for mounting vertically. Apart from the drip-water proof design, they are also built wave-wash proof (Fig. 90) and totally enclosed with surface cooling (Fig. 91).

There are suitable designs of terminal boxes to allow of chosing the best arrangement of leads, either brought in in pipes through glands or else composition-filled cable-end boxes; according to needs, these terminal boxes can be turned or put on at a slant.

As regards *special motors*, we have created new types of *loom motors*, forming a natural sequence to the successful development of the small three-phase motor. These new loom motors are characterized by their great adaptability to the needs of loom drive. The excellent results attained with cast aluminium rotor windings in standard motor types made it a natural consequence to use this design for the new loom motors, this all the more so as loom drive makes severe demands on the mechanical strength of the motors and, therefore, rotors are desirable which can stand up to the heavy vibrations and shocks inherent to these drives and which are as indestructable as it is possible to be. To this end, both shaft and ball bearings are designed to be very strong. Efficient external cooling of the motor housing allowed of keeping the temperature rise down, which is a very desirable feature. Both fans and air ducts are so designed that dust cannot collect and hinder the passage of cooling air. The high starting torque means rapid starting of the loom so that the slay movement is strong enough, from the first, and that the pick is properly made. Further, these motors are characterized by low power consumption under standard loom operation.



Fig. 92. — Three-phase loom motor with external cooling and surface for securing the motor. View from driving side.

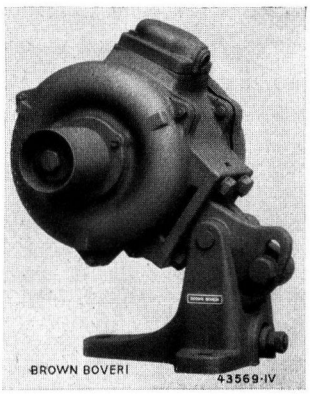


Fig. 93. — Three-phase loom motor with external cooling and cradle to drive loom by belt. View from driving side.

Figs. 92, 93, 94 and 95 show the numerous uses to which these motors can be put, for the most varied arrangements of loom drives with looms of different kinds. Fig. 92 shows one of our loom motors of standard design and with machined mounting surface for securing it. Fig. 93 is the arrangement for combining with a cradle, to drive the loom by means of a flat belt or a rubber V belt. Fig. 94 shows the combination of the motor with a spring type of jockey pulley, with ball bearings, for belt drive when the shafts are close together and whatever the angle of belt pull may be. Fig. 95

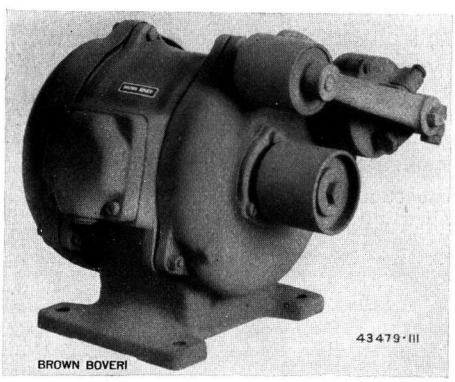


Fig. 94. — Three-phase loom motor with external cooling and built-on jockey pulley of spring type.
(For belt pull from above.)



Fig. 95. — Three-phase loom motor with external cooling and foot bolted on. Seen from driving side.

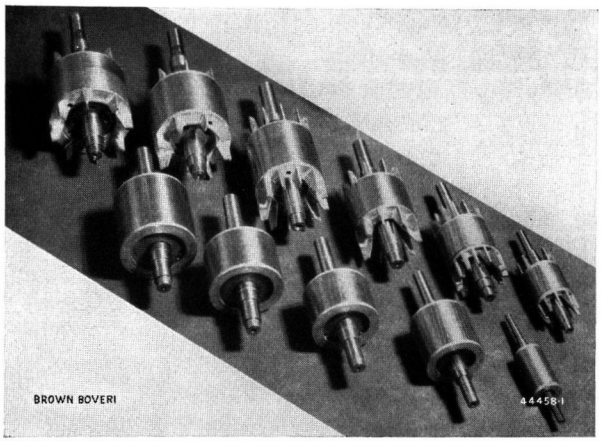


Fig. 96. — Rotors with cast-aluminium winding.

shows the motor with bolted-on foot, allowing of lodging it on the top of the loom or any other textile machine.

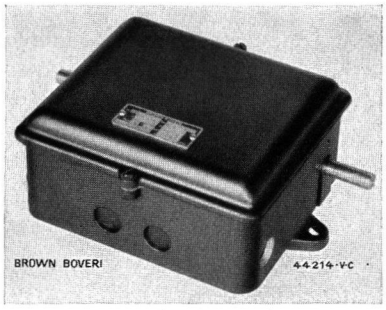


Fig. 97. — Loom switch with free shaft ends.

The use of the cast aluminium rotor winding was extended from the range of the smallest motors up to about 5 kW and for all numbers of poles. The improvement inherent to this type of rotor is thus made available for the whole range of outputs in question. Fig. 96 shows a number of such rotors of different sizes and numbers of poles. The rotors of the loom motors have no cooling blades as these units are only built to the totally-enclosed design.

The *switches* belonging to these motors were also redesigned. As Figs. 97 and 98 show, the switches in question are, now, totally enclosed and dust-proof. The housing and cover are of light metal, the cover being secured by two screws so designed that they cannot fall out; they assure a dust-tight closing.

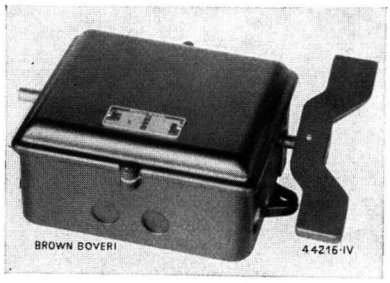


Fig. 98. — Loom switch for pedal control.

The switch design used in loom motor drives, which has given an excellent account of itself, namely the drum type switch with lubricated contacts for frequent switching, has been maintained. The fixed contacts can be used on both sides and, thus, require infrequent replacement only. The loom switch is built as a three-pole cut-out switch and as a three-pole reversing switch and with free spindle end to be connected to the control rod of the loom; it can also be equipped with pedal device for looms with controlled coupling. The switchbox is spray-water proof as well as dust-proof; it can be used not only in loom mills but in other services where a dusty atmosphere is to be expected, where spray water has to be reckoned with and where switching is of frequent occurrence.

The increased interest manifested during the course of the last year for *regulated drives of spinning and doubling frames* gave us an opportunity to deliver, to various countries, large numbers of these drives with the new *spinning regulator* referred to in last year's report. These drives have been most satisfactory. The adjustment, by means of



Fig. 99. — Cotton ring-spinning frames with variable speed drive by three-phase shunt commutator motors with spinning regulators.



Fig. 100. — Cotton ring-spinning frames with step-pulley drive by totally enclosed squirrel-cage motors with external cooling and built-on switchboxes.

a single key, of the regulated values is much appreciated. This allows of the spinning regulator being set easily without any adjustments of the excentric cams, so that the exact speed diagram is attained which is most suitable to the spinning and doubling frame driven and the yarn number worked to. Thus, our new spinning regulator, working together with our three-phase shunt commutator spinning motor, offers the highest degree of adaptability to the spinning process being carried out, makes for easy as well as efficient supervision and for the best utilization of the spinning and doubling frames used. Regulated drives of this kind can, even, be used to advantage in plants which produce only one kind of yarn as they encourage investigations into the possibilities of using other and higher spinning speeds and lead directly to better production and more competitive conditions. Fig. 99 shows a plant equipped with our motors and regulators, in 1936.

In cases in which it is thought advisable to do without the advantages inherent to variable-speed spinning, in order, for example, to keep first costs low, squirrel-cage motors can be used. We have developed a simple driving arrangement for mills of this kind, for belt drive over a *step pulley* and jockey pulley and using externally fan-cooled, totally-enclosed motors (Fig. 100). Both motor and driven machine are equipped with two-step pulleys of double width. The diameters are so chosen that the speed difference between the two steps is about 12 %. The cop bottom is spun at the lower speed and the upper part of the cop at the higher one. Compensation of the periodic variable thread tension is not possible, here. Thus, such extensive and manifold improvements of working process in a mill as are characteristic of the spinning regulator combined with the commutator motor are out of the question, here. Nevertheless, the number of thread breakages can be kept down to a moderate number during the starting period and the spinning speed as compared to ordinary line transmission drive, can be increased, which means increased production.

Apart from the special design for ring spinning frame drive, several other interesting applications have been found for the three-phase shunt commutator motor, in the course of last year. Thus, for example, for driving aluminium rolling mills, leaf bridges, braces and rotary presses. A noteworthy order was that for the drive of a rotary machine 34 m long with 15 printing sections, for the newspaper "Paris-Soir". Each unit is driven by a 50-H. P. three-phase shunt commutator motor with a speed regulating range of 1 : 5, combined with an auxiliary drive and overhauling clutch, through a noiseless chain. Regulation is, entirely, automatic with all interlocks and signalling devices requisite to perfect and reliable running. For the drive of the printed units when coupled together, there is a special relay to see that the load is evenly distributed on the various motors.

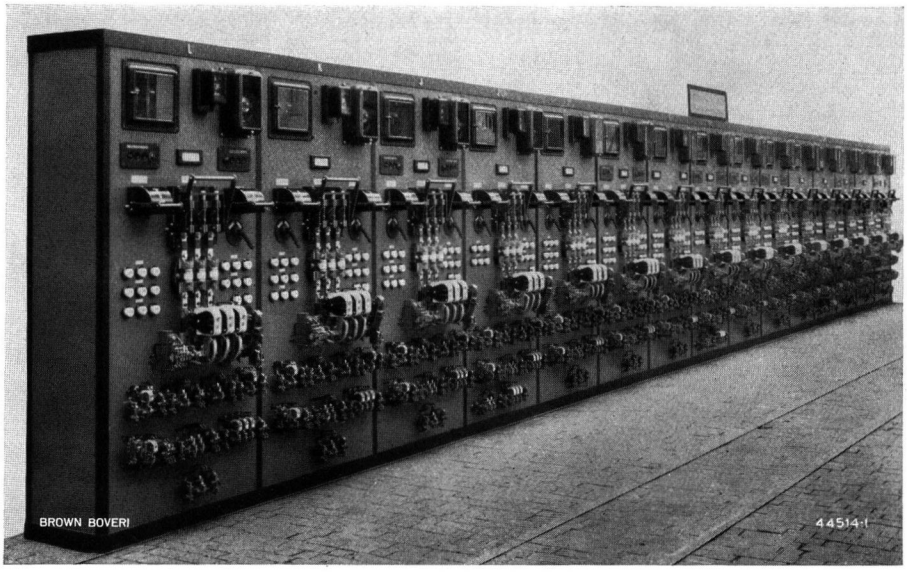


Fig. 101. — Paris-Soir printing plant, Paris. Switchboard for a rotary machine drive.

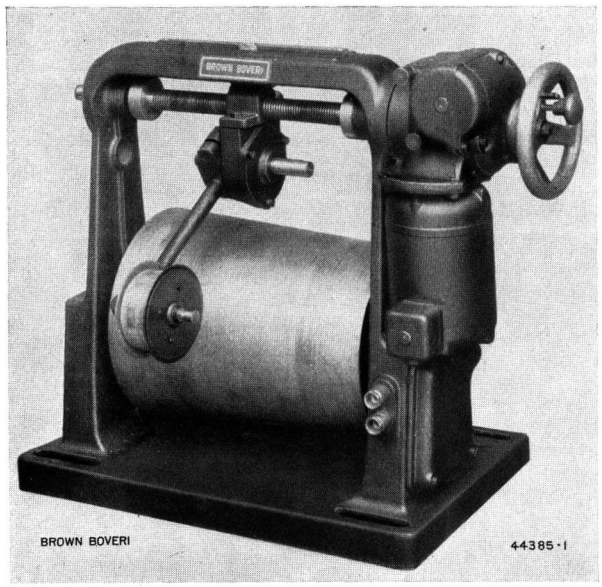


Fig. 102. — Frequency generator built into conical pulley for sectional drive of paper-making machines.

Fig. 101 shows the switchboard, 14 m long, of the said drive. In order to assure good supervision in service, all apparatus is mounted exposed and placed so as to be easily seen and got at, on the front of the board.

For the regulation of the paper draw in the *sectional drive of paper-making machines*, we use as mall three-phase generator on each driving set, which is driven through a conical pulley so as to allow of setting the exact speed as compared to the pilot speed (draw adjustment). As, in most cases, it is desirable that this generator and the drive should take up as little space as possible, we have brought out a new design in which the generator is lodged in the conical pulley. By suitable arrangement of a fixed stator and exciter winding the usual slip rings have been eliminated which reduces supervision to a minimum and increases reliability. The electric properties of this generator (Fig. 102) are so chosen that the electric differential supplied by it is sure to come into synchronism after the starting up of the driving set.

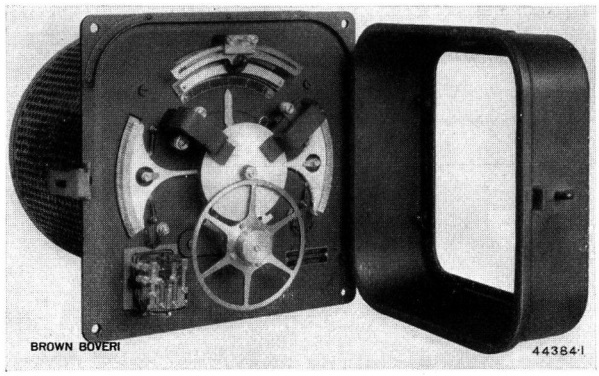


Fig. 103. — Draw regulator with built-in synchronizing relay.

The requisite synchronizing relay which has only got to handle low currents has been built into the draw regulator (Fig. 103) which does much to simplify outer connections and reduces the costs of lodging the apparatus in the switchboard.

The field of application of our standard three-phase motors has been further widened by the re-designing of *geared motors* and *gears for motors*. Fig. 104 shows motors of this kind with planetary gear drives built by the v. Roll Iron Works in Clus, (Switzerland). The pleasing design and coaxial layout of motor and gear shaft are striking features, here. The gears are oil-lubricated and entirely shut off from the motor. The high degree of precision in the execution of these gear wheels makes the machine a suitable one for the severest of continuous-service requirements. The reduction ratio can be graded by suitable choice of the gear wheels, so that, practically, any speed required can be provided.

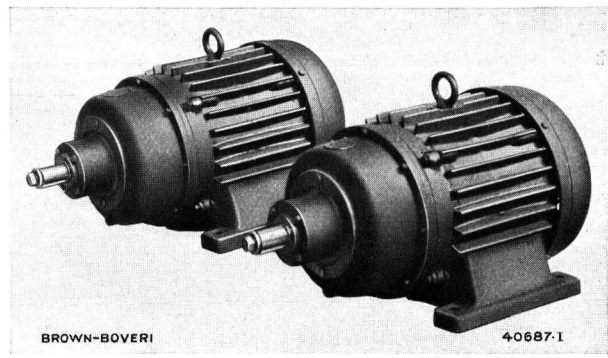


Fig. 104. — Three-phase geared motor, totally-enclosed design.

A special built-on jockey pulley is, now, used for three-phase motors driving through a

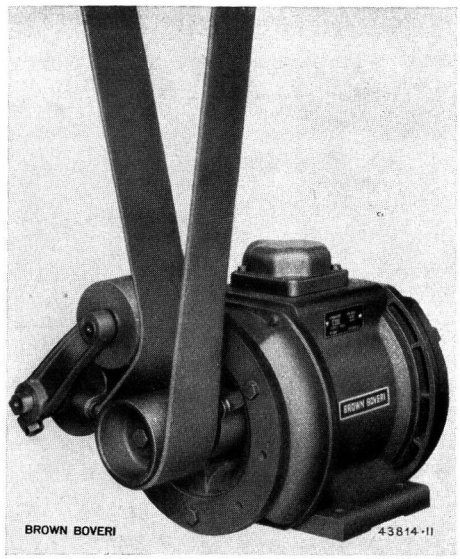


Fig. 105. — Three-phase motor, 2·2 kW, 1420 r.p.m, with built-on jockey pulley.

belt and where both the speed ratio is very large and the shafts are placed close to one another (Fig. 105).

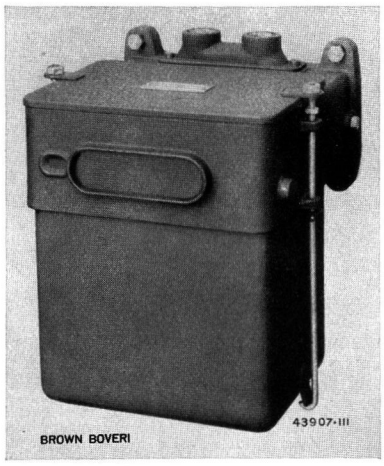


Fig. 106. — Switchboxes Types OMKe or OSM 4 d.
Design with double pipe branches.

The jockey pulley can be secured on the motor according to the position of the belt and what the sense of rotation may be. The spring, built into the housing of the jockey pulley, can also be adjusted so that the desired belt tightness can be set to. A safety device prevents the jockey pulley being thrown backwards when the belt is in process of being stopped.

Built-on jockey pulleys can be delivered with open and enclosed three-phase motors, of 0·1 to 6·6 kW. The design, which meets all the needs of practice, the easy mounting and low costs, should assure a wide field of application to the jockey-pulley motors in question.

In order to prevent a motor subjected to the *counter-current braking*, utilized in standard services of all kinds, from being started up in the opposite sense of rotation, we have developed a *reversing switch* to be placed on the shaft of the motor. When the speed passes through zero, a contact is opened and the circuit of the voltage coil of the brake switch is opened, which causes the latter to open. The contact of the reversing switch is sprung and is made of solid silver, so that it works reliably even when there is vibration and can be said never to burn down under frequent switching.



Fig. 107. — Fault-voltage tripping device for switchboxes.

In the case of small motors, when braking and starting periods are so short that the time lost for carrying out the switching processes would be felt, the contact of the reversing switch can be inserted on the current circuit of one of the motor phases. When the motor speed passes through zero, it is, thus, connected up as a single-phase unit and cannot develop any torque for rotation in the wrong sense. This allows of making quite sure that the motor will only be braked to a stop.



Fig. 108. — Switchbox Types OH 4 e or OSH 4 d.
Design with ammeter.

The line of our *motor-protection switches* with oil-immersed contacts has been extended by the addition of a new type for 64 A (Fig. 106). A new type for 125 A is being studied. These are, both, for hand and for remote control by coil; in the latter case push buttons may or may not be built into the switch housing. The design is, fundamentally, the same as the type described in last year's report. The switch has been made suitable for the most varied requirements and special demands by bringing out a number of special designs and by redesigning the connection parts for the bringing in of the leads.

To meet an increasing demand for efficient protection against dangerous accidental contact voltages which occur in electric plants, we developed a *fault-voltage tripping device* with spring operation (power-storage operation), which is designed to be lodged in several of our standard motor-protection switchboxes (Fig. 107). There is a very sensitive voltage coil one end of which is connected to the metal part to be protected (motor housing, for example) and the other to an auxiliary earthing

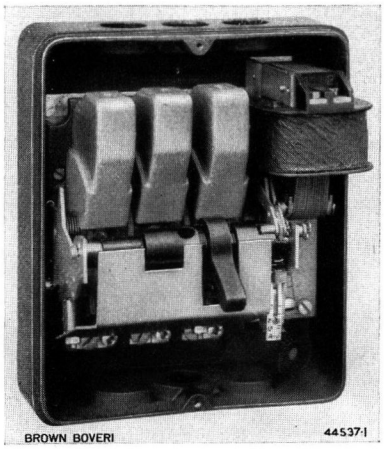


Fig. 109. — Switchbox Type NM 1.

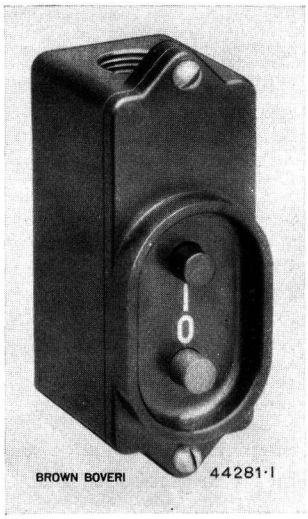


Fig. 110. — Double push-button. Rated voltage 500 V, rated current 4 A.

which it is easy to create. If, now, a voltage of 20 V or more appears on the metal body in question (due to a fault of insulation, for example) the coil frees a power-storage (spring) device which discharges its stored energy with great force on the tripping rod of the switch.

In spite of the smallness of the apparatus the whole device is insensitive to violent vibrations.

An original variation of the basic design of *star-delta motor-protection switch* has been brought out. This is for 40-A rated current and for both hand and coil control. Usually, with switches like this, combined with motor protection, a main switch and change-over switch are necessary, which means using three contactors in the case of remote control; here, however, there is only one contact system with ten contact pieces and this makes the apparatus compact and inexpensive.

A further advantage is that one single movement of the operating organ suffices to operate it and the transition from star to delta position is carried out independently of the operator according to a time which can be adjusted to. To this end, there is a clockwork, also oil-immersed, the running time of which can be regulated between about 3 and 15 seconds.

All the other organs of the switch (Fig. 108) correspond to those of the series of motor-protection switches, with oil-immersed contacts, which were mentioned in last year's report and has now been enlarged. Our well-known directly-heated thermal releases are used, here, as well. The reliability of these releases has been testified to by the successful installation of hundreds of thousands of them. The thermal releases are inserted straight on the phase current of the motor, in the switches in question, so that the said motor is not only properly protected when running but also during starting.

The increasing demand for a competitive and reliable *motor-protection switch* for *low current ratings* caused us to bring out a new type (Fig. 109) both for hand and for remote control.

This very small switch has a housing of insulating material in the base of which there are apertures to allow of introducing armoured pipes or glands for bringing in the leads. The interior design is very simple to follow, despite the compactness of the apparatus, and contacts as well as thermal releases are very accessible. The latter, like all our thermal releases, are directly heated, an innovation, however, is an additional bi-metallic element which so influences the tripping device that the switch continues to trip at the current to which it is set, even when there are changes in the external temperature.

In the design for remote control by coil, the housing is a little bigger; control can, here, be effected through a remote push-button or, if so desired, by the switch lever, as in the case of hand control, the said lever serving to show, at the same time, whether the switch is open or closed.

This small switch can also be equipped with the fault-voltage tripping device as protection against dangerous accidental contact voltages and it can then be used as a station switch for small plants in which protective earthing connection cannot be carried out.

There are many variations to the design of this switch to meet a multitude of requirements. The countersunk mounting in switchgear panels is both simple and pleasing.

For remote operation of this switch, as well as of the other small motor-protection switches for remote control built by us, we have developed a small

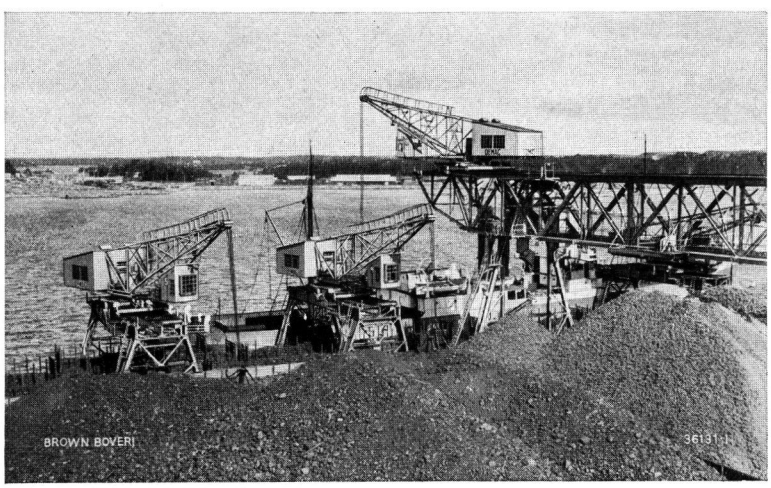


Fig. 111. — View of the coal and ore-loading plant of the Helsingfors Magasins A/B. Mechanical part delivered by Messrs. Demag A.-G., Duisburg.

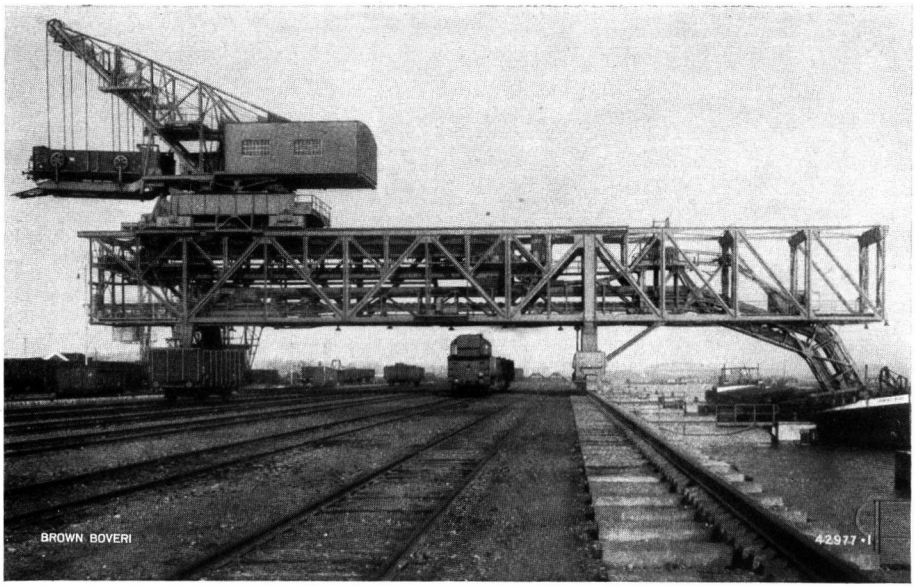


Fig. 112. — Truck tipper in the coal-handling plant of Born, belonging to the Dutch Railways.

double push button (Fig. 110). The housing thereof is also of insulating material with an opening to introduce an armoured pipe or gland. Red and black colours allow of distinguishing the push-buttons.

Our *hoisting-gear equipments* with single-phase commutator motors continue to give an excellent account of themselves and this has meant gratifying repeat orders for us. The special connections developed by us have proved so successful in the case of loading and unloading plants that a not inconsiderable increase in the former loading capacity of the said plants has been achieved as compared to what can be attained with three-phase induction-motor drive, this over and above the well-known advantages of our single-phase commutator motor drives, namely:— starting without losses, far-reaching speed variation, electric braking, low power consumption.

We had the opportunity to deliver to the *Helsingfors Magasins A/B, Helsingfors* (Finland) the electrical equipments for two high-power loading bridges. These clients have had similar equipments of ours in service for some years and been most satisfied with their performance. These bridges are, one, for quay work and, one, for storage-site work; the hoisting and closing mechanism of each is equipped with a single-phase commutator driving motor about 50 kW, with the requisite control gear of the latest design in safety brake-lowering connection. The other drives, such as rotating mechanism, crane and crab-travelling mechanisms, and that for bridge-displacement are provided with three-phase, induction motor drives with special connections created specially for this plant, to meet the different safety requirements imposed.

The drives, which call for very frequent switching, as, for example, 400 switchings per hour and more, are controlled by cam-type controllers with hammer-type contacts. We have mentioned this interesting apparatus on several occasions, in these reports. It can stand up to very frequent switchings and calls for very little attendance.

Our electro-hydraulic thruster has been used throughout instead of the former brake-lifting electromagnets. This device has met with great success and has been described here in former yearly reports. Fig. 111 shows a loading bridge and two portal cranes of the Helsingfors plant.

In our report of the year 1935, we drew attention to our new *sub-synchronous braking connection with reversed phase* and referred to the different advantages inherent to this connection as compared to earlier ones with three-phase induction motors. In the meantime, we equipped a whole series of plants with this new control system; the results have been most satisfactory and fully up to expectations. One of the most important installations is the coal handling plants in Born (Holland) Fig. 112. This coal port is equipped with two truck-tipping bridges, namely:— a truck-tipper which can develop 45 tons and is composed



Fig. 113. — View of the rolling leaf bridge at Oosterdoksluis, belonging to the Dutch Railways.
Bridge open.

of a fixed gantry carrying the travelling mechanism (mechanical equipment by Demag A.-G., Duisburg) and a 45-ton truck-tipper composed of a moving gantry on which are rails on which the slewing crane runs (mechanical equipment by A.-G. J. Pohlig of Cologne).

The powerful hoisting gears of these tippers can — as shown in Fig. 112 — raise and tip full railway trucks with their 20-t load. It will be obvious that to move weights of this magnitude a control system must be used which not only allows the driver a wide range of speed variation but gives him complete and delicate control of the movements at all times. Careful reflection led to the adoption of our new super and sub-synchronous braking connection, with reversed phase. There is no free-fall position with this connection and it gives speed regulation over a wide range and allows of very slow movement of the load, under electric braking.

A rolling leaf bridge was put into service, last year, for the Dutch State Railways, at Oosterdoksluis, Amsterdam. This bridge of the latest design is shown in Fig. 113.

This leaf bridge has a total length of about 35 m and weighs about 510 t. The winding gear for the leaf movement is driven by a *three-phase shunt commutator motor* of about 20 H. P. with a wide range of speed variation, which is necessary in order to bring such heavy weights to a slow stop

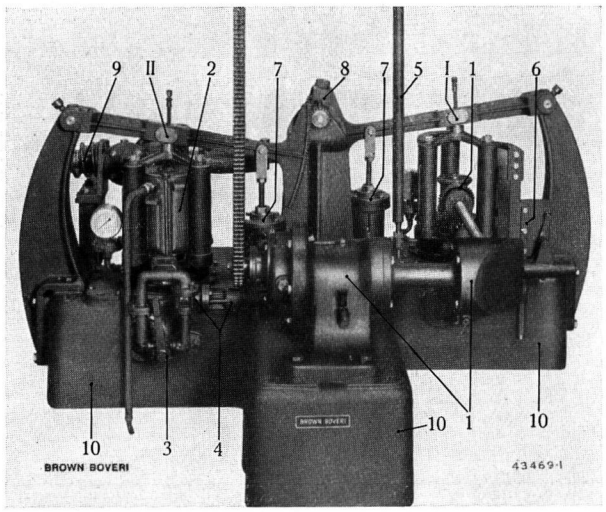


Fig. 114. — View of the oil-pressure travel regulator.

I. Actual-speed piston.
II. Specified-speed piston.
1. Gear of actual-speed piston.
2. Electric motor of specified-speed piston.
3. Oil-circulation valve.
4. Control valve T of the specified-speed piston.
5. Control rod of valve T on specified-speed piston.
6. Control curve of valve S of actual-speed piston.
7. Power storage.
8. Mechanical differential-gear.
9. Pneumatic brake-pressure regulator.
10. Bed plate designed as oil tank in which gear pump and centrifugal pump are lodged.

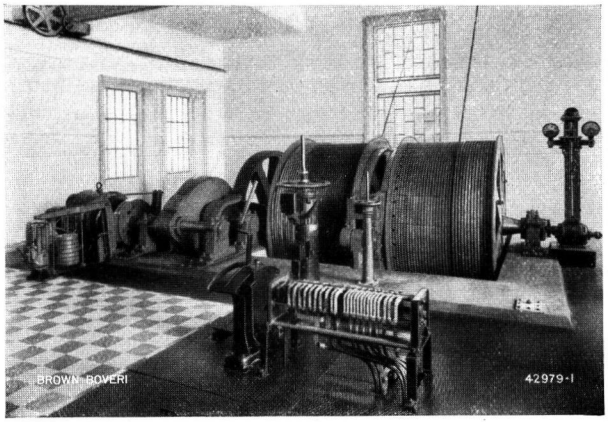


Fig. 115. — Cia. das Minas do Carvao de San Pedro da Cova, Porto. View of the mine hoist with single-lever control and electro-hydraulic thruster as brake raiser.

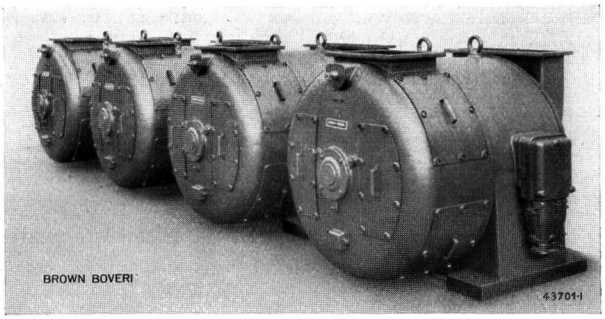


Fig. 116. — Externally-cooled three-phase shunt commutator motors 91/18·4 kW, 750/150 r. p. m., 220 V, 50 cycles.
Drive of drilling derricks.

in their end-travel positions and especially to allow of the bridge coming softly to rest in its lowest position. The preference was given to a shunt commutator motor as it allows of attaining the desired speed regulation without losses and simply, without requiring a big number of auxiliary safety and control devices. This type of motor should find an increasing field of application in moving-bridge equipments like this one.

We desire to say that we have developed an *oil-pressure travel regulator.* A detailed description of the new oil-pressure travel regulator will appear in our March Number, 1937, so that a summary description will suffice, here. The object of the apparatus is to exercise continuous control on the speed-curve characteristic specified for and to impose the said characteristic on those hoisting gears in which there is no sympathetic connection between control-lever displacement and speed of the cage, this happens in the case in three-phase hoisting equipments. Our travel regulator is independent of the centrifugal governor and friction drives and has no similarity to the flow regulator of steam-driven hoists; it is based on the following principle:— A gear pump and a centrifugal

pump drive oil under pressure below two spring-weighted pistons which are connected through a common differential gear. The gear pump is driven by the hoisting engine so that its influence on the differential mechanism is proportional to the "actual" speed. The centrifugal pump is electrically driven and runs continuously. Its effect on the differential mechanism depends on the "specified" speed, a result attained through throttling an oil circuit, more or less in accordance with the displacement of the hoist cage. If both forces acting on the differential are equal, the latter remains in equilibrium; if the "actual" piston predominates the differential moves to actuate the brake pressure regulator in the brake-applying sense and this as long and as strongly as is necessary to bring the "actual" speed back to the "specified" speed. If the "specified" speed side predominates, the differential moves in the opposite sense, but in this sense it swings free and does not affect the brake regulator as no application of brakes is desired. The travel regulator watches over the travel in absolutely reliable manner, and regulates down to the lowest speeds for coming to a landing station. It prevents, under all circumstances, that the cage should come up to the landing stage at a speed greater than that laid down for coming to a stop (no over-winding).

Fig. 114 shows our travel regulator on a plant so equipped by us.

To drive this mine hoist, there is a three-phase induction motor, 170 kW at 750 r. p. m. controlled by a cam-type controller with hammer contacts and individual spark blow-out. The life of this type of contact is considerably greater for service conditions than is that of friction-surface contacts. There is a single-lever control pedestal to actuate the controller in question, which is seen clearly in Fig. 115. This illustration also shows the electro-hydraulic thruster (on the extreme left) used here for brake raising on the holding brake.

Among electrical equipments for hoisting plants built in 1936 by us mention may be made of that of a hoisting plant with a Koepe pulley of 5·5 m diameter to handle a net load of 4000 kg at 10 m/s hoisting speed, from a depth of 1250 m. A three-phase induction motor of 500 kW at 2000 V, 50 cycles is used and the oil-pressure travel regulator, just described is also fitted.

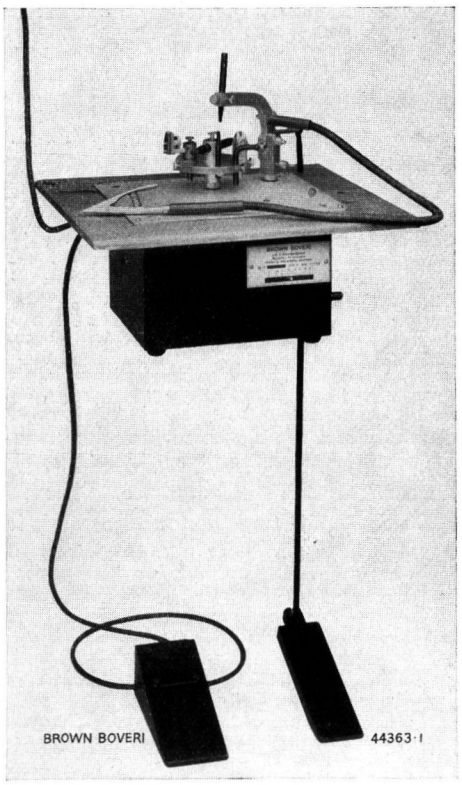


Fig. 118. — Soldering and welding apparatus Type TLsk 3, ready for service, countersunk mounting.

For the first time, we used shunt commutator motors in a *boring plant for the electric equipment of 14 drilling derricks.* The plant has, now, been put to work and has given great satisfaction. The motors are flame proof with external cooling (Fig. 116) and for 90/18 kW continuous rating at 750/150 r. p. m.

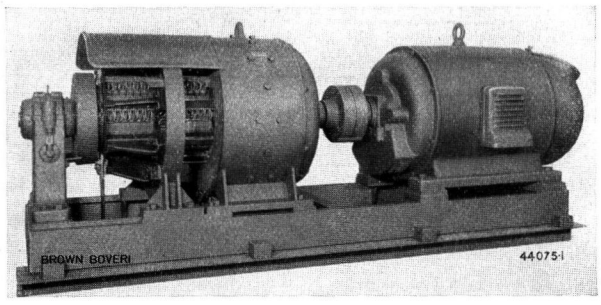


Fig. 117. — Multi-site welding converter. Generator 4000 A, constant voltage 40 or 50 or 60 V, 1500 r. p. m. Motor 500 V, 50 cycles, 265 kW.

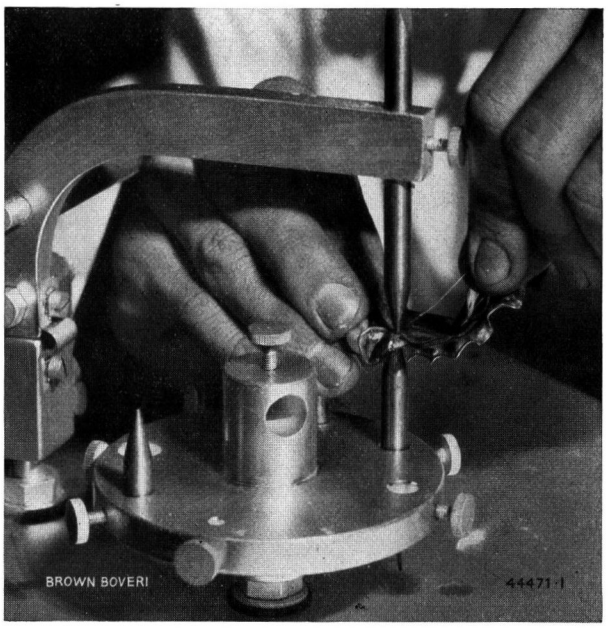


Fig. 119. — Soldering a hook to a dental steel plate by means of the soldering and welding apparatus, Type TLsk 3.

They are started up and their speed regulated by brush displacement, and braked in this way, through a mechanical remote-control arrangement from a control pedestal located in the drilling operator's post. All the severe service requirements were met by these motors without accessory equipment being necessary, a great advantage as space was restricted.

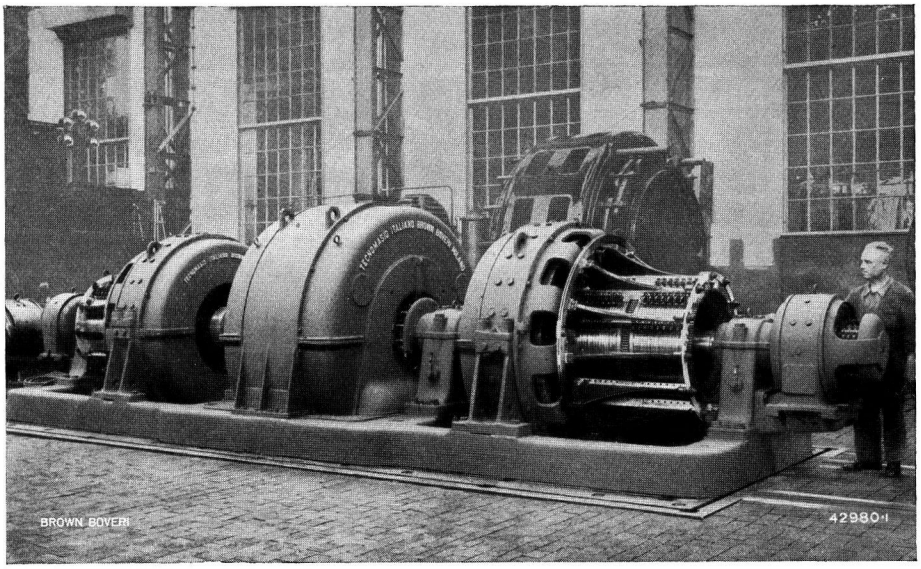


Fig. 121. — Two D. C. generators, 750 kW, 0—100 V, 7500 A, 600 r. p. m. coupled to synchronous motor, exciters overhung.

B. ELECTRIC ARC WELDING.

Apart from the welding machines and transformers developed by us for D. C. and A. C. arc welding each for one welding site, our 40-V plants for welding on several sites at once (multi-site welding plants) with smooth regulation of the welding current have met with ever-increasing success.

The *Ateliers et Chantiers de Penhoet* in *St. Nazaire* already possessed three welding central stations to supply their extensive welding shops, with a total welding current of 16,000 A at 40 V supply voltage. Quick-acting over-current protection regulators were introduced with very great success to all the three welding central stations.

The duty of these regulators is to cause the two other stations to contribute power automatically to the third one if it happens to be momentarily overloaded. As, further, the location of the connecting point of the welding sites to the distributing systems varies very much, these clients ordered from us a fourth and portable welding set, in order to avoid considerable transference of welding power. This new set is for 4000 A. The portable station is mounted on a railway truck 11 m long and is always connected in parallel to whatever fixed supply system is to be supported, namely the one which carries a heavy load, on account of having a great number of welding sites working at the same time. This portable central station, like the other ones, has automatic voltage and over-current protective regulation. It brings the total welding-current output up to 20,000 A sufficient for the supply of 310 welding sites. Fig. 117 shows the multi-site welding converter of the portable station.

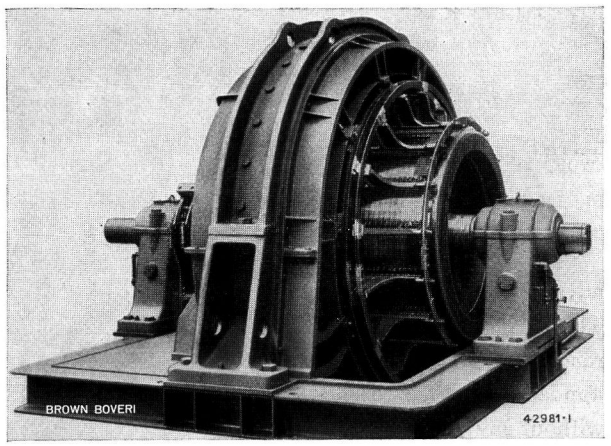


Fig. 122. — Six-phase rotary converter, 230—410 V, 6000 A, 48/51 cycles, 360/383 r. p. m.

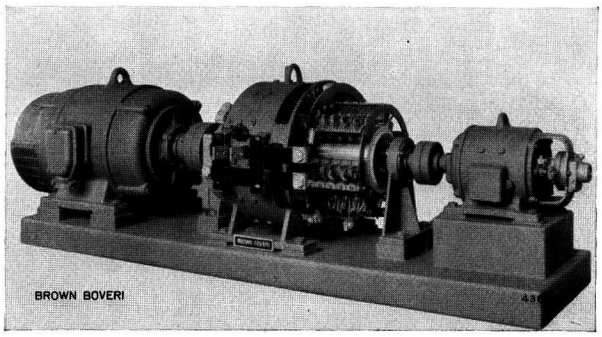


Fig. 120. — D. C. generator 6—14 kW, 6—14 V, 1000 A, 1450 r. p. m. Design with two shaft ends coupled to three-phase motor and exciter.

While on this subject we would say that we have developed a *small soldering and welding apparatus* for workshops, for dentists, opticians, jewellers and precision mechanical work (Fig. 118). This apparatus gives smooth regulation of the welding current between 80 and 650 A at a voltage of a few volts. Regulation is carried out without contacts on the windings or resistances, which is very

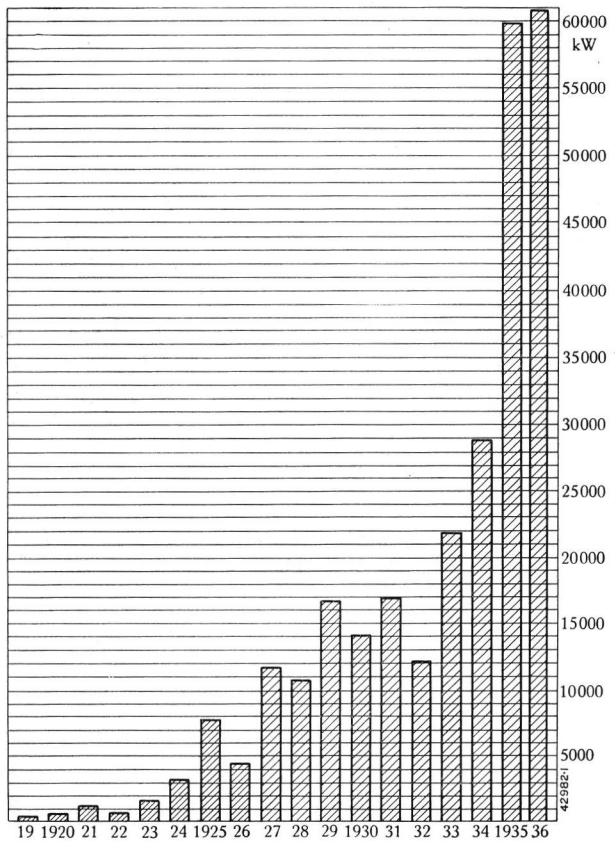


Fig. 123. — Power input of all electric furnaces built by the Brown Boveri Concern.

advantageous. The weight of the apparatus is 18 kg. The current can be regulated smoothly over the entire range mentioned. The different electrodes can be applied on a small rotary table, this quickly and without any difficulty. The requisite tools for soldering and welding as well as a pedal-controlled switch can be delivered. The apparatus can be connected to the lighting circuit; it allows of soldering gold between 18 and 22 carats and of welding rustless wires or fine sheet metal such as are being increasingly used, to-day.

C. HEAVY-CURRENT MACHINES FOR ELECTRO-CHEMICAL PURPOSES.

We have developed new designs in this field (Figs. 120). These machines of welded construction are very compact. A number of heavy-current generators have been built during last year for electro-chemical plants, for 4000, 8700, 11,500 A and 15,000 A. Fig. 121 shows the last machine mentioned built together with its driving motor. Fig. 122 shows a rotary converter, built by one of our concessionaries, for 2460 kW, 383 r.p.m., 6000 A, 410 V.



Fig. 124. — Biscuit and enameling firing electric furnace for pottery and decorative firing of porcelain. Max. temperature 1000° C, furnace chamber dimensions 600 × 900 × 900 mm, furnace capacity abt. 0·5 m³, input 25 kW, 500 V, 50 cycles.

D. ELECTRIC FURNACES.

The number of furnaces delivered increased considerably during last year. This favourable development is, certainly, due, in the first place, to the far-seeing metering policy adopted by many power-producing

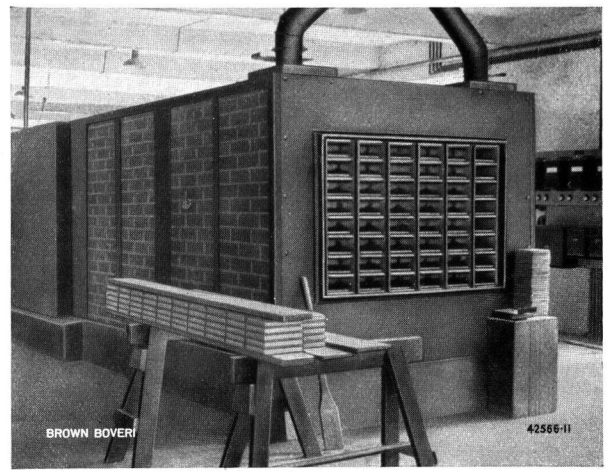


Fig. 125. — Electric furnace of multi-channel, push type for enameling firing of wall tiles. Max. temperature 960° C, input 70 kW.

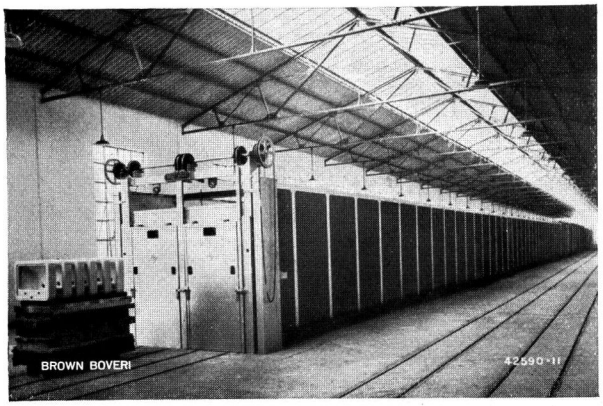


Fig. 126. — Electric double-tunnel furnace for firing sanitary ware, fire clay objects and vitrous china. Max. admissible temperature 1400° C, length of furnace 110 m, production 3800—7500 kg in 24 hours.

companies, which saw in the big calorific power consumer a welcome outlet for current and one which only took active power and was characterized by only moderate load-peak requirements. The development of the electric furnace in the last year is, however, also due to the success our designs have met with. Fig. 123 gives a graphic illustration of the number of furnace plants built by our concern since this branch was developed, this in each calender year. It is seen that the years of the industrial crisis caused some retardation but no stoppage of activity.

It was, chiefly, the ceramic industry which offered new fields of application to the electric furnace in the past year. A furnace of 0·5 m^3 available interior heating area and for 950° C was built for biscuit firing and enameling firing of pottery and the firing of enameled colours on porcelain; this unit differs from the usual ceramic furnace in different respects. By means of a very special distribution of the heating power in the floor and side walls it was found possible to attain uniform distribution of temperature while dispensing with the usual heating of the furnace door and back wall. The heating elements are laid in half-open slots in the refractory lining

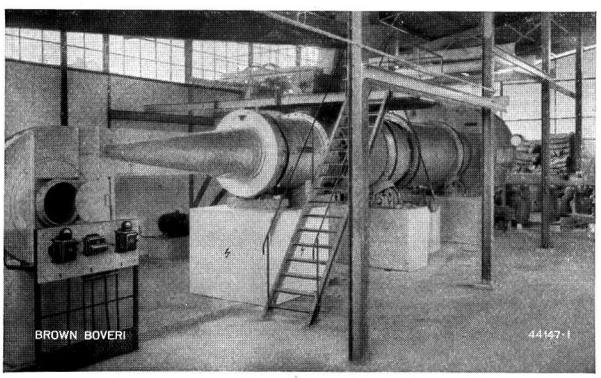


Fig. 127. — Electric air heater with fan plant for a drying drum of the Büttner type. Max. power input 1500 kW at 660 V three-phase supply.

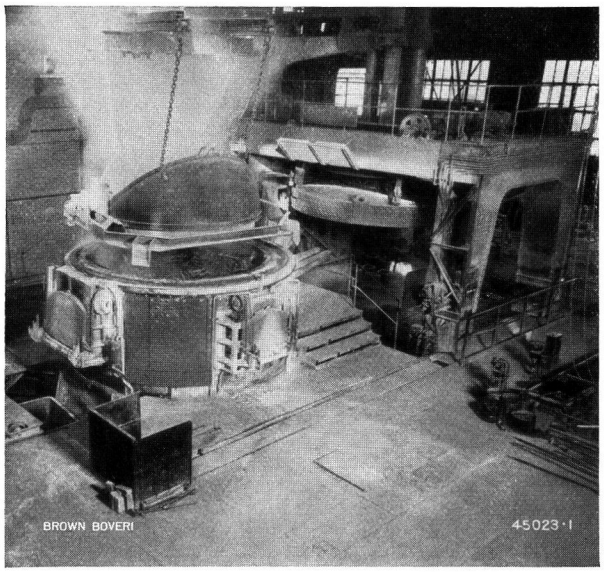


Fig. 128. — Arc-melting furnace for steel, to take a charge of 15—18 t, with removable cover and grab-charging.

and, contrary to a common conception, they have absolutely no deleterious effect on the ceramic charge. This type of furnace has already been built for several plants and has given general satisfaction. Fig. 124 shows one of these furnaces, charged.

For the enameling firing of wall tiles, a continuous-push multi-channel furnace was built for a Swedish firm with 48 channels (Fig. 125). This unit is dimensioned for a production of 6900 tiles in 24 hours and a burning temperature of 960° C. Special devices allow of a high degree of heat recuperation so that the kWh-consumption per net kg is only 0·213 kWh/kg. The scrapped material on account of breakage was about half what may be expected from a coal-fired furnace and the scrapped material on account of poor quality was reduced from 20% to 7%. The furnace is, therefore, very

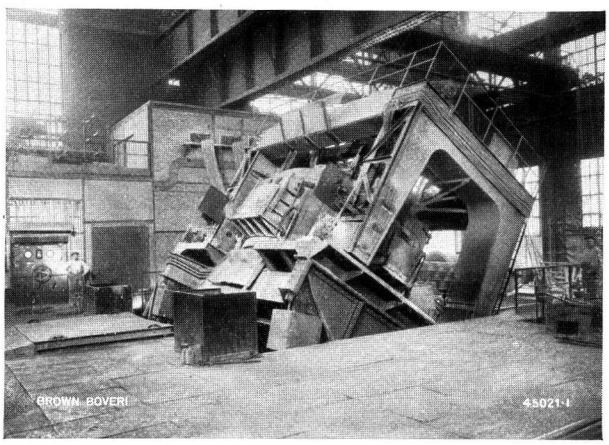


Fig. 129. — Arc-melting furnace for steel, to take a charge of 15—18 t, with removable cover and grab-charging.

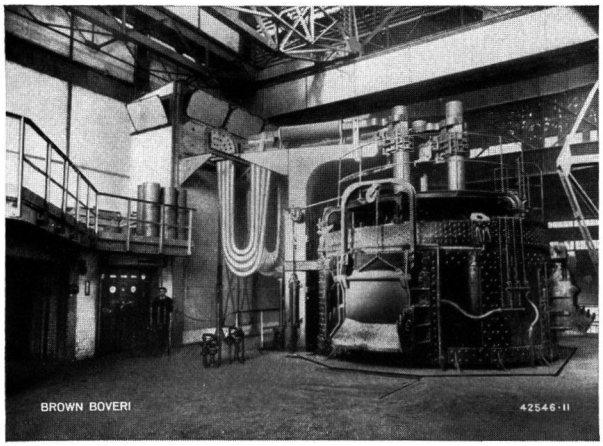


Fig. 130. — Biggest arc-type melting furnace on the Continent. Brown Boveri design. For melting and refining steel. Charge 30—36 t. Maximum power input 5000 kW.

economical both from the point of view of heat consumption and of production quality. For this reason, the same firm has ordered a second one and is considering buying a third unit in the near future.

The double tunnel-type furnace built by Tecnomasio Italiano Brown Boveri, Milan, for *S.A. Materiali Refrattari, Milan* for the high-temperature firing of sanitary fire-clay objects has been put into service and has met all guarantees as regards heat consumption and quality of products. The furnace, shown in Fig. 126, is built for 1400 ° C and a max. production of 37 m^3/24 hours for a gross charge of 350 kg/m^3.

The tunnel-type furnace mentioned, here, last year, for biscuit firing and high-temperature firing of hard porcelain, for the *Porzellanfabrik* in *Langenthal* (Switzerland) designed to take the entire production of the works (which, up till now, was handled by six round furnaces), was erected last year. It was started up towards the end of 1936.

There is more attention being paid, of late, to the use of electrically-generated heat for various drying processes. We would mention an *air heater* of 1500 kW to heat up 6000 m^3/h of air from the room temperature to 650 ° C. This hot air is used to dry fruit residues in a rotating drum. As shown in Fig. 127, the air heater was so designed that it could be completely lodged in the plant. It has worked for one season and shown itself extremely adaptable to production conditions.

Further, our bright annealing furnaces with Grünewald pots have found some interesting applications. Horizontal chamber furnaces have, up till now, been used exclusively for the Krupp nitriding process. The pieces treated have to be placed in the furnace in sheet-metal boxes, into which ammonia gas is led. As it is impossible to make these boxes tight, the consumption of the said gas is very great, during the 80-hour duration of the process. The Grünewald annealing pots allow of eliminating this drawback, especially when the pieces treated are cylindrical. The Locomotive Works, Winterthur ordered a first Grünewald bright annealing plant for the nitriding of bushings of airoplane motors. This furnace has a pot capacity of 800 mm height and 600 mm diameter, 36-kW power consumption, highest service temperature 850 ° C; ordinary service temperature for nitriding 500—550 ° C.

Figs. 128 and 129 show arc furnaces of our latest design with removable cover and supply by a grab device, for a 15—18-t charge. Our biggest arc furnace for a 30—36 t charge is shown in Fig. 130.

E. THE ELECTRIC BOILER.

Electricity is cheap as a source of power, but expensive as a source of light. For the latter purpose, however, it is an extremely suitable agent indeed and this explains its rapid expansion in the field of lighting. To utilize electricity for heating purposes is very extravagant from the point of view of financial outlay, as the equivalent amount of heat can be obtained from various fuels at a fraction of the cost. Here again, however, the exceptional adaptability of electricity to the purpose has been a preponderant factor in the case of a number of small apparatuses, such as irons, hot cushions, tea kettles, cooking ranges, hot-water accumulators, etc.

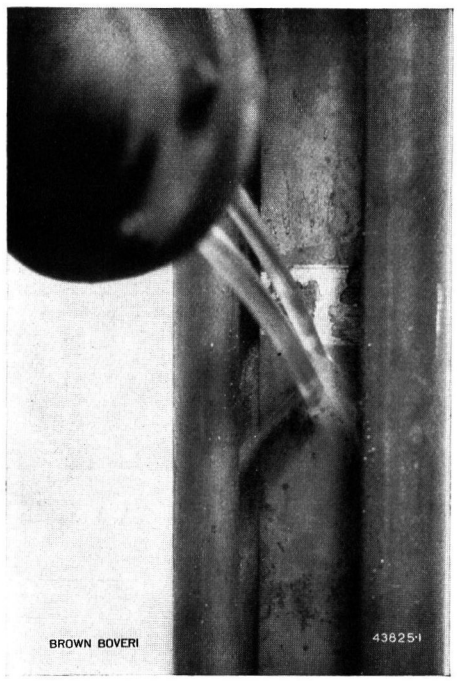


Fig. 131. — Element from a Brown Boveri water-jet boiler.

The resistances are formed by the water jets of small section and considerable resistance. It is thus a typical high-voltage boiler. There must be no spraying when the jet impinges on the electrode and this is assured by a patented Brown Boveri electrode design. The boiler is an all-metal unit without built-in ceramic parts.

A far-seeing metering policy applied by

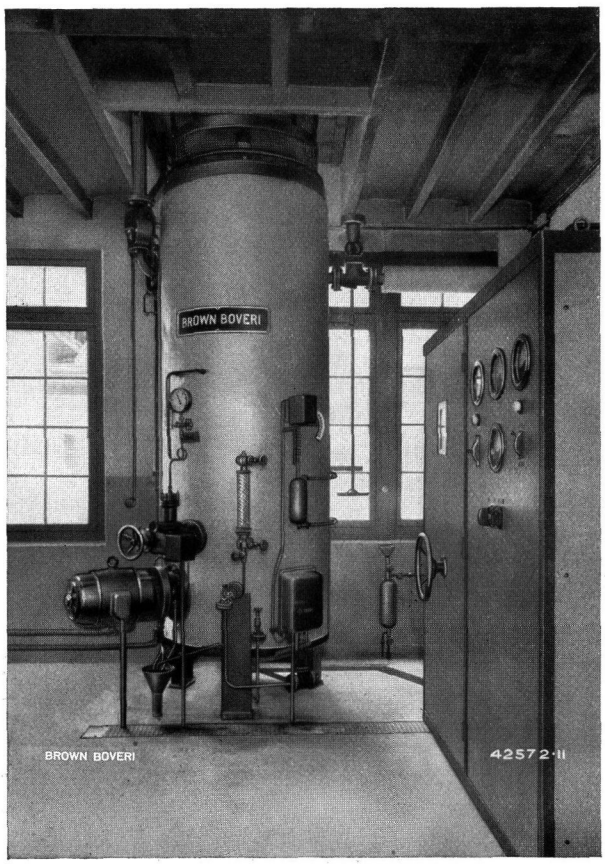


Fig. 132. — High-voltage electric boiler for 800 kW, 4000 V placed in the Fédération Laitière du Léman, Vevey (Switzerland).
The circulating pump is seen as well as the regulating apparatus for water level and steam pressure.

the electric power supply companies has assisted the development of electric household apparatus, the object pursued being to utilize power at the low-load periods of the day. In recent years, big quantities of electric power have been utilized to generate steam and hot water, in industrial and heating plants, in countries which possessed a big hydro-electric power supply. This field of consumption of electricity was opened up during the recent years of severe industrial depression, when there were considerable amounts of power available for which no application could be found and which were, finally, disposed of at a very low tariff, determined by the cost of coal fuel, at the time. Delivery of electric power to electric-boiler plants is generally made on the condition that the supplier can cut off power, at any time, after giving preliminary warning thereof, when a more advantageous outlet for the said power is available.

For this reason, the combination of an *electric boiler and a Velox steam generator* is very advantageous. The latter can be started up within a few minutes at small expense or, alternatively, cut out. The possibility of having a type of steam boiler which can be put into service and cut out of service after a short running time and of being able to switch in or switch out the electric boiler at any moment, according to the requirements of the electric power supply authorities, means being able to utilize excess power at all times, to the great advantage of the power producer and of the power consumer, as well, this not only during industrial depressions but at other times, also.

Fig. 131 is an element of the Brown Boveri water-jet electric boiler which we give here in order to recall the principle on which this boiler is based. The electric resistance is formed of water jets which have a high resistance owing to their small section, a quality making the water-jet boiler suitable for high voltages. By suitable choice of the section, length and number of water jets the resistance offered by the jets can easily be made to suit any system voltage encountered. It is very important that there should be no spraying when the jets impinge on the electrodes, in order to prevent flash overs. The illustration shows how the electrodes are shaped — a patented Brown Boveri design — so that no spraying occurs. The high resistance of the water jets allows of operating with water containing much salt, i.e. with small blow-down volumes. There are no *ceramic parts* immersed in

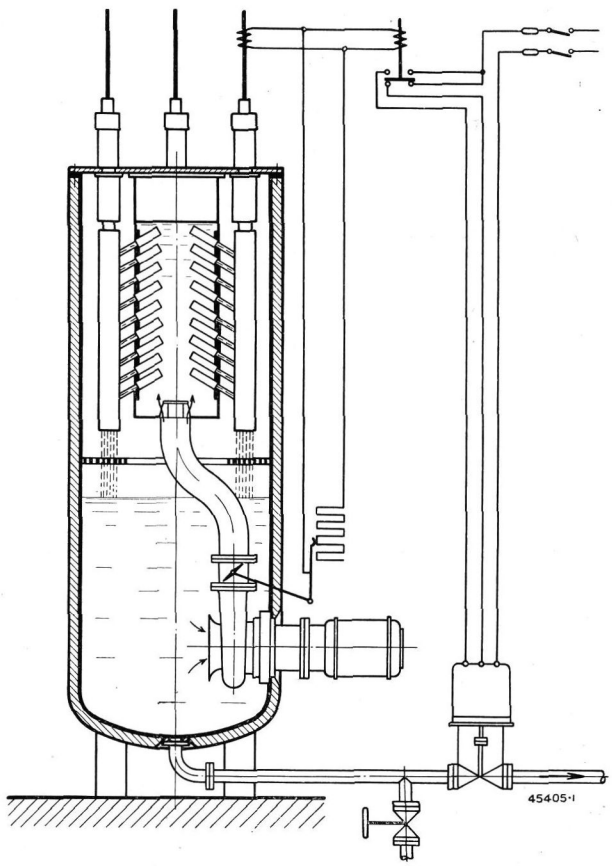


Fig. 133. — Automatic blow-down device for the electric boiler.
If the resistance of the water jets gets too low, that is to say if the throttle valve, for a given load be too far closed, then the blow-down valve is opened by a motor.

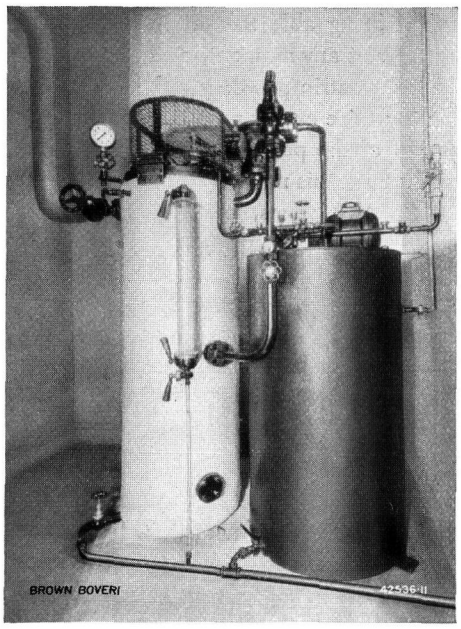


Fig. 134. — Low-voltage electric boiler for 100 kW, 380 V in the Latterie Luganesi, Lugano (Switzerland). Feed-water tank beside boiler. Regulation is automatic, to a given pressure.

the water, in order to lengthen the track of the current, and this is one of the greatest advantages of the Brown Boveri boiler as it means greater service reliability and lower running costs. In all, the only ceramic parts are the bushing insulators. All those who have experienced the unending trouble of which ceramic elements built into the boiler are the seat, will not hesitate to choose the all-metal Brown Boveri boiler. Fig. 132 shows an electric water-jet boiler, 800 kW, 4000 V. The circulation pump with its motor, the pressure-regulating devices, the water-level regulating devices, which all work automatically, are shown in this illustration.

The principle of the automatic *blow-down regulator,* which we have developed in order to facilitate and improve the boiler service, is shown in Fig. 133. There is a given number of water jets for each load on the boiler, for a given salt concentration of the water and there is also a determined position of the butterfly-type load-regulating valve inserted on the pressure pipe from the circulation pump. When the salt concentration of the boiler water increases, the regulating valve must be further closed, and the number of water-jets diminished, the load remaining constant. There is a movable electric resistance combined with the regulating valve which determines the strength of an auxiliary current in function of the position of the valve, i. e. of the salt concentration. This auxiliary current is compared to the load current of the boiler and utilized to open the motor-driven blow-down valve. After the elapse of a blow-down time determined by a time relay, the blow-down valve is closed again while the water-level regulator allows fresh water to flow to the boiler. The process repeats itself until the salt concentration of the boiler water goes down sufficiently. This blow-down device in which the resistance of the boiler is used as a measuring resistance has the great advantage that the bushings, which being immersed are subject to wear, are not used as a measuring distance.

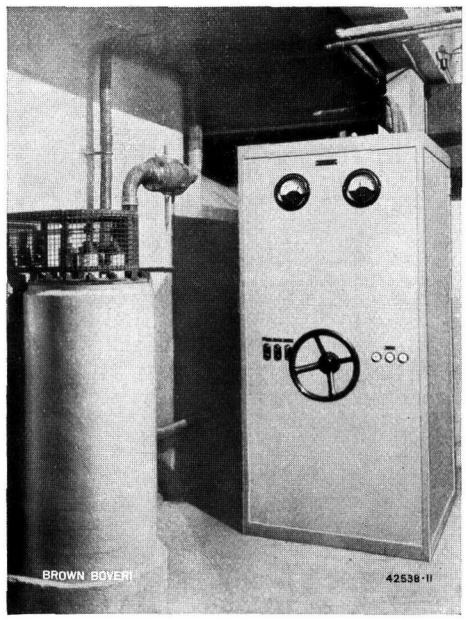


Fig. 135. — Low-voltage hot-water boiler, for 400 kW, 380 V in the Selve Works, Thoune (Switzerland). The boiler adapts itself automatically to the heat requirements.

Last year, we also took up the building of *low-voltage steam and hot-water boilers* for voltages up to 500 V. In this case and contrary to high-voltage boiler design, we use immersed electrodes instead of water jets. No built-in ceramic parts are necessary, on account of the low voltages. The load is varied by altering the immersion of the electrodes, i. e. by lowering or raising the water level in the boiler. It will be clear, however, that this cannot be carried out at any speed. When load is thrown off with a return to a lower water level, the water of the boiler must evaporate or be allowed to flow off through an outlet valve, with a corresponding loss of heat; in the case of a central-heating boiler it must be driven into the expansion tank. As the requirement for steam increase, the boiler has to be filled up again by the feed pump. This is accompanied by the further difficulty that when a large quantity of cold water is injected into the boiler the conductivity of the boiler water and with it the passage of current falls for a determined electrode immersion, and also that much heat is required to heat up this new water. Thus, when the load rises, the evaporation begins by falling which may cause big pressure fluctuations in automatic service. We got over this difficulty, inherent to the principle of the boiler with immersed electrodes which is, in other respects, so suitable, by preheating the feed water in an accumulator lodged inside the boiler and by bringing it up to as near the evaporating temperature as is possible. This means that it is no longer necessary to furnish the heat required to warm

the feed water when the load goes up and a greater amount of steam is immediately generated. In order to shorten the time necessary to fill up the boiler, the feed pump is made considerably bigger than would be necessary for full-load feed-water supply. In ordinary service, the excess quantity of water is allowed to flow back through a spring-loaded overflow valve, from the pressure pipe of the feed pump into the feed-water tank. This measure insures very stable operation of the boiler and pressure fluctuations are reduced to a minimum. Fig. 134 shows a low-voltage electric boiler, 100 kW, 380 V, 6 kg/cm² abs in the Latterie Luganesi, Lugano (Switzerland) and running to the general satisfaction of the client.

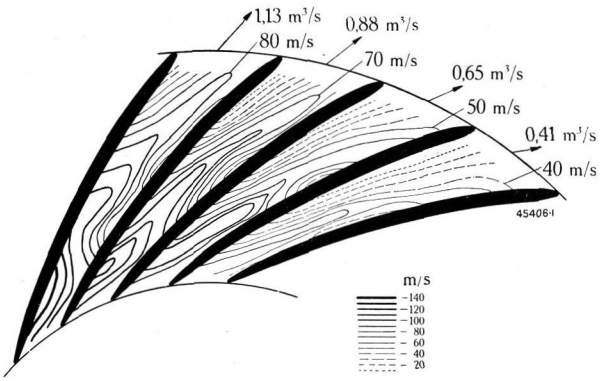


Fig. 136. — Curves of equal speed in the blade channels of a running blower disc at different outputs.

The very different speeds on the two sides of the blade are noticed at once, as well as the pressure jumps at the end of the blade.

The *low-pressure hot-water boilers* are, fundamentally, the same as the low-voltage steam boilers. The water is heated up in the boiler to the temperature corresponding to the head of water in the central heating system above the boiler. This water, at about 110—130° C, is mixed with the water in the central-heating circuit by means of a circulating pump. An automatically-controlled valve regulates the amount of water mixed according to requirements. If a boiler of this kind is added to a big heating plant, the improved water circulation improves the heat transmission to the radiators, an additional and welcome amelioration. Fig. 135 shows a low-voltage electric boiler for 400 kW, 380 V, in the central-heating system of the Selve works, Thoune (Switzerland).

F. COMPRESSORS AND BLOWERS.

Our development work on turbo-blowers, begun 30 years ago, has given new and encouraging results in recent months. When investigations were first started, there was, really, very little known of the processes of which the passages between the vanes of the rotor and the stationary passages were the seat. At first, these channels were adjusted purely empirically with the object of getting as good a flow as possible. Then, through tests, which required great pains and patience, we managed to collect pressure and flow-velocity measurements from the rotor. These measurements were made through the

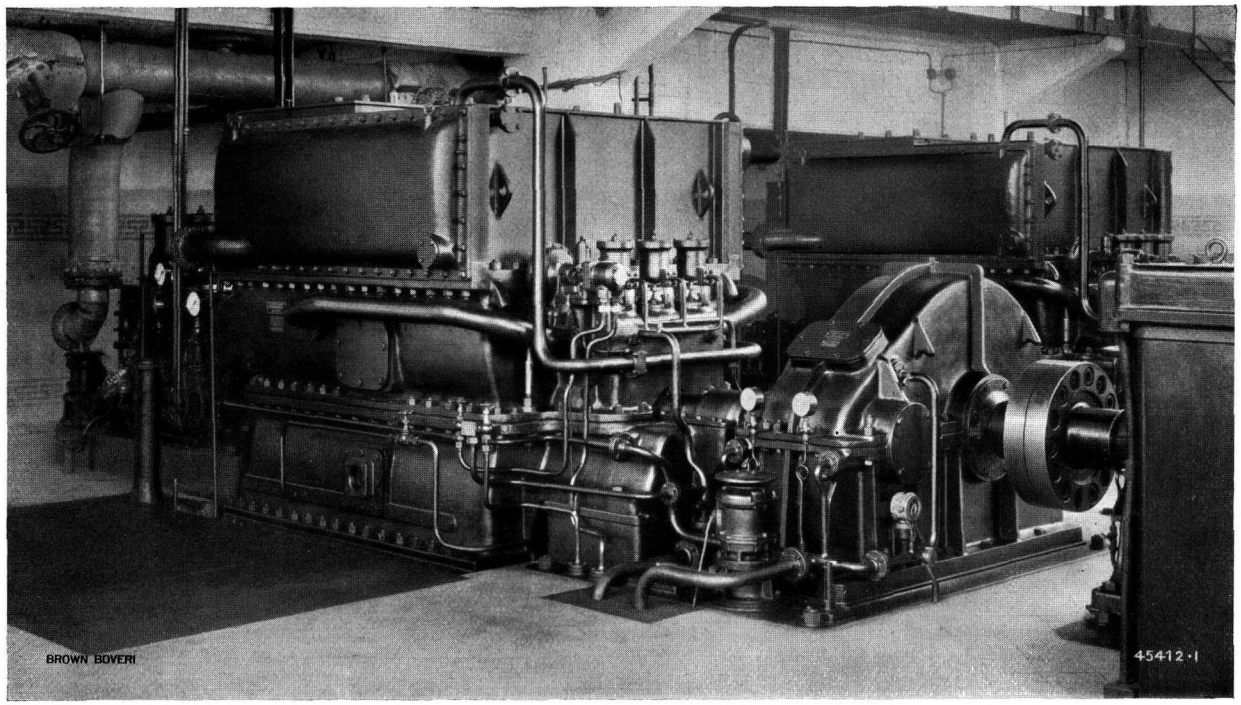


Fig. 137. — Charging-compressor sets for a charged absorption process in a nitric acid works.

The compressor compresses 330 m³ of ordinary air to 8·5 kg/cm² abs and requires 1780 kW for this. The hot gases come back from the process at 7·5 kg/cm² abs and 500° C and are able to produce 1400 kW in the gas turbine. The remaining 380 kW are furnished by a driving motor, which, however, is built for 1400 kW, so as to be able to act as a stand-by.

hollow shaft and they were the first practical investigations to give valuable data on the real flow process and power exchange in the channels formed by the rotor blading. Fig. 136 recalls these exceptional measurements, which allowed of improving the

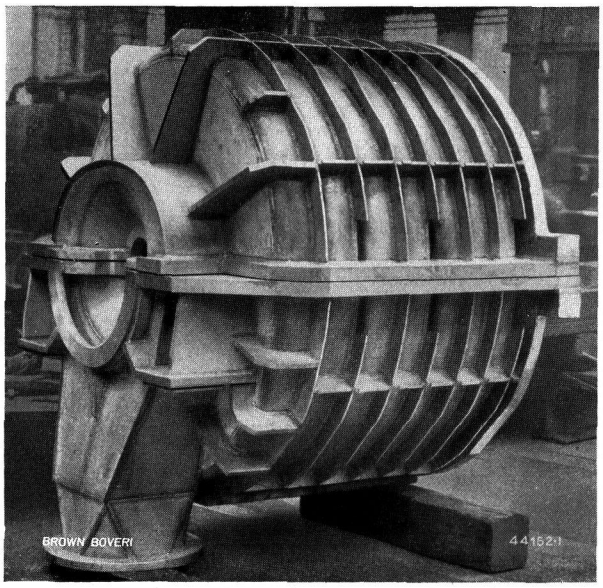


Fig. 138. — One of seven compressors for nitric-acid works to deliver 315 m³/min of nitrate gases at 7·4 kg/cm² abs.

The whole compressor with shaft and discs is made of rust-proof chrome-nickel steel. The gases come back from the process at 5 kg/cm² abs 100° C and flow through a gas turbine in the housing of the compressor, giving 360 kW back to the compressor shaft.

turbo-blower considerably and explained some incomprehensible phenomena inherent to this class of machine. The cause of the violent pressure fluctuations in the stationary passages was revealed, the same applies to the whining note given out by the early blowers and to the unexpected lack of stability in the air delivery. It was also made clear why the efficiency of pressure conversion was considerably lower than that of power generation. New flow measurements carried out on models showed what were the most advantageous shapes to give to the suction and pressure channels, to the diffusers and to the reversing passages, in order to keep losses as low as possible. As Fig. 143 shows, for example, these investigations, together with careful attention to every constructive detail, allowed of arriving at really good blower efficiencies.

These high efficiencies of our modern turbo-blowers when used in conjunction with gas turbines open up new fields of application in *charged chemical processes* and *charged combustion processes.*

In the first development stage, the Büchi charging process was difficult to carry out and could only be applied to big engines, because of the considerable losses in the charging set. The process has only been applied with entire success on a broad basis within the last few years, that is to say since the efficiencies of the charging machinery have been im-

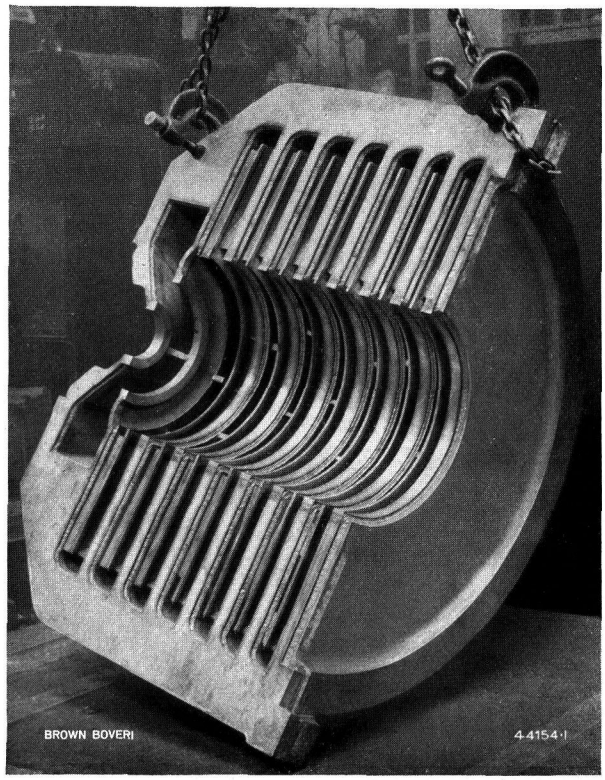


Fig. 139. — One of seven rust-proof chrome-nickel steel cylinders of welded construction to deliver nitrate gases.

The cylinder and water-cooled chambers are entirely built up of metal sheeting welded together.

proved to such an extent that the power produced by the gas turbine sufficed not only for charging, but for scavenging and cooling the Diesel engine, as well.

In the case of the Velox steam generator, as well, combustion under pressure, which is an essential element of its working principle, is only a profitable process if the efficiencies of the gas turbine and charging blower are high. This is because the power input required for the charging blower is as much as 30 % of the steam power produced by the Velox and poor efficiency of the charging set means that far too much additional power is required to drive the set, thus bringing down the efficiency of the Velox itself as a steam generator. To-day, such strides have been made that the charging set does not only take very little additional power but, under certain conditions can, even, return power to the supply system.

1. *Charging compressors with exhaust-gas turbines in the chemical industry.*

In the chemical industry for the production of nitrogen and nitric acid, the absorption and also the adsorption process in the catalyst is often more advantageously carried out under high pressure and temperature that is to say as a charged process, the hot gases exhausted from the process being utilized in a gas turbine to drive the charging compressor. All the gas channels and reaction chambers are now much reduced in size, owing to the high pressure

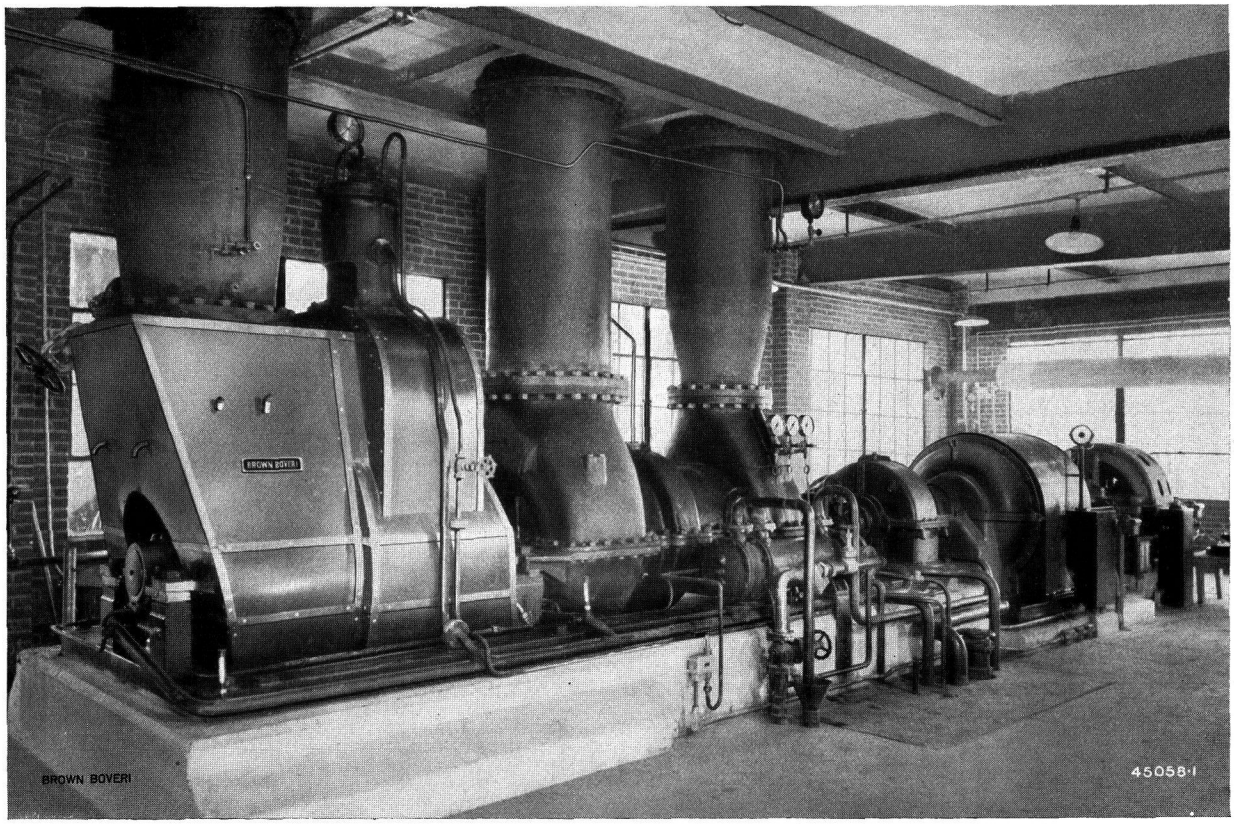


Fig. 140. — Big charging set composed of an axial blower, exhaust-gas turbine and generator, delivered to the Sun Oil Co., Philadelphia, U. S. A.

The blower compresses air and takes about 4400 kW. The hot gases restituted by the process produce about 5300 kW in the gas turbine, so that a generator delivering about 900 kW can be driven through a reduction gear, which restitutes this power to the electric supply system. The starting motor seen on the extreme right is for starting the set and bringing it up to about 1/5 of the rated speed; there is also a starting combustion chamber in which the air is heated up by oil flame during the starting period and until the chemical process is fully going.

and high velocities, the absorption processes and heat transmissions in the heat transmitting apparatus take place advantageously and, despite the higher pressure used, big savings are effected, both in apparatus and buildings. Fig. 137 shows two charging compressors which compress 330 m^3 of air for an adsorption and absorption process, to 8·5 kg/cm^2 abs. The gases regained from the process, at 7·5 kg/cm^2 abs and 500° C are utilized in the built-on gas turbine and generate, therein, 1400 of a total of 1780 kW required to drive the compressor, the remainder being made up by a built-on electric motor, which has to provide the entire power required for compression, during the starting-up period.

Fig. 138 shows one of a set of seven compressors ordered from Brown Boveri for making nitric acid. The nitrate gases produced by adsorption of ammonia on the catalyst are compressed up to 7·4 kg/cm^2 abs. The hot residual gases drive an exhaust-gas turbine, lodged in the casing of the compressor and which restitutes 360 kW of power to the shaft of the compressor. Every part of the compressor (cylinder, shaft and wheels) is made of stainless chrome-nickel steel. The cylinder is cooled by external water jackets. This rather complicated body is entirely welded from chrome-nickel steel sheeting (Fig. 139), a fine testimony to our welding process and the skill of our welders.

Figs. 140 and 141 show an especially interesting charging set for a chemical works in America. This set not only takes care of the charging required for a certain process but returns a considerable amount of power to the electric system thanks to heat supplied to it, together with high turbine and blower efficiencies. This set comprises an axial compressor requir-

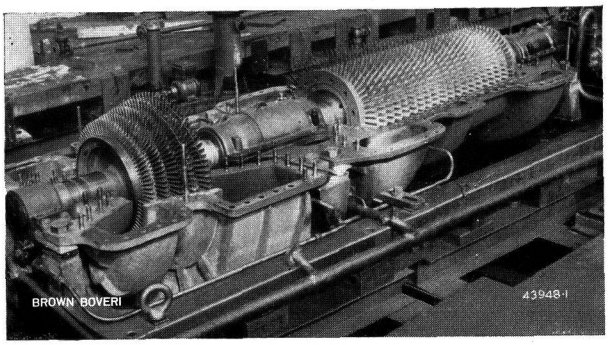


Fig. 141. — Charging set for a compressor output of 4400 kW, composed of an axial compressor, a gas turbine and a generator, which restitutes about 900 kW to the electric supply system.

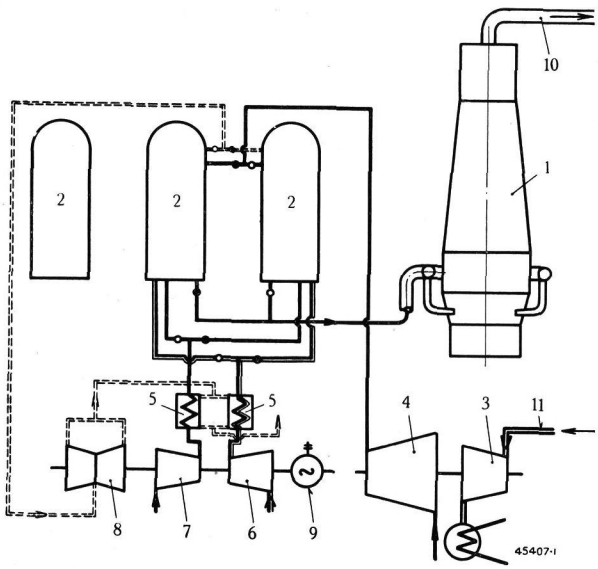


Fig. 142. — Diagram showing a Velox blast-furnace, air-blast plant with charged Cowper stove.

The Cowper stove is charged by blast-furnace gases at about 2·5 kg/cm² pressure and high velocity. This allows of making the Cowper stove smaller and it shortens the time required for charging it. Only two Cowper stoves are required (and a stand-by) for the process.

1. Blast furnace.
2. Cowper stove.
3. Steam turbine.
4. Blast-furnace blower.
5. Preheater for charging air and gas.
6. Charging blower.
7. Charging-air blower.
8. Exhaust-gas turbine.
9. Auxiliary motor.
10. Gas pipe to Velox steam generator.
11. Steam pipe from Velox steam generator.

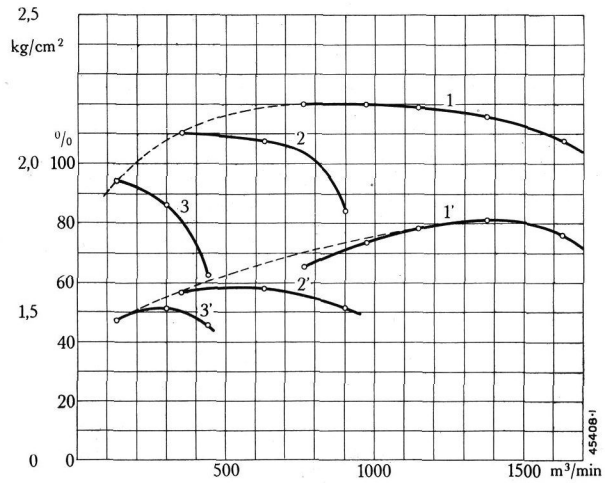


Fig. 143. — Pressure-volume curves 1—3 and efficiency curves 1′—3′ of a Brown Boveri turbo-type blast-furnace blower for 1500 m³, 2·1 kg/cm² abs, for different settings of the movable diffusers.

Delivery is stable and efficiency good, down to low loads.

ing about 4400 kW, a gas turbine, driven by the gases at 500° C restituted by the chemical process, and producing 5300 kW and a synchronous generator coupled through a reduction gear which returned the excess of 900 kW to the electric supply system.

The starting of this set and the apparatus for that purpose are also worthy of note. As long as the chemical process is not in full swing, the temperature of the gases returned is low and the same applies to the output of the gas turbine. An auxiliary starting motor is used, seen on the extreme left in Fig. 140, to bring the charging set up to a fraction of its rated speed, 20 %, for example. Under these conditions the compressor output is only about 1 % of its full-rated figure and the starting motor and the starting power called for are correspondingly small. To raise the speed further, the air delivered by the compressor is, first, forced through a branch pipe into an air-cooled *starting combustion chamber*, here it is heated up to 500° C, by oil flame and then led to the gas turbine. As is known, the output of the latter increases with the absolute temperature of the driving gas, so that it, now, supplies more power so that, by keeping up the heating of the compressed air, the charging set is brought up to full speed, rapidly. The starting motor is coupled to the charging set by an overtaking coupling and it is, thus, caught up by the gas turbine and cut out after the starting

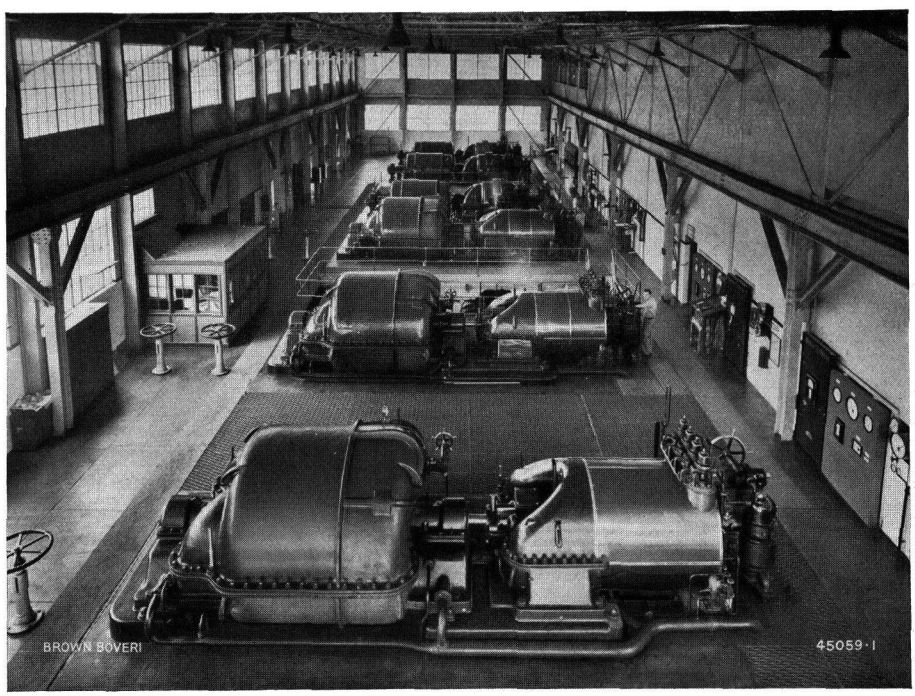


Fig. 144. — Blower plant for Praetoria, three converter blowers for 1500 m³, 0·88/2·15 kg/cm² abs, driven each by a synchronous motor of 2860 kW.

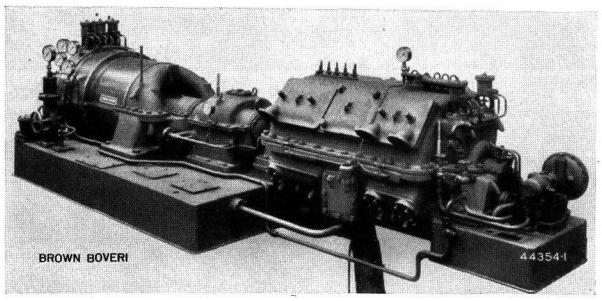


Fig. 145. — Turbo-compressor VW 509.
It can be utilized for as low outputs as 50 m³/min at 8 kg/cm² abs and it has thus entered a field which was, formerly, held by cell-type compressors and reciprocating compressors exclusively.

process is at an end. The starting combustion chamber is placed outside the machine chamber as a connection piece between the inlet and outlet gas ducts over the set. This starting process and some special devices are patented.

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

The phenomena of enhanced heat transmission from a gas to the wall of the gas tube, under the effect of high-pressure and high gas velocity, made use of in Velox steam generators, has led to the suggestion being put forward that it would be advantageous to use a *charging process to heat the blast of a blast-furnace.* Fig. 142 shows a diagram of a charged blast-furnace plant. The cowper stove is heated up by blast-furnace gases at a pressure of about 2·5 kg/cm² abs at 800—900° C. Two charging blowers bring gas and air to the desired pressure; an exhaust-gas turbine utilizes the hot gases coming from the Cowper stove, and drives the charging compressor. As the Cowper has to be pressure proof, in any case, for the heating process no special cost is incurred by charging under pressure, which

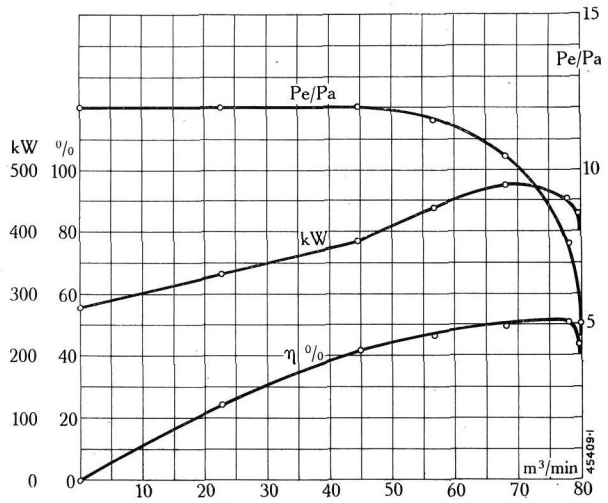


Fig. 146. — Test results taken on the smallest high-pressure turbo-compressor yet built.
Despite its small size, the efficiencies are so high that the turbo-compressor with steam-turbine drive is the most preferable solution, for low outputs as well, when the other advantages of the turbo-unit are taken into account.

also, makes it possible to use the Velox principle, i. e. to work with high speeds, reduced hot-gas sections and small heat transmission surfaces and, thus, to reduce the unwieldy dimensions of the modern Cowper. Of course, the pressure of the blast-furnace gases must be, somewhat, increased so that the higher resistances of the smaller Cowper can be overcome, at discharging. As charging and discharging of the cowper stove take place at about the same pressure, there is the further advantage that equal times are required for charging and discharging and that two instead of three Cowper stoves (as before) are required for operating a blast furnace.

Out of a considerable number of blower plants for steel works delivered, Fig. 144 shows the blower

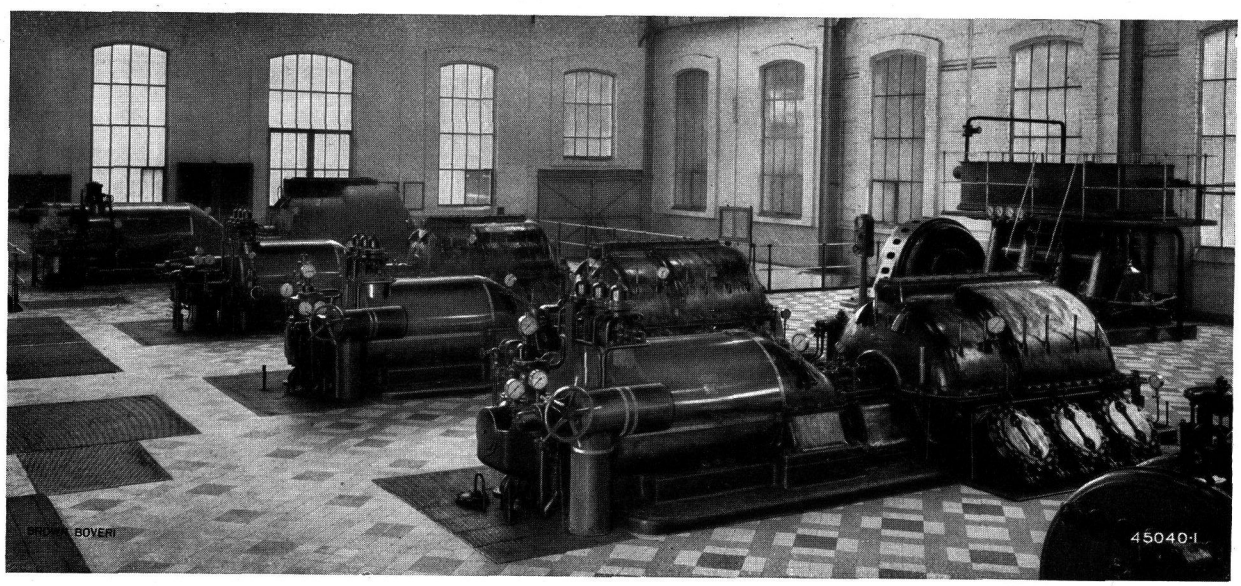


Fig. 147. — Compressed-air station of the Charbonnages de Beeringen (Belgium) with four turbo-compressors for 350 to 600 m³/min of air delivery and 8 kg/cm² abs pressure.

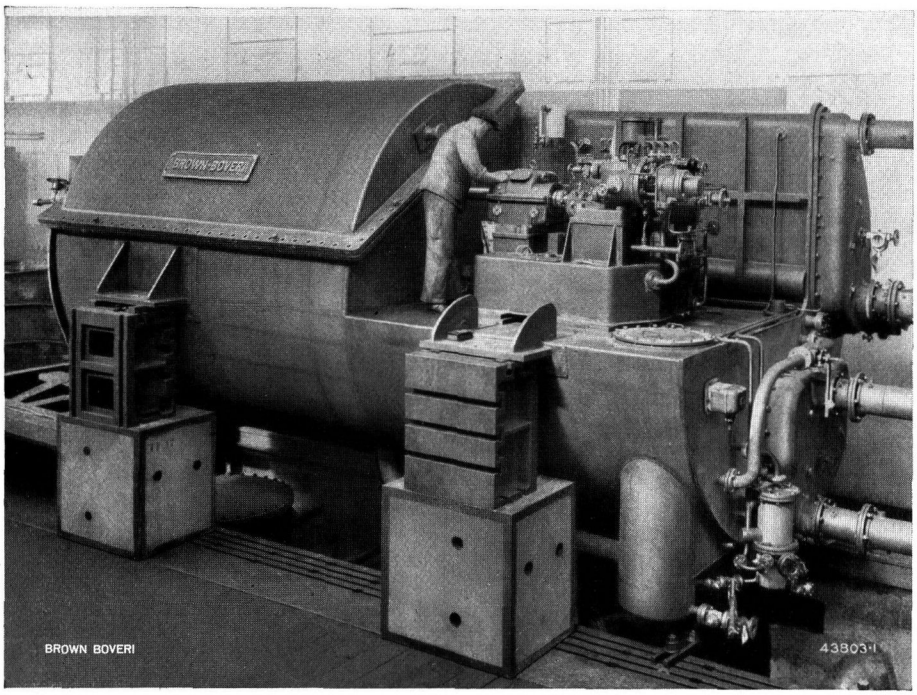


Fig. 148. — Steam-turbine driven Frigibloc for a Polish artificial-silk mill, to deliver 1,300,000 kcal/h at 13° C.
To prevent heat exchange, the turbine is outside the Bloc proper.

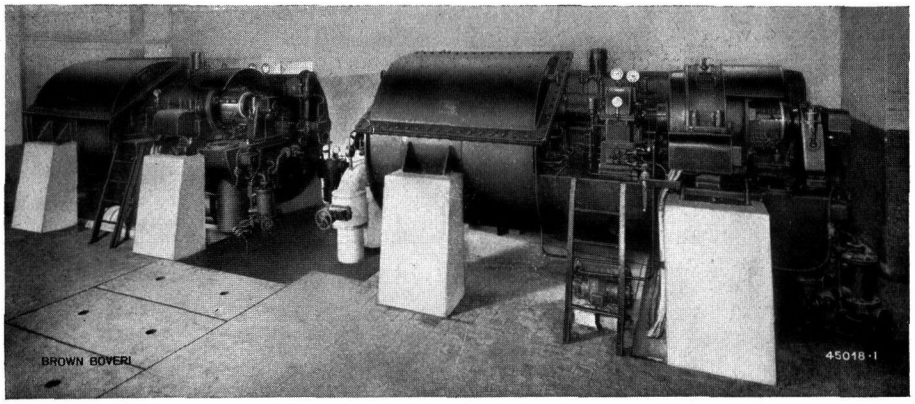


Fig. 149. — Two Frigiblocs each for 320,000 kcal/h belonging to the Brasserie Richard Frères Ivry sur Seine (France) driven by D. C. motors.
To facilitate brush supervision, the motor is outside the Bloc proper.

plant in Praetoria of the South African Iron Steel Industrial Corporation. Thanks to excellent results achieved with the first two 2860-kW blast-furnace blowers driven by steam turbines, a third unit was ordered and, later, a high-pressure turbo-compressor, which is shown in Fig. 145. Interesting measurement records taken from a big blast-furnace blower are given in Fig. 143. This unit is in the plant of the Lancaster Steel Corporation Ltd., in Irlam. The blower has the patented movable diffusor blading which allows of a range of air delivery down to no-load. At rated output, the efficiency attains 80 % and remains excellent over the whole range of output regulation by means of the movable blades, down to small loads.

3. *Compressed-air generation.*

In the field of compressed-air generation for pneumatic tools and for outputs of less than 100 m^3/min, two-stage reciprocating compressors and Roots (cell-type) compressors have been used exclusively up till to-day, because, both in efficiency and price, they were more advantageous than the turbo-compressor. However, the advantages inherent to the turbo-machine and its driving steam turbine are so great, as far as running and upkeep are concerned, that there has long been a demand for a practical, small turbo-compressor. To-day, thanks to improvements introduced to both blading and housing it has been found possible to create a new turbo-compressor model with an output of 50—80 m^3/min of air at a pressure of 7—10 kg/cm^2 abs, the efficiency of which is only slightly below that of a cell-type compressor. Fig. 145 shows the new machine, which has nine compressor discs in a water-cooled housing and a central intermediate water cooler. Fig. 146 gives the measurement results attained. The efficiency of 50 % must be considered good, when the big pressure ratio

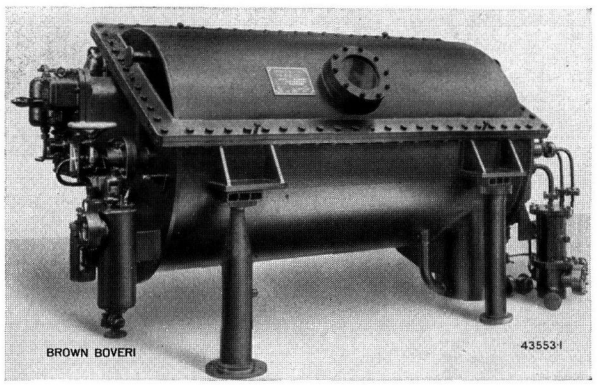


Fig. 150. — The smallest Frigibloc built up till to-day, for 50,000 kcal/h.

and small volume of air handled are taken into consideration. The range of regulation is a striking feature, the volume of air delivered being variable from overload down to zero by means of the regulated turbine.

The compressed-air central station of the Charbonnages de Beeringen is shown in Fig. 147. Owing to the excellent performance of Brown Boveri compressors, this station has been gradually built up until to-day, it contains four Brown Boveri turbo-compressors of 350 to 600 m^3/min of air and 8 kg/m^2 abs delivery pressure.

G. REFRIGERATION.

The output range of our Frigibloc has been increased by one biggest and one smallest model. Thanks to the little space it takes up, its simple and rapid erection and its great economy, the Frigibloc offers remarkable advantages in big refrigerating plants as compared to other refrigerating machines built up of different, independent elements. In small plants, chiefly in trades and on board ship, the fact that no supervision is called for together with the compact design makes the Frigibloc a most advantageous acquisition. When steam-turbine and D. C. motor-drive (Figs. 148 and 149) are used the drive is not inclosed in the Frigibloc itself, this in order to prevent heat exchange between the turbine and the Frigibloc, in the first case and in order to allow of commutator attendance, in the second case. The compressor shaft is, then brought out through a sealing gland in the housing independent of the machine and having oil sealing. The Bloc thus remains entirely gas-tight. Fig. 150 shows the smallest Frigibloc built, so far, for a refrigerating capacity of 50,000 calories, intended for breweries, small refrigerating plants, ships, etc.

H. AERODYNAMICS AND AEROPLANES.

Military aeroplanes are called on to fly at altitudes of 5—10,000 m and to plane down rapidly and unobstrusively; at no far distant date, commercial planes will certainly be required to fly at very high altitudes, as well, in order to increase travelling speed and bring down the time of intercontinental journeys. As at such altitudes the weight of air drawn in falls considerably (for example at 5000 m alt., it is only 50 % of that at sea level), Brown Boveri created a type of high-speed turbo-charging blower for aeroplanes, driven through a reduction gear from the aeroplane engine; this was used during the War. These charging blowers are driven, to-day, by the Büchi process, that is by a gas turbine fed from the engine exhaust, which is a great improvement on the former arrangement. The reduction gear is eliminated and the somewhat complicated coupling between the high-speed blower and the reciprocating engine with its cyclic irregularity is dispensed with; further no useful engine power is used for charging.

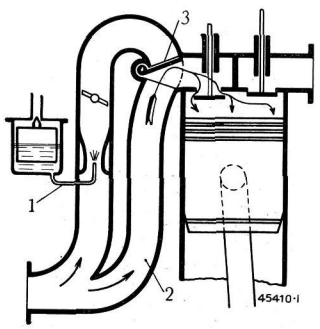


Fig. 151. — Diagram of charged petrol engine, with scavenging.

During the scavenging period, the scavenging air is led round the carburettor, in a by-pass pipe with two-way valve, this in order to avoid waste of fuel.

Charging of petrol-fed aeroplane engines can be carried out with or without cylinder-chamber scavenging. When *scavenging* is applied, the valves, cylinder chamber and gas-turbine blade wheel are efficaciously cooled and the remainder of the burnt gases is driven out; the output of the engine, for a given charging pressure, can be increased above that of the charged but unscavenged engine. To carry out scavenging, however, the air drawn in must be carried round the carburettor according to a patented Brown Boveri process (Fig. 151 shows the method, diagrammatically), during the scavenging process in order to prevent unnecessary waste of petrol. There is a by-pass 2, parallel to the carburettor 1. Valve 3 switches the carburettor out of the air-suction branch during the scavenging process and allows the air drawn in to flow straight to the engine through the by-pass. This change-over device is not required when *petrol injection engines* are used, for which there would appear to be a future in aviation; in this case the charging process is the same as with the Brown Boveri-Büchi charged Diesel engine.

In ordinary unscavenged petrol engines the temperature of the exhaust gases is about 800°, so that special cooling measures must be taken to protect the blades and disc of the gas turbine. The exhaust gases are led from the different sets of cylinders, as in the case of Diesel charging, to two or to three separate sets of nozzles of the gas turbine. There are cooling nozzles inserted between the exhaust-gas nozzles, through which cold air flows to the gas

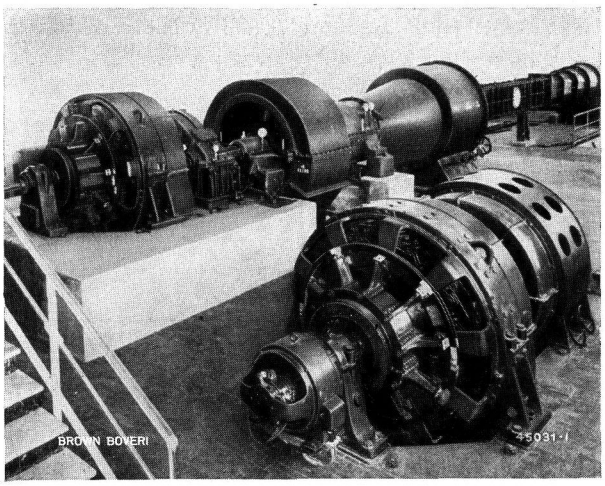


Fig. 152. — View of the super-sound velocity wind tunnel of an aerodynamic institute.

Models of aeroplane types, projectiles, etc. can be tested in this tunnel; up to speeds of 2300 km/h. A multi-stage axial compressor driven by a 1000-kW D.C. motor drives the air through a circuit.

turbine and cools its housing, blades and disc while avoiding the engine in its course. By using high speeds (r. p. m.) for the blower and turbine disc and by using high-temperature proof material as well as by careful design, it has been found possible to bring down the weight of the charging set for aeroplane engines to about one tenth of that of the usual weight of a charging set for a stationary engine.

It is obviously desirable to test out the effects on the engine of flight at high altitudes first on the test bed before doing so in trial flights. To this end, our firm builds so-termed *altitude-test stands* in which aeroplane engines are fed with combustion air at the pressures and temperatures met with at high altitudes, as, for example, 0·25 kg/cm^2 abs and — 50^0 C, and in which a flow of high-altitude air over the engine itself can be reproduced, if desired.

In this field of development, we would recall that our firm also builds *wind tunnels for aerodynamic investigations at super-sound and sub-sound velocities.* Fig. 152 shows a super-sound measurement wind tunnel built, according to Prof. Ackeret's suggestions, by Brown, Boveri & Co., Ltd., Baden and Tecnomasio Italiano Brown Boveri, Milan. Aeroplane parts, projectiles, etc. can be tested in this tunnel under wind velocities up to 2300 km/h. The air is driven through a circuit by a multi-stage axial blower, the tunnel being under a pressure of only 0·20 kg/cm^2 abs in order to reduce the driving power necessary for the compressor. A variable-speed D. C. motor of 1000 kW drives the blower, the said motor being supplied from a converter set, seen in the illustration.

IV. TRACTION.

A. ELECTRIC LOCOMOTIVES AND COACHES.

We mentioned, in last year's report, the efforts made by various railway managements to render their respective traffic systems, based on conceptions which were becoming somewhat obsolete, both speedier and more flexible, by the introduction of light fast-running motor coaches or motor-coach trains and to win back, in this way, part, at least, of the passenger traffic lost to road competitors. This brought the *motor coach* to the fore, while tending to relegate the heavy locomotive to the background, an evolution which has been marked by the lively interest recently manifested for electric motor coaches on systems which were already electrified and for Diesel-electric motor coaches on the non-electrified lines.

At the beginning of last year, the *Swiss Federal Railways*[1] gave an order to Swiss electro-mechanical manufacturing plants for the electrical equipment of two three-coach trains, of the light-weight high-speed type.

The German State Railway Company ordered from Brown, Boveri & Cie. A.-G., Mannheim similar three-unit A. C. motor coaches for 120 km/h maximum speed, this to complete an earlier order for double unit motor coaches which had given general satisfaction. The delivery comprises 13 three-coach unit trains each made up of three closely-coupled coaches. The connections are such that both end coaches can be driven without middle unit or else the two end coaches with two coaches between them. Further, as many as three such trains can run together in multiple-unit control connection. Each coach unit has a driving bogie and runner bogie. The continuous output rating of a three-unit motor train is 6 × 305 H. P. at 84 km/h. The motors are nose-suspended, of standard type. As in the case of the double motor coaches already delivered, the transformers are suspended to the coach body, below, and project down into the driving bogies (Fig. 153). The total weight of a three-unit-train is 144 t, there being 188 seats, which gives a specific tare of 770 kg per seat.

Tecnomasio Italiano Brown Boveri, Milan got an order from *S. A. Ferrovia Nord, Milan* for the electric equipment of three four-axle motor coaches (3000 V D.C.). The 12 former motor coaches of this railway, for which our concessionaries delivered the electric equipments, had nose-suspended motors while the new ones have motors rigidly secured in the frames of the bogies. Drive is from the motors to a gear wheel running on a stationary quill-shaft length. The springs forming the flexible connection to the driving wheel are built directly into the said gear wheel. This is yet another application of our spring-coupling drive design, mentioned in the last report, and which has given such satisfactory results on the R$_e$ 2/4 201—207 light motor coaches of the Swiss Federal Railways. Our design of drive

[1] According to the second programme of electrification of the Swiss Federal Railways, the Gossau-Sulgen (22·432 km) and the Giubiasco-Locarno (17·662 km) line sections were electrified. This brings the total of full-gauge line kilometers electrified up to 2,098·571 at the end of 1936, out of a total of 2868 km.

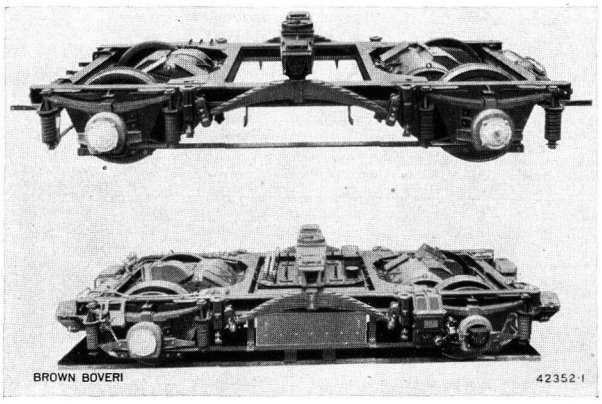


Fig. 153. — Bogie for double-unit and triple-unit motor coach.
Upper illustration:— Bogie with built-in motors.
Lower illustration:— Bogie with built-in motors and transformer.

with rigidly secured motors and rotating quill-shaft and spring couplings were given a trial on two driving axles of the double motor coach built by other makers on the Rotterdam-Hoek van Holland line of the Dutch Railways; these coaches were put into service in 1935.

The Czechoslovakian Brown Boveri Werke got an order from the *Czechoslovakian State Railways* (C. S. D.) for the electric equipment of two Diesel-electric motor coaches having, per bogie, a Diesel engine with main generator with mixed self and separate excitation, of 132 kW, 1320 r. p. m., 250 V and a nose-suspended driving motor for 120 kW one-hour rating at 800 r. p. m. The Brown Boveri output-relay control is used on these coaches.

The electric equipment of a *Diesel-electric trolley-wire inspection coach* should be mentioned, here. The *Austrian Federal Railways* ordered it from Brown Boveri-Werke, Vienna. This is a two-axle unit with a repair and inspection platform which can be raised and swung round. It has compressed-air and hand braking, two driver's cabs and a measuring bow. The electrical equipment comprises a counter-compounded generator driven by a Diesel engine, 107 H. P. at 1600 r. p. m., a nose-suspended motor, 58 kW, and the requisite control gear.

In the field of *electric* and *Diesel-electric locomotives* the most important order is that of light express locomotives placed by the *Cie du Chemin de fer Paris-Orléans* (P.-O.-Midi) with our French concessionaries, the Cie Electro-Mécanique and with the Cie Fives Lille. Fundamentally, the design is the same as that of the Type 2 D_o 2 express locomotive for 1500 V D. C. and about 4000 H. P., 120 km/h (140 km/h) max. running speed delivered in 1925, on which occasion two units were built for testing purposes. The same driving motors are used in the new locomotives and the same drives (Brown Boveri individual axle drive) on both sides and located outside, combined with inner frame, and the same bogie design. Electrical and mechanical details, only, have been changed in the subsequent units ordered since the first two. Thus, the 8 new units, Nos. E 538—545, have no regenerative braking as they are not intended for mountainous line sections.

The mechanical part of the 8 new locomotives is built by the Cie de Fives Lille in their shops in Fives. The Cie Fives Lille also build the motors of three locomotives in their Givors shops, according to drawings by the Cie Electro-Mécanique. All individual axle drives are built in the Bourget shops of the latter company and the rest of the electric equipment in their Le Havre shops, as well.

The total number of express locomotives which the P.-O.-Midi and the Chemin de fer de l'Etat have ordered from the Cie Electro-Mécanique has now reached 68, including the units at present building; these are all of the same type and represent a total weight of about 9000 t.

Brown, Boveri & Cie. A.-G., Mannheim got an order for the transformation of a two-axle locomotive, built in 1906 for single-phase A. C. current, 5000 V, $16^2/_3$ cycles. This unit may be said to present an almost historical interest as regards the development of single-phase traction. It is of axle sequence B_o and is driven by two 147-kW one-hour rating, nose-suspended motors. Our concessionaries have to deliver the reduction gear drive with protective casing, the transformer, a hand-operated cam switch and the balancing choke coil.

A locomotive of the B_o-B_o axle sequence for 20,000 V contact-wire voltage, 50 cycles was put into service, last year, successfully. The single-phase current is transformed to D. C. in a mutator and supplied as such to the driving motors, the terminal voltage of which is controlled from the high-voltage side of the transformer supplying the mutator. After the two 1 B_o 1 B_o 1 + 1 B_o 1 B_o 1 locomotives No. 11,801 and No. 11,851 of the Swiss Federal Railways this is the third and successful application of our new high-voltage control.

We, also, got an order for the electric equipment of three big Diesel-electric locomotives, this year. One is a big 2 D_o 1 + 1 D_o 2 unit of about 220 t total weight for the *Rumanian Railways*, for which Messrs. Sulzer Bros., Winterthur (Switzerland) are general contractors. The equipment includes two Diesel sets of each 1900 H. P. continuous and 2200 H. P. one-hour rating with Brown Boveri-Buchi charging and eight driving motors with individual axle drive and the electric equipment and the complete control apparatus (servo field-regulator control).

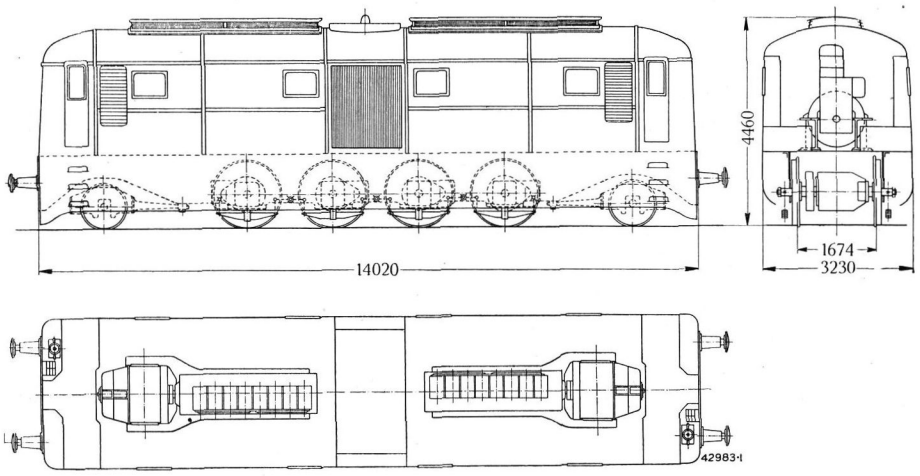


Fig. 154. — Diesel-electric locomotive of 1 D_o 1 axle sequence, 900/1000 H. P. of the Buenos Aires Great Southern Railways.

The locomotive develops a one-hour tractive effort of 24,000 kg at 35 km/h and a max. running speed of 100 km/h. It is intended for the Campina-Brasov (gradient up to about 2·8 %) line section and must haul 600-t trains. Both halves of the locomotive are identical, but one half cannot work alone. This locomotive is one of the most powerful and biggest Diesel-electric units ever built.

Two other wide-gauge Diesel-electric locomotives for which Messrs. Harland & Wolff Ltd., Belfast, are general contractors, are being built for the *Buenos Aires Great Southern Railway*. They are of the 1 D_o 1 type with a total weight per unit of 94 t. The max. running speed is 112 km/h and the one-hour tractive effort developed at 27·2 km/h is 7050 kg. Fig. 154 gives a type illustration of the locomotive, which has two eight-cylinder two-stroke Diesel engines each of 450 B. H. P., continuous rating. Our servo field-regulator control and multiple unit control is provided for. Our material per locomotive will consist of:— two generator sets each composed of one main and one auxiliary generator, the control equipment, instruments, safety devices and small material.

Further, *Messrs. Allis Chalmers Mfg. Co., Milwaukee,* got an order for the electrical equipment of a four-axle, Diesel-electric shunting locomotive type B_o-B_o driven by nose-suspended motors. The machine weighs 96 t and develops a tractive effort of 19,200 kg at 6·3 km/h. Brown Boveri servo field-regulator control is fitted.

Intensive work has been done, during 1936, on the further development of traction material (motors and apparatus for tramways and full-gauge lines). The tendency to increase the running speed, particularly of electrically-driven trains led to modifying the design of the *current collector* and the creation of a type which offered less air resistance at high speeds. As a result of our efforts in this field, we booked

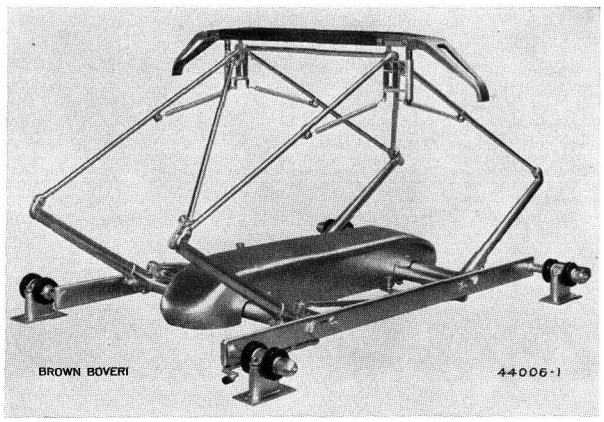


Fig. 155. — Pantograph current collector of special streamline design.

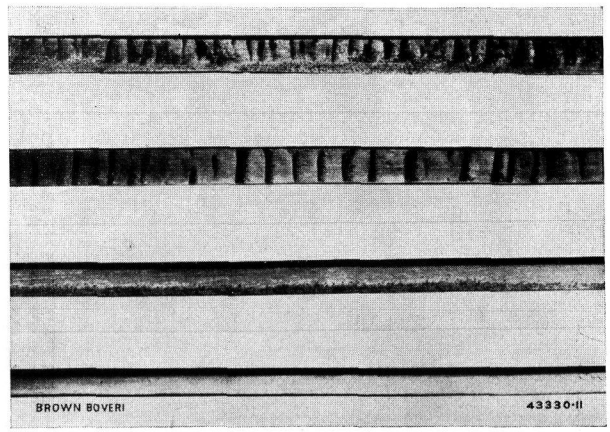


Fig. 156. — Four lengths of contact wire from the Basle tramway system.

First and second illustrations from above:— two wire lengths which were, originally, of 85 mm² belonging to the road passage underground of the Baden Station-Hirzbrunnen, built in on 3rd Sept., 1930 and changed on 19th July, 1935.

an order for 230 of the new pantograph current collectors which combine all the fundamental advantages of our older design with several new features. These collectors are intended for the new 90 two and three-unit trains of the Dutch State Railways which generally place their order with Dutch firms. The equipments in question will be used on the Arnhem-Utrecht-Gouda-Rotterdam, Gouda-Haag and the Amsterdam-Utrecht-Eindhoven line sections. These pantograph current collectors have carbon contact pieces which assure perfect current collecting of 1000 A at 60 km/h and also of 350 A at a speed of 150 km/h (Fig. 155).

Fig. 156 shows the influence of *carbon contact pieces* fitted to the current collectors as regards the contact wire that is to say on the surface of the wire on which the collector piece slides and, therewith, the reduction of the *sparking* which is so *troublesome for neighbouring radio sets*. This figure shows different lengths of contact line taken from the Town of Basle system at different times. The first and second illustration, above, show two lengths of contact conductor with an original section of 85 mm² taken from the Basel DR-Hirzbrunnen road-passage under railway station, put up on Sept. 3rd, 1930 and replaced on July 19th, 1935. With service using "Lyra" type current collectors with U-shaped aluminium contact pieces, there were very marked grooves formed in the said contact wire, these were considerably smoothed out by the utilization of Brown Boveri pantographs with elevated contact piece supports having aluminium contact pieces during the last three months before the contact wire was changed. The third illustration shows a piece of contact wire of 70 mm² section taken from the Blumenrain-St. Johann suburban line section, put up

on March 19th, 1928 and changed on July 26th, 1935. There were no grooves formed on this wire with standard contact-wire height. At the beginning of the last service period of about three months duration with Brown Boveri pantograph current collectors, the wire had a rough surface which was transformed, after the three months in question, into a smooth surface, but not into a polished one. The fourth illustration shows a length of contact wire of 50 mm^2 section taken from the Güterstrasse line and replaced on Sept. 26th, 1935 that is to say fifteen days after all pantographs had been equipped with carbon contact pieces. The wire which had been smoothed by the use of Brown Boveri aluminium contact pieces during some months (see third illustration) became highly polished in only 15-days service with carbon contact pieces.

The general tendency to increase the travelling speed of full-gauge trains is also felt in tramway service as well. This can be attained either by an increase in the maximum running speed or else by increasing the acceleration at starting and retardation at braking. The conditions thus created make the nose-suspended traction motor a less desirable type than heretofore, as has been explained elsewhere. In order to attain for the vehicles in question the advantages of quiet running and little wear, we have developed a new cardan drive. The motor is rigidly suspended in the main frame or in the bogie frame and drives the pinion of a reduction gear through a cardan joint coupling. The big gear wheel of the said reduction gear is on the driving axle. The reduction gear is lodged in a casing carried, on one side, on the axle and, on the other, on the bogie frame. The well-known Hardy discs are used advantageously as Cardan couplings for all outputs met with in standard practice. Big reduction ratios of the gear are desirable as they allow of using small high-speed traction motors. The desired result is attained by milling the pinion of the reduction gear out of the shaft itself. This kind of drive has met with much success. After a year's trial with one of them, the Milan Tramways ordered 110 such drives for 60 coaches, from Tecnomasio Italiano Brown Boveri, Milan. These drives have, each, an output of 26·5 kW at 27 km/h and, including the motor, they only weigh, each, 350 kg.

If the output of the motor is so big that its length exceeds the available space which must remain for the Cardan shaft, the design can be so modified that the motor armature is mounted on a quill through which the cardan shaft is passed, with sufficient play for unavoidable relative movements. The cardan shaft and the quill are coupled together at the end of the motor opposite that of the reduction gear. Last year, an equipment of this type was delivered to the Bologna Tramways. Drive and motor weigh 450 kg, the output being 40 kW at a speed of 23 km/h.

During last year, the *Rigibahn Gesellschaft A.-G.*, Lucerne, decided to electrify the Rigi line section which begins at Vitznau (440 m above sea level) and leads to Rigi Kulm (1751 m above sea level). This is Europe's oldest mountain railway, which was opened as far as Staffel on May 21st, 1871 and, as far as Rigi-Kulm, on June 27th, 1873 (total length of line 6857 km, steepest gradient 25 %). The Riggenbach rack system was used here for the first time. Electrification should bring down running charges and speed up service. D. C. at 1500 V has been chosen. As first stage, three rack coaches (Fig. 157) each of 16-t tare have been ordered, to carry 80 passengers and to push a passenger coach of 6·3 t tare holding 60 passengers. The Swiss Locomotive and Machine Works, Winterthur are delivering the mechanical parts of these coaches and the electrical equipment is composed of two motors of 165 kW one-hour rating, allowing of attaining a speed of 14·6 km/h on the up-gradient. The max. running speed on the up-gradient is 18 km/h while, on the down-gradient, on the steepest gradient it is 12 km/h. On the down-gradient the motors work with lowered

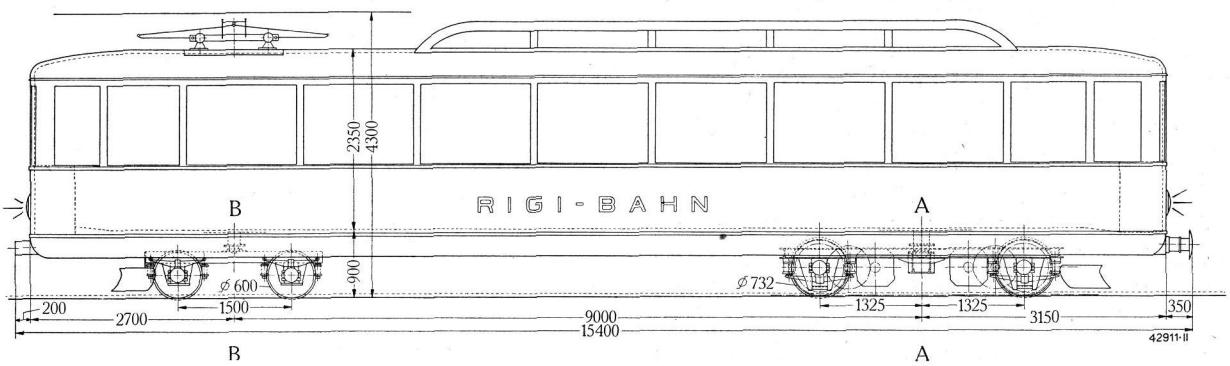


Fig. 157. — Drawing for one of the new geared motor coaches of the Rigi Railway.

A. Driving bogie. B. Runner bogie.

pantograph as auto-exciting generators, delivering current to resistances. We are delivering the entire electric equipment of all three coaches including traction motors, starting and braking controllers with 15 starting and braking steps, the starting and braking resistances, the electric signalling devices of six push coaches and the electric heating equipment. The basic traffic load should be covered by the three new coaches and the existing steam locomotives are retained, for the time being, for peak traffic requirements.

The *electric air-heating* system developed by us with all the improvements we have introduced has met with great success. We delivered electric apparatus for air heating for eight coaches for international service to the Dutch State Railways and the latter placed a repeat order for 12 more of these equipments, in August of last year. Per coach, there is a voltage change-over switch, various contactors, relays, series resistances as well as two heating couplings per coach of our standard design but having mechanical interlock which only allows of changing the couplings by using an interlocking key kept in the locomotive. In accordance with the heating voltages used internationally of 3000 or 1500 V, 1000 V and 50 cycles the voltage change-over switches have four service positions. The change-over of the switches in question is carried out by hand, on these coaches.

The air-heating systems delivered to the *Swiss Federal Railways* have been increased by the following equipments: — A steam heating element has been built into four passenger coaches for international service, apart from the electric heating for 3000 and 1500 V D. C. and for 1000 V single-phase A. C. at $16^2/_3$ and 50 cycles.

When the train is hauled by steam locomotive, the air is driven over the steam-heating element and over the heating resistances which, of course, are not under current. In the coach itself there are only the sheet metal ducts for the distribution of air and these are used both for steam or for electric heating. Thus, a number of valves which are in danger of getting frozen up with the ordinary steam-pipe systems are eliminated. Further, the weight of the steam-heating equipment is lower than with the ordinary direct steam-heating systems.

Up till now, it was considered sufficient to cut off the flow of hot air to the respective compartments by using a hand-operated air valve. Rotary magnets have now been fitted for operating the valves and these are governed by the thermostats of the individual compartments. The fact that the steam elements generate a lower temperature than those of the electrical elements means that a much greater amount of air is needed. The greater volume of air is advantageous for summer ventilation. A ten-fold exchange of air per hour is attained, a considerable improvement on the former five-fold renewal of air. As running speeds increase, the question of artificial ventilation is becoming more and more imperative as the opening of windows is getting intolerable. A solution entailing the use of ceiling ventilators holds out promise of satisfactory results.

This has been done, for example, in the case of seven light trailer coaches on the Swiss Federal Railways, which have electric air heating and a ventilator equipment. In the coaches in question not only are electro-magnetically controlled air-valves on the air ducts used but similar valves are built into the armature of the ceiling ventilators.

We have tried out our air-heating system on a new motor coach on the Basle Tramway system with successful results. The coach heats up quicker than with ordinary heaters, partly because there is a bigger amount of heating power used in air heating and, partly, because the coach fills rapidly with hot air, before partitions, floor, ceiling and seats have reached the temperature of the hot air. The built-in thermostat regulates the temperature in the coach to 12—13 ° C. There is better distribution of heat with air heating. Although the Basle Tramways made efforts to get better heat distribution, in coaches with ordinary heating system, by dividing up the radiators, the results were only partly successful. There are always localized hot areas under the seats below which the radiators are placed.

Air heating offers the advantage of improvement of cleaning facilities. There are no radiators under the seats. Upkeep should be easier and cheaper than with the ordinary heating system.

Finally, we would say that the Swiss Federal Railways have placed an order with us for the train preheating plant for Neuchâtel Railway Station; to replace the expensive and troublesome system now in use of heating up trains in advance by means of electric locomotives.

Twenty *train-lighting generators* for a one-hour output of 3150 watts, 105 A, 24—30 V, 370—2000 r. p. m. were built, for the first time, to a nose-suspended motor design for the Dutch State Railways. These generators have armature roller bearings and axle roller bearings. This equipment opens up an interesting prospect as the higher running speeds coming into favour and certain climatic conditions make belt drive more and more unsuitable.

B. VELOX LOCOMOTIVES.

Fig. 158 shows the projected layout of a Velox express train locomotive 5500 H. P. for 180 km/h

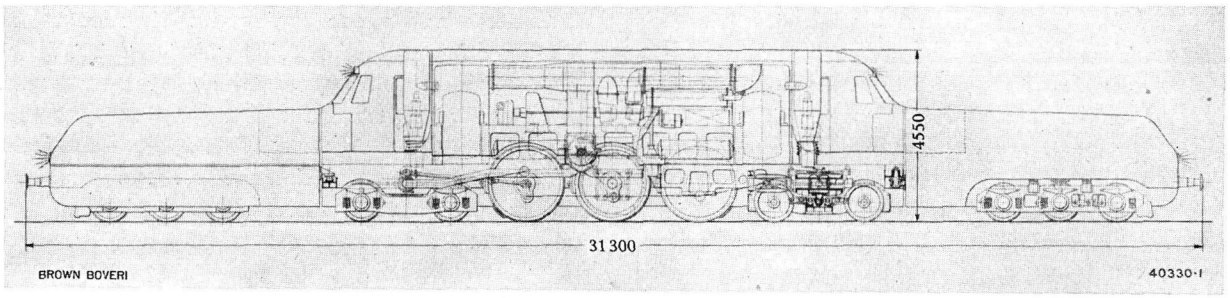


Fig. 158. — Project of a 5500-H. P. Velox-locomotive, for 180 km/h running speed.
There are two Velox units on the locomotive, each for 20 t/h of steam at 60 kg/cm² abs and 400° C. The Velox steam generator allows of lodging any power desired on a locomotive.

travelling speed. The tare with 10 t of oil and 60 t of water is 230 t. It has two independent Velox units each for 20 t/h of steam, 60 kg/cm² abs, 400° C. The wheels are driven, independently, by high-speed steam engines of high efficiency. The working out of this project showed once again, that there is no difficulty to be encountered in getting any output desired from the locomotive with Velox steam generators. The high efficiency of the Velox steam generator and of the machinery plant is especially advantageous on a locomotive on account of the lowering of running charges, lightening of the weight of the locomotive and increase in the radius of action.

C. DIESEL-MECHANICAL VEHICLES.

Fig. 159 shows the frame of a Diesel engine coach of the German State Railways, driven by a high-speed Maybach four-stroke engine. The Brown Boveri charging set seen in the centre, above, brings up the output of the said engine considerably.

Fig. 160 shows a truck engine by Ad. Saurer A.-G., Arbon (Switzerland). The small charging set seen on the right increases its output from 150 to 225 H. P. Fig. 161 shows a locomotive engine of the American Locomotive Co., Auburn, the output of which has been raised from 600 to 900 H. P. by the built-on charging set.

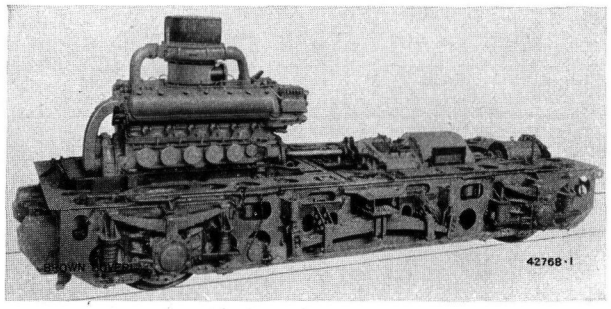


Fig. 159. — Frame of a Diesel engine coach of the German State Railways, driven by a Maybach six-cylinder four-stroke engine.
The engine output is increased by about 50% by means of the charging set seen in the centre above.

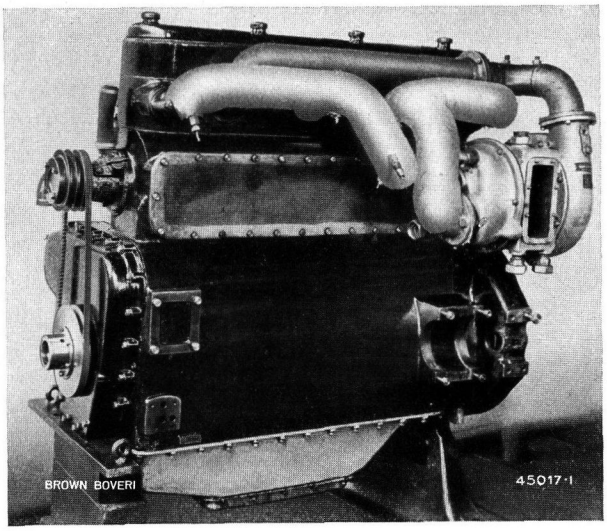


Fig. 160. — 225-H.P. four-cylinder truck Diesel engine by Messrs. Saurer, Arbon (Switzerland), charged by the blower seen on the extreme right.

There is considerable electric equipment required for this type of vehicle. Thus, Brown, Boveri & Cie. A.-G., Mannheim got an order for equipments of this type for 30 four-axle Diesel-fluid-transmission driven motor coaches with Voith fluid gear and for 30 driving trailers. Control of these coaches is electrical and was

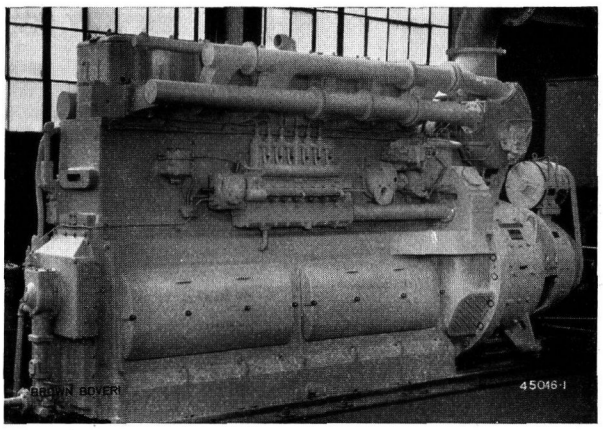


Fig. 161. — 900-H. P. locomotive engine of the American Locomotive Co., Auburn with Brown Boveri charging set.

designed to allow drive from the driving trailer, so that trains made up of two driving coaches and two driving trailers can be driven from one driver's cab. Several of the auxiliary services are also electrically controlled:— the remote supervision of the Diesel engines, the lighting and the hot-air heating. This equipment comprises per coach the following chief parts:— one generator for generating auxiliary current with automatic voltage regulation, two driver controllers, one Diesel injection adjuster for remote control of the Diesel engines, two motors for hot-air heating, one converter set 110/112 V for feeding the Diesel-engine glow plugs, two control-current couplings, a series of measurement and supervision devices. The 30 control coaches each have a driver's cab equipment, two control-current couplings and electric lighting.

V. MARINE DRIVES.

A. VELOX PLANTS ON SHIPS.

Surprising possibilities as regards the utilisation of the Velox steam generator in naval and merchant vessels have arisen as a result of the wide experience gained in stationary plants and of the constructional progress realized as regards space and weight saving. Thus, investigation has shown that a Velox to produce 80 t/h of steam at 60—80 kg/cm² abs, with all its accessories, only weighs about 55 t and is so small that two instead of the former one boiler of the same output could be lodged in a torpedo-boat boiler room 7 m wide. Thus, the usual boiler space for three boilers allow of using six Velox boilers to produce 480,000 kg/h of steam. The maximum output of a Velox can be kept up continuously without any disadvantage to the Velox itself, or additional power for draught and at the highest efficiency, contrary to what occurs with ordinary marine boilers under forced conditions. Fig. 162 shows the layout in a vessel of two boilers, 80 t/h steam production, as just described. The Velox is placed, horizontally, the steam separator vertically. The charging set (gas turbine, charging compressor and auxiliary turbine) is placed horizontally over the Velox.

We investigated, for ourselves, how a *Velox steam generating plant could have been lodged on the Cunarder-White Star liner "Queen Mary"* and how it would compare with the actual boiler plant. The result is so interesting that we reproduce it in Fig. 163 which shows the striking difference in space required.

TABLE IV.

Data	Actual boilers of Queen Mary	Projected boilers of Velox type
Steam output (continuous) t/h	800	960
Number of boilers	24	12
Length of boiler room in m .	80·5	32·9
Floor area „ „ „ m² .	1962	690
„ „ „ „ „ m²/t of steam	2·46	0·72
Space up to B deck . . m³ .	26,162	9424
„ „ „ „ . . m³/t	32·6	9·8

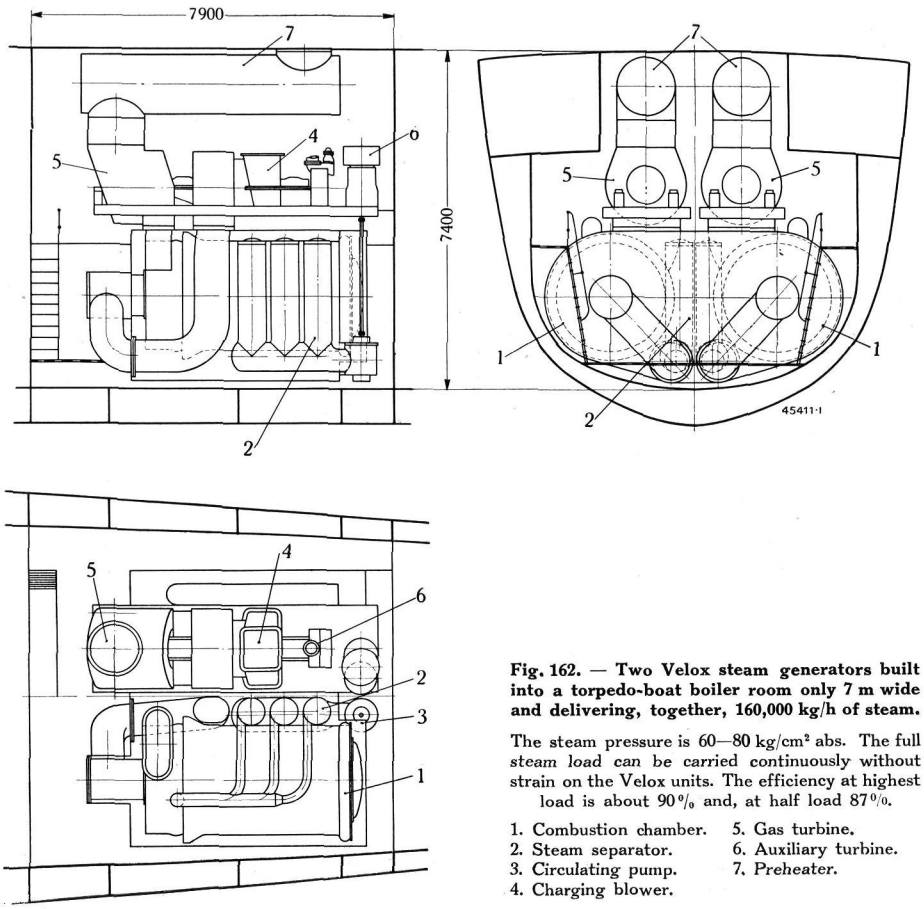


Fig. 162. — Two Velox steam generators built into a torpedo-boat boiler room only 7 m wide and delivering, together, 160,000 kg/h of steam.

The steam pressure is 60—80 kg/cm² abs. The full steam load can be carried continuously without strain on the Velox units. The efficiency at highest load is about 90% and, at half load 87%.

1. Combustion chamber.
2. Steam separator.
3. Circulating pump.
4. Charging blower.
5. Gas turbine.
6. Auxiliary turbine.
7. Preheater.

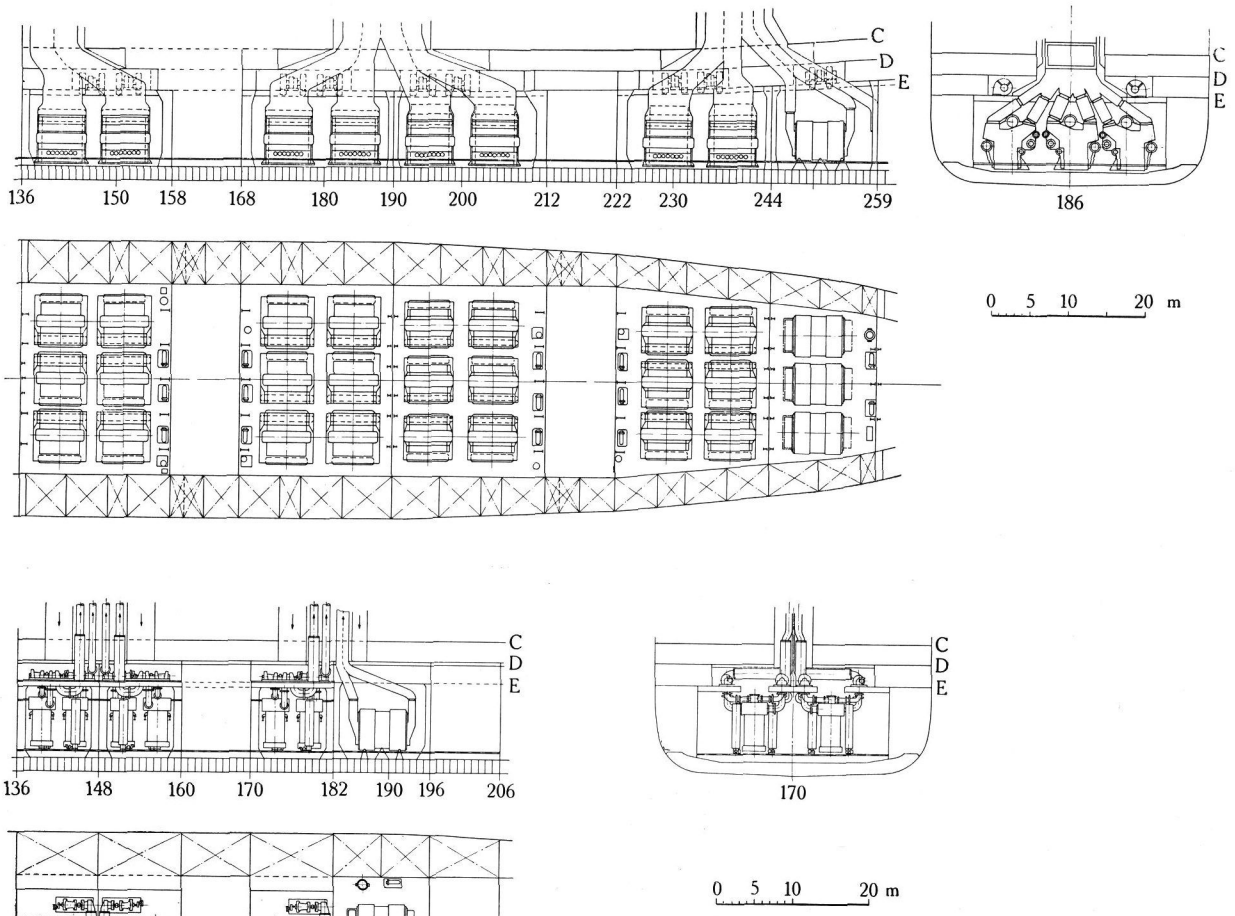


Fig. 163. — Boiler plant of Cunarder-White Star liner "Queen Mary" as compared to a Velox plant of 20 % bigger output.

The Table IV summarizes the chief data for both boiler designs, as far as the main boilers are concerned.

In connection with these figures it must be said that the Velox steam generators suggested are standard units which have already been thoroughly tested, giving a thermal efficiency of 94—95 % and still over 90 % at 1/4 load. This would mean a considerable saving in fuel and less bunker space. The reduced dimensions of the uptakes are, also, worthy of note and the great gain in area on the 'tween decks.

B. MARINE AUXILIARIES AND THEIR DRIVES.

Economical service and operating reliability of the marine boiler and turbine plants depends to a great extent on the quality and reliability of the auxiliaries and their drives, as was pointed out in the case of stationary Velox plants, as well. Among the auxiliaries in question, there are slow-running cooling-water pumps, circulation pumps, condensate pumps and fans, as well as fast-running boiler-feed pumps, turbo-blowers, D. C. generators, fuel and governor-oil pumps. In marine plants, as well, the simplest method of driving is the use of individual, electric drives, the auxiliaries being, then, located at the most suitable points and driven at the speeds most suitable to their individual characteristics. From the economic point of view, as well, electric drive is advantageous especially when it is from a Helux dynamo driven from the main turbine. Unfortunately, the electric drive is not guaranteed against trouble on the electric supply system. The drive of the auxiliaries by steam turbines is much more reliable. As, however, individual drive of the many auxiliaries is unsuitable from the point of view of cost and steam consumption, it is more advantageous to group them together and drive them by a single, bigger and more efficient steam turbine, through reduction gears, each at the speed best suited to it. The disadvantage of this layout is the long connections to and from the pumps, which are, often, difficult to lay. Brown Boveri has created a specially small type of steam turbine for these pumps, taking up little space and running at relatively high efficiency. Pages 69/71

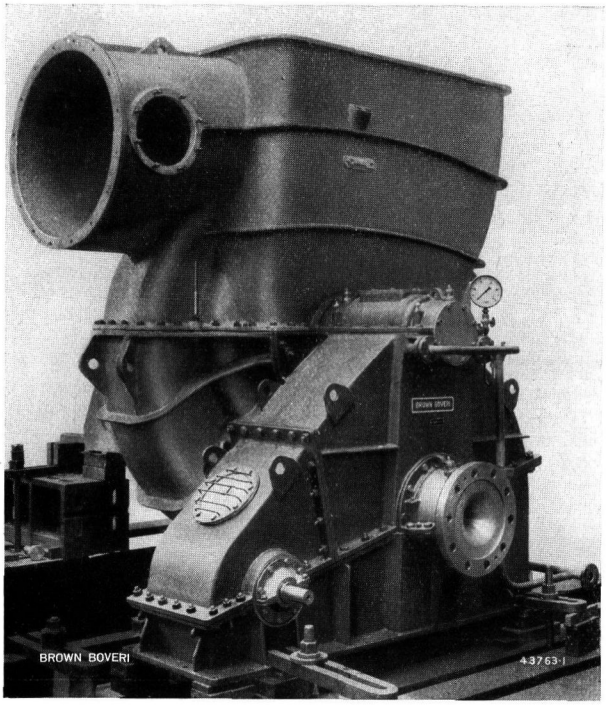


Fig. 164. — Big scavenging blower for a 20,000-H. P. two-stroke marine Diesel engine.

The blower runs at 4000 r. p. m. and delivers 1340 m³/s of air at 1·35 kg/cm² abs. It is driven through a reduction gear by a special 1450-H. P. Sulzer two-stroke auxiliary Diesel engine running at 600 r. p. m. Between the high-speed blower and the Diesel engine subjected to cyclic irregularity there is a flexible coupling having a determined flexible characteristic. This coupling is lodged in the big gear wheel.

show a large number of marine auxiliaries built by Brown Boveri, which, however, can also be used in stationary plants.

The *scavenging blowers* for marine Diesel engines also belong to the marine auxiliaries. Fig. 164 shows one of two of these blowers for scavenging two 20,000-H. P. two-stroke Diesel engines and which are interesting owing to their size. Each one is driven through a reduction gear by a 1450-H. P. Sulzer two-stroke auxiliary Diesel engine and delivers 1340 m^3/min of air at 1·35 kg/cm^2 abs. There is a flexible coupling in the big gear wheel with a definite spring characteristic, which separates flexibly the fast-running blower, acting like a big flywheel, from the reciprocating engine characterized by its cyclic irregularity.

In the field of *electric drives for auxiliaries* for submarines we have delivered numerous drives for a variety of auxiliary machines and devices. These include a number of starters of special design developed by us (two-pole system cut outs, semi-automatic starting, no-voltage trips, built-in starting resistances). These starters were often combined closely with the motor in question and Fig. 165 shows an example of this.

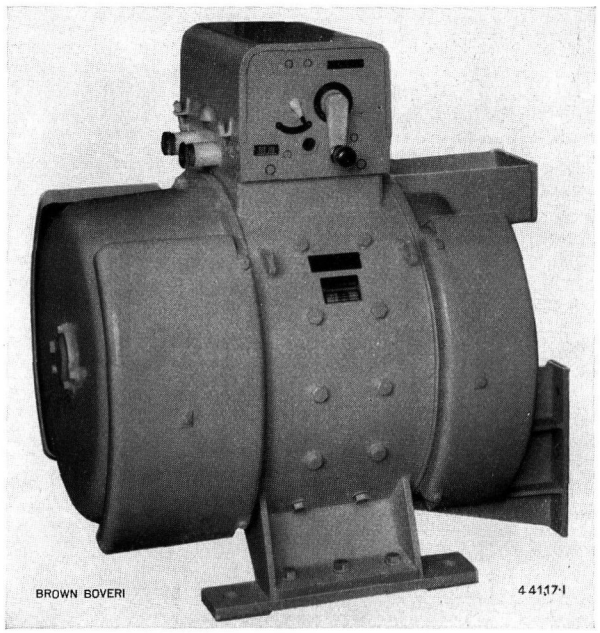


Fig. 165. — D. C. motor, wave-wash proof for drive of a submarine high-pressure compressor, with built-on starter. 83/104 H. P., 110/170 V, 530 to abt. 650 r. p. m.

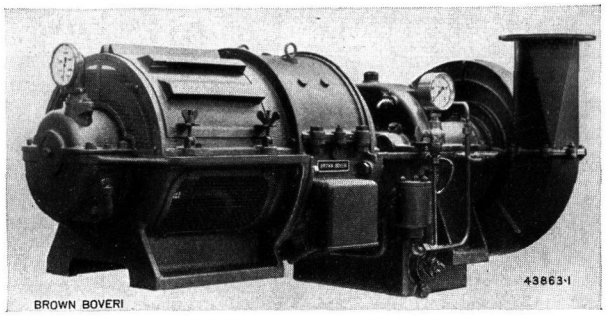


Fig. 166. — Submarine tank blower set, 55 m³/min, 1·033/1·55 kg/cm², 5600/20,800 r. p. m., 80 kW, 110/135 V.

The high-speed blowers (20,000 to 30,000 r.p.m.) for the submerging tanks of submarines will always be given preference over straight-driven blowers as they are so much lighter. Fig. 166 shows one of latest design of which a large number were delivered in the course of last year.

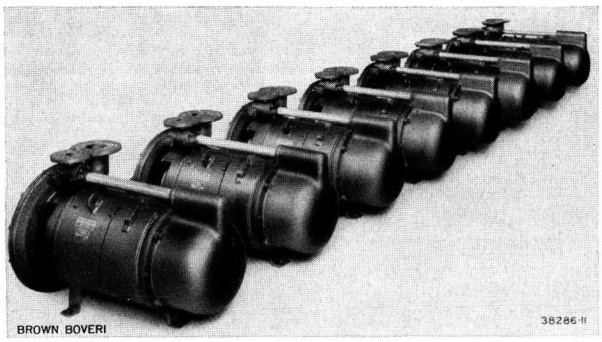
C. ELECTRIC SHIP PROPULSION.

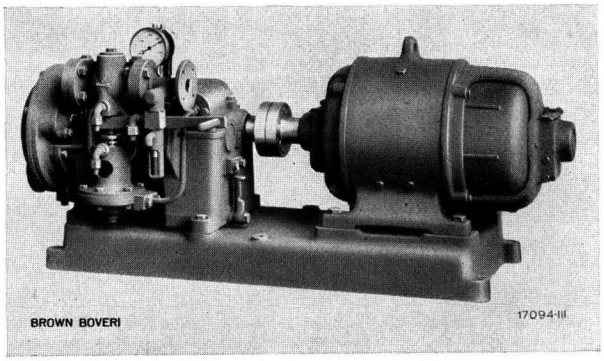
We have gained still further considerable experiences in this field.

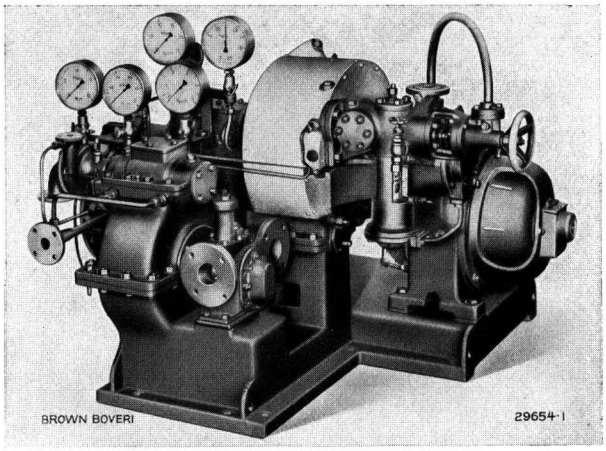
Thus, one of our licencees booked an order for the electric equipment of a Diesel-electric drive for two scouting cruisers. The Ward-Leonard connection is used for control of these plants.

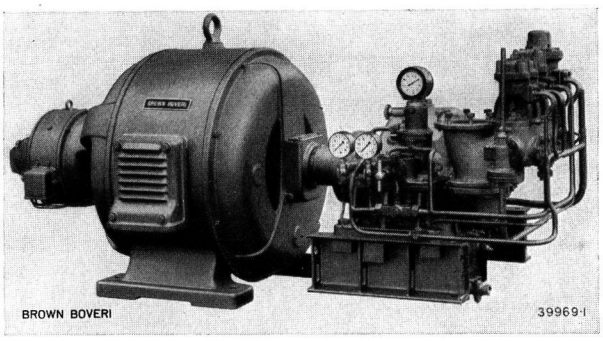
We also got orders for the electric gear for submarines of various navies in the course of last year.

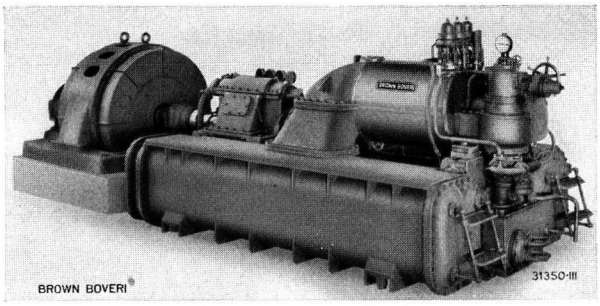
In our last year's report, we were able to mention a *single-screw 9500-t freighter* having Diesel-electric

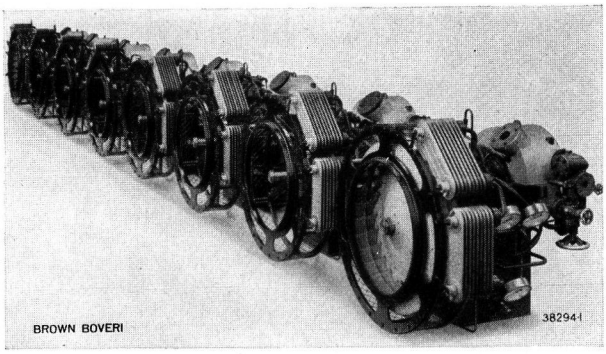


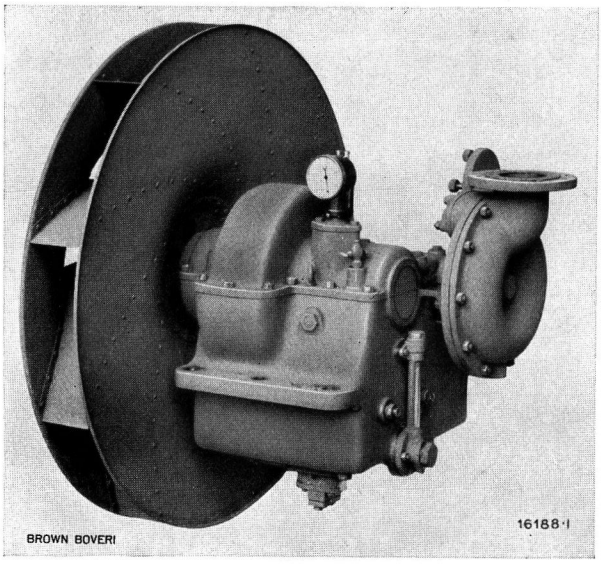


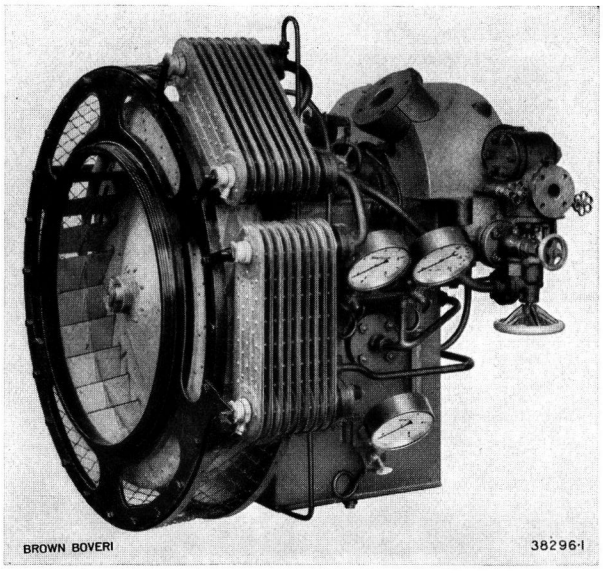




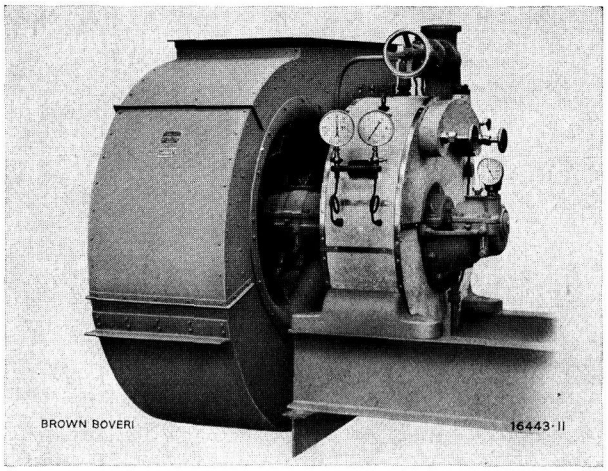


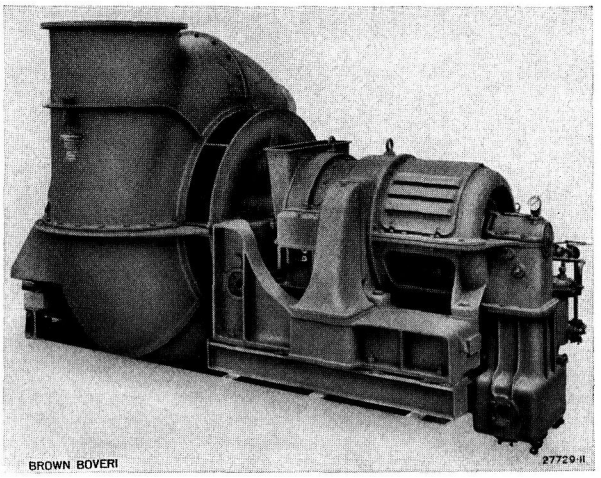


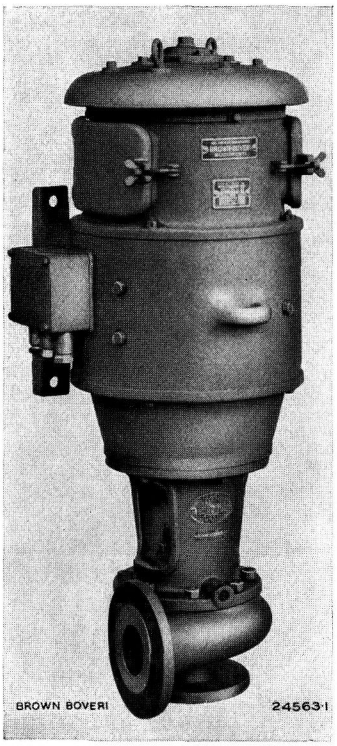


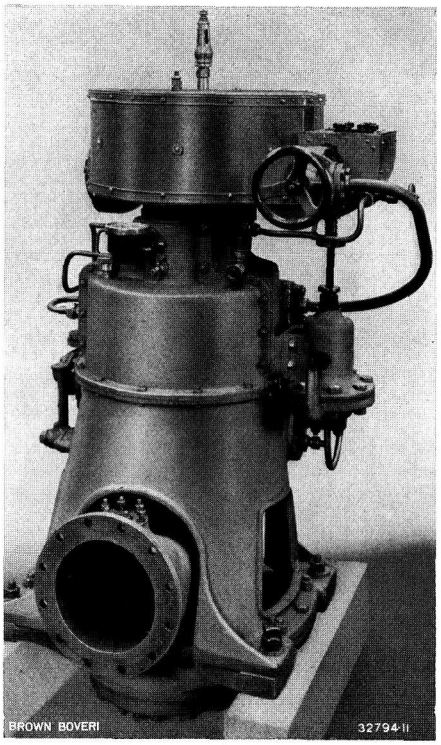


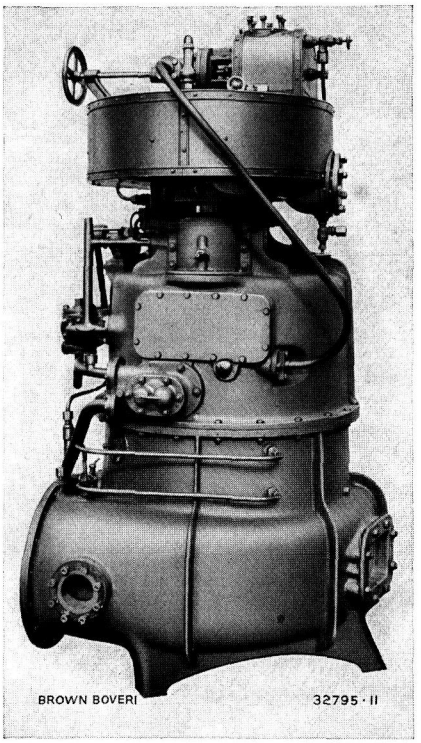
Brown Boveri marine auxiliaries:— Generators for D. C. and A. C. fans.

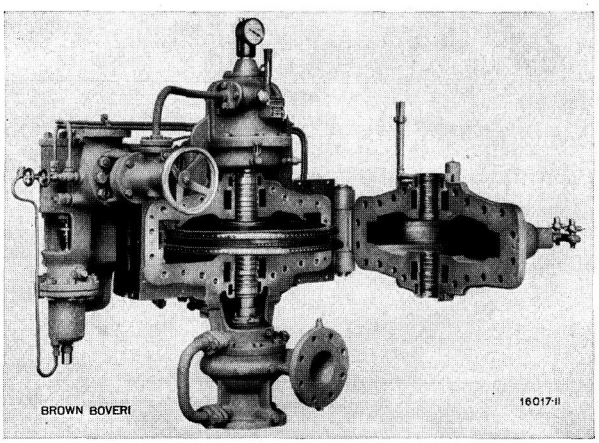


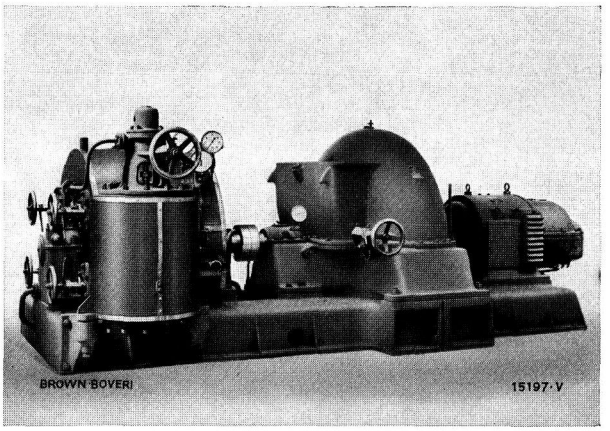




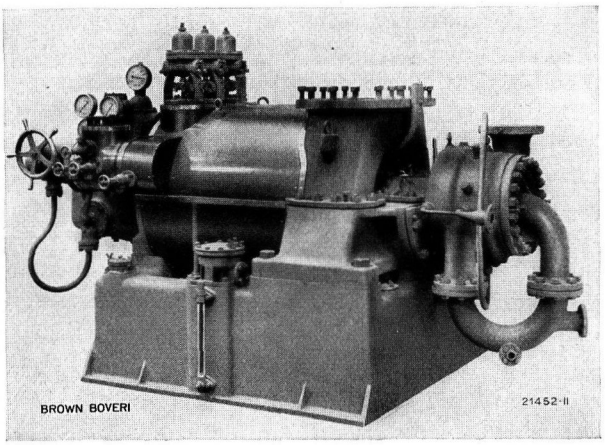


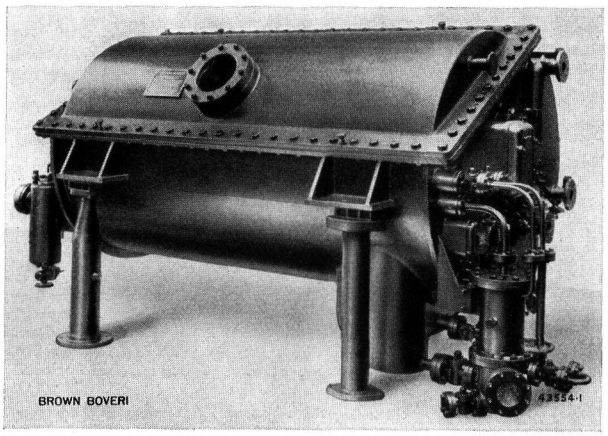


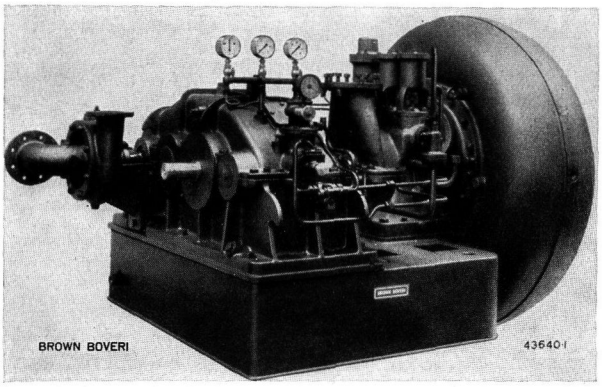


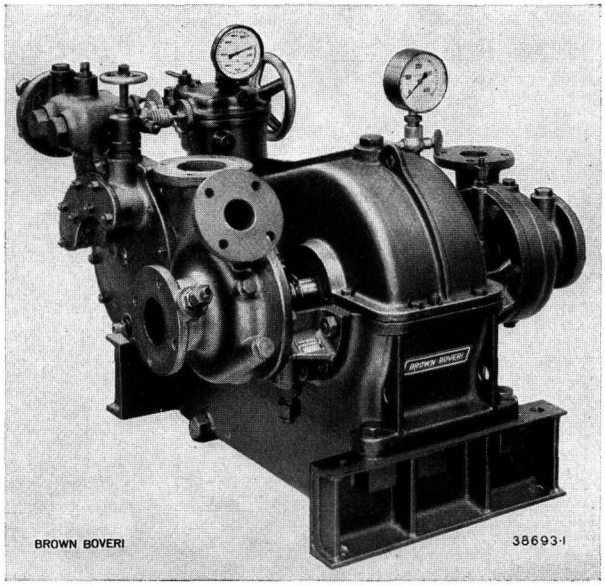


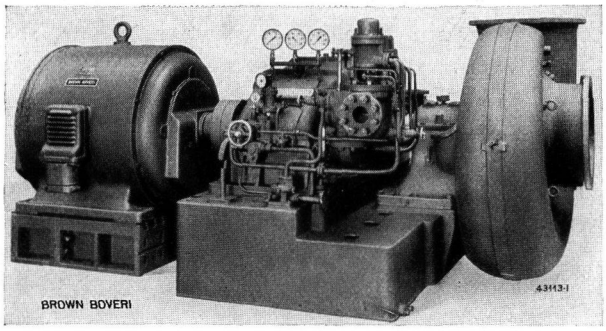
Brown Boveri marine auxiliaries: — Fans, scavenging blowers, feed pumps, circulation pumps (C. E. M.)











Brown Boveri marine auxiliaries:— Feed pumps, pump sets for condensing plants, Frigiblocs.

propulsion, 6800 H. P., which was ordered from Brown, Boveri & Cie. A.-G., Mannheim; this is the first Diesel-electric marine drive built to the system developed by us with A. C. generators working in parallel.

The vessel, the *"Wuppertal"* belongs to the Hamburg-Amerika line and was launched in the middle of Sept. 1936. On the 30th of Nov. 1936 it carried out its maiden trip to Australia. A more detailed description of this drive will be published later and we only desire to say a few words on the subject here.

The main engines are three three-phase synchronous generators each of 1900 kVA, 250 r. p. m., 2000 V, 50 cycles. These are driven by MAN Diesel engines. There is a propeller motor which is composed of a synchronous motor 6800 H. P., 125 r. p. m. and an induction motor of 900 H. P., 62·5 r. p. m. in a common housing. The latter unit is used when much manœuvring has to be carried out or when the vessel has to run slow for long periods and under economical conditions.

There are three converters to excite the machines composed of an induction motor and a D. C. generator,

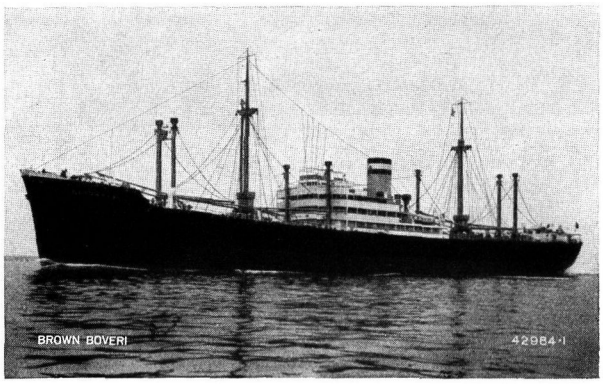


Fig. 167. — Motor ship "Wuppertal" of the Hamburg Amerika Line. With Diesel-electric drive (A. C.) Brown Boveri system.
All auxiliaries below deck as well as lighting are supplied by A. C. three-phase current.

of these, two are required for ordinary service, the third being a spare, or else it can be used for the D. C. auxiliary system.

It is to be noted that the entire auxiliary system of the vessel, pumps, fans, excitation converters, electric kitchen, heating and lighting works under three-phase current; only the deck auxiliaries (winches, capstan for the anchor) are run with D. C. Contrary to the usual custom of using D. C. throughout for such purposes, we have a big vessel, here, using three-phase A. C. for the auxiliaries below deck. There are two Diesel three-phase generator sets 175 kVA each to feed the auxiliaries. However, the system can also be supplied from the bus-bars of the main-driving system through two transformers. This arrangement results in very economical service, at sea, it makes operation simple and saves the auxiliary Diesel engines.

The two main generators suffice for manœuvring so that the third can feed the auxiliaries during that time if it is not desired to make use of the auxiliary generators.

The starting and controlling of the main motor consists in asynchronous starting and then falling into step of the motor when its D. C. excitation circuit is closed. The close regulation of the speed of the vessel is carried out by the speed regulation of the Diesel engines, while wide steps are attained by putting into service one, two or three main generators. The switching in or cutting out of the generators is carried but by simple switching of these units when they are unexcited, which saves time and delicate synchronizing operations.

This marine plant is quite a new departure in marine drives and great expectations are entertained as to the economical qualities of the vessel. Brown Boveri also delivered all auxiliary equipment below deck, that is:— auxiliary motors, remote-signalling plant and installation.

Apart from a big number of submarine drives, we and our licencees have built twelve Diesel-electric marine drives in the course of the last six years. These are given in the following Table:—

TABLE V.

No.	Type of vessel	No. of propellers	Total output on shafts in H. P.	Type of current
1	Fire-extinguishing vessel "Santa Barbara" for Genoa harbour	2	150	D. C.
2	Coastal-defence battle-ship "Wainömoinen"	2	4000	„
3	Coastal-defence battle-ship "Ilmarinen"	2	4000	„
4	Sounding vessel for the River Scheldt	1	64	„
5	Mine-layer "Olav Tryggvason"	2	1400	„
6	Saloon passenger paddle vessel "Genève"	—	920	„
7	Ferry vessel "Bevik-Stathelle" (Norway)	1	60	„
8	Scouting cruiser (building) .	1	570	„
9	Scouting cruiser (building) .	1	570	„
10	Single-screw freighter "Wuppertal" 66 H. A. L. . . .	1	7700	A. C.
11	Ice breaker (building) . . .	3	4000	D. C.
12	Sister vessel to 10	1	6800	A. C.
	Total		30,234	S.H.P.

NOTICE.

It gives us much pleasure to be able to inform our readers that the Swiss Federal Institute of Technology, Zurich, conferred the honorary title of Doctor of Technical Science on its former pupil, our present valued collaborator,

Mr. W. G. NOACK (Dipl. Ing.)

on the 20th November, 1936, on the occasion of the official inauguration of the scholastic year 1936/37. — A decade of creative and constructive work, in the service of our firm, devoted to the whole field of thermal machinery and crowned by the invention and development of the Velox Steam Generator has, thus, found its recognition and well-merited reward.

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