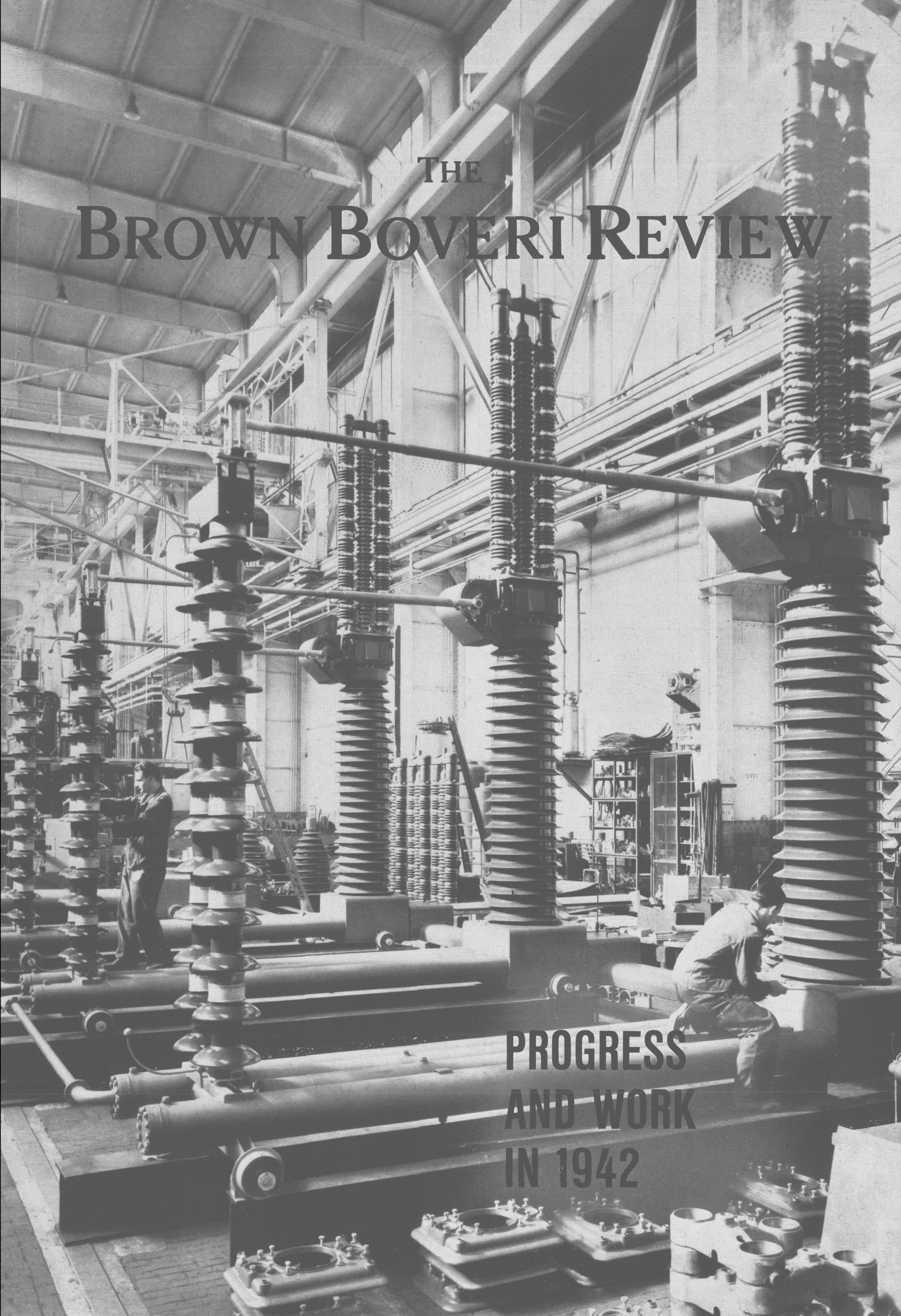
The Brown Boveri Review



PROGRESS AND WORK IN 1942

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PROGRESS AND WORK IN 1942.

INTRODUCTION.

IN this our traditional annual retrospective number we can again look back on a year of intensive development work. The tendency to concentrate on work of this nature which has characterized the last three years would appear to warrant a cursory survey of the circumstances governing research in general in a big industrial undertaking such as that of Brown Boveri under the very varying conditions prevailing during periods of trade boom, economic depression, and war.

Development and research work invariably originates either in personal initiative with a definite aim in view or in the desire to exploit operating experience and suggestions emanating from the operating field, although there is not always a clear dividing line between the two forms of work. In every case it is imperative to call a special department into being and to maintain it alongside the normal manufacturing process. From this very fact, however, certain difficulties arise which are not always of the same magnitude and nature.

To a certain extent the problem is easier during periods of economic depression when the best brains can be released from the production side for research and development work and plenty of experience is also available from the operating field. Unless reserves have been set apart for this purpose during periods of trade boom, however, the foregoing factors cannot be fully exploited due to the decreased revenue failing to cover the enormous cost of work of this nature. To make the financial resources last as long as possible pure research work has to be drawn out over a long period or confined to the solution of more or less urgent development problems. Apart from the resulting undesirable retardation of the research work the importance and urgency of the problems may be incorrectly evaluated with unpleasant consequences upon the return of normal conditions.

The situation can become particularly critical when a depression — as already experienced — is comparatively closely followed by a prosperous period. The manufacturing side then takes first place with the result that valuable men are automatically withdrawn from development and research work, which is thus naturally restricted. With the greatly increased demand it is virtually no longer possible to decide which of the many urgent and important requirements are natural developments and likely to be retained in more normal times and which are merely a result of the boom. Advantage can therefore only partly be taken of the financial means then available.

During periods of war the situation is further aggravated through material restrictions and, in particular, staffing conditions which virtually preclude the continuity so necessary in research and development work. Moreover, experience from the operating field is difficult to obtain, for customers are far too busy meeting the increased demand to bother much about communicating their observations. In times like the present we are thus more or less thrown back on our own resources and the direction of the research and development work becomes one of the most arduous and important duties of the technical management of the undertaking.

Notwithstanding these difficulties we are maintaining development and research work on a big scale and have recently again invested large sums in equipment for this purpose. We are well aware that this involves a considerable amount of risk and expense, inasmuch as upon the return of more or less normal conditions with the possibility of again being able to count upon the collaboration of the operating field, much of our work, which is so far ahead of normal developments, will be subject to considerable modification.

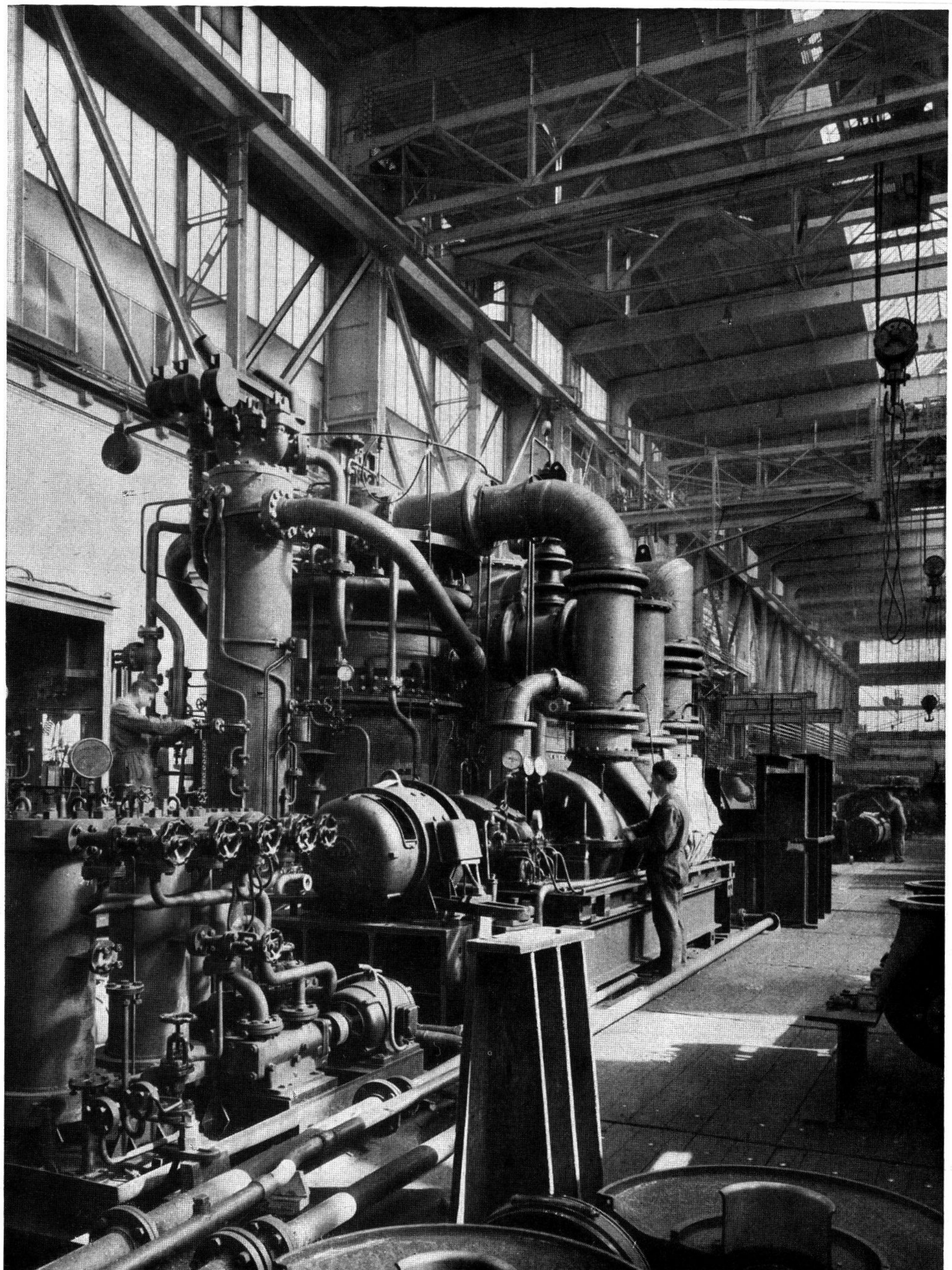
I. GENERATION OF ENERGY.

A. VELOX PLANTS.

There is little to report this year in regard to the construction and placing into service of new Velox boilers. A boiler for a steam output of 12 t/h was delivered to a Roumanian Cement Mill already possessing a Velox unit, burning both natural gas and fuel oil. A further boiler of 27 t/h steam output at 38 kg/cm^2 abs and 435^0 C was supplied to Finland for a metallurgical works, where the entire steam requirements for the drive of the blast furnace blower and of the electric generating unit are furnished by this one boiler. The only reserve is constituted by the power from the public supply system, which also serves to operate a small blast blower in order to keep the blast furnace in service when the main blower is out of commission. The fuel of the Velox is blast furnace gas. The boiler may, however, also be operated with oil, to which it can be switched over without interruption of service. The entire machinery equipment is contained in a single room, the Velox boiler being in the midst of the remaining machines (Fig. 1).

We shall have occasion to report next year on a similar Velox plant which was also ordered from us with the entire remaining equipment, including a 7000 kW steam turbine, and using natural gas as fuel. By then, many projects connected with the enlargement of oil plants and the reconstruction of destroyed installations, on the study of which we are at present engaged, will have attained a more definite form. Wherever natural gas and oil residue — two by-products of the oil industry — are available, the Velox boiler is undoubtedly the best source of energy.

The main obstacle standing in the way of its general introduction is the impression prevailing in many places that it is essentially a peak-load and standby boiler. This opinion has its origin in the fact that the first Velox boilers, because of their sensationally small space requirements and their quick starting characteristics, found application mainly as standby and peak-load boilers. That these two advantages are not the only ones which can be claimed for the Velox boiler is proved by extracts from various reports received by us in the course of the last year. Thus the English publication "Electrical Times" of August 6th, 1942, quoting from a presidential address to the Electric Supply Authority Engineers' Association of New Zealand, states: "The outstanding novelty is the Velox boiler plant at Evans Bay, incidentally the first of this type to be installed in the Empire (see The Electrical Times, May 26th and July 7th, 1938). Selected primarily for its quick-starting characteristic, to minimise interruption to Wellington's essential services, the Velox boilers have been frequently operated for extended periods on account of their high thermal efficiency. This is maintained at about 95 % over the whole range from a quarter to full load. Each



Velox boiler for an output of 32 t/h on the test bed.

Even the largest Velox boilers are completely assembled and subjected to a test run at the manufacturers' works. Here is a further difference distinguishing them from the usual type of boiler.

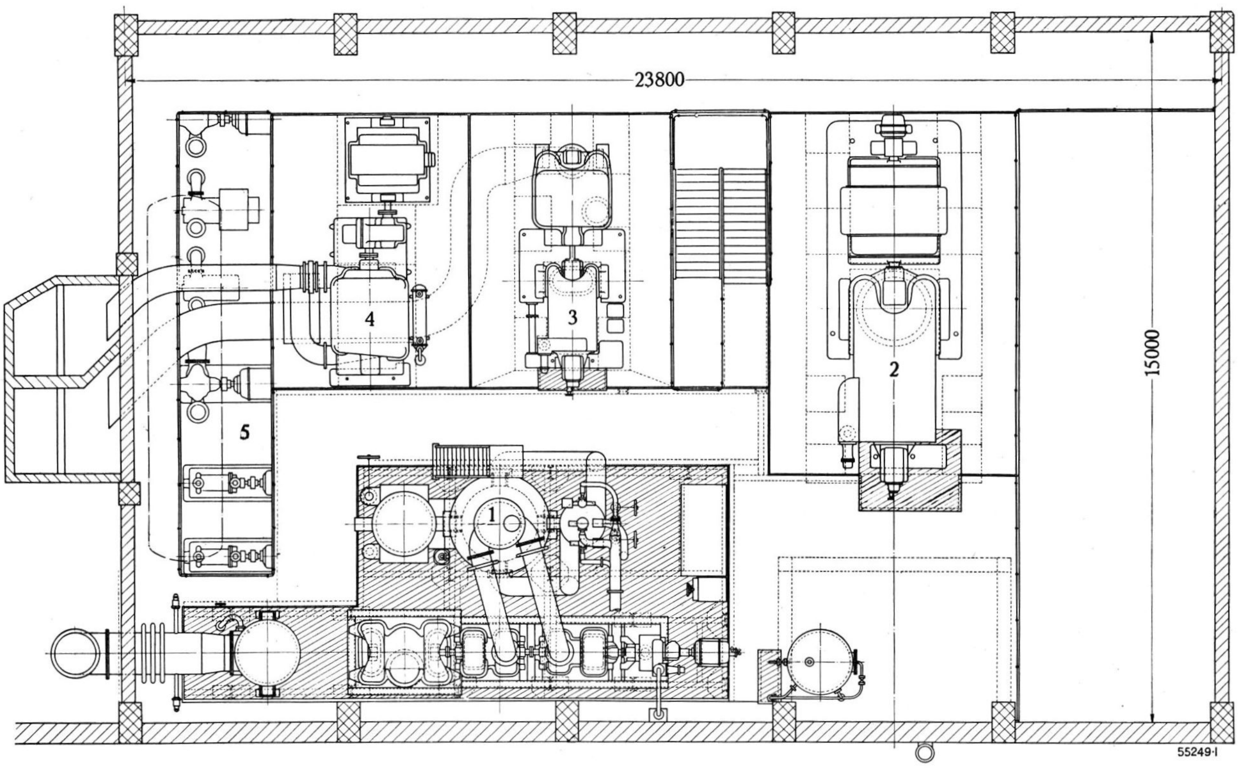


Fig. 1. — Blast and power installation of a metallurgical works using Velox boilers as steam generators.

The Velox boiler is installed in the same room as the generating and blast units. It is full-automatically regulated and can be looked after by the same personnel which is responsible for the attendance of the other machines.

1. Velox boiler.
2. Turbo-set.
3. Turbine-driven blast unit.
4. Motor-driven blast unit.
5. Auxiliary machines.

of the two boiler units is rated 100,000 lbs at 225 lbs per sq. in., and during four years' service they have given entire satisfaction."

A detailed report, giving a full account of all happenings and operating experience obtained with a natural-gas-fired Velox installation, which has now 50,000 service hours to its credit, was published in the November/December number of the Brown Boveri Review for 1942, to which we particularly wish to refer again here. Further evidence of the service reliability of the Velox is provided by news arriving from South America, which was received by us with somewhat mixed feelings, as it was to the effect that the customer had decided not to order a third Velox steam generator for his plant, because the two existing Velox boilers had proved themselves so reliable over a period of several years' service that the management considered they could do without a standby unit.

Good news was also received of our peak-load Velox boiler installation at the City of Riga.[1] This installation is provided with a fully automatic starting arrangement. From October, 1939 up till the end of 1941 the boiler was put into service 200 times and always operated entirely satisfactorily, in spite of the fact that since 1938, when it was originally put to work, the boiler has not been subjected to any overhaul or modification.

The advantages of the Velox steam generator for supplying steam to test installations were discussed in the special marine number of the Brown Boveri Review, September/October, 1942.

The further development of the Velox steam generator has not been interrupted in spite of the war. On the contrary, the reduced number of orders resulting from the hostilities, has made both time and personnel available for carrying out studies and practical tests. Our efforts have been directed in particular towards the solution of the pulverised fuel problem, and substantial progress has been made in the use of pulverised fuel for Velox boilers.

Work was also done on simplifying and perfecting the Velox components, as well as in widening the field of application of the Velox principle. This latter can advantageously be applied to all devices in which

[1] The Brown Boveri Review 1942, p. 217.

a heat transfer is effected, provided the quantities of heat involved are sufficiently large, so that the savings in heating surface and the reduction in size of the combustion chamber and the parts containing gas, compensate the costs of the special design and of the additional machinery equipment such as the charging set. Many processes of the chemical industry, the heating of the blast in iron and steel works, and the firing of separate superheaters and intermediate superheaters for steam power stations can make use of the Velox principle. That hot water for heating installations can advantageously be produced in Velox boilers has been proved by a number of plants.[1] A recently completed installation is illustrated in Fig. 2.

B. STEAM TURBINES.

The steam turbine business has not been interrupted by the war, although it has suffered a number of restrictions. Various installations were put into service, but none of them was of such outstanding nature as to justify special mention in this review. Perhaps worthy of note is the putting into service of a 30,000 kW set in France, which at the special request of the customer, because of his good experience with that type, was built as a three-cylinder machine, although the requirements could have been fulfilled with a two-cylinder design (Fig. 3). This is clearly shown by table I and Fig. 4, in which the main data of a turbine of the year 1927 and one of the same output of the year 1942, supplied to the same customer, are compared.

As shown in the table, the turbine supplied in 1942 was 12·4 % better in heat consumption and at the same time 33 % lighter in weight and 14·5 % shorter than the turbine of the year 1927, which at that time represented an outstanding development. Our welded construction has — in spite of the larger heat drop — enabled the new turbine to be built as a two-cylinder machine. In this design the low and intermediate pressure rotor consists of independent discs welded together to form a single drum. The

[1] The Brown Boveri Review 1941, p. 89.

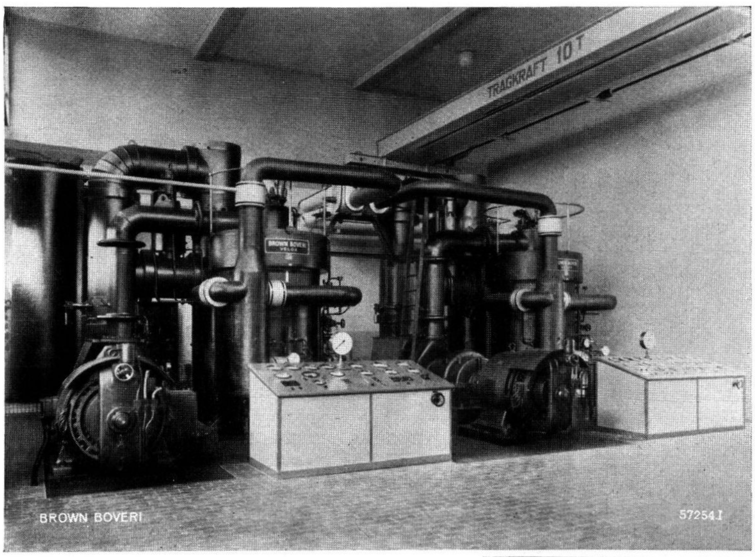


Fig. 2. — Two Velox hot water boilers

each for an output of 7·5 million kcal/h at a service pressure of 16 kg/cm² and for an outgoing temperature of 190° C. Oil is used as fuel.

The special characteristics of the Velox boiler: high efficiency, small space requirements, quick starting and fully automatic regulation are advantages which are as much appreciated for hot water production as for steam generation. Due to the absence of the superheater and steam separator, and due to the use of the circulating pump for delivering the water to the heating system, the Velox installation is extremely simple and compact.

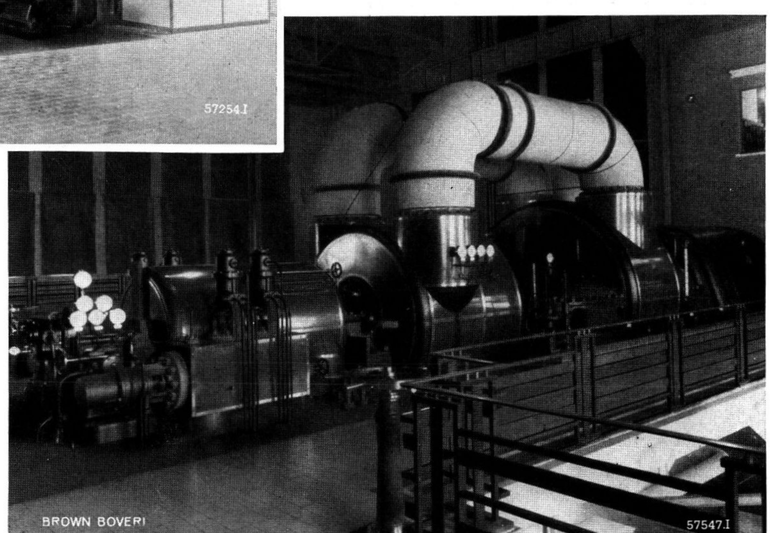


Fig. 3. — 30,000 kW three-cylinder turbine,

with built-on valve chests welded to the high-pressure cylinder. In addition to the saving in space, this construction results in a saving in the number and length of the pipe connections and of flange joints. Since 1924 more than 100 such three-cylinder machines with a total output of over 2·5 million kilowatts have been supplied.

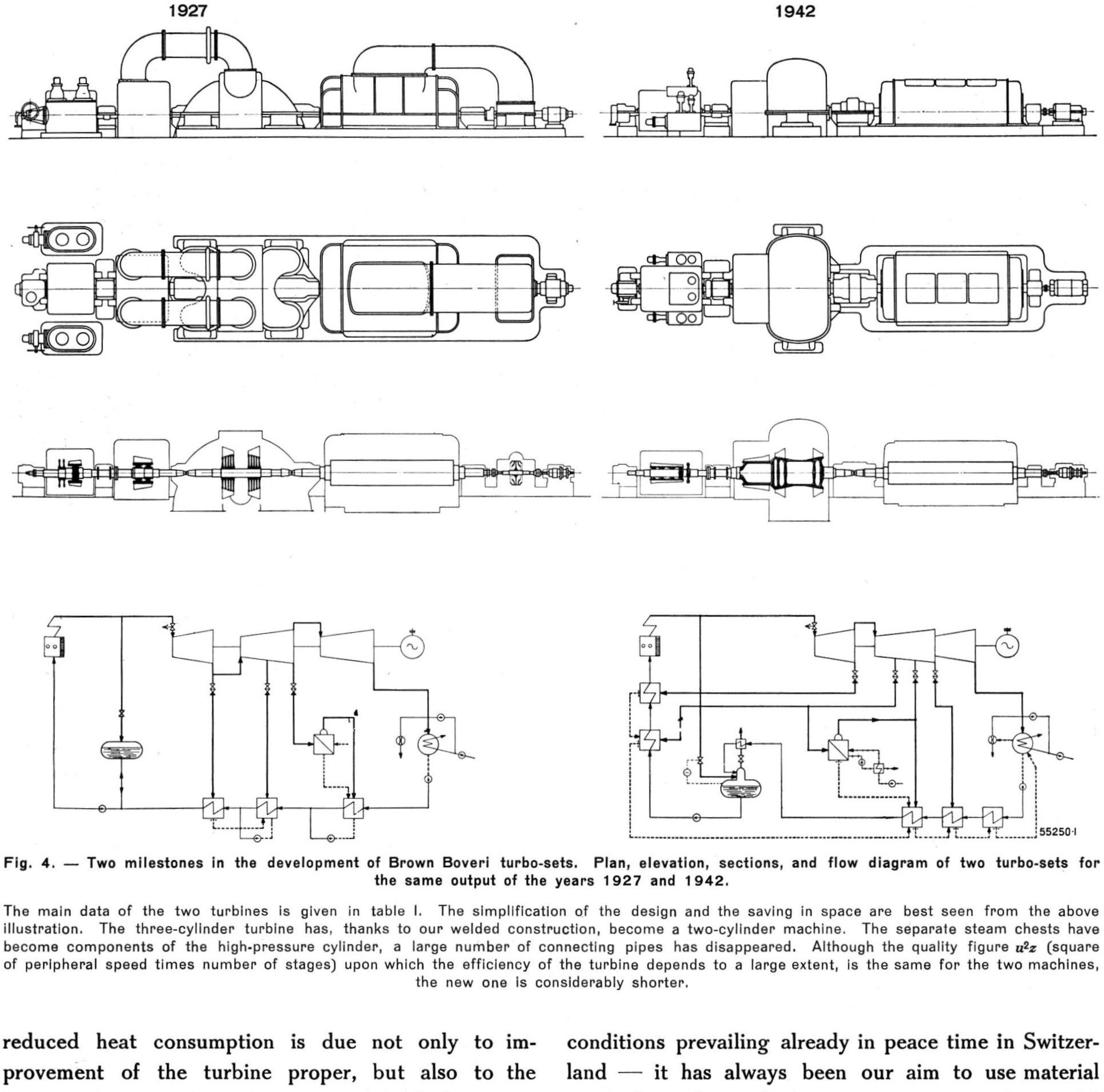


Fig. 4. — Two milestones in the development of Brown Boveri turbo-sets. Plan, elevation, sections, and flow diagram of two turbo-sets for the same output of the years 1927 and 1942.

The main data of the two turbines is given in table I. The simplification of the design and the saving in space are best seen from the above illustration. The three-cylinder turbine has, thanks to our welded construction, become a two-cylinder machine. The separate steam chests have become components of the high-pressure cylinder, a large number of connecting pipes has disappeared. Although the quality figure u^2z (square of peripheral speed times number of stages) upon which the efficiency of the turbine depends to a large extent, is the same for the two machines, the new one is considerably shorter.

reduced heat consumption is due not only to improvement of the turbine proper, but also to the increase in pressure and temperature of the steam and of the final temperature of the feed water heated by extracted steam.

Fig. 5, which illustrates a power station in which some of these turbines are installed, shows that a construction appropriate to its purpose may at the same time be architecturally pleasing.

As already mentioned, the war has not been without effect on the number of orders received. The delivery difficulties in connection with certain semi-manufactured parts, the quota restrictions and the shortage of materials, have naturally had a restraining effect on turbine manufacture. On the other hand, they meant for us only minor modifications of design, as — due to the raw material and export conditions prevailing already in peace time in Switzerland — it has always been our aim to use material sparingly and to eliminate every excess of material by quality and suitability of the design. A typical example of this economical construction is our welded rotor.[1] Because this rotor is built up of separate discs which are formed from relatively light steel forgings, and for which ordinary, or only slightly alloyed steel may be used, the unfabricated material is still available to-day, as it does not entail any difficulties in the steel works, where it does not require for its manufacture the use of large forging machines which are at present reserved for defence orders. The only design alteration which was effected to our welded turbine shafts, was the manufacture in separate

[1] See The Brown Boveri Review, 1942, p. 205; 1941, p. 343; 1936, p. 11.

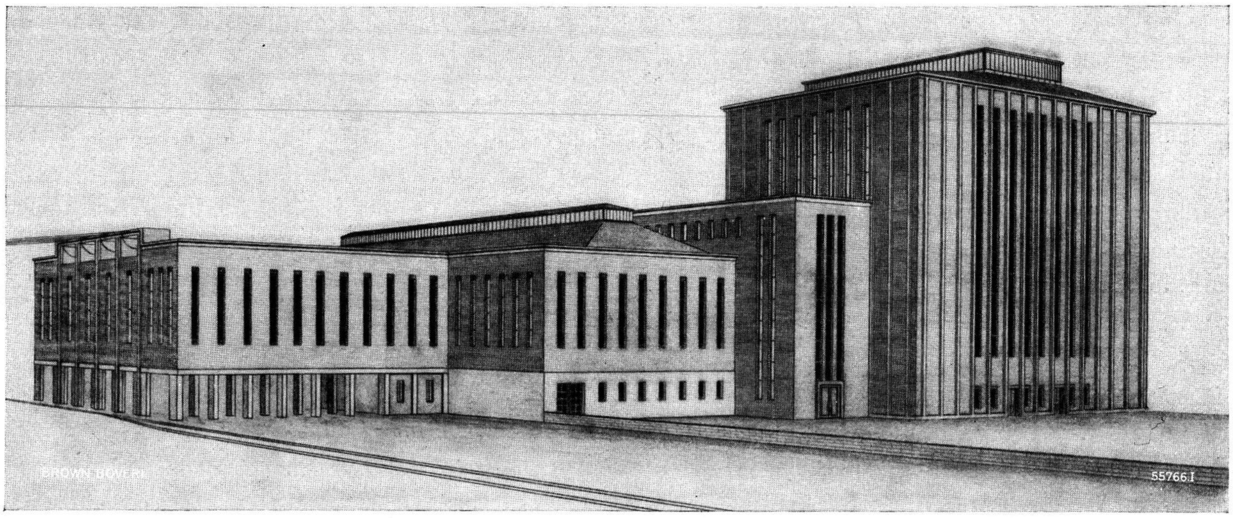


Fig. 5. — Modern power station building.

From right to left: Boiler house, pump house, turbine house, and switchgear building. In this station will be installed two turbo-sets each for an output of 35,000 kW, 50,000 kVA, a large transformer and switching plant with control room, all supplied by Brown Boveri.

TABLE I

Year of manufacture		1927	1942
Output	kW	28/35,000	28/35,000
Live steam pressure	kg/cm^2 abs	26	71
Live steam temperature	°C	400	485
Cooling water temperature	°C	27	27
Heat drop at normal full-load	kcal/kg	256	305
Feed water heating	stages	3	4
Final feed temperature	°C	155	180
Steam consumption, including steam extracted for feed heating	kg/kWh	4·66	4·03
Heat consumption	kcal/kWh	2875	2520
Number of cylinders		3	2
Total length of set	m	21·00	17·96
Width of set		5·00	5·00
Weight of the turbine including bedplate for turbine and generator	t	142	94·7
Weight of generator	t	109 (40,000 kVA)	76 (50,000 kVA)

pieces of the shaft end and of the last disc, which were formerly forged out of one piece.

As a general rule, cast steel, which is still obtainable, suffices for the turbine cylinder. For very high pressures and for very high superheat temperatures we created designs already before the war which avoided the use of highly alloyed steels or reduced their use to a minimum. In these designs the steam connections and nozzle boxes carrying the high pressure and high temperature steam, are welded into the casing which is in contact with steam at a much lower pressure and at a lower temperature than the live steam. The casing may therefore be made of cast steel, or for extreme conditions of cast alloy steel, which, however, because of the small dimensions of the parts, requires only very small amounts of alloy elements.

We have also found a way to save using highly alloyed steel for bolts. We make the bolts for flanges which are subjected to large temperature differences always very long and insert between the nut and the flange a piece of tube. In this manner, the stresses which are set up particularly during starting and stopping of the turbine, due to the different expansions of the flange and of the bolts, are distributed over a longer extension length, so that they are reduced and the bolts can accordingly be made of low alloy steel.

The packing strips in the glands, on the other hand, require the use of rare metals. As, however, the quantity necessary for a turbine is small, there is no urgent need of a substitute.

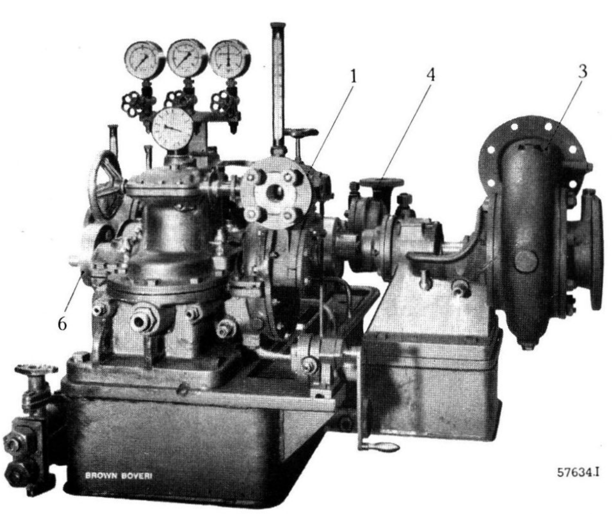
In the case of blading for high temperatures, we have not considered employing a substitute for the chrome steels (which have proved so satisfactory up to the present) beyond a certain blade length. It can be assumed that the required quantities will still be obtainable in the future. Brass blades, on the other hand, have been almost entirely replaced by chromium-plated steel blades.

In the case of bearings we continue to employ white metal, but the bearing lining is made appreciably thinner and much more adherent by the use of improved manufacturing methods. Ample lubrication and suitable arrangement of the oil supply enable every direct contact of the shaft with the metallic bearing lining to be avoided in service. We have to thank the necessity of economising bronze for a really considerable improvement which we have effected to our segmental thrust bearings. Instead of making the segments entirely from bronze, we now make them of steel and cover them with a loose thin plate of bronze or aluminium. Experience has shown that such thrust bearings can carry several times the load of the former ones, and that seizing-up upon sudden application of the load is practically excluded. The reason for this is that the cause of the seizing has been eliminated. Seizing occurs because of the deformation of the segment when upon sudden application of an extreme load the heat developed locally cannot be conducted away through the segment sufficiently rapidly, and the heated part accordingly begins to buckle. This causes the load to increase still more at the point of contact, the oil film becomes thinner and finally breaks. If the bearing surface is constituted by a thin and good heat conducting plate which lies snugly on the bearing surface, this plate can expand freely, while at the same time the heat generated is conducted away to the underlying support. The load thus remains distributed over the whole surface. We have protected this design by patents.

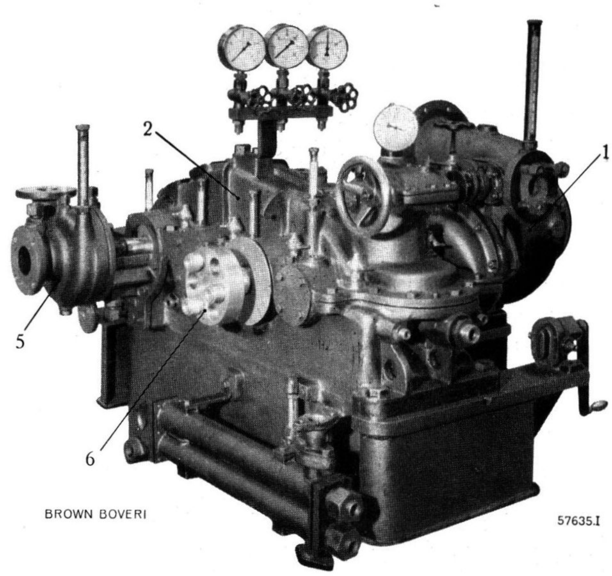
The arrangement of ventilating oil tanks and similar devices which we described in last year's retrospective number, can also be classed among the economy measures. Operating experience during the year under review has confirmed that the ventilation considerably increases the life of the governing and lubricating oil, due to the fact that the ventilation prevents the condensation of water and thereby eliminates one of the main causes of ageing of the oil.

For the thermal insulation of turbines we now use almost exclusively long fibre glass wool. This is packed into mats which are laid directly on the walls to be insulated. Asbestos, which is now hardly obtainable, can be dispensed with.

A further measure brought about by the war is the creation of a stock of turbines up to medium sizes. These turbines are completely manufactured with the exception of the nozzles, the blading of the impulse part, and the coupling. Only in this manner is it possible, with the present difficult raw-material supply conditions, to accept and maintain short delivery



a.



b.

Figs. 6a and 6b. — Two views of a combined condenser pump set with small turbine for steam installations.

The combination of all pumps into a single set simplifies the attendance and achieves a saving in the consumption of the auxiliaries. The gear enables each pump to be operated at the speed at which it has the highest efficiency.

Normally the pumps are electrically driven, but if the current fails, the turbine comes into operation.

1. Driving turbine, speed up to 13,000 r. p. m.
2. Gear with different driving wheels.
3. Circulating water pump.
4. Condensate pump.
5. Jet water pump.
6. Motor coupling flange.

times. The measures referred to enable us to adapt the turbines to the specified steam conditions and corresponding outputs. We have at present about fifty turbines in stock, as well as a number of rough machined rotor forgings for large turbines.

Small Turbines.

The development of a simple design of small turbine which we reported last year has led us to create two further types which have now come into production and which, thanks to their special characteristics, find a ready sale.

The first refers to a small turbine made for outputs of 20 and 45 kW. Its rotor consists of a single-row impulse wheel, which, however, has the steam jet re-directed on to it a second time by means of reversing segments. The bearings are grease-lubricated roller bearings, and the governing is effected by throttling of a single nozzle valve. In addition to the speed regulator, an overspeed safety governor is provided which actuates the emergency stop valve. Both the machines are very robust, they weigh 180 and 250 kg, respectively, and require little attention and service. They are used for driving small generators, fans, pumps and similar devices (Figs. 6a and 6b).

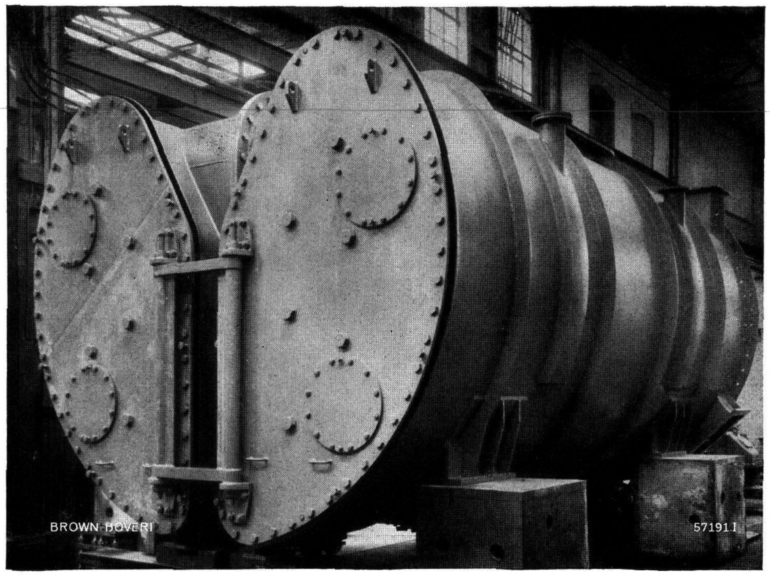


Fig. 7. — Condenser split along the vertical centre line, the two halves being held together by a *bolted flange*.

Surface over 3000 m². The large size necessitates splitting the condenser to enable it to be transported by rail.
This condenser also follows the OV design introduced by us in 1911 which has since proved itself in regard to both thermal performance and mechanical construction.

The second type is considerably larger. This turbine can give up to 500 kW. Its rotor is constituted by a two-row impulse wheel. The governing gear consists of a mechanically operated nozzle valve and a hand-operated overload valve. The bearings are also grease-lubricated roller bearings. The speed range is from 3000—5500 r. p. m. This turbine is used mainly for the standby drive of electrically driven feed pumps or circulating pumps. In addition, it is used for driving generators, fans, and other machines which are required to operate only occasionally.

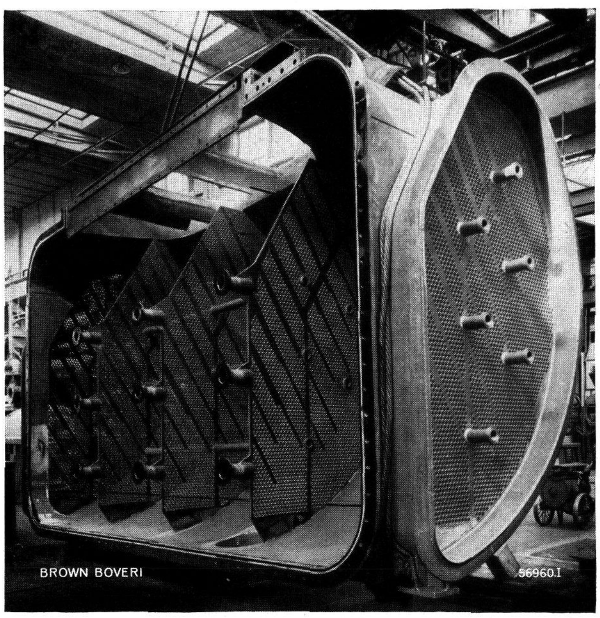


Fig. 8. — View towards separation flange of the condenser illustrated in Fig. 7, showing the interior before tubing.

The tubes, which are given a slight curvature, protected by patent, to enable them to expand and contract freely with changes of temperature, are rolled into the tube plates at both ends.

Condensers.

A condenser design which we have supplied for a 30,000 kW plant is illustrated in Fig. 7. In order to be able to transport the condenser by rail in spite of its large dimensions, it is split along the vertical centre line, the two halves being bolted together by a flange along the outer periphery (Fig. 8). This condenser also follows our proved OV design.

Fig. 9. — Condensers and condenser auxiliaries of a 30,000 kW turbo-set.

The turbine has two exhausts and accordingly two condensers are provided. In the present case these are arranged perpendicularly to the axis of the set. They are of the two-part pattern so that during cleaning only 1/4 of the cooling surface is out of service at a time. Duplicate circulating pumps are also supplied, the one dimensioned for 2/3 and the other for 1/3 of the total cooling water quantity. The two pots, one on each side of the condenser, house the cooling-water filters. They are disposed, according to an arrangement popular in France, at the same level as the pump and are easily accessible for cleaning. A disadvantage of this arrangement is, however, the fact that the strainers are smaller than those usually placed in the inlet channel and therefore have a greater flow resistance.

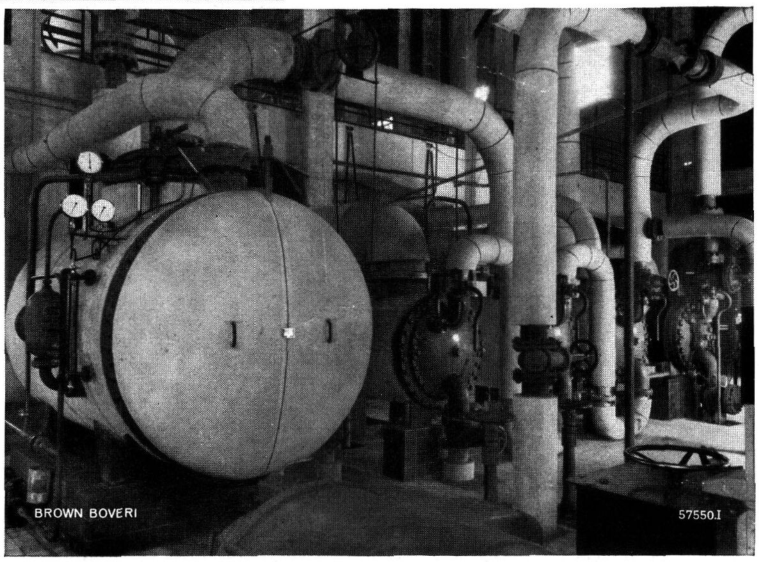


Fig. 10. — Raw-water evaporating and feed heating installation.

The illustration shows the good accessibility of the various apparatus of a 30,000 kW plant. There are four feed heaters which raise the temperature of the feed water to 160° C.

Already last year, we mentioned that the shortage of non-ferrous metals had necessitated the replacement of brass tubes by iron tubes. More recently, copper-plated tubes have been used for coolers and condensers. Another, but less valuable, substitute for brass tubes are galvanised steel tubes. These represent a temporary solution already resorted to in the first world war, and which was promptly abandoned as soon as the war ended.

Figs. 9 and 10 show the condensating and feed-water heating and treating plant of a large steam turbine.

C. COMBUSTION TURBINES.

The past year was richly filled with studies and tests. The gas turbines under construction are nearing completion, so that we hope in our next year's retrospective number to be able to give more detailed particulars. Our most interesting market for gas turbines so far, namely the American oil refineries, has unfortunately disappeared because of the war.

At the head of the gas turbine tests are those with pulverized fuel. We have made considerable advances, and many of the problems have been solved. Operation during long periods has, however, shown that many details have still to be worked out before a permanent solution is arrived at.

We also gave considerable time to the study of plants for which the gas turbine in its present state can be looked upon as the ideal driving machine, namely where gas or liquid fuels are available, and where the efficiency is not of great importance. Such applications are the drive of blowers for steel works, peak-load and standby plants, and certain generating installations for special purposes, in all of which the power per unit is within the range of 1000 to 10,000 kW. Higher economy may be attained when the gas turbine is combined with blast generation and blast heating.

An important factor with the air-cooled gas turbine is the recuperation of the heat rejected. The larger the exhaust gas quantity per kilowatt of useful energy, the more important it is that the exhaust gases leave the plant at a low temperature, in order to ensure high efficiencies. Already with gas-turbine plants of medium size large recuperators do indeed enable efficiencies to be obtained which are not far behind those of the best steam turbine installations of the same size. The most economical size of recuperator is determined by the manufacturing costs, by amortisation, by the yearly service hours, and the cost of fuel. Lengthy studies based on numerous projects and cost calculations have shown that for instance with 4000 operating hours per annum and a fuel price of about 3 shillings per 1000 m^2 of blast furnace gas, the most economical recuperator is one with a heating surface of 1·5 m^2 per kW useful output of the turbine. Two gas-turbine installations at present under construction will have recuperators of this size. The same investigations have shown further that a recuperator with the most favourable heating surface, calculated, for instance, on the basis of 6000 hours and with a cost of fuel of 3 centimes per 1000 kcal, would enable a plant efficiency of some 27 % to be obtained.

D. GOVERNING GEAR.

Under this heading last year a number of new *governors for thermal machines* were described. These meet virtually all the governing requirements of machines operating alone or in parallel with others or with whole networks. During the past year we continued perfecting the new designs to ensure their general application. A detailed description and particulars of the application of these new governors will be found in previous numbers of this journal[1].

A number of interesting problems had also to be dealt with in the field of the *remote governing of power stations*. In one particular case a branch of a transmission line interconnecting two power stations

[1] The Brown Boveri Review 1940, p. 171, and 1941, p. 362.

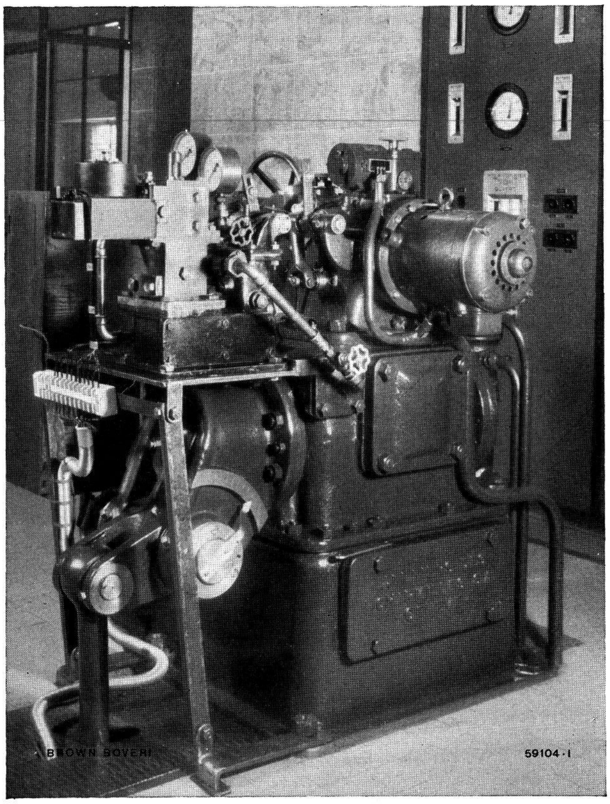


Fig. 11. — Combined direct-acting frequency-dependent power regulator and speed regulating gear for a 40,000 H. P. Pelton wheel in the Dixence Power Station (Switzerland).

The power regulator keeps constant the power in a distant line feeding another supply system. The instantaneous value of the power transmitted is indicated to the regulator by a carrier-current system. The regulator acts directly on the oil control gear instead of on the speed adjusting gear.

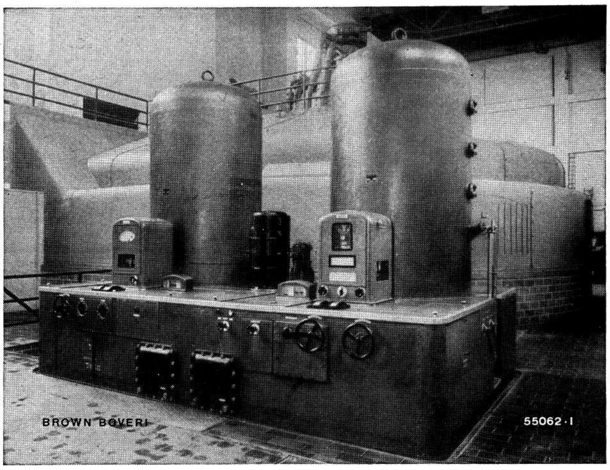


Fig. 12. — Electric primary governor in Reckingen Power Station, in service since 1941.

The electric primary governor replaces the mechanical pendelum of the turbine governor. Since it functions reliably down to less than 10 % of the rated voltage it can be connected to the alternator terminals. A pilot-generator is not necessary. A small additional weight suffices to ensure that the turbine inlet opening closes smoothly should the voltage supply completely fail. In contradistinction to other governors which cause the turbine inlet to open unless they are provided with relatively complicated and far from reliable additional gear, this type of governor closes the turbine in case of complete voltage failure.

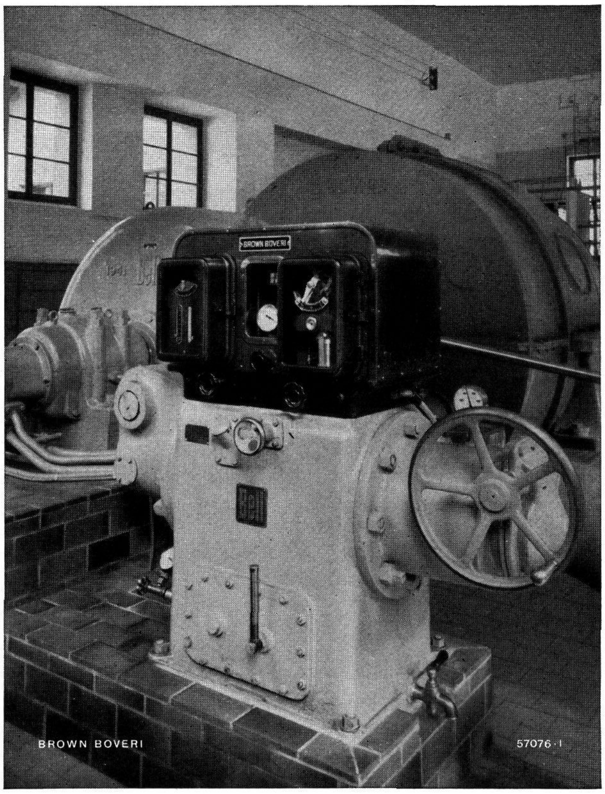


Fig. 13. — Electric governor mounted on the governing gear of the 4500 kVA Pelton hydro-alternator set at Ganterbach-Saltina Power Station (Switzerland).

The three-phase voltage transformer provided for the voltage regulator can also be used for the primary governor. It is only with the electric primary governor that the governor driving problem can be solved in such a simple manner.

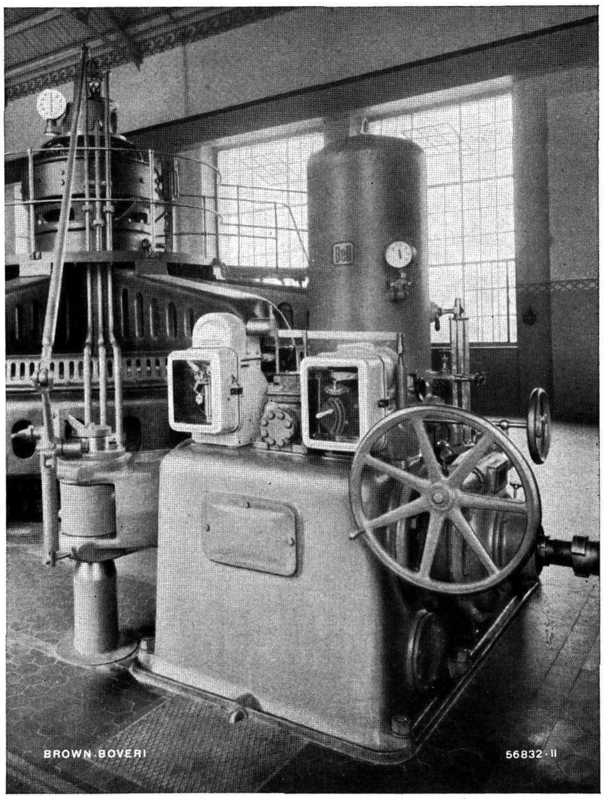


Fig. 14. — Electric primary governor for regulating the speed of a 2000 kVA, 107 r. p. m., Kaplan turbine set in the Aarau Municipal Power Station.

This was the first electric primary governor to be installed, in 1938. It proved extremely satisfactory from the very beginning.

was required to deliver a certain output independent of load fluctuations caused by other consumers connected to the power stations. This requirement was met by a frequency-dependent power regulator which acts directly on the turbine governor (i. e., influences the oil control gear directly instead of through the speed adjusting gear) in relation to the power flowing in the branch line, the measured value being transmitted on the carrier-current principle. The speed of response varies with the difference between the prescribed and actual output values, so that stable operation, combined with high regulating speeds, is obtained. The equipment was developed in close collaboration with the Ateliers des Charmilles.

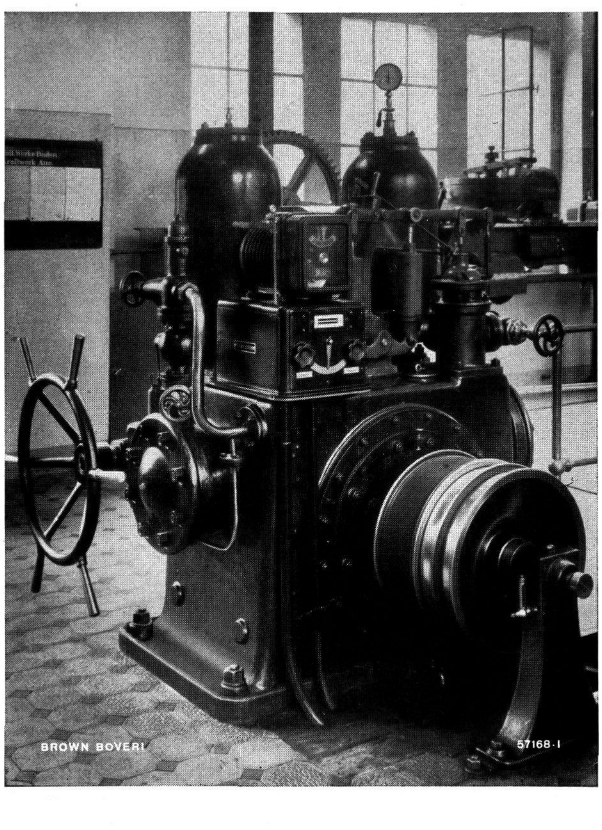


Fig. 15. — Modernized turbine governor for a 1240 kVA, 94 r. p. m., Francis turbine set in the Aue Power Station of the Baden Municipal Undertakings (Switzerland).

The mechanical pendelum of the turbine governor installed in 1905 was replaced by an electric primary governor. Preparations for the changeover were made well beforehand in collaboration with the turbine manufacturers so that the turbine was only out of service for one day. The simple solution of the driving problem was the chief factor leading to the selection of the electric primary governor.

Fig. 11 shows the new control gear fitted on the existing turbine governor.

The development of the electric primary governor was proceeded with. Several of this new, most promising type of governor were put to work in various plants, the most important being that in the Ganterbach-Saltina power station (Fig. 13). The primary governors in the Reckingen, Aarau, and Baden (Aue) power stations are again shown in Figs. 12, 14, and 15, respectively.

E. GENERATORS.

As a result of conditions entailed by the war electricity is in greater demand than ever before. New power stations are being built, existing stations modernized to increase their capacity, and plant more efficiently protected to diminish the risk of breakdown.

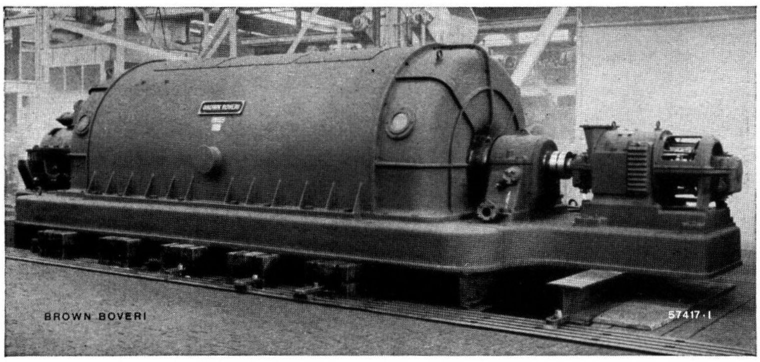


Fig. 16. — Three-phase turbo-alternator rated 50,000 kVA, 3000 r. p. m., 10,500 V, 50 cycles.

To keep the machine as short as possible, despite the high rating, the fan of the cooling system is lodged in the basement. This fan is usually motor-driven, but in certain cases can also have a special steam turbine. The driving motor can be supplied from the station power system or through a transformer from the alternator direct. The separately installed fan affords better air inlet and outlet conditions and enhances the efficiency of the fan and, in consequence, also that of the alternator.

Notwithstanding the increasing difficulties on the raw material market it appears that some progress is being made in planning the construction of new power stations. Such a tendency is all the more gratifying because customers are beginning to abandon their former prejudice against the use of aluminium for the windings of electrical machines. As described in detail last year, we thoroughly investigated the technological properties of aluminium at an early date and have even built the largest units with aluminium windings.

In the case of existing power stations a considerably greater output and, in particular, a higher annual efficiency can be obtained — generally without alteration to buildings — by replacing entire generating sets, this notwithstanding the use of aluminium for the windings. In such cases considerable quantities of copper may be released, which can be re-utilized either for the new machines themselves or for other highly-stressed machines, e. g., traction motors. The modernization costs are frequently repaid through the increased energy production.

In view of the shortage of energy and raw materials it is more than ever important that supply failures due to faults of all kinds and damage to equipment should be kept down to a minimum. Brown Boveri began developing protective gear at an early date and the equipment now available virtually excludes shut-down and damage in service.

(a) *Turbo-generators.*

The work in connection with the reduction of losses was systematically continued. Whereas in previous years we had chiefly discovered and eliminated local sources of losses in the stationary part[1], last year intensive investigations

[1] J. Prévost: The Brown Boveri Review 1941, p. 367.

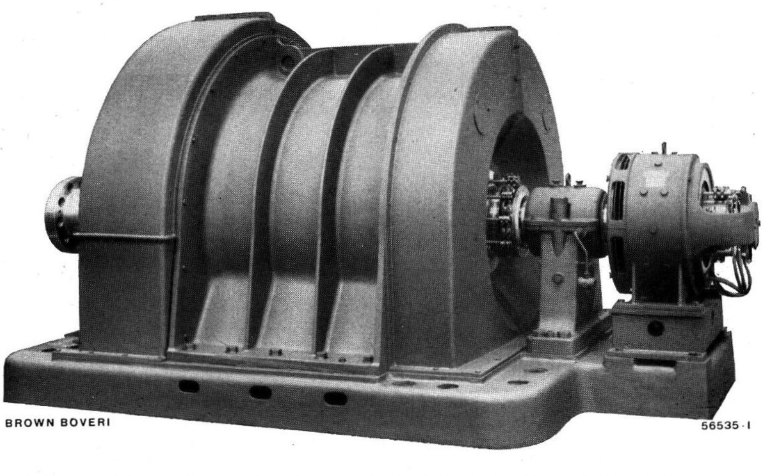


Fig. 17. — Three-phase alternator rated 4500 kVA, 8000—8400 V, 750 r. p. m., 50 cycles, for the Gurtnellen Power Station of the Central Switzerland Power Co., Lucerne.

Totally-enclosed pattern, with air inlet and outlet through ducts, enclosed flywheel, cast stator, rotor designed for speeds up to 1400 r. p. m. The special, material-saving design of the stator frame is rendered possible by the axial stator ventilation.

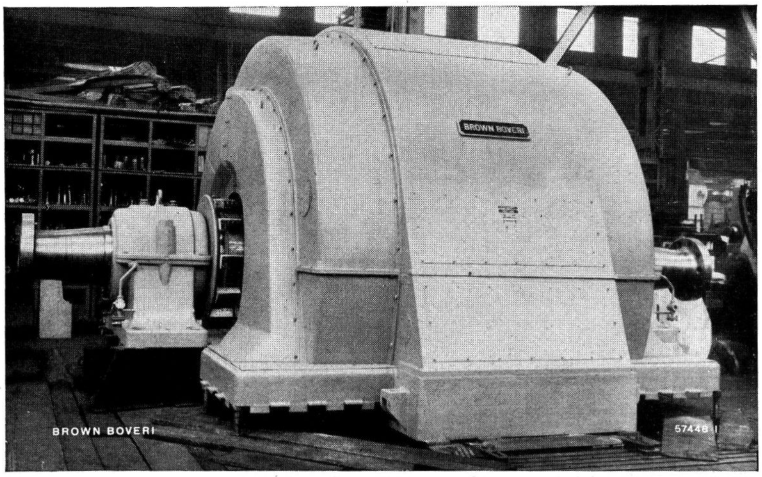


Fig. 18. — Three-phase alternator rated 32,500 kVA, 12,000 V, 50 cycles, 500 r. p. m., for drive by two overhung Pelton wheels on either side.

To shorten the axial length of the set the exciter had to be incorporated in the alternator housing. The commutator remains nevertheless readily accessible.

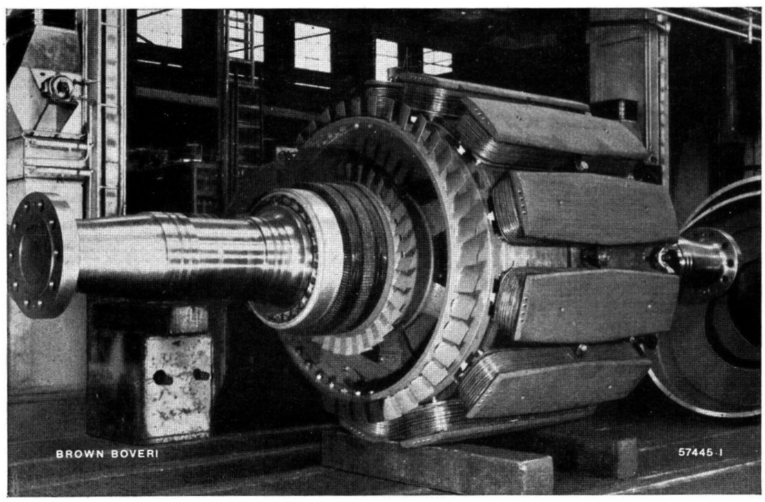


Fig. 19. — Alternator and exciter rotor of machine in Fig. 18.

The two cast steel shaft extensions are flanged directly on the Pelton wheel spider.

were begun with a view to suppressing or at least reducing those inherent in the rotor. This work was little affected by the prevailing shortage of copper, inasmuch as the total amount of winding copper required for large turbo-generators is split up between the rotor and stator windings approximately in the ratio of 36 to 64, so that for the time being it has only been considered necessary to substitute aluminium for copper in the case of the stator winding. In consequence, our well-tried design of rotor has not had to be modified. For the output range up to 20,000 kVA, however, aluminium had to be generally employed for the stator windings; this entails special supports and fixing of the coil heads owing to the lower strength of aluminium. Fig. 16 depicts one of the numerous high-power turbo-generators constructed during the past year.

(b) *Diesel-driven Generators.*

As a result of the war business in generators for drive by Diesel engines was hardly less brisk that in preceding years. The emergency sets with internal combustion engines mentioned in our review of progress of previous years have recently often been supplied for operation with wood-gas in Switzerland due to the shortage of liquid fuels.

(c) *Hydro-electric Generators.*

In this field most of the innovations were due to conditions on the raw material market. Aluminium windings were introduced and large generators constructed with cast-steel shafts, which can be supplied by the Swiss foundries. The latter innovation may be retained even when forgings again become readily available.

During the year a large number of generators of all sizes were again completed (Figs. 17—19), while others were put in hand. Among the generators supplied for the modernization of existing industrial power stations that for the Gattikon Wool Weaving Mill in

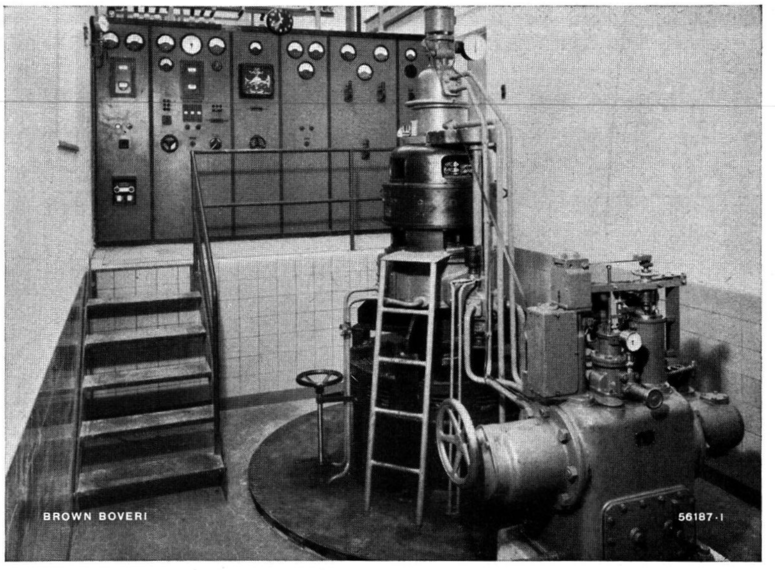


Fig. 20. — Three-phase alternator rated 390 kVA, 400 V, 50 cycles, 600 r. p. m., with associated switchgear in the wool weaving mill of Schmid's Söhne A.-G., Gattikon (Switzerland).

This hydro-electric plant was installed to exploit more fully the available water power instead of an antiquated, low-power, belt-driven turbine plant.

the Sihl Valley is a typical case (Fig. 20). The old 200 H. P. turbine driving the looms mechanically was replaced by a set comprising a 450 H. P. turbine and a 390 kVA alternator. The increased power cannot all be utilized in the mill and the excess forms a welcome additional source of energy for the local electricity supply. The replacement of obsolete and uneconomical turbines, which in some cases (e. g., the Wängi Weaving Mill or the Schweizerische Leinenindustrie, Niederlenz) has enabled up to three times the original output to be obtained, not only permits a far better utilization of existing water power, but occasionally also helps to alleviate the electrical energy shortage.

II. POWER TRANSMISSION, DISTRIBUTION, AND CONVERSION.

A. POWER TRANSMISSION OVER LONG DISTANCES.

In our review of progress last year we referred to the memorable informal meeting of the Swiss Association of Electrical Engineers on the 13th December, 1941, and stated that the question of the most suitable current system for the transmission of big blocks of power over long distances could only be cleared up by exhaustive investigations and tests; these were continued systematically during the intervening year.

The first problem was to investigate two methods of compensating for capacitive and inductive effects on long alternating-current transmission lines proposed in technical literature. The one employs the Taylor quadrature booster which is connected with its primary in shunt to, and its secondary in series with, the line, thus compensating the charging current and the inductive voltage drop in the line through the currents in the booster primary and secondary windings, respectively. It is claimed that this arrangement permits increased power transmission without risk of instability and enables the "natural load" (load without reactive component) to be transmitted to any desired distance. Our tests were carried out on an artificial line comprising two symmetrical π-sections. The booster itself and the auto-transformer for reducing the resulting higher voltage down to the original value were both connected to the centre of the line. One end of the latter was fed by a 170 kVA synchronous machine and the other connected to the Aargau Cantonal Electricity Supply's system. Our tests showed that the curve of the active power P_W delivered at the end of the line as a function of the angle δ_L * is merely displaced along the horizontal axis (Fig. 21). The booster causes a constant phase difference $\delta_K = -43^0$ between the voltages at the sending and receiving ends of the line; the static power which can be stably transmitted, however, is not increased, inasmuch as in these questions of stability not the absolute value of the power in function of the angle, but simply the variation of the power with the angle is of importance.

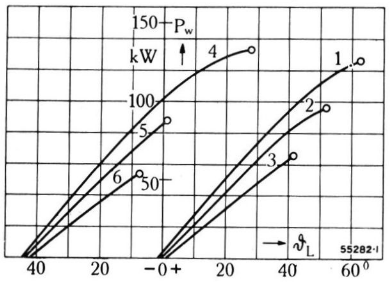


Fig. 21. — Three-phase transmission line with and without compensation by Taylor quadrature booster.

Active power P_W at end of line in function of angle δ_L.

1. U_1 = constant = 280 V
2. U_1 = constant = 240 V } Non-compensated line.
3. U_1 = constant = 200 V

4. U_1 = constant = 280 V
5. U_1 = constant = 240 V } Compensated line.
6. U_1 = constant = 200 V

U_1 = Voltage at beginning of line.
U_2 = Voltage at end of line = constant = 240 V.
o = Synchronous alternator falls out of step.

On the occurrence of sudden load changes there was practically no distinguishable difference between the curves of the active power P_W for the compensated and non-compensated lines, apart from the characteristic difference of $\delta_K = -43^0$. *Our tests conclusively corroborated our earlier published views, based on theoretical considerations, that the static and dynamic stability of the line would not be improved by Taylor's method of compensation.* In consequence, its practical application cannot be entertained even should the booster be so designed that the magnetizing current compensates the line charging current — as alternatively proposed by Taylor — inasmuch as in this case merely an additional quadrature reactance of known effect is connected in the line.

* δ_L is the electrical phase angle between the voltages at the sending and receiving ends of the line. The angle is measured by a wattmetric method.

With the second method, which initially appeared really promising, synchronous machines in shunt and series connection are employed to compensate the line capacitance and inductance effects. To stabilize the series machine it was rigidly coupled to the quadrature machine. The under-excited quadrature machine compensates the capacitive current, the negatively over-excited series machine the inductive voltage drop in the line. An artificial line with two symmetrical π-sections was again used for these tests, one end being fed by the same 170 kVA generator as before and the other also connected to the Aargau Cantonal Electricity Supply's system. The tests gave the following results:— With quadrature compensation alone and regulation of the excitation current of the quadrature machine so that the quotient of the terminal voltage divided by the current input, i. e., the inductive quadrature reactance, remains constant, the power which can be stably transmitted is not increased owing to the simultaneous rise in the surge or characteristic impedance. With series compensation alone (the quadrature machine only being used to stabilize the series machine) either the quotient of the voltage at the terminals of the series machine divided by the current of the latter, i. e., the capacitive series reactance or the excitation is kept constant. In the first case the increase in the active power P_W delivered at the end of the line as a function of the phase angle δ_L between the voltages at the sending and receiving ends of the line is greater than without compensation

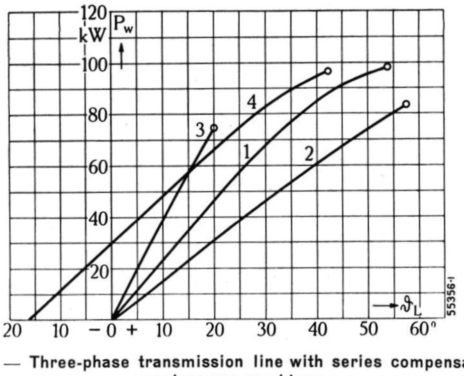


Fig. 22. — Three-phase transmission line with series compensation by synchronous machines.

Active power P_W at end of line in function of angle δ_L.

1. Non-compensated line.
2. Non-compensated line with series machine unexcited.
3. Capacitive series reactance = constant.
4. Excitation of series machine = constant (corresponding to overexcited service condition).
   Voltage at sending end of line = voltage at receiving end of line.

o. Alternator and synchronous machine fall out of step.

(cf. curves 1 and 3 in Fig. 22). In the second case the active-power — phase-angle curves are merely displaced along the horizontal axis (cf. curves 2 and 4 in Fig. 22). With maximum excitation of the series machine the displacement $\delta_K = -16^0$. The importance of this result from a practical point of view will be clear from Fig. 22, which shows that neither one method of operation nor the other raises the static stability limit.

Under these conditions very little advantage is to be anticipated from combined shunt and series compensation and the tests have shown that although the angle δ_L is smaller at the static stability limit than without compensation the maximum active power which can be transmitted is not increased in the least. The

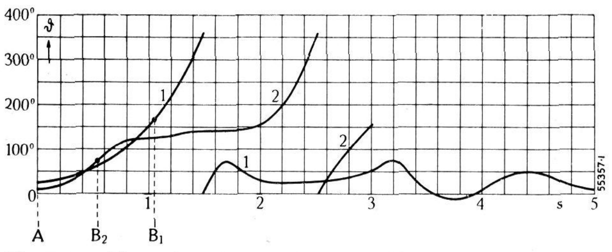


Fig. 23. — Three-phase transmission line with compensation by synchronous machines.

Variation of angle δ (angle between direct component of rotor voltage and constant voltage at end of line) with time upon occurrence of a three-pole short circuit at the centre of the line.

1. Without compensation. Alternator does not fall out of step.
2. With series compensation. Alternator falls out of step.

A. Short circuit initiated.

B_1. Short circuit ruptured. Duration of short circuit = 1·05 sec.
B_2. Short circuit ruptured. Duration of short circuit = 0·54 sec.

Falling out of step of alternator not prevented despite shorter duration of short circuit.

dynamic stability of the whole set-up was also investigated, three-pole short circuits being initiated at the centre of the line, i. e., between the two π-sections, and disconnected more or less rapidly; prior to the short circuit the load transmitted was of the order of two-thirds of the "natural load". Without compensation of the line the alternator did not fall out of step on short circuits of 1·05 sec. duration, although it slipped a double pole pitch during the resulting equalizing process (Fig. 23, curve 1). With series and quadrature compensation stability is definitely worse; e. g., curve 2 in Fig. 23 shows the falling out of step of the generator on a short circuit of only 0·54 second for the case of series compensation.

The result of the tests in connection with the three-phase long-distance power transmission system with series and shunt-connected synchronous machines is therefore briefly as follows:— The static stability of transmission is not increased, while the dynamic stability is impaired. High-speed regulation of the series machine might conceivably improve stability, however.

The negative result of the investigation of the foregoing two methods of transmission led to the idea of seeking a solution of the stability problem by dispensing with boosters along the transmission line, and in due course a so-termed L compensation, comprising a series inductance and a quadrature capacitance arranged at the sending end of the line, was suggested.

The mode of operation of this method can best be explained by taking a line of length $s = 1500$ km and a frequency $f = 50$ cycles, i. e., the length of a quarter of a wave. This line represents a so-called "Boucherot circuit" (combination of a condenser and a tuned reactance) which transforms power with constant voltage at the receiving end of the line into power with constant current at the sending end. If a synchronous alternator is now connected through suitably proportioned compensating elements to the transmission line — the voltage at the receiving end of the line remaining constant — the voltage across the machine terminals will necessarily be constant due to the constant current delivered to the line. Theoretically, therefore, there is an absolutely rigid connection (i. e., independent of the load) between the machine voltage and the voltage at the receiving end of the line, so that stability conditions are the same as for the machine alone without the line. This fundamental property of the L compensating method can be readily extended to other lengths of line.

All tests were carried out with the same 170 kVA synchronous alternator supplying the Aargau Cantonal Electricity Supply's system through the artificial symmetrical π-type line.

For the first preliminary test an artificial line of length $s = 3400$ km, corresponding to 57 % of the wave-length and with a surge impedance $Z = 2{\cdot}35$ ohms per phase, was set up without compensation. Synchronization with zero current was effected, as anticipated, without difficulty, although the vectors of the voltage across the machine terminals and at the receiving end of the line were mutually displaced by 180^0.

The test with *static compensation* was carried out on an artificial line of $s = 950$ km in length, corresponding to 16 % of the wave-length, and with a surge impedance $Z = 3{\cdot}80$ ohms per phase.

The *static compensation* at the generator end was provided by a series-connected inductive reactance $X_l = j \times 3{\cdot}64$ ohms per phase and a shunt-connected capacitive reactance $X_q = -j \times 1{\cdot}88$ ohms per phase. The capacitance had to be selected somewhat larger than theoretically necessary with the result that the angle tended to vary with the active load. Synchronization was effected without difficulty, and with constant excitation and constant voltage at the end of the line it was found possible, by increasing the driving torque of the alternator, to transmit a greater and greater active power. The experimental set-up did not permit the maximum transmissible active power,

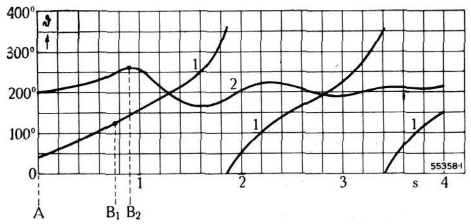


Fig. 24. — Three-phase transmission line with L compensating element, but no boosters along the line.

Variation of angle δ (angle between direct component of rotor voltage and constant voltage at end of line) with time upon occurrence of a three-pole short circuit at the centre of the line.

1. Without compensation. Alternator falls of out step.
2. With compensation. Alternator does not fall out of step.

A. Short circuit initiated.

B_1. Short circuit ruptured. Duration of short circuit = 0·75 sec.
B_2. Short circuit ruptured. Duration of short circuit = 0·9 sec.

Compensation prevents falling out of step of alternator notwithstanding longer duration of short circuit.

i. e., the static stability limit, to be determined; it is in any case much higher than without compensation. As criterion for the static stability, for instance, the so-termed synchronizing power, i. e., the quotient of the alteration of the active power divided by the alteration of the field spider angle, can be taken; the presence of the compensating element, however, results in this value being practically doubled.

The *dynamic stability* was determined by short-circuiting the terminals of all three poles in the centre of the line and connecting a 1100 kVA synchronous machine to the far end instead of the supply network. With *non-compensated line* and an initial load $P_1 = 16$ kW the machines remained in step on a short circuit of $t = 0{\cdot}46$ sec. duration; with $t = 0{\cdot}75$ sec. they were permanently thrown out of synchronism (Fig. 24). With *line compensation* the synchronous machines remained in step both with $P_1 = 17$ kW and $t = 0{\cdot}9$ sec. (Fig. 24) and with $P_1 = 28$ kW and $t = 3{\cdot}0$ sec. At the moment of short-circuit disconnection there is an active-load surge and an over-voltage on the compensating capacitive reactance, the magnitude of which depends on the angle between the field spiders of the two machines.

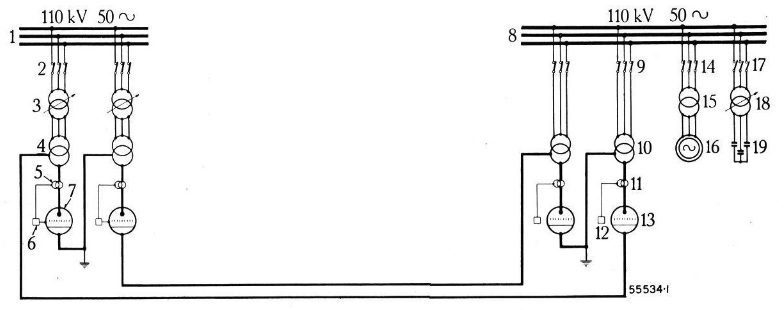
From the tests it is clear that both the static and the dynamic stability are substantially improved by the L booster.

The absence of boosters along the line naturally makes the voltage distribution dependent on the power transmitted. The theoretical value, however, is nowhere exceeded as long as only the natural load is transmitted. For branch-lines, therefore, the problem of voltage regulation is being specially studied.

Recapitulating, it also appears possible to solve the problem of the transmission of big blocks of power over long distances with extra-high-voltage alternating current, if the so-termed L-compensation with series inductance and quadrature capacitance is employed. These compensating reactances have simply to be installed in the sending or receiving station, and can be considered as an integral part of the alternators. Power can be transmitted to any desired distance without substations of any kind along the line, exactly as in the case of direct current.

As to *direct-current transmission* we have continued the investigations in connection with the Wettingen-Zurich transmission demonstrated on the occasion of the Swiss National Exhibition in 1939, and are at present constructing one stage of an experimental unit with a rating of 10,000—15,000 kW at a transmission voltage of 35,000 V. A similar single-phase unit will be subjected to extensive continuous tests in a Swiss power station in the course of this year with a view to furthering the development of high-voltage mutators. This is intended to form a basis for a three-phase set of approximately three times greater output and voltage.

Complementary to our remarks concerning d. c. high-voltage transmission in last year's review of progress we now reproduce a diagram in Fig. 25 in order briefly to illustrate how such a transmission



1. Busbars of generating station.
2. Circuit-breaker.
3. Regulating transformer.
4. Mutator transformer.
5. Current transformer.
6. Grid control gear.
7. Mutator.
8. Busbar of receiving station.
9, 14, 17. Circuit-breakers.
10. Mutator transformer.
11. Current transformer.
12. Grid control gear.
13. Mutator.
15. Transformer.
16. Synchronous machine.
18. Regulating transformer.
19. Condensers.

Fig. 25. — Simplified diagram of power transmission plant for high-voltage direct current.

would function.[1] At the sending end the d. c. voltage is maintained constant with the help of an on-load tap-changing switch and grid control gear; a slight compounding effect may also be incorporated. The desired power is adjusted at the receiving end by grid control. For reactive current compensation, voltage regulation, and pilot purposes a synchronous machine must also be installed. Instead of the latter, static condensers could be employed, these being regulated by means of a regulating transformer. As shown in Fig. 25, however, both compensating devices can be used simultaneously. According to the three-phase systems connected by the transmission line, regulating transformers may be installed or completely dispensed with.

[1] Ch. Ehrensperger, Bulletin S. E. V. 1942, p. 111.

Notwithstanding the fact that considerable attention was again given to the development of a practical extra-high-voltage d. c. circuit-breaker during the

Fig. 26. — Power transformer assembly bay.

A new winding and insulation construction has enabled both the dimensions and the weight of power transformers to be greatly reduced. Partly due to this fact even the largest transformers can now be dispatched by rail completely assembled.

past year and that many suggestions were made with a view to solving this interesting but difficult circuit-breaker problem, such switchgear must be dispensed with until the development work is completed. In point of fact, as will be seen from Fig. 25, d. c. circuit-breakers are not really necessary for a simple transmission line, inasmuch as each mutator set can be disconnected on the three-phase side, thus also protecting the transmission equipment. Moreover, the mutator grid control gear suppresses faults on the line and in the mutators themselves so rapidly that the three-phase circuit-breakers do not even trip. In the event of an earth fault on the line the grid relays of the set affected pick up and change the mutators in the sending station over to d. c. - a. c. operation, thus enabling the magnetic energy formed by the direct current and the inductance of the line to be recuperated in the three-phase system of the sending station. This is an extremely effective and rapid method of suppressing earth faults without tripping the a. c. circuit-breakers. The grid control in the receiving station remains blocked during this process, inasmuch as the valve action of the mutators prevents a reverse current flowing.

B. TRANSFORMERS.

Among the power transformers built in the course of the year those for the Innertkirchen Power Station of the Oberhasli Power Co. (Switzerland) are worthy of special mention. These are a special design with cable boxes, their rating being 47,500 kVA with 150 kV on the high-voltage side. The advance represented by these transformers — incorporating as they do the insulation principles mentioned here last year — is best illustrated by comparison with the 26,000 kVA units supplied to the same undertaking in 1928. If the corresponding particulars of the latter are denoted by 100 % the following percentages are obtained for the 47,500 kVA transformer:— The cross-section of the core is less than 80 %, its weight only 72 %, and the weight of the oil about 84 %, although the rating is nearly doubled. The overall weight is 75 %. Nevertheless the efficiency is 0·2 % higher. Fig. 27 shows the two transformers to the same scale. Even the overall dimensions of the new transformer are much smaller than that rated practically 50 % less. This fact enabled the new transformers to be lodged in a recess in the rock structure of the underground Innertkirchen Power Station. The small overall dimensions also permitted the 47,500 kVA transformer to be transported by rail practically fully assembled (a number of accessory parts only having to be removed), whereas the 26,000 kVA transformer of 1928 had to be dismantled for dispatch. This avoids lengthy and difficult erection work on site. Even the tank of the older transformer had to be made in two parts for

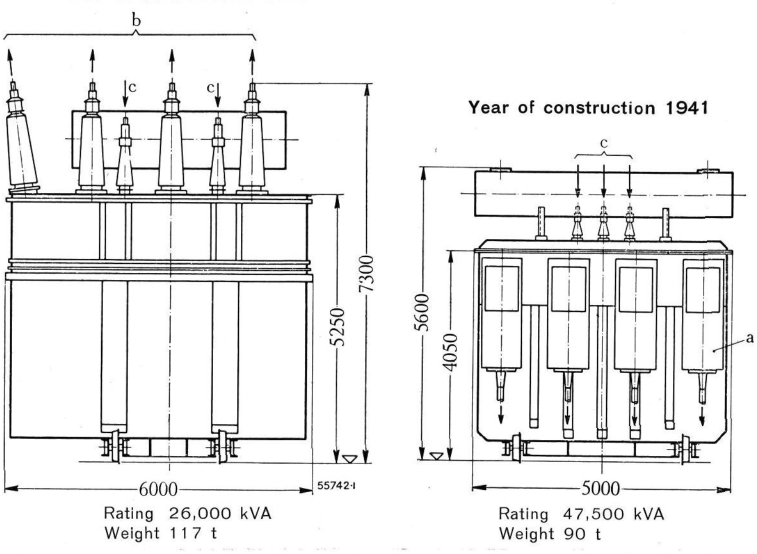


Fig. 27. — Comparison of external dimensions of two transformers for the same high voltage, but of different rating and year of construction.
a. Cable boxes. b. High-voltage terminals. c. Low-voltage terminals.
The difference in the dimensions is striking. Notwithstanding the 80 % higher rating the bulk of the transformer built in 1941 is only about 64 % of that of the transformer constructed in 1928 (dimensions over terminals).

Physical dimensions and weight are rarely a criterion for the capacity of plant. It is the innovations and high specific rating which count.

reasons of transport. The importance of the saving in material needs no special emphasis under present conditions. *With the same amount of material 2·4 times more power can now be transformed than in 1928, striking proof of what can be achieved by research work undertaken in a spirit of enterprise.*

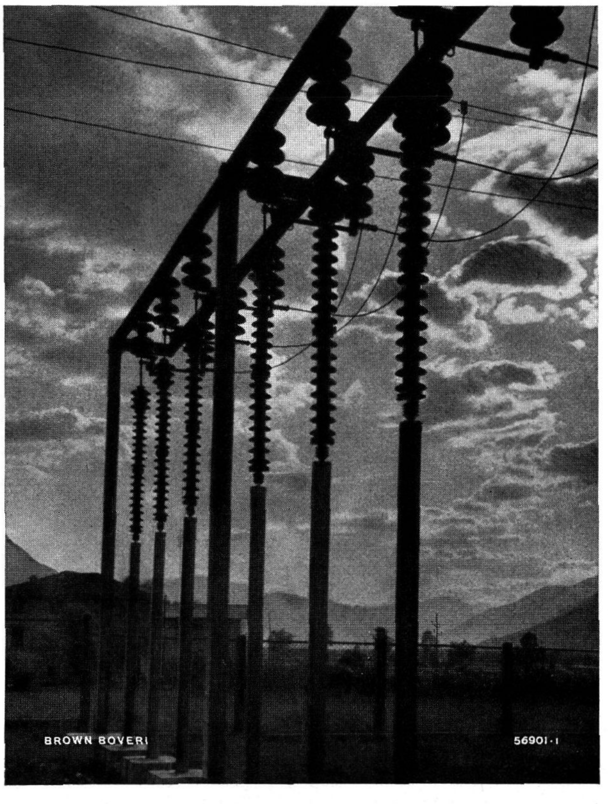


Fig. 28. — Lightning arrestors for the protection of a substation against over-voltages, rated voltage 50 kV, rated discharge capacity 4000 A, suspended mounting with guide tube to prevent swinging.

Modern lightning arrestors form a basis for the correct coordination of the system insulation.

C. NETWORK PROTECTION.

In our last review of progress we dealt exhaustively with the technical development of lightning arrestors. A gratifying feature of the past year was the demand for arrestors with an increased rated discharge capacity, a large number of our series with a rated discharge capacity of 10,000 A and voltage ratings of 30—125 kV having been sold. The past year with its many thunderstorms — at least as far as Switzerland was concerned — might be taken as a large-scale experiment to prove the suitability of arrestors for over-voltage protection. The numerous arrestors we have supplied for various systems stood up to this test extremely well and have proved their reliability under practical operating conditions (Fig. 28).

With the entering into force of the new voltage standards of the Swiss Association of Electrical Engineers and also of the revised directives for the protection of electrical installations against atmospheric over-voltages the rated voltages of our standard arrestors in particular had to be adapted to the new definitions. We took advantage of this opportunity firstly to grade the rated voltages of our standard arrestors as far as possible in conformity with the mostly encountered network voltages, and, secondly, to overhaul the design of the arrestors. When planning this standard range particular importance was attached to maximum adaptability to operating requirements. Mounting heights have been substantially reduced and the employment of a unit construction has enabled a pleasing and practical standard design to be obtained for the various methods of mounting (e. g.,

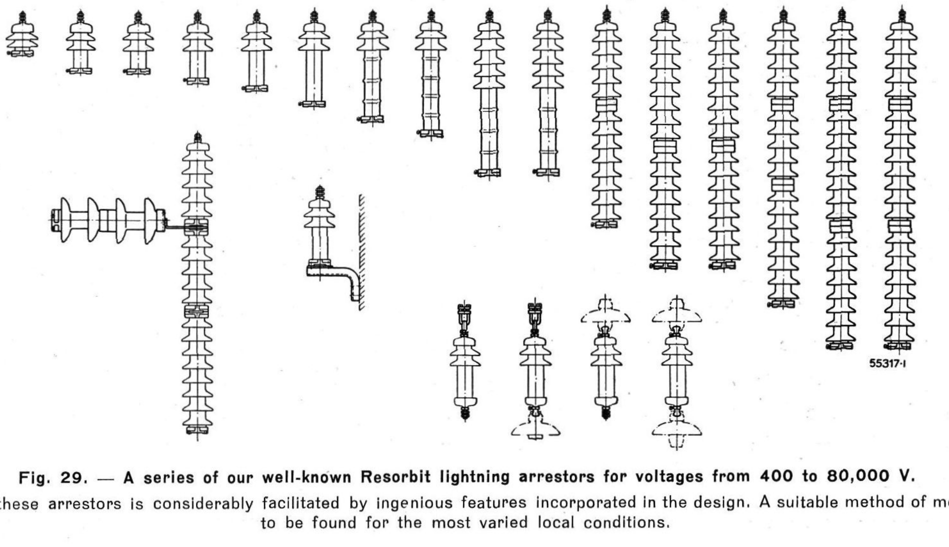


Fig. 29. — A series of our well-known Resorbit lightning arrestors for voltages from 400 to 80,000 V.

The mounting of these arrestors is considerably facilitated by ingenious features incorporated in the design. A suitable method of mounting is always to be found for the most varied local conditions.

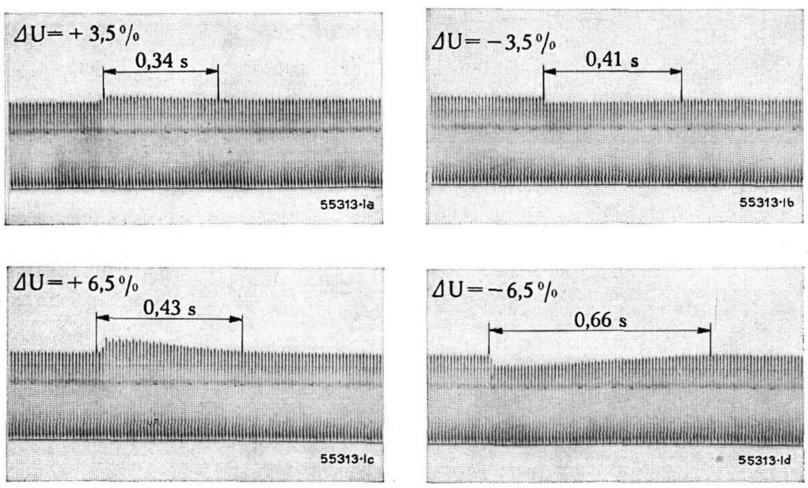
floor, vertical, bracket, suspended, or insulator mounting, with or without stays) which will be appreciated by every operating engineer (Fig. 29).

About two years ago we put on the market arrestors for the protection of low-voltage systems of the same high quality as the high-voltage arrestors, which were originally tested by the Swiss Association of Electrical Engineers High-voltage Research Commission in accordance with the "Directives for the protection of electrical installations against over-voltages". Thanks to the courtesy of the electricity supply undertakings in the Canton of Zurich an opportunity was provided last year of studying the problem of the protection of low-voltage installations with these arrestors in practically the only trustworthy form, i. e., with the arrestors fitted in house installations and the installations complete with arrestors subjected to travelling waves generated in the supply line by means of the mobile impulse plant of the above-mentioned Swiss Association of Electrical Engineers High-voltage Research Commission. These investigations enabled valuable information to be obtained concerning the essential points of the protection of low-voltage systems and also on the most suitable method of connecting the arrestors. Without wishing to forestall a possible detailed report it may be stated that our low-voltage arrestors came through these important tests extremely satisfactorily.

On the occasion of the demonstrations in connection with the fiftieth anniversary of the foundation of our firm in September, 1941, a carrier-current system was used for the control of the high-speed distance-relay panels to demonstrate the selective reclosing of circuit-breakers on an artificial line. After this miniature set-up we desired to try out the carrier-current interconnection system in practice and were afforded an opportunity during the past year. In March, 1942, the equipment developed by us, which is designed for operation in connection with the reclosing of air-blast high-speed circuit-breakers, was installed in a 50 kV line between Gösgen and Laufenburg power stations.

D. NETWORK REGULATION.

The *sliding-coil regulating transformers* which have been mentioned in this annual review of progress on several occasions, are now supplied with a new type of servo-motor for the displacement of the sliding coils. Hitherto the coils were moved through the intermediary of a spindle by a servo-motor controlled by a relay in function of the voltage to be regulated. The rapidity of response achieved in this way, however, was only sufficient to smooth out gradual voltage fluctuations. In order to obtain a better regulating effect on sudden and successive voltage alterations, therefore, the new type of servo-motor already referred to is combined with a control regulator connected to the voltage to be regulated which governs the rotary motion of the servo-motor. The spindle and driving motor and the associated control relay are therefore now dispensed with. In the case of the first of the new transformers to be constructed the rotary motion was transmitted to a crankshaft from which the sliding coils were suspended. As will be seen from the oscil-



Figs. 30—33. — Regulating characteristic of our sliding-coil voltage transformers with improved regulating gear in function of time on occurrence of voltage fluctuations of ± 3·5 % and ± 6·5 %.

Note the extremely short regulating times of only 0·34 and 0·41 or 0·43 and 0·66 sec.

lograms in Figs. 30—33 the new arrangement results in regulating times of only 0·41 and 0·34 seconds with voltage fluctuations of $\pm$ 3·5 % and 0·66 and 0·43 seconds for alterations of $\pm$ 6·5 %, i. e., only about 1/20 of the previous values. For the tests the transformer was fed on its unregulated side and loaded with resistors on its regulated side. Upon the occurrence of sudden fluctuations in the unregulated voltage the time required for the regulated voltage to return to its normal value was measured oscillographically.

E. CIRCUIT-BREAKERS.

The development work in this field practically exclusively concerned the *air-blast high-speed circuit-breaker* of which experience under very varying service conditions is increasingly available. There was a particularly big demand for circuit-breakers with automatic reclosing device. We originally held the view that high-speed reclosing would chiefly be called for in connection with extra-high-voltage systems, and so initially gave more attention to reclosing devices for outdoor circuit-breakers with ratings of 87—220 kV. As a result, only relatively very few indoor circuit-breakers (for 37 kV) had hitherto been supplied with this feature. During the past year, however, it was found that there was a real need for the reclosing feature in medium-voltage systems, i. e., systems with voltages of 6—50 kV. Whereas in extra-high-voltage systems faults are extremely seldom, due to the high insulation levels and other precautionary measures taken, the same cannot be said about medium-voltage systems where faults are frequently caused by birds, flying hay, branches of trees, etc. Moreover, greater importance is now also attached to continuity of service in medium-voltage systems. These considerations have led us to take up the design of indoor-type, air-blast, high-speed circuit-breakers with reclosing feature for voltages up to 30 kV. The circuit-breakers (Fig. 34) in question can be employed as desired with or without high-speed reclosing device, an auxiliary air receiver being provided for reclosing purposes. They are therefore more universal in application than our circuit-breakers of the same voltage rating hitherto marketed.

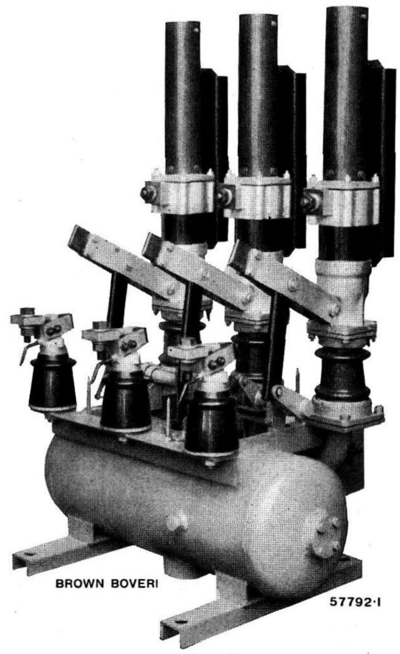


Fig. 34. — Air-blast high-speed circuit-breaker rated 30 kV, with reclosing device, for indoor erection.

Air-blast circuit-breakers with reclosing device now also reduce outages in medium-voltage systems to a minimum.

The layout and mode of operation of different medium-voltage systems entail three different methods of reclosing.

Variant I.

Apart from the usual circuit-breakers, which may already be installed, the switching station is equipped

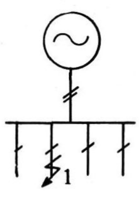


Fig. 35.

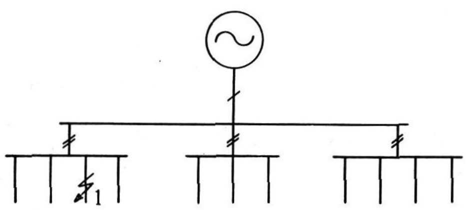


Fig. 36.

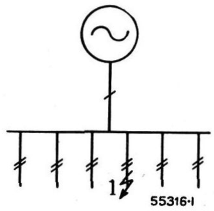


Fig. 37.

Figs. 35—37. — Diagrammatic arrangement of air-blast high-speed circuit-breakers with three reclosing variants.

= Circuit-breaker without reclosing device. = Circuit-breaker with reclosing device. = Persistent fault.

It is sometimes possible to improve the continuity of supply with relatively simple equipment. One of the best means is the reclosing device which can be applied to air-blast high-speed circuit-breakers in a very simple manner.

with *one* additional air-blast high-speed circuit-breaker with high-speed reclosing device (Fig. 35); in extensive installations the busbars can be split up into sections each with its own reclosing circuit-breaker, a so-termed section circuit-breaker (Fig. 36). The line switches are not provided for reclosing.

In the event of a fault the section circuit-breaker instantaneously trips and recloses after an interval of 0·1—0·2 second. If the disturbance is of a transient nature, therefore, service is immediately restored on all lines. Should the fault persist at point 1, however, the line affected will be definitely disconnected by the associated line circuit-breaker after a further lapse of time determined by the setting of the relays protecting this circuit-breaker.

The section switches must therefore be designed for an "off-on" switching cycle. The interval between the operations can be set to approximately 0·1—0·2 second.

An advantage of this arrangement is that only *one* circuit-breaker need be provided for reclosing per station or group of lines. Existing installations can therefore be arranged for the new mode of operation by installing one single additional circuit-breaker, provided that the rupturing capacity of the circuit-breakers already installed is *sufficient.*

Variant II.

Each line (Fig. 37) is allotted an air-blast high-speed circuit-breaker with reclosing device designed for an "off-on-off" switching cycle. An adequate supply of air must therefore be available for two successive rupturing operations. The "dead" interval is only 0·5—1 second. The cost here is greater than with variant I, but in the event of a fault the healthy lines are not interrupted — not even momentarily — as in the case of variant I.

Variant III.

This differs from variant II merely in the length of the "dead" interval, which is only of the order of 0·1—0·2 second, as required for certain systems. Compared to variant II, however, a number of modifications in design are entailed.

The employment of water or small oil-capacity circuit-breakers is restricted to variant I with its simple "off-on" switching cycle. With these types of circuit-breakers the arc extinguishing agent must be allowed sufficient time to return to the arc extinction chamber after every opening operation before a further rupturing operation can be permitted. In view of the very short time intervals of variants II and III this is out of the question. The air-blast high-speed circuit-breaker alone fully meets the conditions of all three variants.

The multiple-break principle adopted for our high-voltage air-blast circuit-breakers has proved particularly advantageous both from the electrical and the design and manufacturing point of view. In this way circuit-breakers for any rupturing capacity and voltage can be constructed, which is not possible — at least not to the same degree — with any other design principle. The whole voltage and power range can be covered with standardized arc extinguishing elements. These are tested individually and enable circuit-breakers for practically every possible combination of voltage, current, and rupturing capacity to be built.

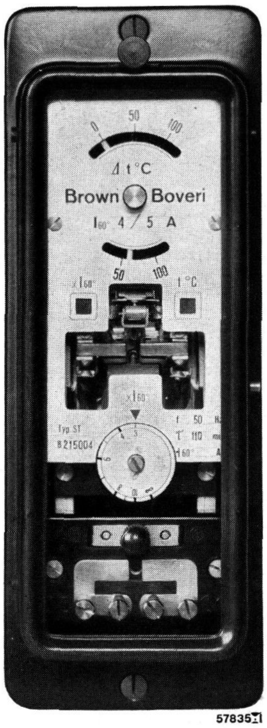


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Fig. 38. — **Secondary thermal relay.**

This relay permits full utilization of the protected object and at the same time affords reliable protection against harmful overloads. Instantaneous and maximum temperature indicators enable the condition of a machine, transformer, or section of line to be accurately determined.

F. RELAYS.

Our *thermal relay*, which appeared in 1938, was the first relay on the market affording effective overload protection on the basis of the thermal image. In the course of the year under review the development of the *thermal secondary relay* was completed and the first model manufactured exhibited at the Swiss Industries Fair at Basle (Fig. 38). All the experience collected with the thermal series relays and also the special possibilities and requirements accruing from operation through current transformers have been incorporated in the new apparatus. The inherent power consumption — an important factor for a secondary relay — is only 7—8·5 VA. Time constants can be selected between twenty minutes and two

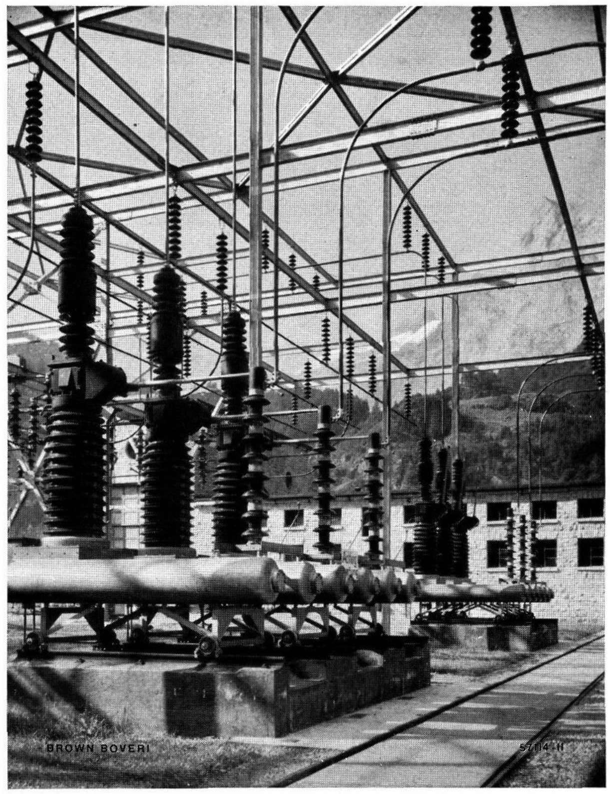


Fig. 39. — 150 kV installation with air-blast high-speed circuit-breakers.

The Kraftwerke Oberhasli A. G., Innertkirchen (Switzerland) who have had Brown Boveri air-blast high-speed circuit-breakers in operation in their 16 kV installation for some years past also chose circuit-breakers of the same type for two 150 kV outgoing lines. The lightweight, clearly-arranged, and neat construction of our outdoor-type model is particularly striking for voltages of 100 kV and over.

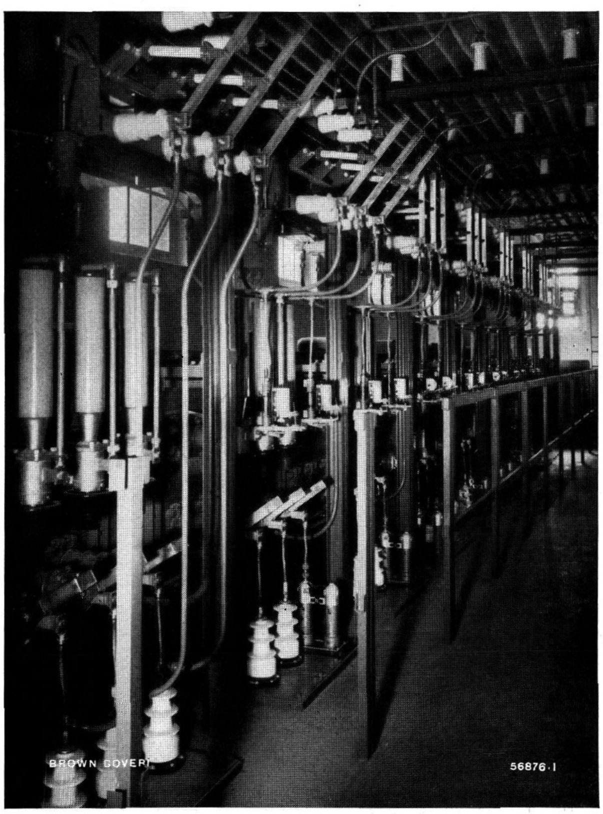


Fig. 40. — Rear view, Fig. 41. — Front view of air-blast high-speed circuit-breaker of 16 kV switchgear.
This entirely oil-less switchgear is employed for the requirements of the Innertkirchen Station itself and for the supply of neighbouring villages.

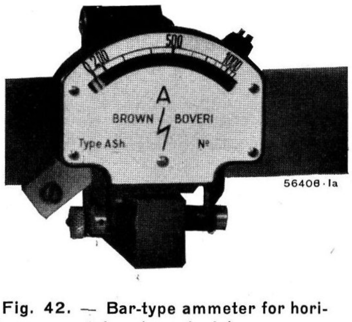
For safety's sake the circuit-breakers were selected for a test voltage of 64 kV and a rupturing capacity of 250 MVA. They are so constructed that given suitable running of the wiring on the high-voltage side they are completely separated from the low and control voltage parts turned towards, and invariably accessible from, the inspection gangway. The pneumatically operated isolating switches are pneumatically blocked when the circuit-breaker is closed. The necessary current transformers are fitted like bushing insulators.

hours, thus giving a high degree of adaptation to the object to be protected.

The thermal secondary relay incorporates all of the features introduced by us for the first time in the thermal series relay — faithful thermal image, indication of instantaneous and maximum temperatures, adjustable tripping temperature, and temperature compensation — partly in an improved form — as well as the familiar features of our secondary relays such as testing terminals, visible contacts, and simple attendance.

G. SWITCHGEAR.

Outdoor and indoor switchgear construction was completely dominated by the air-blast high-speed circuit-breaker. For instance, Fig. 39 shows the outdoor substation at the Innertkirchen Power Station of the Oberhasli Power Co. (Switzerland) taken into service towards the end of last year. This was partly equipped with Brown Boveri 150 kV air-blast high-speed circuit-breakers. Figs. 40 and 41 depict the 16 kV indoor switchgear at the same power station for dealing with the station power requirements and for distributing the energy to lines serving neighbouring villages. The air-blast circuit-breakers are so constructed that given suitable running of the wiring on the high-voltage side they are completely separated from the low and control voltage parts turned towards and invariably accessible from the inspection gangway. The isolating switches have pneumatic control gear and are pneumatically blocked when the circuit-breaker is closed. The necessary current transformers are fitted like bushing insulators.



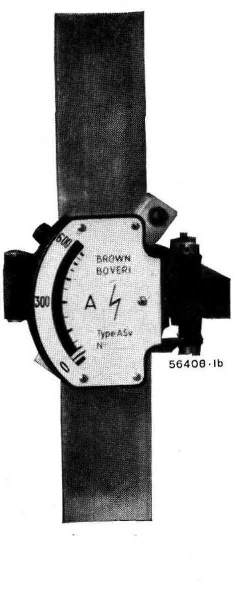


Fig. 42. — Bar-type ammeter for horizontal and vertical bars.

Metering ranges 0—300, 0—600, and 0—1200 A.
Note the particularly simple method of mounting which makes for clear arrangement and ease of checking.

A noteworthy innovation for switches and switchgear of all kinds is formed by the *bar-type ammeter* (Fig. 42) which has been developed from the relay ammeter, mentioned in our review of progress the year before last, by adding a magnetic system. The iron core surrounds the current conductor as in the

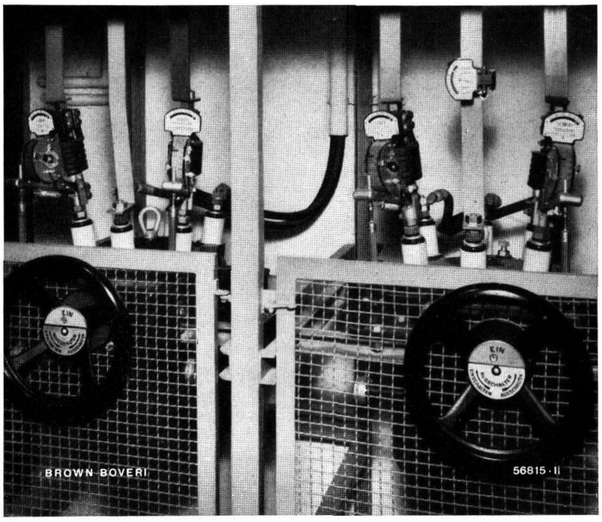


Fig. 43. — Modern arrangement for directly measuring the current in a line with short-circuit-proof relay and bar-type ammeters in a switching station in our workshops.

The illustration shows how a space-saving and clearly arranged metering equipment can be built up from these metering instruments.

case of the well-known bar-type current transformers and can be swung open for fitting on the conductor without the latter having to be mechanically disconnected. The reglementary distance between current-carrying conductors is hardly affected, due to the small dimensions of the apparatus. As shown in Fig. 42 instruments for horizontal and vertical conductors only differ in the marking of the scale. For the time being, metering ranges of 300, 600, and 1200 A only are available. The metering error is at most $\pm$ 5 % of the scale value as long as the simple installation rules are observed. For instance, for metering ranges of 300—600—1200 A the instrument should not be less than 5 – 10—20 cm from right-angled bends, while neighbouring parallel conductors should be more than 5—10—30 cm away. A special screw permits of correction of the reading within $\pm$ 5 % of the full deflection.

Ease of mounting and compact and economical construction give these ammeters a wide field of application. For instance, the current in a complicated busbar system can be measured at any desired point or the current distribution in parallel conductors supervised. Fig. 43 shows a bar-type ammeter in a 5 kV installation. A check on the current is thus rendered possible even where current transformers are lacking or where space conditions or cost prohibit the use of orthodox metering gear.

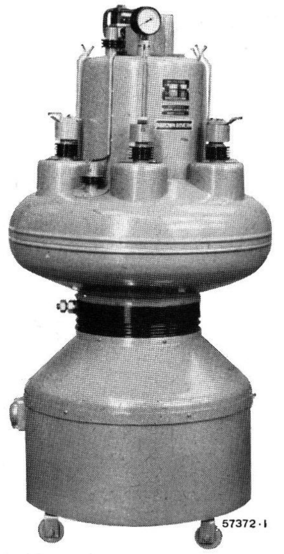


Fig. 44. — Air-cooled pumpless mutator.

Continuous rating 500 A at 600 V. The mutator is insulated from the earthed fan casing on which it is mounted. The latter is provided with swivelled rollers. The pumpless mutator is the ideal convertor, inasmuch as it combines low weight and small space requirements with high efficiency.

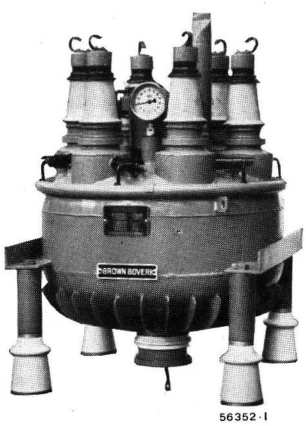


Fig. 45. — Air-cooled, pumpless, high-voltage mutator.

Continuous rating 10 A at 12,000 V d. c. The mutator is equipped with controlled grids for the suppression of short circuits and voltage regulation. Pumpless mutators are eminently suitable for mounting in switchboard frameworks in small substations and transmitting stations, and also for replacing damaged glass-bulb rectifiers.

H. MUTATORS.

Much of the work in this field was connected with the development of the high-voltage transmission which has already been referred to in these notes.

The construction of air-cooled pumpless mutators with ratings up to 500 kW, which are meeting with an ever-increasing demand, was pushed forward in the course of the year. The 500 A type (Fig. 44) was installed in a whole series of Swiss traction substations and has given very satisfactory results. Large numbers of this type for d. c. voltages between 550 and 1500 V have already been supplied or are under construction for export.

Air-cooled pumpless mutators for broadcasting stations with d. c. voltages up to 20,000 V are in course of development, while a 12,000 V type has already been completed (Fig. 45). These are particularly suitable for directly mounting in the switch cubicle (Fig. 46) and are provided with controlled grids for voltage regulation and the suppression of short circuits. Practical service has proved this new type fully to meet the requirements of broadcasting transmitters.

In this number of the Review last year we stated that the standardization of the air-cooled types for currents up to 3150 A had been completed. The mutator-bloc (Fig. 47) continues to be popular in industrial and traction circles.

The development of single-anode tanks (mutator units) has already led to important orders being received. One concerns a plant for 5760 kW and 8000 A. Fig. 48 shows the mutator units of a plant with an aggregate rating of 7000 kW at a voltage of several thousand volts.

In the course of the year the report came to hand of the successful setting to work of the mobile mutator substation of the Compania Paulista de Estrados de Ferro at the end of 1941. This well-known Brazilian railway company which undertook the electrification of a section of its system some years ago with 3000 V d. c., employs the substation on sections of track where locomotives fitted with regenerative braking equipment pay back energy into the contact-wire system when running downhill. As will be seen from Fig. 49 the substation is mounted on two trucks coupled together, the one bearing the three-phase circuit-breaker, transformer, and two mutators, and the other the auxiliary set, control and supervisory switchboard, d. c. switchgear with section and feeder switches, and the wave absorber. A detailed description of this interesting mobile station will appear in one of the next numbers of this journal.

A new application for mutators arose out of the enquiry of a foreign customer concerning the starting and synchronization of three synchronous condensers of 7600 and 18,000 kVA rating installed in a power station. A proviso, however, was that two of the three machines were not to be started as induction motor. According to practice hitherto the only alternative would have been to mount a separate starting motor on each machine. Owing to the big initial outlay involved by such equipment for the three machines it was decided to compare it with the cost of the theoretically known possibility of connecting the machines as "mutator motors" for the starting process, i. e., until they are thrown in parallel with the system. The comparison was decidely in favour of the latter arrangement, which was finally ordered.

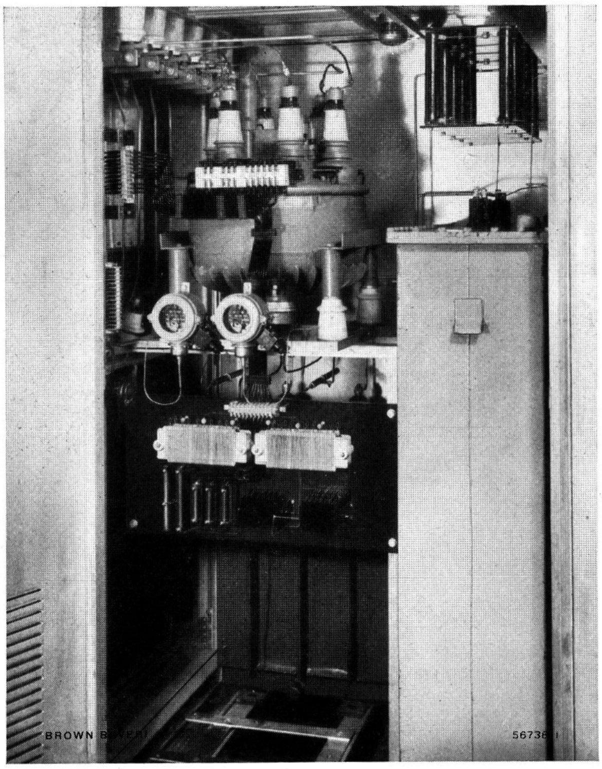


Fig. 46. — Air-cooled, pumpless, high-voltage mutator mounted in switchboard framework of a mobile transmitter.

Particularly noteworthy is the saving in space effected through the omission of the pump plant.

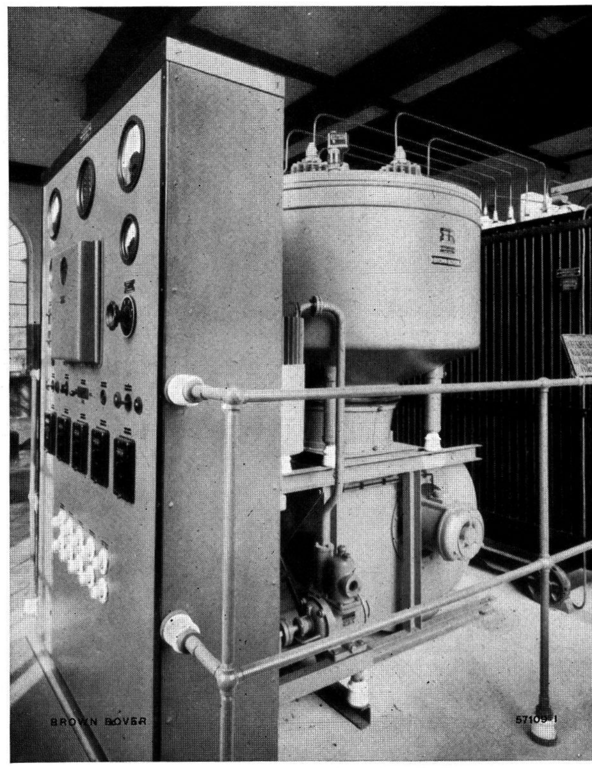


Fig. 47. — Mutator-bloc with air-cooled mutator, rated 600 kW, 580 V, in the "am See" Substation of the Biel Municipal Electricity Supply.

The omission of the water cooling equipment represents a big simplification and reduction in cost.

Fig. 48. — Single-anode mutators for a 7000 kW high-voltage plant.

The illustration shows the air-cooled tanks on the test bed.

Special advantages of single-anode mutators: High efficiency, ready interchangeability, standby equipment simple and inexpensive.

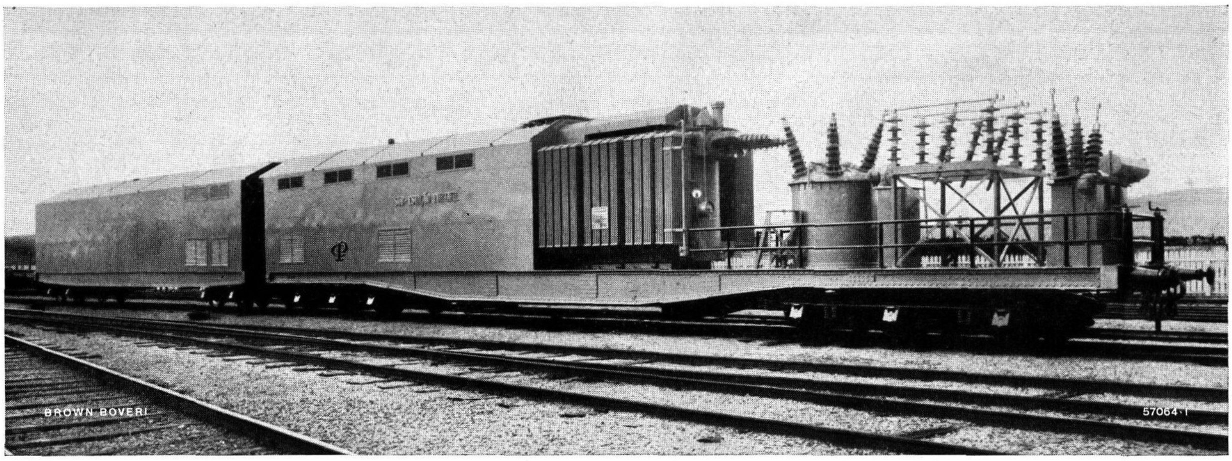


Fig. 49. — Mobile mutator plant rated 3000 kW, 3000 V, primary voltage 88,000 V.

This plant is noteworthy through the provision of the mutators with full-automatic control gear and controlled grids for energy-recuperation and compounding purposes.

View of complete plant (from right to left): Equipment for incoming line, oil circuit-breaker, mutator transformer, mutator truck with casing, truck for d. c. equipment and switchboard, with casing. This plant, an outstanding achievement of the Swiss engineering industry, has been in operation on the Paulista Railway, Sao Paulo (Brazil), for over a year with excellent results. It is entirely due to the mutator that mobile substations are possible at all on d. c. railways.

In this case the machine is connected to the system through a transformer and a mutator, and brought up to synchronous speed and synchronized with the system with the characteristics of a separately-excited d. c. motor, the mutator being employed both as a "commutator with three segments" and starter. The workshop tests carried out with the first equipment of this kind to be constructed, together with the third new machine of 18,000 kVA, 15 kV rating, which we also had to supply, proved entirely successful. With a maximum duration of the starting and synchronizing operation of four minutes none of the parts of the machine are even normally stressed. The only actual subsequent alteration to the machine itself was the fitting of a small commutator controlling the mutator, which, designed for a control power of the order of 0·1 kW, is flanged on the end of a shaft extension and only takes up an amount of space equivalent to a cube with sides not exceeding 50 cm in length. The entire equipment can be changed over to either of the three machines in the power station by means of appropriate isolating switches, notwithstanding the fact that two of the machines are rated 5 kV and the new one 15 kV. This mode of starting is of advantage where two or more machines have to be started or space conditions do not permit of the installation of a starting motor.

A new static quick-acting regulating equipment has been developed for the *regulation of mutators,* the shifting of the ignition point being achieved through an induction regulator coupled to a hydraulic servo-regulator. This apparatus has been designed particularly for the regulation of mutators in chemical applications, its main advantages being high regulating speed and effective handling of short circuits and backfires. Since it can be constructed for the regulation of any physical or electrical magnitude, however, its application is very wide.

Finally, the tests in connection with the development of a *mechanical rectifier* were concluded. In the course of this year the erection of a large plant for about 8000 A at a variable d. c. voltage of 300—400 V will be completed.

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

A. MOTOR DRIVES AND ASSOCIATED CONTROL GEAR.

In the textile industry the demand for *three-phase shunt commutator motors* with *spinning regulator* continued to increase due to the multifareous advantages of the spinning process and the resulting greater production and improvement in quality of the spun yarn. Apart from the automatic speed regulation to obtain constant thread tension (Fig. 50) the fact that the speed can be conveniently adjusted by hand is found of particular advantage when new fibres have to be spun. The spinning speed can be adapted to the often rapidly changing conditions (e. g., reduced for the processing of staple fibres, increased for cotton) without the slightest modification to the drive. A number of improvements have been incorporated in the motor and spinning regulator. Two scales are now provided on the starting lever side (Fig. 51). Both of these indicate the brush displacement in function of the speed, the lower one the initial speed, i. e., the speed with which the cop bottom is spun, and the upper one the instantaneous spinning speed. In this way operation is even further simplified and the still more accurate check on the spinning process thus rendered possible enables an increased production and improved quality of the spun yarn to be achieved.

The new *thread tension measuring apparatus* mentioned in last year's review of progress was also improved. Two metering ranges are now provided, one for fine, the other for coarse spinning frames, so that one and the same apparatus can be used for a large range of counts. The apparatus has met with a good reception in spinning circles and has proved to be a useful adjunct for the ready determination of the most suitable spinning regulator setting (Fig. 52).

Increased interest was shown in *variable-speed doubling frame drives.* In view of the many factors which have to be taken into consideration in the doubling process makeshift speed-adjusting devices are being more and more replaced by modern variable-speed drives, which alone are capable of meeting the increased demands. The loss of time involved by the changing of mechanical parts, such as pulleys, gear-wheels, and the like, is entirely eliminated. The speed

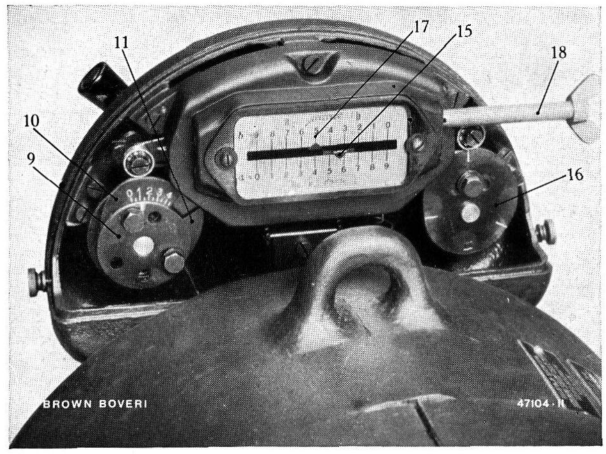


Fig. 50. — Basic and periodic speed regulation are given on scales and can be independently set on the spinning regulator during service with a removable spanner (cover of regulator removed).

9. Basic cam.
10. Adjustable cop-starting piece.
11. Adjustable cop-finishing piece.
15. Scale with pointer for basic regulation.
16. Periodic cam.
17. Scale with pointer for periodic regulation.
18. Setting spanner.

The employment of our spinning regulator results in both an increase in production and improvement of the quality of the spun yarn.

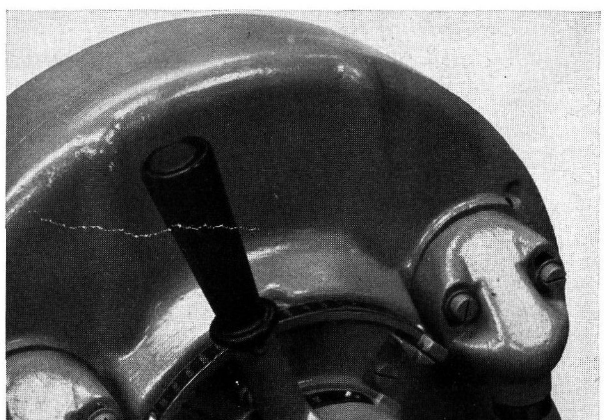


Fig. 51. — Starting and braking lever of a spinning-frame motor. Two scales enable the spinning speed to be read off in terms of both the instantaneous and set values of the brush displacement.

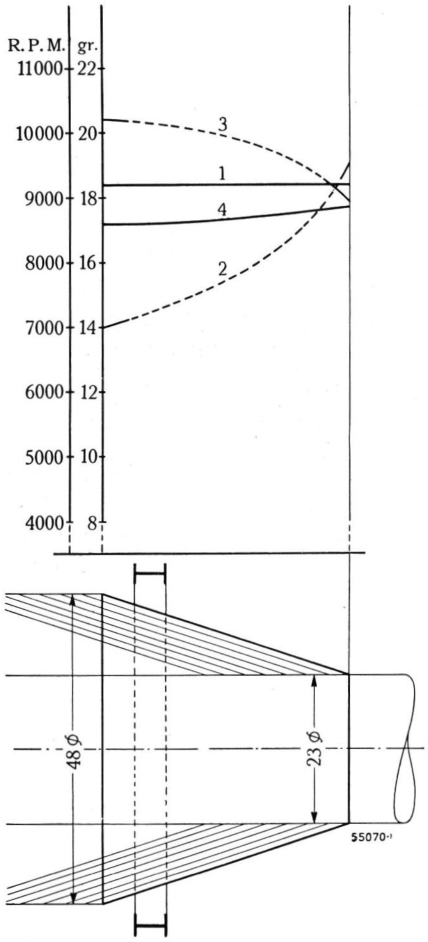


Fig. 52. — **Spinning speeds and thread tensions for a conical wound bobbin on a ring spinning frame for large cop sizes and constant balloon height when spinning with No. 30 warp.**

Ring diameter 51 mm, cop one-third full.

1. Spinning speed.
2. Thread tension with constant spinning speed of 9200 r. p. m.

The necessary speed curve 3 for the approximately constant thread tension 4 was found on the spinning regulator within a few minutes.

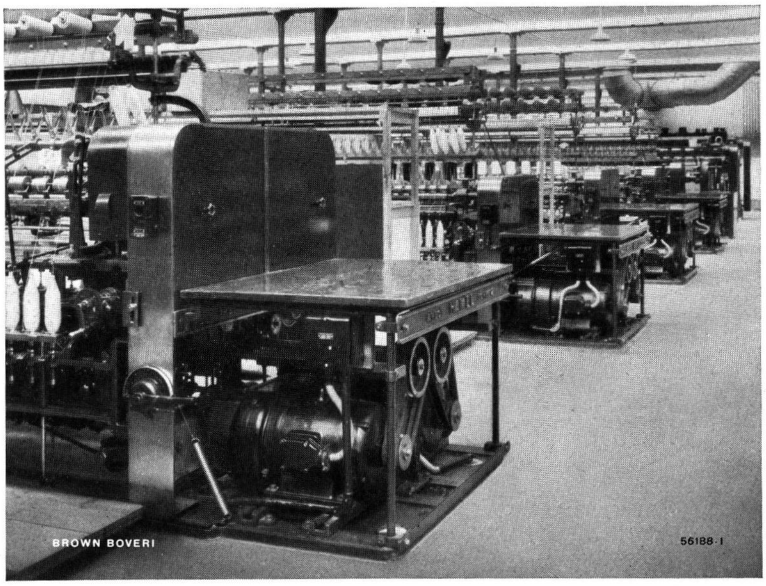


Fig. 53. — **Ring doubling frames in a wool weaving mill with variable-speed double drive by three-phase shunt commutator motors.**

No time lost in changing pulleys. The speed is always the highest possible for each twist.

is always the most favourable as well as the maximum possible (Figs. 53 and 54).

Speed frames must be started smoothly so that the vee-belt of the differential gear drive will not slip on the cones, otherwise the correct relative speed of the flyers and bobbins will not be maintained and "bang-offs" will be inevitable. We meet this condition by mounting the flyer driving motor on the headstock and slowly shifting the belt from the loose to the fast pulley. Modern, heavy, high-capacity flyers make even greater demands on the drive. For instance, two speeds, the lower one for the beginning of the winding-on and piecing of the roving, the other as

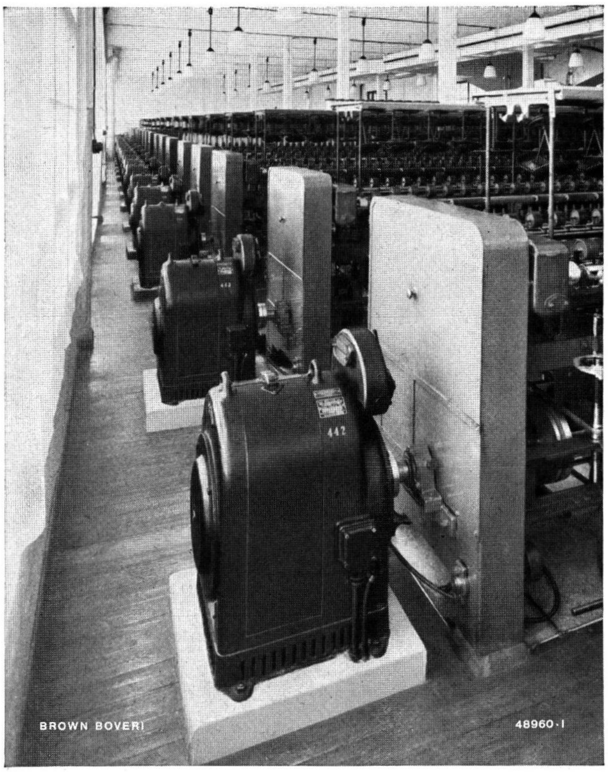


Fig. 54. — **Rayon doubling frames for bobbins with parallel layers of yarn.**

The automatic doubling regulator raises the speed during the winding-on process and results in a considerably increased production.

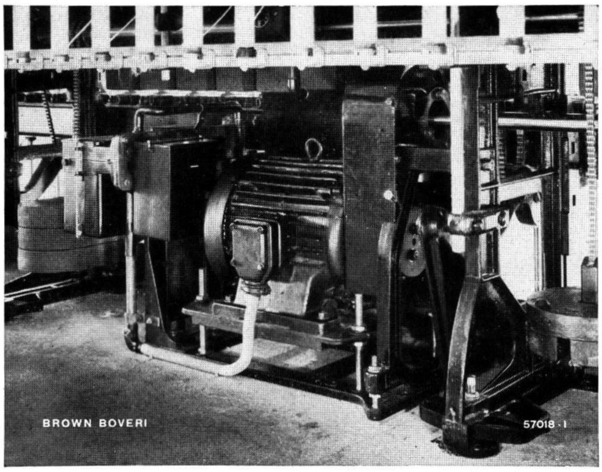


Fig. 55. — Flyer drive with two speeds and smooth starting gear.

For the beginning of the spinning operation and piecing of the roving a reduced speed is available for a short period. Operation is simple with the existing control rod.

working speed, are frequently required. For such cases we have developed a special drive with which smooth starting is achieved through the use of special motor windings and simple, partly automatic starting gear. The impulses are imparted with the existing flyer control rod by means of an associated control switch. The operations to be carried out by the mill hand are thus extremely simple, i. e., the same as hitherto (Fig. 55).

The tendency *to simplify operation with remote-controlled switchgear* is proved by the numerous orders for contactor control gear for spinning-mill

Fig. 56. — Bank of metal-clad switchgear for a triple carding set drive.

The remote-controlled apparatus is clearly arranged; for starting and stopping readily operated push-buttons are provided on the machines.

preparatory machinery, carding and combing machines, and wool carding and finishing machines of all kinds. The switch equipment and contactors must be protected against dust and dampness and are therefore of the metal-clad type combined into banks. This gives a neat installation which can be readily supervised and also provides protection against accidental contact and damage (Fig. 56).

In the *paper industry* our regulating equipments with electrical feed drive for continuous wood grinders, again aroused great interest.

To ensure economical operation of such grinders the feeding of the logs of wood to the stone must be so regulated that the power required by the grinder, i. e., the power consumption of the driving motor, remains constant. In this way not only is the supply system relieved of heavy load fluctuations, but the quality of the wood pulp is considerably improved.

For this purpose we build electrical feed drives which are progressively regulated from standstill to maximum speed on the Ward-Leonard principle by a power regulator. To protect the mechanical feed gear of the grinder against overloads due to irregular feeding of the logs (this may be caused by the shape of the logs or the way they lie in the pocket) an

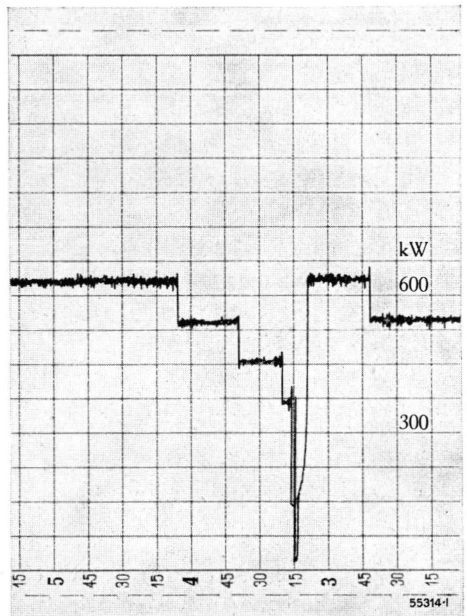


Fig. 57. — Power diagram of a wood grinder drive at various loads.

The feed and regulating equipment maintains the load constant at the adjusted value, despite the onerous grinder working conditions.

appropriate protecting regulator is employed which operates upon the feed torque exceeding a certain value and may reduce the feed to zero, if necessary, and through a visual or acoustic signal warn the operator that the feed should be attended to.

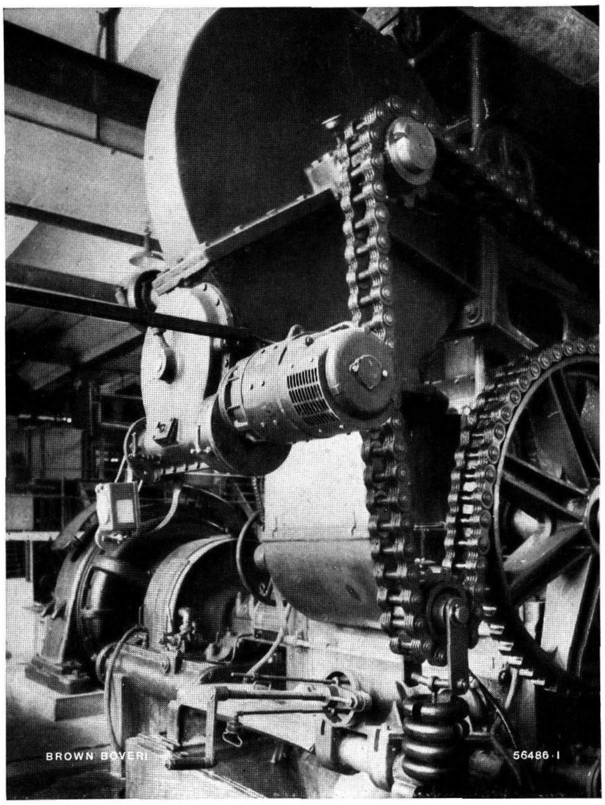


Fig. 58. — Electric feed drive for a continuous-feed wood grinder, rating 736 kW.

The feed motor drives the triple-thread worm shaft of the feed gear through built-on gearing and is regulated by a power regulator to give a constant load on the grinder motor. A recording instrument driven from the worm shaft, which indicates the mean rate of feed and the number of cubic metres ground, together with the instruments in the switchboard, facilitates the checking of the grinding process.

Although in the case of grinders the regulating conditions are very onerous, excellent results are obtained with our equipment, as will be seen from the diagram in Fig. 57.

By reason of their appropriateness and their low power consumption our electrical feed drives have been successfully applied both to new and existing grinders. An example of the latter case is illustrated in Fig. 58.

The *sectional drive* of paper-making machines with central draw control and regulating equipment, briefly referred to in our review of progress in 1941,[1] has been further simplified and improved. Two drives of this new design were taken into service in Brazil last year, erection and setting to work being successfully carried out in a very short time by our Brazilian agents' staff. The fact that such drives can be put into operation by non-specialists simply on the basis of the working instructions is clear proof of the progress made. One of these drives is illustrated in Fig. 59. Geared motors are mounted on the shaft-ends of the drying cylinders, while motor-gears drive the other sets. The draw control equipment and the starting gear of the contactor type (instead of hand-operated starters on each motor) are installed at a central point away from the paper-making machine. In consequence, the space requirements of the drive

[1] The Brown Boveri Review 1941, p. 27.

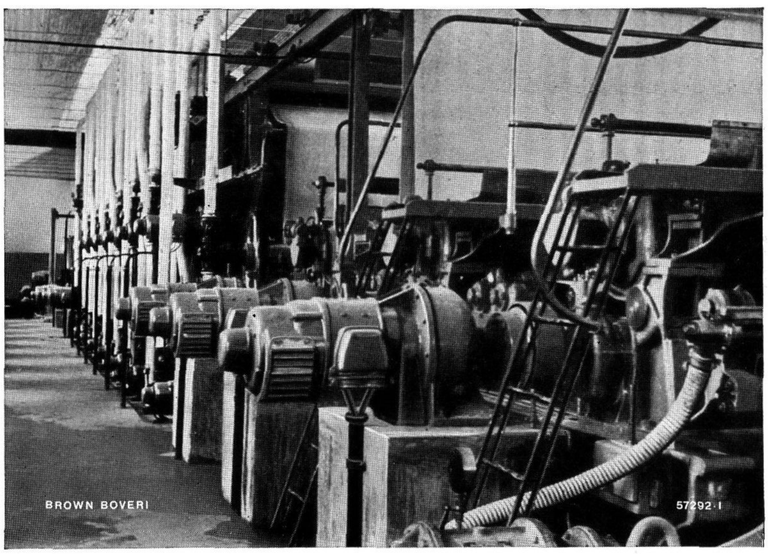


Fig. 59. — Sectional drive of a paper-making machine with 27 driving sets.

The motor-gears and geared motors mounted on the shaft-ends of the drying cylinders, together with installation of the draw control and starting gear away from the paper-making machine, enable the drive to be installed in the minimum of space and make for good accessibility to the machine.

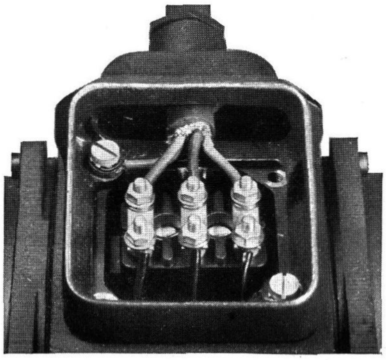


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Fig. 60. — Six terminals
(standard design), for star or delta connection.

Figs. 60—63. — Terminal arrangements for small motors enabling them to be readily adapted to various voltages.

Terminals and winding ends are clearly marked so that the change-over from one voltage to another can be **easily and quickly** made with the help of the diagram supplied.

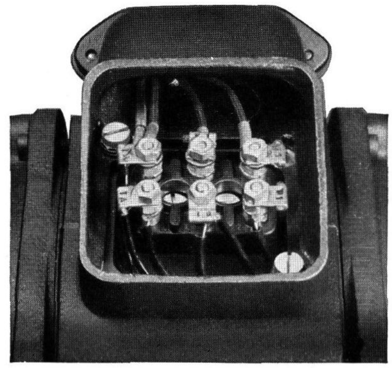

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Fig. 61. — Six terminals with six fixed and six detachable winding ends for two or three voltages in the ratio 1 : 1 · 7 : 2 with direct-on starting.

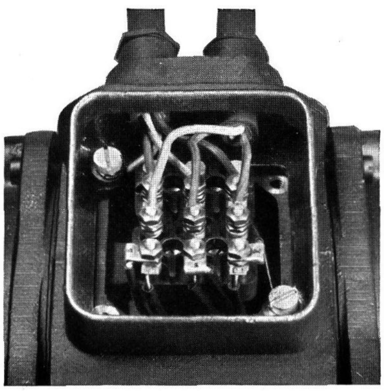

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Fig. 62. — Nine terminals with fixed and detachable winding ends, for two voltages in the ratio 1 : 1 · 3 or 1 : 2 with star-delta starting.

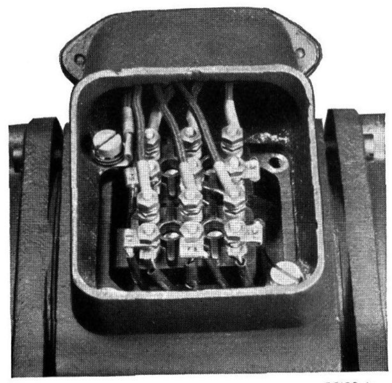

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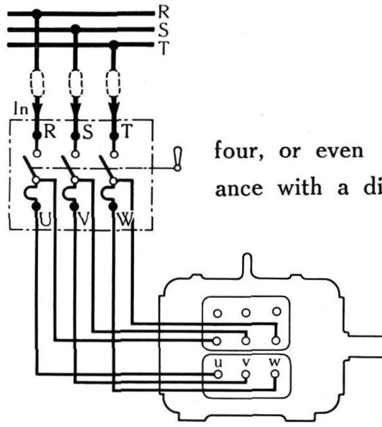
Fig. 63. — Twelve terminals with fixed and detachable winding ends, for three voltages in the ratio 1 : 1 · 5 : 2 with star-delta starting.

are reduced to a minimum and accessibility has also been improved on this side of the machine.

In view of the shortage of liquid and other fuels *electric motors* are being increasingly employed for the *drive of mobile machines*. For such applications the possibility of using one and the same motor for various supply voltages is of primordial importance. Suitable winding connections were of course already available. The problem, however, was to simplify the change-over so that any electrician could adapt the motor to the desired voltage. For this purpose we have evolved terminal arrangements with six to twelve terminals, to which fixed or detachable connections are connected so that the motor can be conveniently employed for two, three, four, or even five different voltages, in accordance with a diagram fitted in the terminal cover (Figs. 60—63).

In this connection a switching arrangement is of interest with which one and the same thermal release can be employed



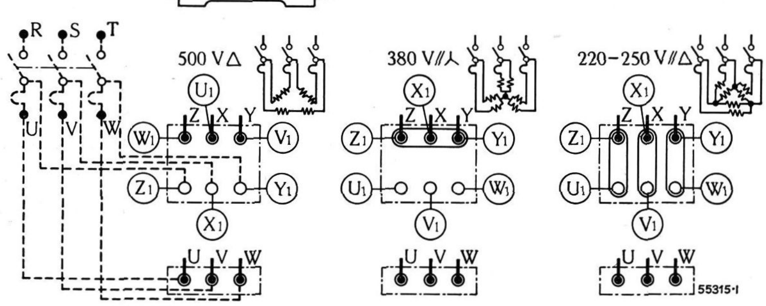
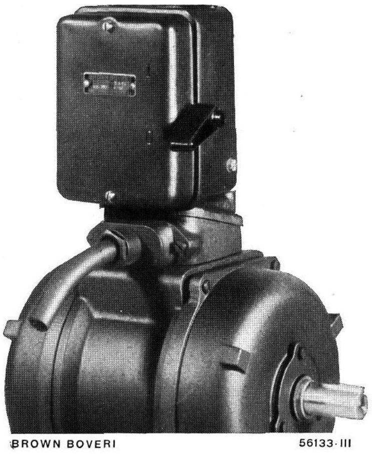
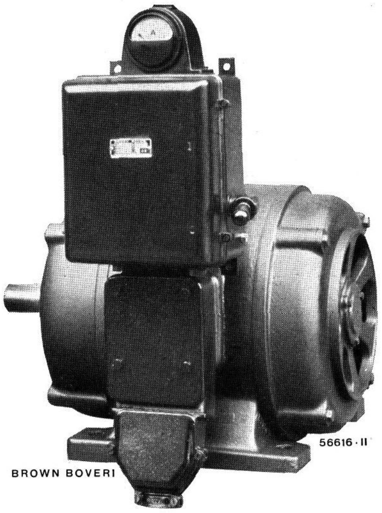


Fig. 64. — Connection of thermal releases with unchanged setting for motors for various voltages.

According to the service voltage only the terminal leads marked U_1-V_1-W_1-X_1-Y_1-Z_1 and the links of the terminals have to be differently connected. The setting of the releases remains unchanged in all cases, so that mistakes which might impair the protection of the motor are out of the question.





Figs. 65 and 66. — Three-phase motors with built-on motor protecting switch.

All Brown Boveri industrial switchgear with air-break contacts can be mounted on the motor in a pleasing and practical manner, no special parts being involved. Installation is greatly simplified as a result.

for operation with multi-voltage motors. Experience has shown that the changing of the releases of the motor protecting switch is frequently neglected, and the protective elements for the highest service current retained so that the motor is often no longer correctly protected. With the switching arrangement already referred to the thermal releases of the motor protecting switch are connected directly in the winding phase circuit and thus need only be proportioned for this current which does not vary with the connection of the winding. An example of this arrangement is shown in Fig. 64. The releases can be incorporated in the motor protecting switch in the usual way or combined to form a separate thermal relay, preferably mounted directly on the motor. The latter method is of advantage where the switch is installed some distance from the motor; the releases operate a small contact included in the control circuit of the motor.

New designs of *motor protecting switches, relays, control switches, etc.,* have also been developed *for mounting on motors.* These take advantage of the facility with which our industrial switchgear can be combined into small banks. For mounting on motors the terminal box is so designed that the box of the switch is also screwed on directly, thus enabling the special supports hitherto necessary to be dispensed with. Inasmuch as the various connecting parts developed for our industrial switchgear, such as conduit glands, cable boxes, etc., can be attached to the terminal box, combinations meeting the severest demands in every respect are obtained (Figs. 65 and 66).

Instead of our *small motor protecting switches* rated 10 A and 500 V, with casing of moulded material, a design with steel casing has been evolved. This has the advantage of greater mechanical strength and enables various connecting parts and accessories, such as conduit glands, cable boxes, ammeters, etc., to be employed. The casing is designed both for mounting on motors and semi-flush mounting in switchboards or machines (Figs. 67 and 68).

Figs. 67 and 68. — Small motor protecting switch rated 10 A, with dust- and splash-proof steel box.

On left for surface mounting, on right with frame for semi-flush mounting. Reliable protection is just as important and warranted in the case of small motors as with large motors, especially since its cost is moderate in comparison to that of the motor.

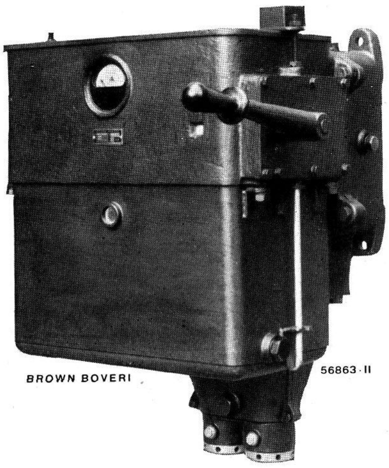


Fig. 69

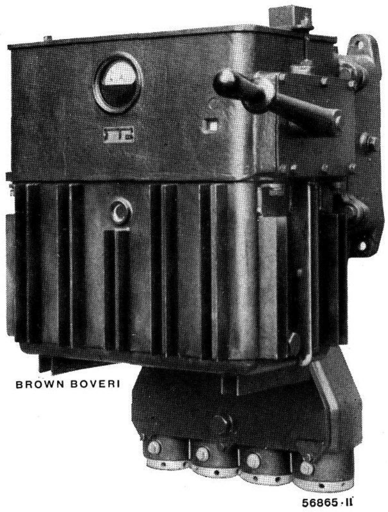


Fig. 70

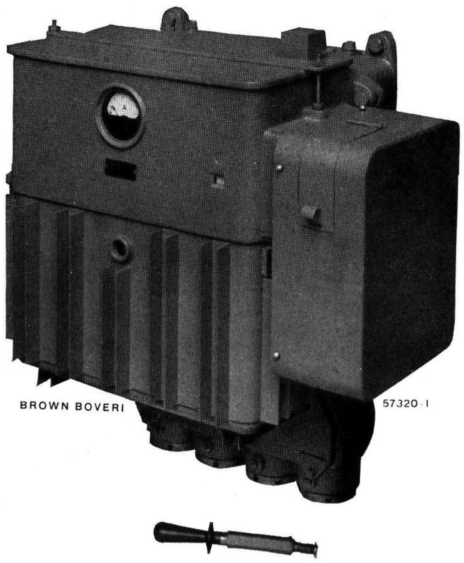


Fig. 71

Figs. 69—71. — Motor protecting switch with oil-immersed contacts, ratings 250, 400, and 600 A.

Figs. 69 and 70. Model for hand operation.
Fig. 71. Model with remote-operated oil-pressure control gear.

Practical construction and high switching capacity make these apparatus particularly *suitable for low voltages* and heavy currents.

Our series of *motor protecting switches* with oil-immersed contacts has been extended by three further types rated 250, 400, and 600 A at 500 V. These are hand-operated switches with thermal releases which are directly heated even up to the highest current ratings. A high-speed closing device renders the contact-making speed independent of the motion of the handle and prevents fusing of the contacts when switching in on short circuits. All of these switches can be provided with the usual accessories such as ammeter, low-voltage release with and without time-lag, auxiliary contacts, etc. To facilitate installation and lead entry the switches are provided with a special connection box which is first mounted alone. The leads can thus be conveniently drawn in and sealed with compound, if necessary, before the switch itself is fitted (Figs. 69—71).

For remote operation of these switches motor-driven pressure-oil control gear is substituted for the handle. The control gear is operated by momentarily depressing the closing button, whereupon after the elapse of a few seconds the switch closes. To switch out either the low-voltage coil circuit is interrupted or a tripping coil circuit closed.

These switches are characterized by the high current they can break, as given hereafter.

Type rated	250	400	600 A
Breaking current (r. m. s.) at 500 V, 50 cycles			
p. f. = 1 * . .	5000	8000	12,000 A
p. f. = 0.1 . .	3000	4800	7000 A

* Also dynamic and thermal limiting current for 0·5 second.

The trend to *modernize old-type machine-tools* has been met with interesting drives. A typical example is an equipment for a Landis grinding machine in a Swiss engineering works which was formerly driven by a single motor over numerous belts and pulleys (Fig. 72). Instead of these mechanical transmissions the various motions are each taken care of by a separate motor. For the main drive (of the work) a d. c. Ward-Leonard-controlled motor variable in speed between 360 and 1800 r. p. m. and mounted directly on the work headstock is employed. The speed is automatically varied according to the diameter of the work by a special device. The appertaining Ward-Leonard set is also mounted directly on the machine.

Before modernization

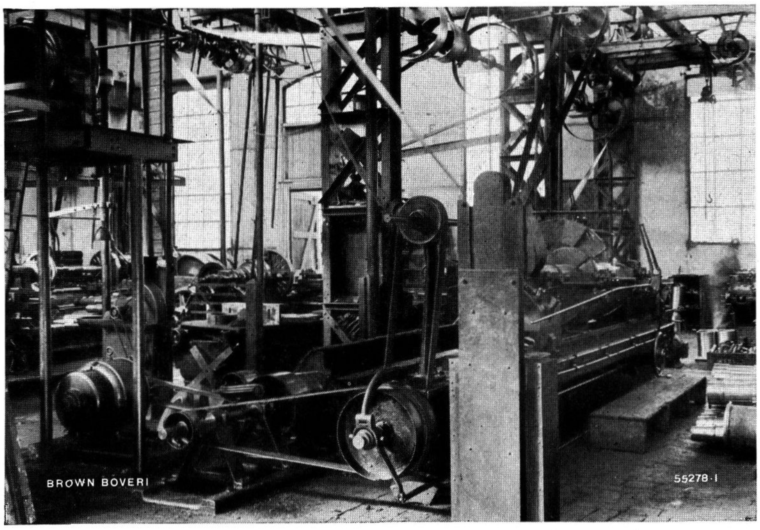


Fig. 72. — **Landis cylindrical grinding machine with antiquated lineshaft drive and a single driving motor.**

Drive not sufficiently adaptable and difficult to adjust.

After modernization

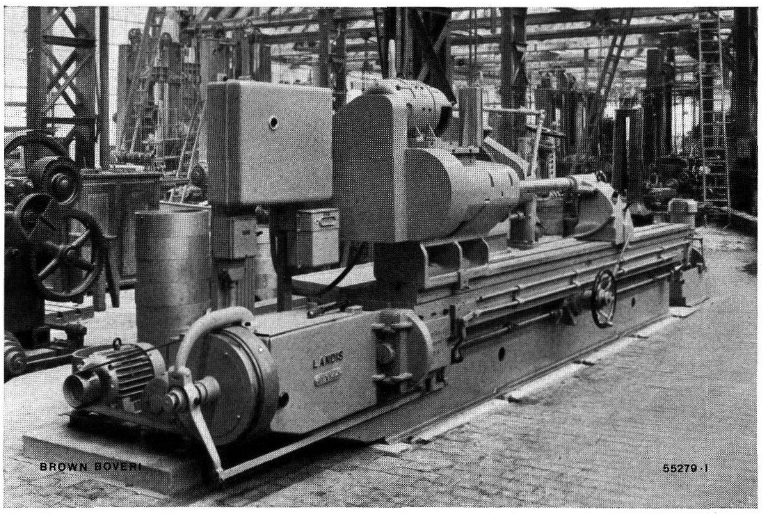


Fig. 73. — **Landis cylindrical grinding machine after modernization of drive, i. e., substitution of five individual drives for lineshaft drive, a d. c. Ward-Leonard-controlled drive being employed for automatically adjusting the speed to the diameter of the work.**

Result: Increased production with simple attendance; cumbersome belt drives dispensed with.

The success of the transformation is evident at a glance. The antiquated machine is "rejuvenated" and makes quite a modern impression.

The grinding wheel spindle is driven by an 11 kW three-phase totally-enclosed induction motor. Smaller pony motors, also of the totally-enclosed pattern, are provided for the in-feed to the wheel, table traverse, and pump for the cooling agent. All of the motors are controlled by push-buttons on the head and tail stocks. The very few switching devices required are lodged in a small frame (Fig. 73).

The machine is now not only more accessible, but its attendance has been simplified and its production quite considerably increased.

B. ELECTRIC WELDING.

The increasing use of aluminium and its alloys in engineering applications induced us to turn our attention to the welding of sheet aluminium. The first obvious step was to endeavour to employ without modification the seam welding machines developed by us for iron and which were mentioned in our annual retrospective number last year. Although this is possible, difficulties are encountered due to the approximately five times lower resistance and greater thermal conductivity of sheet aluminium, while for the same distance between, and length of, the welding arms the capacity of the machine must be increased. [1]

These considerations led us to develop a spot welding machine specially designed for the *welding of sheet aluminium;* this is shown in Fig. 74. To enable the power consumption to be kept down to a minimum the length of the upper welding arm can

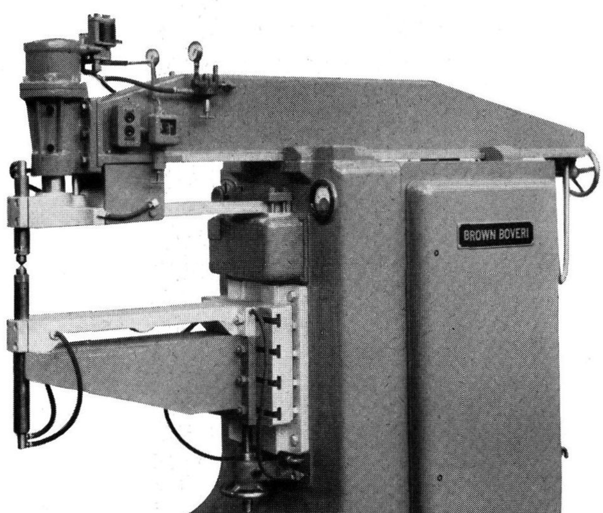


Fig. 74. — *Spot welding* machine for sheet aluminium up to 3 mm in thickness. Nominal rating 550 kVA with arms 1600 mm long and 430 mm apart.

This machine is particularly suitable for welding large, unwieldy aluminium objects, e. g., side walls of vehicles.

be adjusted between 400 and 1200 mm by means of worm gear, whereas the lower arm is of fixed length and must be changed for shorter or longer lengths when necessary. The distance between the arms is adjustable between extreme limits of 270 and 430 mm. Current and output can be regulated on the infinitely variable principle from zero to the maximum possible value. The machine can be employed for seam welding by substituting rollers for the electrodes. The rollers are driven through infinitely variable gearing built in the machine casing. Regulation is effected by a separate contact-less regulating transformer designed for direct connection to the high-voltage system. This transformer is installed in a separate high-voltage cabin and controlled by simple remote control gear. It is usually important from an operating point of view that high-power spot welding machines should be connected directly to a high-voltage system, so that the low-voltage system will not be affected by the heavy current surges. A station transformer can then generally be dispensed with.

In conjunction with the current-time regulator and synchronous switch mentioned last year really excellent results have been obtained with our resistance welding machines of both types. In contradistinction to arc welding where to effect a joint an extraneous material, the electrode, is melted through the action of the arc, resistance welding only involves heating the point to be welded and the application of a certain pressure. A current of many thousand amperes at a very low voltage produces the necessary temperature at the required joint. To effect a weld the parts to be welded are forced together with a certain pressure between two water-cooled copper electrodes. Whereas the outside of the material at the point of contact of the electrodes with the work only heats up slightly due to the water cooling and the low electrical resistance, the two faces of the work in contact with one another immediately heat up to such an extent — by reason of the reduced cooling effect and increased resistance — that they weld together under the pressure of the electrodes. Fig. 75 is a ground section of two spot-welded steel plates. The high quality of the joint will be evident from the structure. Fig. 76 depicts a similar section through two aluminium sheets welded together by means of the spot welding machine represented in Fig. 74. Fig. 77, however, showing two

[1] See P. Voegeli, Schweizerische Bauzeitung 1943, I, p. 8.

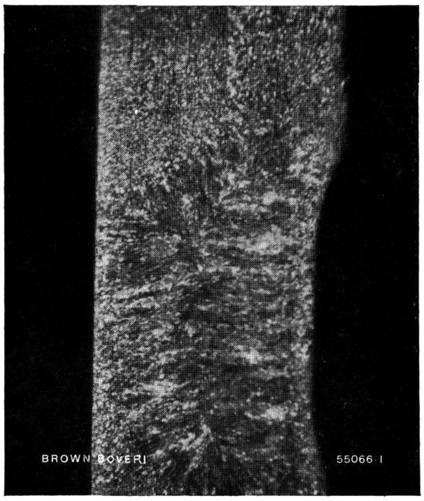


Fig. 75. — Ground section through spot weld of two 2 mm iron sheets.

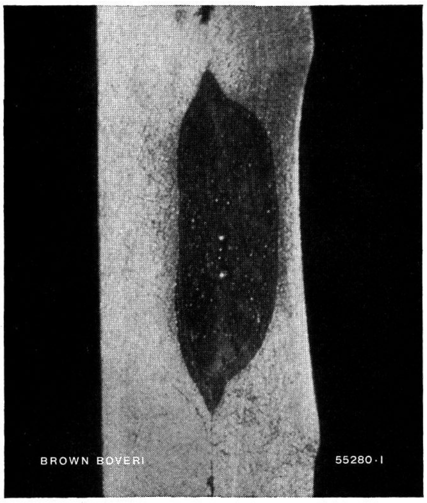


Fig. 76. — Ground section through spot weld of two 1 mm aluminium sheets.

Both figures clearly illustrate an excellent property of the welding machine shown in Fig. 74: Only the right-hand side of the welded sheets bears the inevitable electrode impression, while the left-hand side shows no trace of deformation or damage to the surface whatever. As a result, the time-wasting stopping and filling of the outside of sheet-metal walls is dispensed with, so that painting or any other surface treatment is possible without special preparation, which is particularly important where the side walls of railway coaches and trolley buses, aeroplane and coachwork parts, furniture, locks, etc., are concerned.

seam-welded 0·08 sheets, illustrates the most clearly the foregoing remarks on seam welding. The result of a tensile test on two spot-welded sheets shown in Fig. 78 is also interesting. The original welded joint could not be separated, a kind of "rivet" being produced. Fig. 79 is a view of our resistance welding machine assembly bay.

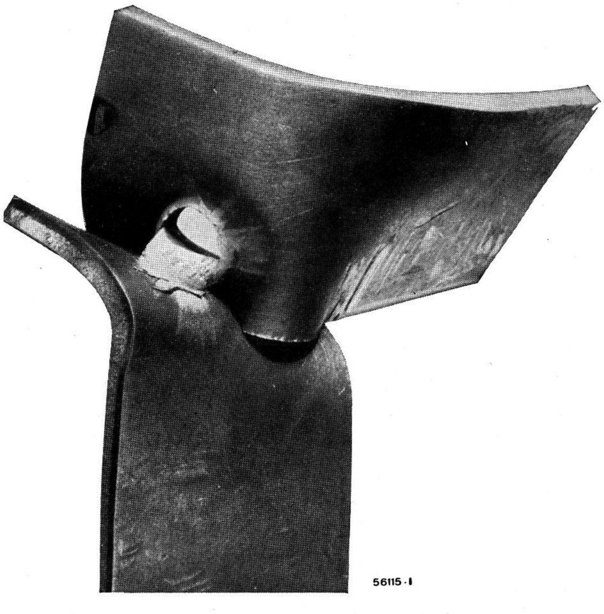


Fig. 78. — Result of tensile test on two spot-welded 3 mm steel sheets. It will be noticed that the welded joint is stronger than the individual sheets.

Fig. 77. — Ground section through seam weld of two stainless steel sheets 0·08 mm thick. Frequency of individual spots 200/sec. without interruption.

The hermetic seam welding of chrome-nickel-steel sheets for extra-high-vacuum pipes is particularly difficult where sheets only 0·08 mm thick are concerned, because the annealed *zone* must not reach the outer surface of the sheets, otherwise the joint would lose its resistance to corrosion and hardness. The illustration shows how well the Brown Boveri welding machines meet this condition. The welded zone (dark inner part) of practically uniform expansion lies so deep throughout that the annealed zone (not visible, because structure unaltered) cannot attain the surface at any point (external edge of light part).

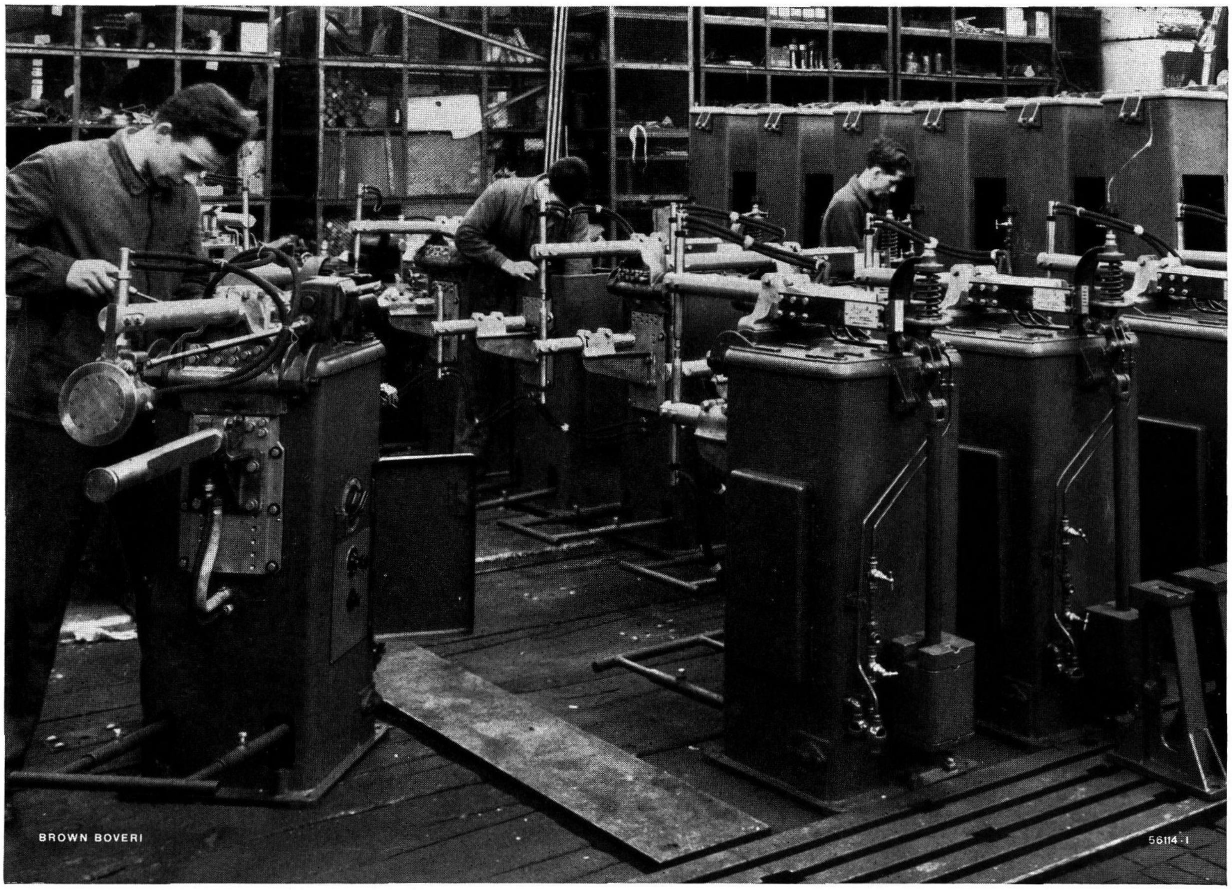


Fig. 79. — View of spot and seam welding machine assembly bay.

The continually increasing demand now enables these machines to be manufactured on mass production lines.

C. ELECTRIC FURNACES, ETC.

The continuing big demand in this field could unfortunately not be fully met due to the shortage of energy.

Of chief interest as far as Switzerland is concerned is the electrical grass dryer. By reason of the excellent results obtained with the large model we decided to develop a *small grass dryer* with a rating of 10 kW on the same heat recuperation principle (Fig. 80). As experience has already shown the new dryer is also very suitable for the drying of fruit and vegetables. Compared with other makes of apparatus our dryer not only has the lowest energy consumption, but permits a higher quality dried product of great uniformity to be obtained, whereby the aroma is also retained. Due to the heat recuperation the energy consumption per kilogram of evaporated water is only 0·9 kWh. As an example of production 200—240 kg of beans can be dried per twenty-four hours.

A *tunnel kiln for the firing of steatite,* and in particular steatite moulded parts, was completed and successfully put into service at the beginning of this year in a Swiss ceramic works (Fig. 81). This is the first electric tunnel kiln in the world to be built for

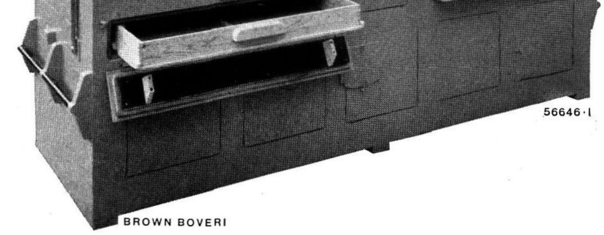


Fig. 80. — Brown Boveri small dryer for grass, fruit, and vegetables, mobile model. Rating 10·5 kW, 380 V, 50 cycles.

This small dryer is suitable both for individual farmers and central fruit and vegetable drying plants.

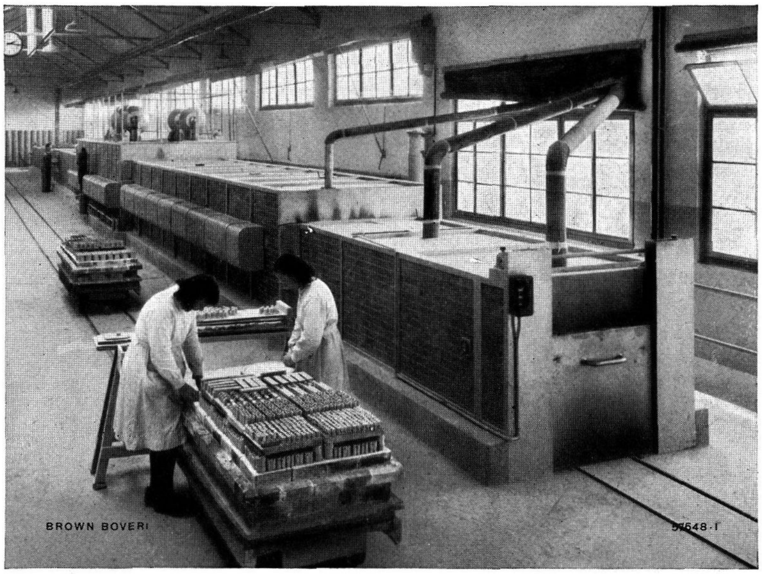


Fig. 81. — Single electric tunnel kiln for the firing of steatite at 1400 ° C. First electric tunnel kiln for firing of steatite.

Higher insulation strength of products and substantial reduction in amount of scrap, together with higher thermal efficiency compared to firing with solid or liquid fuels, are the outstanding features of this new electrothermal application.

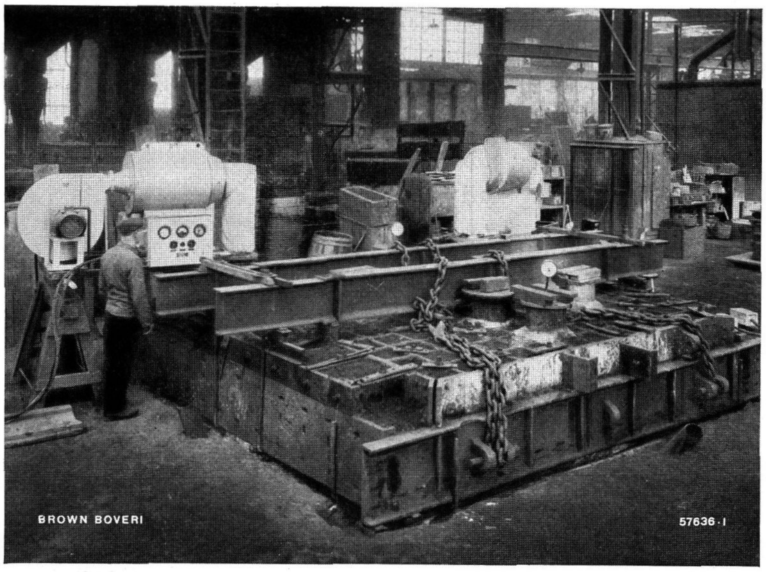


Fig. 82. — Two mobile air heaters, each rated 70 kW, for drying sand moulds.

Electrical drying results in firm, crackless moulds. After completion of the drying process casting can be begun without further delay.

the firing of steatite. The new kiln departs from earlier practice in several important respects. To facilitate charging and to avoid saggars and other charging devices as far as possible, a flat active cross-section was selected for the tunnel, whereby due to the special characteristic of the temperature curve it has been possible to obtain favourable energy consumption figures. By reason of the flat design, the tunnel has heating elements arranged exclusively in the top. This gives a degree of uniformity of heat distribution in the fired products never achieved before. A device for giving a partially reducing kiln atmosphere enables special steatite qualities to be fired.

From an economic point of view important advantages accrue from the use of such a kiln by the ceramic works in question. Referred to pre-war fuel-oil prices the costs for electrical energy are only 25 % more than for the corresponding quantity of fuel oil. Conditions, however, have now changed entirely in favour of electric heating, apart from the fact that the necessary oil for continuous operation of the kiln is not available. Due to saggars being extensively eliminated and the

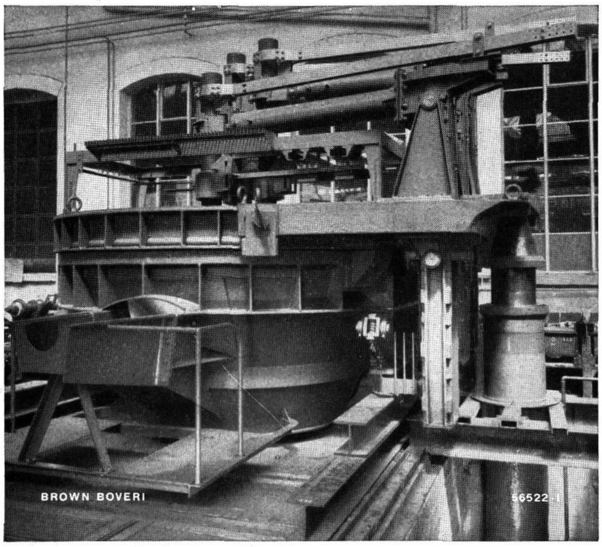


Fig. 83. — Steel melting furnace, capacity 3 t, with conical melting pot and pivoted cover for basket charging.
(Workshop view.)

consequent diminution of charging costs, electrical firing has, moreover, resulted in a substantial reduction in the amount of scrap and a considerable saving on working expenses.

The *air heaters for the drying of foundry sand moulds,* shown in Fig. 82, are proof of the wide field of application of electric resistance furnaces.

Development work has been continued on *arc furnaces.* The basket-charged furnaces put on the market some years ago have been supplemented by a type with pivoted cover (Fig. 83). This model was proposed by the A. G. der Eisen- und Stahlwerke vorm. Georg Fischer, Schaffhausen (Switzerland), and was installed in their works for the first time.

The little iron ore to be found in Switzerland can only be economically reduced in blast furnaces if it is mixed with high-quality foreign ores, and this fact, together with the continually shrinking pig iron imports and the consequent increased shortage of this material, led to the idea of reducing the Swiss ore directly in electric furnaces. We have started building such a furnace and the work is so far advanced that the plant will be taken into service this year. No special stress need be laid on the fact that we attach particular importance to this first *ore-reducing plant* of its kind, which is being installed at the Choindez Works of the L. von Roll'sche Eisenwerke.

D. ELECTRIC BOILERS.

The shortage of coal in many countries has again resulted in an active demand for electric boilers. Orders were received from Spain, Italy, Norway and France, and in Switzerland also the large demand has not fallen off appreciably. As an example of such installations we mention here a high-voltage electric boiler of 2000 kW output with insulated neutral (Fig. 84).

Insulation of the boiler shell, which constitutes the neutral, must be resorted to when the boiler is connected to a system with an arc suppression coil. As known, the capacitive earth current of a system with an arc suppression coil during a single-phase fault is compensated by the inductive current of the coil, so that the earth current is practically nil. The suppression coil is, however, inoperative when the neutral of the system is connected to earth through the boiler. In order to retain the protective effect of the suppression coil, the electric boiler must either be connected to the supply through a transformer, or it must be insulated. An electric boiler with insulated neutral is more expensive than an earthed boiler, but less costly than one with a protective transformer.

In the case of a fault a voltage is established between the neutral of the insulated boiler and earth,

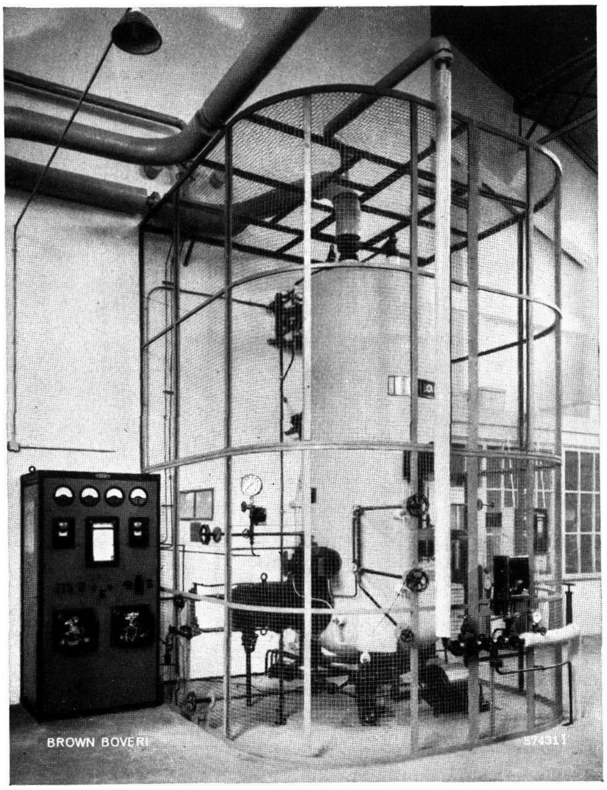


Fig. 84. — High-voltage electric boiler with insulated neutral. 2200 kW, 6000 V, 3-phase, 50 cycles.
Steam pressure 13 kg/cm² gauge.
Because the boiler shell may be subjected to the phase voltage during an earth fault, the plant is surrounded by a protective screen. Attendance is effected by means of insulated drives and from the earthed switchboard which contains the automatic regulators.

and because of this it is necessary to protect it against accidental contact by means of an enclosing screen.

To avoid damage due to short circuits in an insulated network with an earthed electric boiler, we have recently developed a protective arrangement which disconnects the boiler as soon as an earth occurs on the system of the boiler. Contrary to devices of this type used up to the present in which the assymmetry of the current is employed to actuate the relay, the new arrangement makes use of a power relay. On the occurrence of a fault, it causes the boiler to be immediately disconnected, and therefore the insulated state of the network to be re-established, so that the earth indicating devices usually present in power stations can again operate normally.

Of course, the sudden disconnection of an electric boiler without warning is undesirable. If no steam accumulator is present, the stoppage of an electric boiler may lead to a temporary interruption of manufacture. If this must be avoided at all costs, available coal-fired boilers may be kept under pressure by the electric boiler, thus considerably reducing the time required for passing from electric boiler to coal-fired boiler operation. Since with electric boilers, particularly in summer when thunderstorms occur, it is almost impossible to avoid interruptions of current, an occasional stoppage of the boiler due to an earth fault cannot be considered as seriously detrimental to the service reliability.

A large installation has recently been supplied by us to the new wood-sugar factory at Ems (Switzerland). It consists of two boilers each of 6000 kW output at 10,000 V. The steam pressure is 26 kg/cm^2 gauge.

E. COMPRESSORS AND BLOWERS.

1. *Turbo-compressors.*

As in the case of last year, we can once again report the order of an "Isotherm" compressor[1], the output and dimensions of which are close to the attainable limits. Its maximum output is 96,000 m^3/h, its final pressure 8 kg/cm^2 abs. The order comprises also the steam turbine with condenser, feed heater, and evaporating plant. The plant in which this compressor will be erected already contains five Brown Boveri compressors for a total output of 192,000 m^3/h and a driving power of 15,000 kW. An "Isotherm" compressor of smaller output than that mentioned above is shown in Fig. 85.

[1] See The Brown Boveri Review 1941, p. 108 and 1942, p. 196.

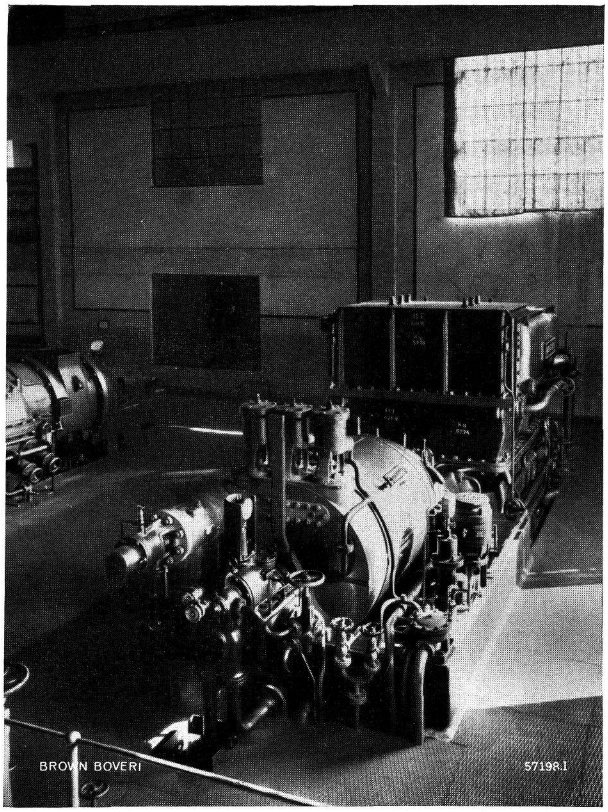


Fig. 85. — "Isotherm" turbo-compressor
for an output of 15,000 to 18,000 m^3/h and a delivery pressure of 8 kg/cm^2 abs, for supplying compressed air to a coal mine. Drive by means of a 1600 kW steam turbine.
The choice of the name "Isotherm" is not unjustified because the special design of this compressor ensures very effective cooling, and enables a close approximation of the isothermal curve to be attained. This cooling is desired not only because of the high efficiency which it permits, but because of the low final temperature which is required for most applications. The cooling surface is accommodated in the two rectangular casings arranged above and below the compressor. In addition to the good cooling, another advantage of the isotherm compressor is the use of an air turbine for the recuperation of the work done in compressing the excess air delivered by the compressor for regulating purposes. By discharging additional air, surge-free operation is obtained throughout the whole range from full load to no load. At the same time, the efficiency at constant speed remains unchanged.

In another plant, an "Isotherm" compressor was supplied to replace a compressor furnished in 1920. The efficiencies which can to-day be attained by our compressors would have enabled approximately 40 % more air to be delivered with the output of the old compressor motor. As, however, it was desired, because of the age of the old motor, not to load it up to its maximum output, the compressor output was limited to a 25 % greater air quantity (Fig. 86).

In addition to the two above-mentioned "Isotherm" compressors about some half dozen compressors of normal design were installed during the year under review (Fig. 87). A large number of compressors are, moreover, awaiting shipment at our works, where

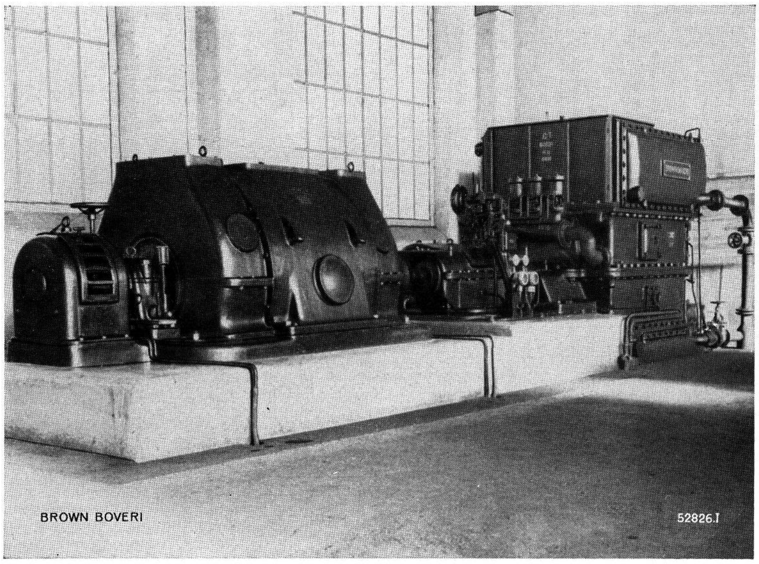
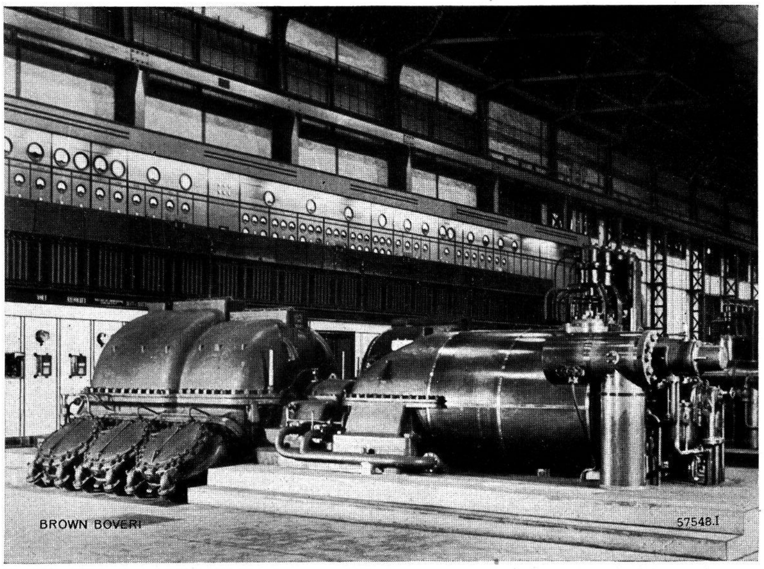


Fig. 86. — "Isotherm" turbo-compressor
for an output of 12,000 m^3/h and a delivery pressure of 8 kg/cm^2 abs.

The illustration shows clearly the regulating valves for the air discharged to the recuperation turbine. This compressor took the place of a compressor supplied by us in 1920, the motor of which, a 1300 kW induction machine, was retained. With this motor, it would have been possible, because of the considerably higher efficiency of the new machine, to drive a compressor delivering approximately 40% more air than the old one. In the present instance, the increase was limited to 25%. It is not difficult to estimate the saving in current resulting from the higher efficiency, and how long it will take for the new set to pay for itself out of the savings realized.

Fig. 87. — Turbo-compressor for an output of 60,000 to 72,000 m^3/h at a pressure of 9 kg/cm^2 abs.

Drive by means of a 7500 kW steam turbine. The same plant has five Brown Boveri turbo-compressors for a total output of 220,000 m^3/h. Because of the satisfactory experience with these existing compressors, and for the sake of uniformity, the old design was retained in spite of the unquestionable advantages of the "Isotherm" compressor.



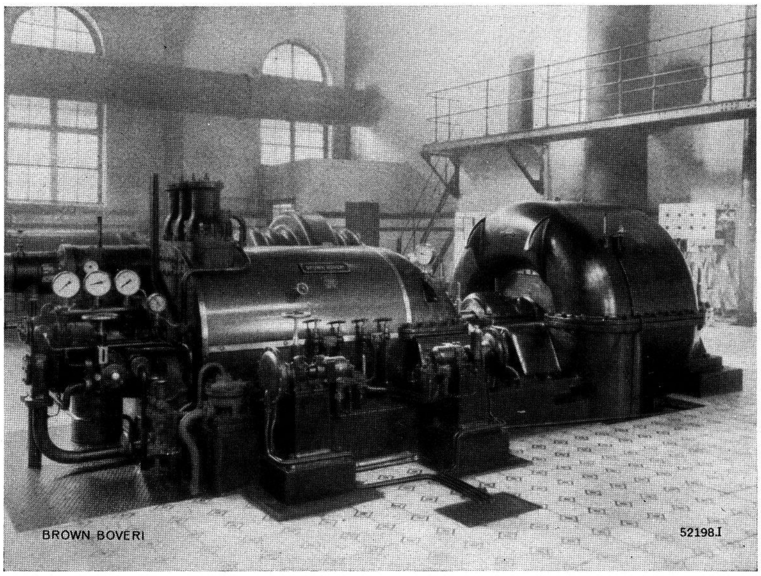


Fig. 88. — Blast furnace compressor for an output of 60,000 m^3/h at a final pressure of 2·2 kg/cm^2 abs.

Drive by means of a 2000 kW steam turbine. The regulating gear for constant output and the device for the prevention of surging are visible in the foreground. Small space requirements, little attendance, high efficiency and great adaptability to strongly varying furnace operation, and steady delivery are the reasons why centrifugal blowers are more and more displacing reciprocating compressors in iron and steel works.

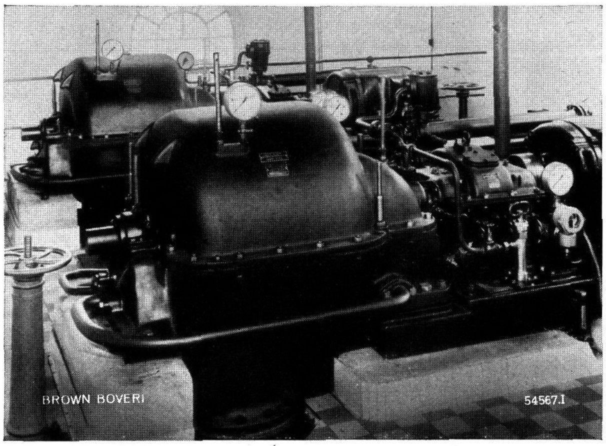


Fig. 89. — Two turbo-blowers each delivering 145,000 to 290,000 N m³ of coke-oven gas per 24 hours.

Pressure difference — 600 to + 2000 mm w. g.
In order to overcome the difficulty of deposits of tar on the inside of the blower, our coke-oven gas blowers are provided with devices for injection of anthracene oil. Hundreds of Brown Boveri gas compressors ranging from the smallest gas exhauster to the largest gas compressor for remote distribution are in service in all parts of the world.

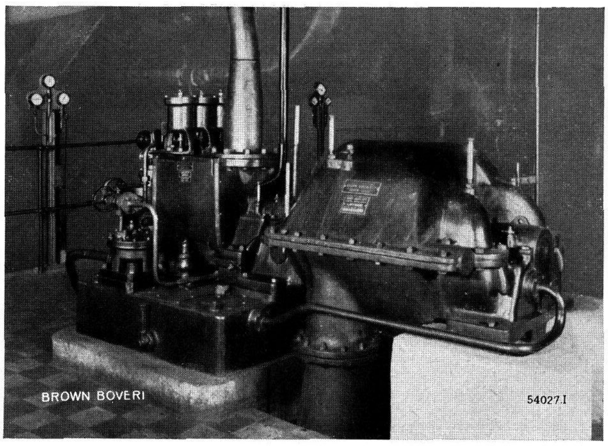


Fig. 90. — Turbo-blower for delivering 110,000 to 150,000 N m³ of coke-oven gas per 24 hours.

Pressure difference — 500 to + 2000 mm w. g., direct drive by means of an impulse turbine, speed 9000/11,600 r. p. m.
The steam turbine enables the gas exhauster to be widely adapted to the fluctuations of the gas distribution system. All regulating problems occurring in practice such as the maintenance of a constant suction pressure at the blower or of a constant final pressure at some point in the distribution system can be solved in a very simple manner with a steam turbine drive. In such installations, there is always a possibility of using the exhaust steam from the turbine. Hence, wherever possible, preference should always be given to the steam turbine for the drive of gas compressors.

they are held up due to transport difficulties or other causes associated with the war.

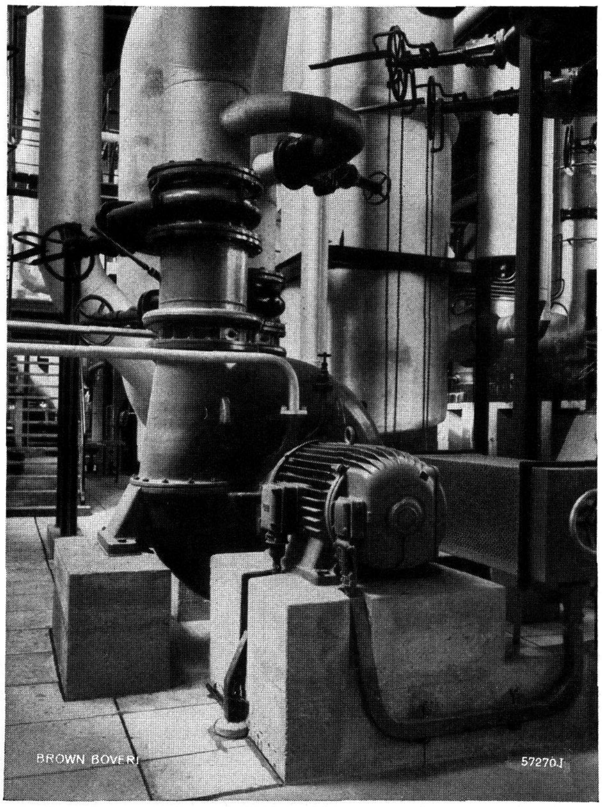


Fig. 91. — Single-stage turbo-blower in acid factory.

The blower compresses up to 13,200 m³/h of gas from roasted pyrites to a pressure of 1050 mm w. g.
In such blowers particular care has to be given to the question of the gland seals. Our long experience and our specially designed gland seal tried out with the most widely varying gases enable us to find the best solution for each particular case.

2. *Blast-furnace and Steel-works Blowers.*

Once again, a considerable number of blowers were supplied and put into service and orders received for an equivalent number (Figs. 88—91). Further attention has been given by us to pre-rotation[1] as a method of regulation, and the design details of this feature have in particular been improved.

3. *Axial-flow Compressors.*

In the field of axial-flow compressors developed by us, and to which we have given special attention, various orders for complete supersonic wind tunnel installations provided us with interesting work. For reasons which are evident we cannot here give closer details of these installations. We would like, however, to recall that the installations delivered by us already in 1934 for the Swiss Federal Institute of Technology at Zurich, and in 1935 for the Italian Research Institute at Guidonia, served as, and remain, models for such installations. The main change in the meantime has been in regard to powers. The test range reaches to-day Reynold numbers up to three times those of the previous test facilities, so that with the same apparatus the compressor powers must be increased in the same ratio.

[1] See also The Brown Boveri Review 1942, p. 53.

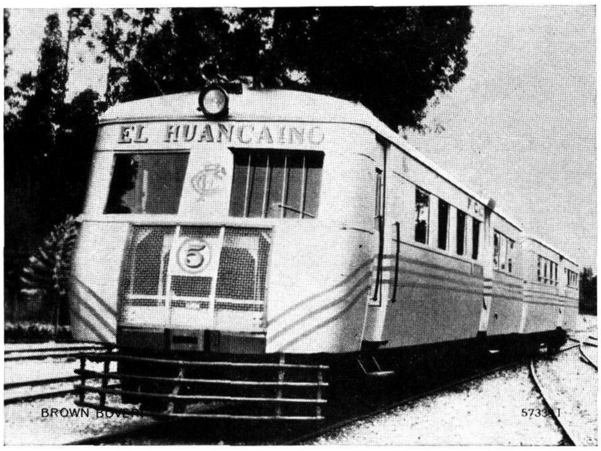


Fig. 92. — Diesel motor-coach of the Ferrocarril Central del Peru.

The motor-coach is equipped with a Saurer Diesel engine type BXD and a Brown Boveri exhaust turbo-charger. The exhaust turbo-charger enables the engine to deliver a greater output at an altitude of 5000 m above sea level than that of the uncharged engine at sea level. This excellent result induced the Railway Company to equip a large number of their motor-coaches with Saurer engines and Brown Boveri turbo-chargers.

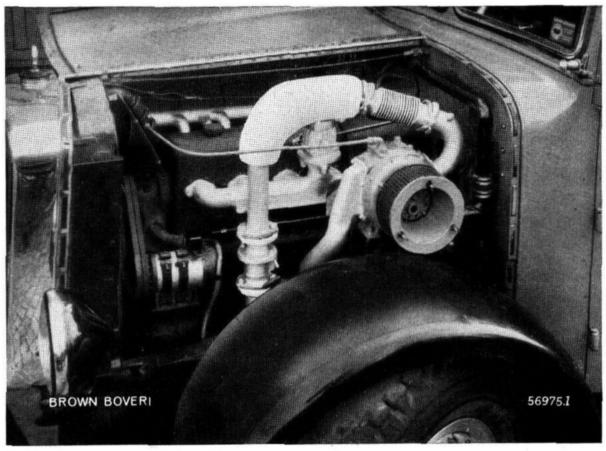


Fig. 95. — Charging set mounted directly on the engine of a lorry operated with wood-gas.

The charger is under the engine bonnet.

Turbo-charging enables the engine to deliver practically the same output as when operating with oil.

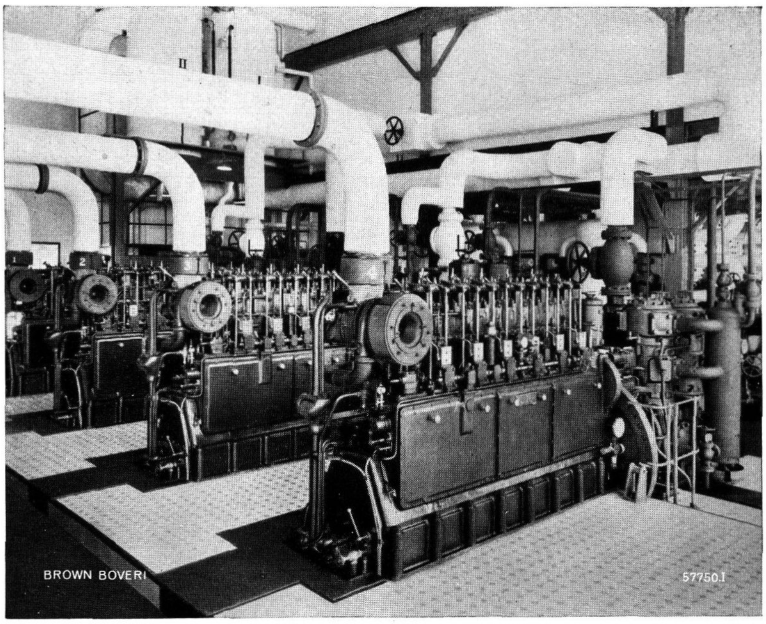
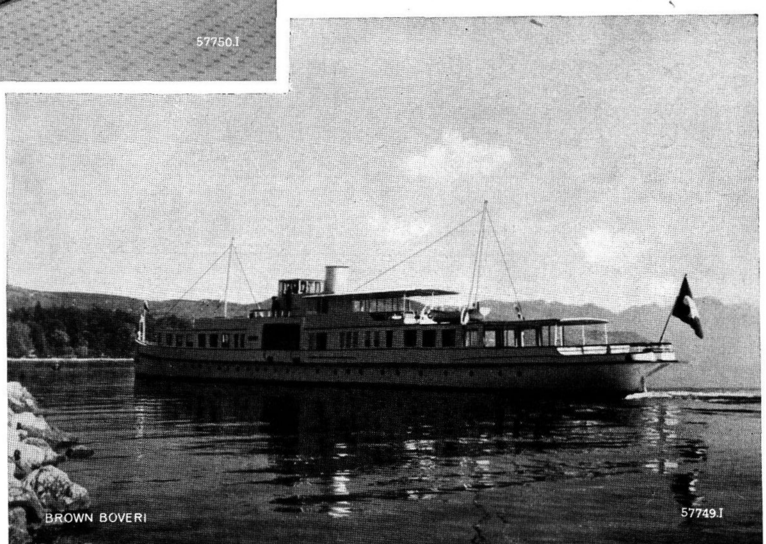


Fig. 94. — A power station with supercharged Diesel engine and Brown Boveri exhaust turbo-chargers at the plant of the Ice and Cold Storage Industries of the Philippines, Manila.

The ammonia compressors are driven by Sulzer supercharged Diesel engines each of 340 H. P. output. The output of the motors without charging is 240 H. P. The photo gives a striking illustration of the small dimensions of the turbo-charger and of the harmonious combination with the Diesel engine.

Fig. 93. — A new Swiss motor-ship with Brown Boveri exhaust turbo-chargers.

This passenger vessel, the M. S. "Leman", owned by the Cie. Générale de Navigation sur le lac Léman, Lausanne, is driven by two Sulzer Diesel engines, each of 340 H. P. output which are supercharged by Brown Boveri exhaust turbo-chargers. The output of the engines without charging is 240 H.P. Due to the usually restricted space conditions on ships, supercharged Diesel engines are particularly suitable for such service.



4. *Exhaust Turbo-chargers.*

(a) *Diesel Engine Supercharging.*

The standardisation of charging sets which we referred to already here last year has now been extended by us up to quite large superchargers (engine outputs up to 4000 H.P.) As an example of a specially interesting installation of turbo-chargers we would like to mention those for the motor-coaches of the Danish Railways. Favourable reports have also been received of the motor-coach installations of the Peruvian Railway Corporation (Fig. 92), the motor-coaches of which climb up to an altitude of 5000 m above sea level, where the engines still give an output larger than that of the non-supercharged engine at sea level. For this purpose, special charging sets were developed by us with a compression ratio of up to 2. Indeed, the whole question of chargers for special applications received our close attention. In this connection we would like to refer here to a new direction of development in combustion engine design, namely the highly supercharged four- and two-stroke-cycle engine with exhaust-gas turbine. The highly pushed pre-compression enables very high mean effective pressures and outputs per unit of cylinder volume to be obtained, so that the engine dimensions are extremely small. These compact machines, which also have a very low fuel consumption, should have a great future for ships, locomotives and similar applications. Suitable designs for the scavenging pumps, chargers and gas turbines herefor have already been worked out by us and are now available for practical realization.

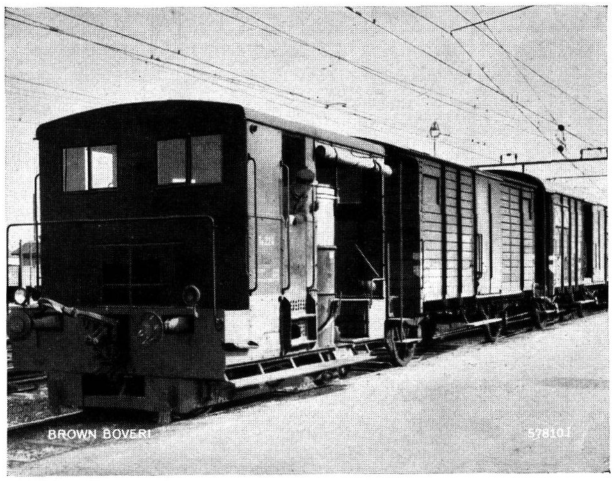


Fig. 96. — Rail tractor on the Swiss Federal Railways.
The driving engine of this tractor is a six-cylinder FBW engine which is now operated with wood-gas. In order to restore to it the full output, the Imbert gas producer is supercharged by means of a **Brown Boveri exhaust turbo-charger.** Such tractors must often stop and restart, when a very high torque has to be developed by the engine. These difficult service conditions are easily met by our wood-gas producer supercharging system.

Figs. 93 and 94 show two cases of application of charging to standard Diesel engines.

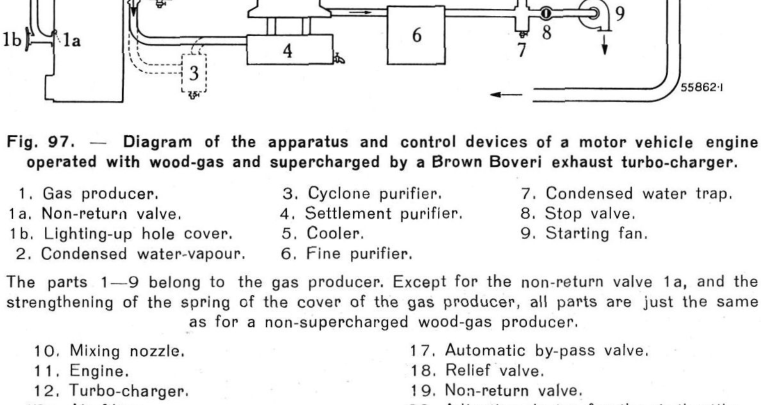


Fig. 97. — Diagram of the apparatus and control devices of a motor vehicle engine operated with wood-gas and supercharged by a Brown Boveri exhaust turbo-charger.

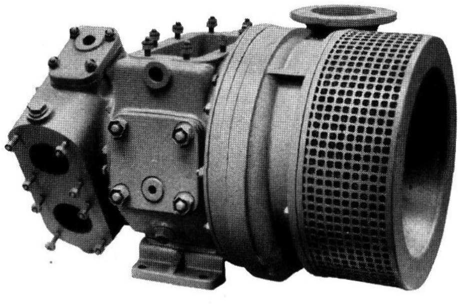
1. Gas producer.
1a. Non-return valve.
1b. Lighting-up hole cover.
2. Condensed water-vapour.
3. Cyclone purifier.
4. Settlement purifier.
5. Cooler.
6. Fine purifier.
7. Condensed water trap.
8. Stop valve.
9. Starting fan.

The parts 1—9 belong to the gas producer. Except for the non-return valve 1a, and the strengthening of the spring of the cover of the gas producer, all parts are just the same as for a non-supercharged wood-gas producer.

10. Mixing nozzle.
11. Engine.
12. Turbo-charger.
12a. Air filter.
13. Tar separator. (only necessary for plants using fuels containing tar).
14. Air throttling valve.
15. Lever for opening the by-pass valve.
16. Mixture throttling valve.
17. Automatic by-pass valve.
18. Relief valve.
19. Non-return valve.
20. Adjusting device for the air throttle.
21. Clutch pedal.
21a. Latch.
22. Gas pedal.
23. By-pass connection.
24. Mixture relief connection.
25. Pressure gauge.

(b) *Wood-fired Gas Producer Machines.*

Further advances were made in the charging of wood-fired gas producers. The past year was devoted especially to studying the results of experience obtained in practical service. As our supercharging devices are approaching perfection, a greater turn-over should be expected, but market difficulties have appeared. The necessity of taking care of tyres has led to regulations limiting the maximum speed, or what comes to the same thing, to not allowing the use of the full motor output. In spite of these regulations, there are numerous power installations where the full engine output is required, for instance, for dredgers, tugs, cranes, etc., and as far as motor-driven vehicles are concerned, especially those operating on mountain routes and in public service, have to give their full output.



BROWN BOVERI 57332 I

Fig. 98. — Standardized Brown Boveri exhaust turbo-charger.

The charger, which is built for six-cylinder engines, has two separate gas inlets. The inclination of the part of the casing carrying the gas inlet flanges can be modified to suit the pipe connections coming from the engine. The turbine casing is water-cooled to avoid objectionable heat radiation. The bearings are self-lubricated.

Up to the present ninety chargers have been supplied for vehicles with wood-fired gas producers, including those for the Swiss Post, Telephone and Telegraph Bus Services. Quite generally, the simple attendance and the ease with which the time tables established in the old times of petrol and Diesel engine operation can be maintained, are especially praised. Fig. 95 depicts a charger mounted on a lorry.

A particularly interesting example of the use of wood-fired producer gas supercharging is afforded by the rail tractors of the Swiss Federal Railways (Fig. 96).

Fig. 97 shows a diagram of a present-day supercharged wood-fired gas producer. The apparatus meets all the requirements of practical service. Mention should also be made of the fact that according to the test report of the experts of the Federal Materials Testing Laboratories in Zurich, up to 60 % increase in power was obtained with Brown Boveri turbo-chargers, compared with non-supercharged wood-fired gas producer installations, further, that the gain in running time when climbing, amounted to 35 %, and that gear changing could be effected with ease. It was also found that the torque of a combustion engine operating with supercharged wood-fired producer gas was practically equal to that of a petrol engine. The wood consumption was practically the same with and without supercharging for the same distance, notwithstanding the considerably increased output and the increased speed thereby made possible with supercharging. Experts are to-day of the opinion that the wood-fired gas producer, thanks to supercharging, will retain its importance after the war.

The superchargers for producer gas installations at present manufactured by us in batches and which are very similar to those for Diesel engines, are intended for engines between 70 and 200 H. P. output (Fig. 98). In addition, we have developed a similar type for engines up to 100 H. P., with a rotor design differing somewhat from the usual construction. It has a particularly low weight (about 18 kg including filter), so that it can be carried without any additional support by the connecting pipes and easily mounted in any convenient place.

(c) *Chargers for Gas Engines.*

Attention has also been given to chargers for gas engines. Due to the shortage of liquid fuels many petrol and Diesel engines have been converted for use with gas supplied by producers fired mainly with coal or wood. Producer gas operation has taken a firm hold especially for the machinery installations of the inland and lake shipping. Supercharging is a very simple means of restoring to an engine its original output, or indeed to increase it beyond its original value even when supplied with poor gases.

Two methods of application may be distinguished. The first is limited to the scavenging of the engine. The scavenging removes the relatively large exhaust gas residue and cools the piston head and the valves. This means that richer mixtures can be employed. The scavenging blower is designed for only a small gauge pressure and for about 40 % of the displacement volume. It is driven by a gas turbine, to which part of the exhaust gases are fed, while the remaining, greater part escapes, somewhat throttled, to atmosphere.

In the second case the engine is supercharged. It is advisable to supercharge the gas producer in the same way as we have introduced it for wood gas supercharging. If the charging blower is placed before the gas producer, it has only to deliver the combustion air which is clean and cool. The sealing of the gas producer, necessitates, on the other hand, special arrangements, which, however, in most cases can easily be provided for.

Where gas engines, which it is required to supercharge, have to operate also with scavenging, a special scavenging air valve has to be provided, or, the inlet valve has to be furnished with a device which interrupts the inflow of gas during the scavenging period.

We ourselves do not build gas producers or engines. We are, however, in a position to advise firms who are interested in supercharging and to supply apparatus required for charging, such as blowers and gas turbines. We would further mention that our small chargers may advantageously be used as gas boosters, where two-stroke-cycle Diesel engines have to be converted to gas operation. As known, the two-stroke engine cannot of itself draw in the fuel, but requires the fuel to be injected by a charging device.

(d) *Chargers for Aero Engines.*

In this field also improvements were made in the past year. For reasons which must be evident, we cannot give here any closer details. We include in this issue, however, an interesting colour photograph of an aero engine charger operating on test. The moving blades, which due to their fast rotation are hardly visible, give a free view of the guide blades which are at bright red heat. Two of these chargers raise the output of a 1000 H. P. engine which at 8000 m altitude would deliver only 480 H. P., again to its full output. The increased output of 520 H. P. corresponds to an output gained of 7 H. P./kg weight of the charger.

F. HEAT PUMPS.

As in the case of the electric boiler, the shortage of fuel is also the cause of the increased interest which is being given to heat pump installations. The heat pump plant of the Steckborn Artificial Silk Co. at Steckborn on the Lake of Constance, referred to last year, has been put into service and has fulfilled all expectations. The heat pump of the Landquart Paper Mill[1] was also put into service and operates satisfactorily. The acceptance test report of the experts of the Swiss Federal Institute of Technology ends with the following words: "We find, therefore, that the guarantees have been fully and entirely met and that the values attained are throughout better than those guaranteed."

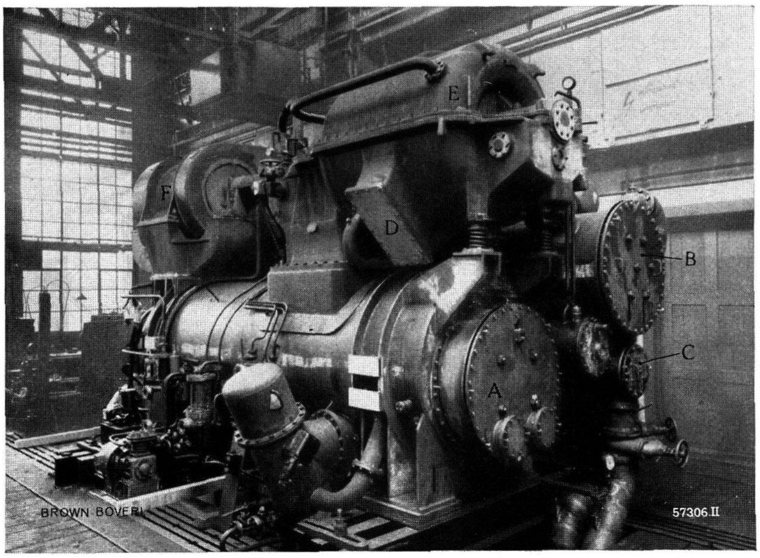


Fig. 99. — "Thermobloc" for the production of hot water for heating purposes from costless heat supplied by the environment.

With an installation such as that illustrated, it is possible to save considerably more than 1000 t of coal yearly. Similar equipments can be supplied for heat outputs down to 200,000 kcal/h.

This is an example of **the use of a heat pump for heating purposes,** heat being absorbed from river water for evaporating the working fluid, Freon 11, which, compressed by a turbo-compressor, serves to raise the temperature of the heating water. The power supplied to the motor terminals is 500 kW, the heat output 2·2 million kcal/h and the rise in temperature of the heating water 45° C. In the above illustration, A is the evaporator, in which the working fluid is evaporated, thereby absorbing heat from the river water supply. B is the condenser in which the evaporated and compressed fluid is condensed by means of the heating water which is thereby heated. C is the supercooler in which working fluid is further cooled. The flange visible at D is for the connection of an additional cooler which is advantageously employed when it is desired to keep the final temperature of compression low. E is the compressor. It is driven by the synchronous motor F.

The report particularly stresses that in addition to the definitely achieved saving in coal, a further important advantage was found, namely, that the air preheated by the heat pump considerably increased the life of the dryer felt. Whereas previously it was necessary to change the felt every four or five months, after introduction of the heat pump, the felt was still serviceable after nine months use.

We have an interesting order at present in hand for a heating plant with a heat pump for the remote heating installation of the City of Zurich. The water from the River Limmat is used to evaporate a liquid

[1] The Brown Boveri Review 1942, p. 58.

chlorfluor-hydrocarbon derivative (Freon 11), which, compressed in the heat pump, raises by means of the heat liberated during condensation of the vapour, the water of a heating system to 74 ° C. The heat pump is electrically driven. Each of the two compressors requires a maximum output of 960 kW, measured at the motor terminals. The total heat output composed of that extracted from the Limmat water and of that supplied in the form of power delivered by the motor and converted into compression work, amounts altogether to about 5 million kilocalories per hour. The temperature of the river Limmat is cooled only to the extent of about $\frac{1}{200^{0}\ C,}$ that is to say, to a hardly measurable extent.

A similar heating unit at present on the test bed is shown in Fig. 99.

A special type of thermo-compressor has reached considerable importance due to the foodstuff situation created by the war. This form of heat pump is employed mainly for drying fruit, vegetables, or grass, as well as for concentrating milk, fruit juice and similar products. The first type has been described elsewhere in this issue (page 42). As an example of

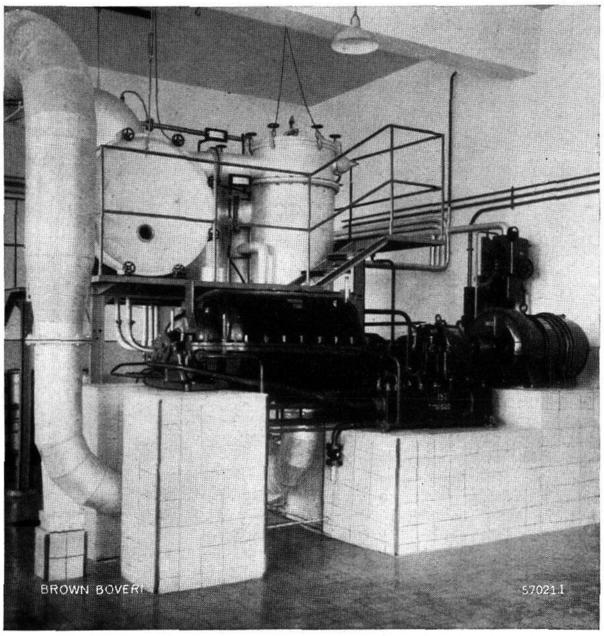


***Fig. 100.* — Thermo-compressor for concentrating milk products.**

The power absorbed at the motor terminals is 73 kW. The evaporative capacity is about 1000 kg of water per hour.
Concentration is the best method of preservation for many liquid foodstuffs. Concentration takes place at a low temperature so that the vitamines are unaffected. With the thermo-compressor only electrical energy and no fuel is necessary. The energy consumption is about 1 kWh for approximately 14 kg of water evaporated.

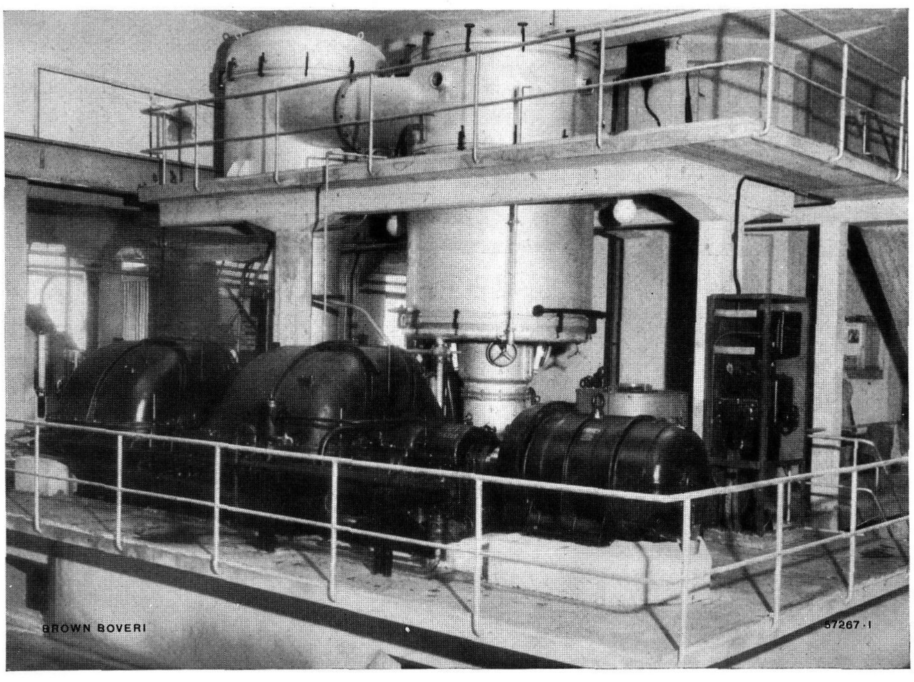


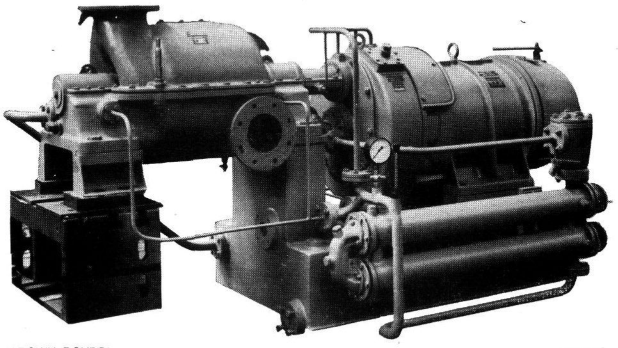
Fig. 101. — Electrically driven, two-casing compressor for concentrating milk, fruit-juice, and similar products.

The power absorbed at the motor terminals is 240 kW. The evaporative capacity amounts to about 3000 kg of water per hour. i. e., the energy consumption is about eight times smaller than the attainable heat output expressed in kW. As only electrical energy and no fuel is used, such concentrating plants are of great importance in countries where there is a shortage of fuel.

Aero-engine exhaust turbo-charger on test bed.

At altitude the charger operates with an exhaust-gas temperature of 900 ° C and 28,000 r. p. m.

Colour photograph taken in the Research Laboratories of Brown, Boveri & Co., Ltd., Baden (Switzerland).



BROWN BOVERI 57212 I

Fig. 102. — Thermo-compressor for a water evaporating plant for the distillation of drinking water.

About 1250 kg of drinking water are produced hourly with a power consumption of 75 kW. Such plants are used both at sea and on land. Their compact arrangement and light weight facilitate their installation in all situations.

the second type mention may be made of an installation for the manufacture of powder milk from skimmed milk and lactose from the by-products of casein and albumin manufacture. The compressor supplied by us for this purpose is capable of removing about 1000 kg of water vapour per hour from the liquid to be concentrated with a power absorption of the compressor of 73 kW (Fig. 100).

In the case of another installation for concentrating milk, fruit, and grape juice about 3000 kg of water is evaporated per hour. The steam is returned to the cooker after compression and used as a heating medium (Fig. 101).

The power absorbed measured at the motor terminals of this thermo-compressor is 240 kW. In this installation 45,000 litres of milk are condensed daily. The coefficient of performance attains the high value of 8, that is, the useful heat energy gained is eight times greater than that of the electrical energy supplied to the motor. Another application of the turbo-compressor is to the distillation of raw water, for instance, for supplying drinking water (Fig. 102).

Many further applications could be quoted. We would like to mention here that in this field we are familiar not only with the compressor part, but also with the remaining apparatus, and are, therefore, in a position to give advice to our customers on such questions. When desired, we are prepared to act as general contractors for evaporating installations. As we ourselves do not manufacture we then sub-contract for the supply of such apparatus to specialized firms with large experience.

IV. TRACTION.

A. ELECTRIC VEHICLES.

Our activities in this field were practically exclusively confined to Switzerland, due to the conditions imposed by the war. Notwithstanding the shortage of raw material the Swiss Federal Railways are pushing forward with the conversion of steam-operated tracks to electric traction.[1]

A repeat order for the electrical equipment for eight shunting locomotives (wheel arrangement C) of a design evolved twenty-two years ago induced us to incorporate the intervening improvements in the new equipment. Without departing essentially from the general layout, which has hitherto proved satisfactory, a reduction in the weight of the motors and ventilating equipment has been achieved. In this connection it might be mentioned that with approximately the same rating and a corresponding gear ratio the weight of the motor has dropped from approximately 7000 to 3300 kg.

The two-day trials specified by the Swiss Federal Railways for the motor-vans built by us in conjunction with other firms were carried out on the 26th and 27th March last year over the Brünig route. This railway is characterized by a relatively short mountain section for rack-and-pinion operation sandwiched between two long valley sections. On the latter sections the maximum speed is fixed at 75 km/h, but drops to 25 km/h on the maximum gradient of 120 in 1000 of the rack section. Since the contact wire on the section of the line between Meiringen and Interlaken was not erected at the time the trials were confined to the Lucerne-Meiringen line. A fast train was hauled each morning and a stopping train each afternoon. The trial train was composed of sixteen

[1] During the past year the Zurich-Oerlikon-Wettingen (20·1 km), Auvernier-Les Verrières (34·4 km), and Meiringen-Interlaken Ost (29 km) lines were put into electrical service, thus bringing the total of electrified lines on the Swiss Federal Railways up to 2284·171 km, i. e., 78 % of the whole system.

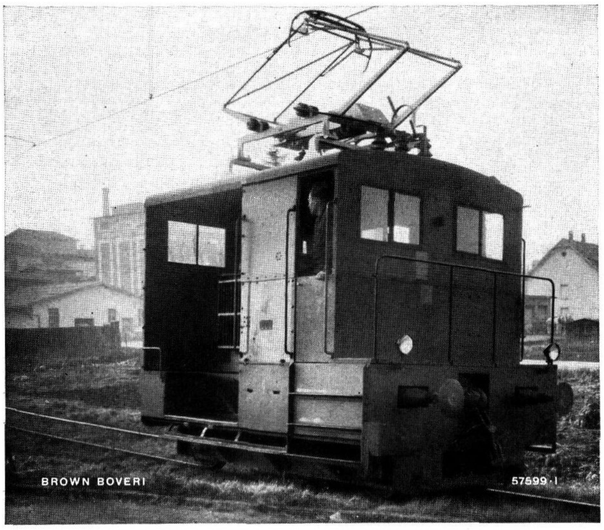


Fig. 103. — Two-axle standard-gauge tractor for the Swiss Federal Railways.

Such tractors were originally equipped with petrol engines, but have now been converted for electrical operation at 15,000 V, 16²/₃ cycles. *Shunting* services, which at the best of times are uneconomical, are thus now rendered independent of foreign solid or liquid fuels and are operated with a form of energy produced in the country. From their very nature, however, the tractors are of course restricted to service where a contact wire is available.

four-axle coaches, totalling 240 t, on the Lucerne-Giswil valley section and four four-axle coaches, aggregating 60 t, on the Giswil-Brünig-Meiringen mountain section. In both cases must be added the weight of the motor-van, i. e., 53 t. The exhaustive measurements in the power and braking circuits were mostly made with recording instruments and corroborated the running diagrams originally compiled. In addition to the check on the running speed and scheduled time the temperature rise in the various machines and apparatus was measured. This remained throughout within the admissible, designed limits.

On the 18th September the first of the nine Swiss Federal Railways tractors to be converted from petrol to electrical operation was tried out on the Münchenstein-Grellingen line. These tractors (Fig. 103) are intended chiefly for service in station yards, but are occasionally also employed out on the track. A condition of the conversion of the tractors from petrol-engine to electrical operation was that the original five-speed change gear should be retained.

The *Furka-Oberalp Railway*, which with the inauguration of electric traction on the Oberwald-Realp section on the 1st July last year now operates the whole of the 96 km long Brig-Disentis line electrically, carried out at the end of June last year check tests on motor-coach No. 43 which proved satisfactory in every respect. The test route comprised the Brig-Disentis section and back to Andermatt (125 km altogether). The run was accomplished with the maximum admissible train weight of 70 t in the shortest possible running time. The temperature rise of the traction motors, transformers, resistors, and other auxiliaries, was checked after each up-hill and down-hill run on the two mountain passes and proved to remain within admissible limits throughout. The running speeds

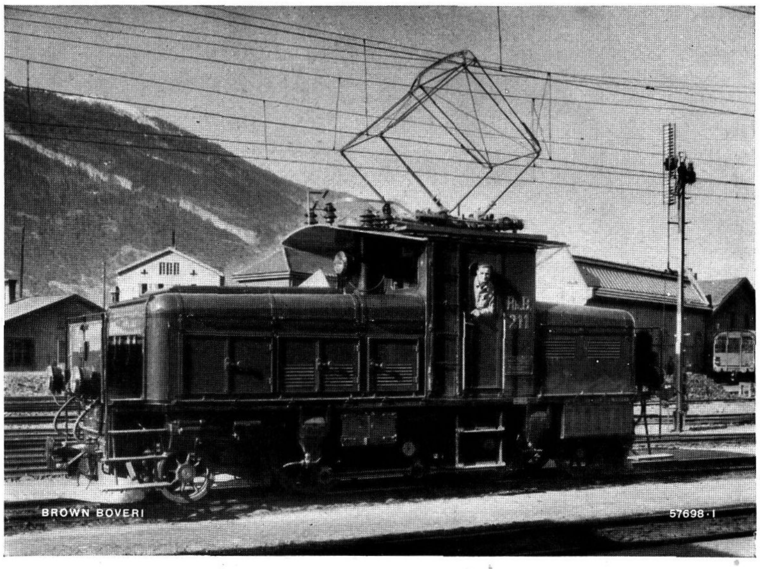


Fig. 104. — Locomotive of the 211 series on the metre-gauge Rhætian Railways, rating 312 H.P., maximum speed 55 km/h, for combined contact-wire (10,500 V, 16²/₃ cycles) and battery operation. This vehicle is employed both for shunting and scheduled services.

In contradistinction to contact-wire shunting locomotives (e. g., as in Fig. 103) this locomotive can be employed on non-electrified sections of track within a radius of action determined by the battery.

and current values during power and electrical braking operation proved to conform to a high degree to the data originally given by us. The five motor-coaches hauled approximately half of the scheduled trains last summer.

Towards the end of the year the first of the *Rhætian Railways* 1-B-1 locomotives of the 201 series with slow-speed repulsion motor and rod drive to be converted for shunting service (present series 211) with high-speed series-wound motor and double gearing was put into service (Fig. 104). This locomotive is an instance of what can be done with a vehicle dating from an earlier development period. Such a transformation not only requires no new material, but due to the progress in dimensioning technique and the better utilization of material a certain quantity of material in short supply, chiefly copper, is often left over.

Following the example of the Rhætian Railways the standard-gauge *Martigny-Orsières Railway* also decided to re-equip two of their four single-phase motor-coaches (8000 V, $16\,^2/_3$ cycles). These were fitted by us more than thirty years ago with Déri repulsion motors which are now being replaced by series-wound motors aggregating 542 kW, transformers with tappings, and corresponding control gear. An order for two motor-coach equipments for 15,000 V, $16^2/_3$ cycles, each with a one-hour rating of 450 kW, has also been received from the *Val de Travers District Railway.*

In our review of progress last year we mentioned that the Swiss Federal Railways had placed an order for trial equipment for the electrical heating of the boilers of two three-axle steam shunting locomotives. The first of these was put into commission towards the end of the past year (Fig. 105).

Each of the locomotives is provided with a tube system in the form of a resistance heating element through which the water flows, the heating element being connected to two transformers located one on either side of the locomotive boiler and having an aggregate continuous rating of 480 kVA. The transformers take their supply from the 15,000 V, $16\,^2/_3$-cycle contact wire through a current collector, mounted on the roof of the driver's cab, and a high-voltage switch. No electrical regulating devices of any kind are provided. The pressure is limited by the injectors in the same way as with coal-fired locomotives. The time taken to get up steam is an hour less than with coal firing, i. e., only half as long. The very first day the trial locomotive was put to work in a medium-size

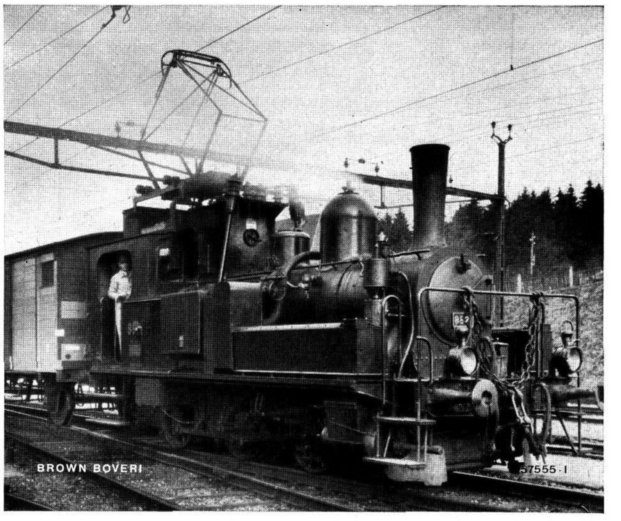


Fig. 105. — Swiss Federal Railways electrically-heated steam locomotive.

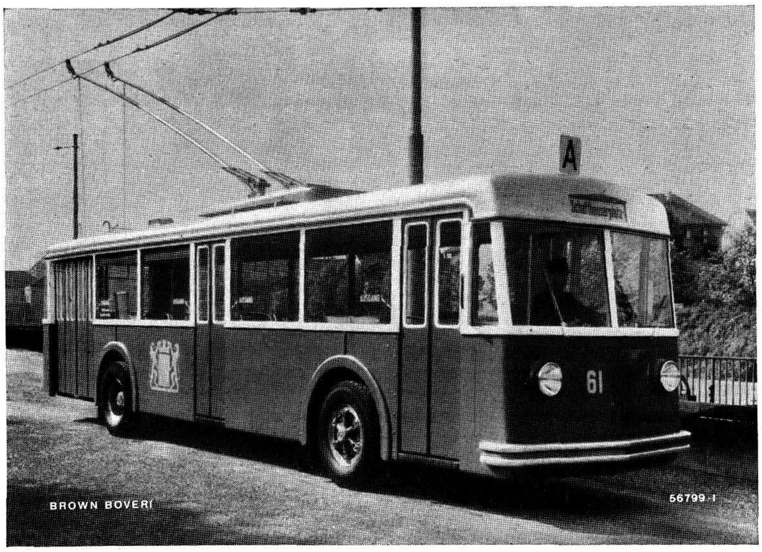
The conversion of such locomotives from coal firing to electrical operation is to be considered as an emergency war-time measure with a view to saving coal and enabling shunting locomotives to be arranged for mixed electrical and coal-fired operation, i. e., on electrified and non-electrified tracks, at short notice.

shunting yard it took over the duties of a coal-fired engine and was found to be able to carry out shunting operations on non-electrified tracks for fifteen to twenty minutes at a time.

The electrical equipment is so arranged that the locomotives can at any time still be fired with coal or operated with mixed electrical heating and coal firing. This half electric, half coal service will be found particularly useful where a relatively large number of tracks are not electrified.

It is of course realized that from an economical standpoint an electrically-heated steam locomotive cannot compete with a coal-fired or straight electric locomotive. The present case merely forms an emergency measure with a view to accelerating the electrification of shunting services rendered necessary through the shortage of coal, but which, due to the material for the extension of contact-wire systems and the construction of electric locomotives being in short supply, could not be achieved in the normal way. This notwithstanding, we can claim to have solved a new and unusual problem at short notice to the entire satisfaction of the purchaser.

Among the rail vehicles put into commission in the course of the year was the second of the four-axle tramcars, series 401, with Brown Boveri Simplex bogies, for the *Zurich Municipal Tramways.* These vehicles are so popular with both the travelling public and the drivers that seven further cars have been ordered for delivery in 1943.

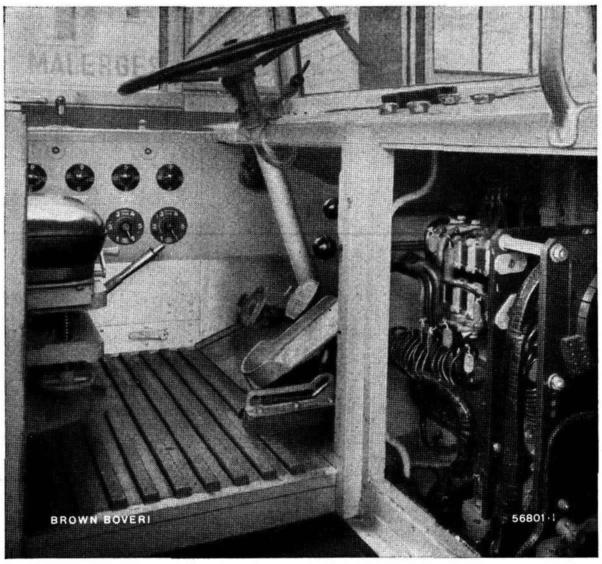


Of the auxiliary apparatus developed for rail vehicles current collectors with carbon sliding pieces for the reduction of radio interference are the most important. The Swiss G. P. O., who operate the national broadcasting stations and naturally have an interest in the promotion of broadcasting, has taken over the sale of such current collectors themselves, disposing of them to the tramway undertakings at two-thirds of the purchase price and thus facilitating their acquisition. Due to the long life of the carbon sliding pieces (over 100,000 km) operating costs are considerably re-

Figs. 106 and 107. — Trolley bus of the *Zurich* Tramways and driver's cabin with control gear.

Largest four-wheeled trolley bus so far built in Switzerland, motor rating 110 H.P., maximum speed 50 km/h, seating and standing capacity 70 passengers, tare 9·2 t.

The trolley bus services at Zurich have developed rapidly. Only the prevailing conditions temporarily prevent their further extension. Plans for new routes have already been completed.



duced compared to aluminium sliding pieces, while the contact wires also suffer far less wear and tear.

Trolley buses with Brown Boveri electrical equipment were put into service during the year in Zurich (Figs. 106 and 107), Lucerne (Fig. 108), and Berne. The four vehicles for each town were all equipped with our new contactor control gear with ten starting resistance notches, one notch for power running

Fig. 108. — Trolley bus of the Lucerne Municipal Transport Services.

Motor rating 100 H. P., maximum speed 50 km/h, seating and standing capacity 52 passengers, tare 8·1 t. — The first trolley bus service was inaugurated in Lucerne just before the outbreak of hostilities.

Fig. 109. — Bus owned by the S. A. des Autotransports du Pied du Jura Vaudois, L'Isle (Switzerland), with Saurer chassis and Eggli coachwork, for battery operation.

This is the first scheduled long-distance passenger transport service in Switzerland to be operated with battery-operated vehicles. The route is approximately 20 km in length and was formerly served by a motor-bus the chassis of which has been retained for the electric bus. A charging set embodied in the vehicle enables the battery to be re-charged along the route. Here, too, the tendency to avoid foreign fuels and maintain services at all cost, is particularly evident.

with full field, ten notches for regulation of the running speed by field weakening without loss of efficiency, and eleven braking notches. Experience has proved this number of notches to be ample to achieve practically smooth starting and braking, so that there is no point in providing a larger number of notches, or expensive multiple notch control gear. In view of the difficulties encountered in obtaining tyres and copper for the contact wires it is now practically impossible to erect further contact wire systems and build new vehicles, but upon the return of normal conditions it is anticipated that the trolley bus will enjoy great popularity as public transport vehicle. In view of this practically certain development we have designed five different sizes of trolley bus equipment which should meet all requirements.

Due to the conditions imposed by the war the demand for *battery-operated vehicles* was very great during the year under review. A contributing factor was probably the excellent experience with, and economy of, the four battery-operated refuse collection vehicles of the Basle Corporation, the electrical equipment for which was supplied by us. Exhaustive trial runs and comparison with similarly built Diesel vehicles prove the electrical drive to be particularly suitable for the working conditions in question. The daily expenses in connection with the electric vehicle are 10 % lower than for a Diesel vehicle and 20—30 % lower than with a corresponding petrol-driven vehicle. For a mean daily run of 50 km these costs amount to Fr. 1.— per km, including the fixed annual charges such as allowance for depreciation, interest on capital invested, insurance, and maintenance, as well as the current annual charges for electrical energy, lubricating agents, renewal of batteries, tyres, and repairs. Apart from the advantages of absence of smell, less noise, easier control, etc., not taken into account when calculating the remunerativeness of such vehicles, municipal undertakings have the additional benefit of also being the energy supplier. Battery vehicles are moreover looked upon with favour by electricity supply undertakings as a welcome addition to the night load.

An innovation for large battery-operated vehicles (Fig. 109) is the fitting of monobloc charging sets on the vehicle itself. This arrangement was provided for the first time on the bus operating between Morges and Cossonay (Switzerland). The increase in the weight of the electrical equipment is offset by the advantage of not having to provide convertor sets or mutators along the route for charging purposes. The battery can be re-charged wherever a suitable plug is available for the connection of the driving motor of the built-in charging set to a public supply. Such sets can also either be mounted together with their appertaining

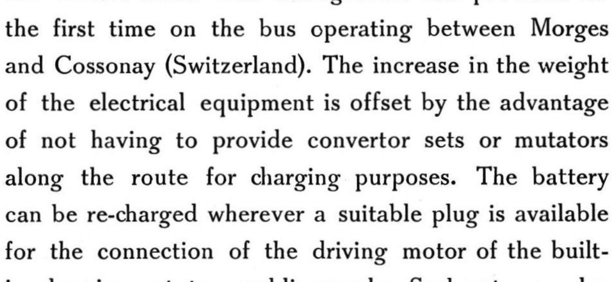


Fig. 110. — Mobile battery charging set.

This is designed for fitting on battery-operated vehicles (as in the case of Fig. 109) to enable the battery to be re-charged along the route during halts. After connection to the three-phase public supply, charging and disconnection from the supply are effected full-automatically.

apparatus on a frame and transported on the vehicle when required for long journeys, or employed in the garage for the charging of other electric vehicle batteries (Fig. 110). It is possible, however, also to use the traction motor as charging machine.

The severe winter experienced last year again showed up the disadvantages of belt drive of the generator of *train lighting equipments.* An aggravating factor is that under present conditions it is impossible to find a high-class substitute for defective or lost belts. The Swiss Federal Railways have therefore decided to replace all of the belt-driven generators on the heavier type of four-axle coaches by the cardan drive developed by us. Private railways, such as the Lake of Constance-Toggenburg Railway and the Berner Alpenbahn-Gesellschaft Bern-Lötschberg-Simplon are also going over to the cardan drive for the train lighting generators simultaneously with the replacement of the existing old-type axle bearings by automatically-lubricated bearings (Isothermos or Friedmann). Some of the generators will be suspended from the bogie, others from the underside of the coach body.

B. GAS TURBINE LOCOMOTIVES.

The descriptive articles of our gas turbine locomotives anticipated in our last year's review of progress have since appeared in the form of numerous publications in the technical press. We refer here nevertheless to the article in the Brown Boveri Review 1942, No. 5, p. 115. Unfortunately, because of the shortage of fuel oil, the locomotive could not this year be kept in service, as we would have desired for obtaining experimental data.

Notwithstanding this, a series of official and test runs were made, during which the locomotive travelled altogether 2000 km, fulfilling the conditions of the specification and furnishing the proof of its suitability. Worthy of note is the test run of March, 1942 over the Baden — Olten — Solothurn — Lausanne — Fribourg — Berne — Olten — Sissach route, during the course of which the fulfilment of the traction conditions set out in the specification was proved.

A further interesting test run with a dynamometer car and a train load of 500 tons on the outward run, and of 300 tons on the home run, took place after installation of additional devices for the fuel-oil operation, namely in December, 1942 on the Basle — Zurich — Chur route. The oil at present employed is heavy fuel-oil, grade III, with a viscosity of 16^{0} E at 20^{0} C, which has to be heated to 80^{0}C before use. The maximum output of the turbine attained during this run was 2800 H.P. and the maximum speed 128 km/h.

Further various test runs were made with the object of determining the air friction resistance of the locomotive. All these runs went off according to programme and entirely satisfactorily.

Finally, mention should also be made of the special starting test, for which the old Hauenstein line with a gradient of 21 in 1000 was chosen. Various electrical connections were tried out for different starting conditions, to test the locomotive for quick starting on a rising grade with a high trailing load, without in any way subjecting the gas turbine to operating conditions or loads more severe than those for which it was designed. The best result was a speed of 40 km/h attained with a 200 ton train load within 56 seconds on the 21 in 1000 gradient, which corresponds to a starting acceleration of 0·19 m/sec.^{2}, whereas the specification provided a time of 100 seconds on a gradient of 18 in 1000, corresponding to an acceleration of 0·11 m/sec.^{2}, for the same speed and train load.

V. HIGH-FREQUENCY AND COMMUNICATIONS ENGINEERING.

A special number of this journal (December, 1941) was dedicated to the high-frequency and communications engineering field taken up by us in 1936, a series of articles dealing with research, development, and constructional work on valves, apparatus, and complete installations. In our review of progress last year, therefore, we were able simply to refer to this special number which had just appeared. During the past year development work in this field was intensively continued as outlined hereafter.

Progress in the *micro-wave field* was confined chiefly to the development of micro-wave oscillators. In the course of our investigations the "turbator" (Figs. 111 and 112) proved to be extremely suitable for very short wave-lengths, i. e., of only a few centimetres. This comprises a cavity resonator organically connected to axially-fixed segments on which a circular stream of electrons influences the high-frequency voltage. The circular stream of electrons is produced through the simultaneous effect of a radial, electrical d. c. field with axial magnetic field, the cathode emitting the electrons lying on the axis of the system. The cavity resonator ensures freedom from harmonics and relatively good stability of the electromagnetic oscillation, conditions which are essential for technical applications.

Parallel to the development of the micro-wave valves the various possibilities of application have been studied. It is well-known that ultra-short radio waves can be transmitted in the form of beams with relatively small aerial arrays and reflectors and that they have the same propagation properties as light, but are practically not absorbed by rain and snow. Moreover, there is practically no interference to reception in this wave-range, so that sactisfactory transmission is possible within the range of vision with very low transmitting powers and simple apparatus. By reason of the wide bands available these waves lend themselves particularly well to multi-channel transmission. The work carried out by us in the micro-wave field concerned on the one hand straight communication problems and on the other the creation of numerous transmission channels by new and promising methods. Special investigations were made in connection with *distance measurement by means of micro-waves* on the reflection principle. Most of the applications are of great importance, particularly where aviation is concerned. Micro-waves will doubtless be widely

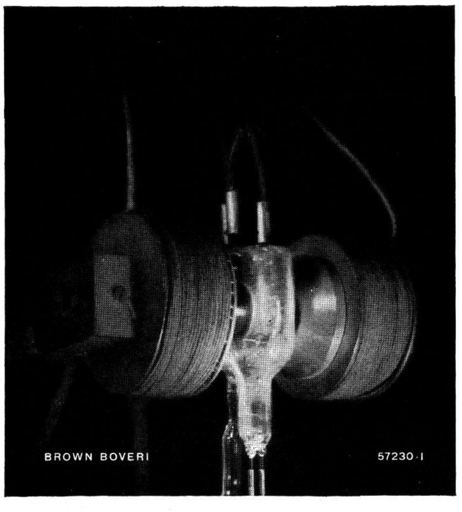


Fig. 111. — Turbator valves for 12 cm wave-length (frequency 2500 megacycles) and 10 W high-frequency rating.

Research over a long period and high-class workmanship have contributed to the making of this little technical wonder.

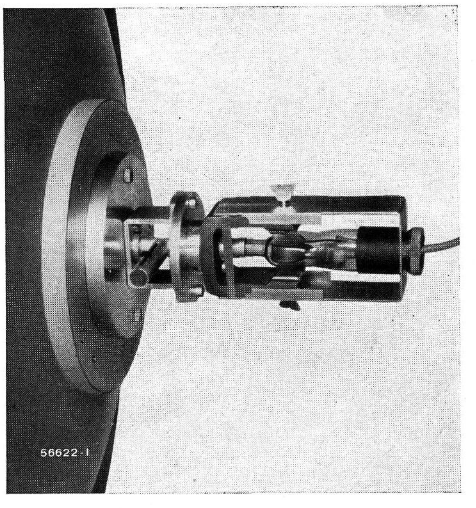


Fig. 112. — Turbator valves for 11 cm wave-length with associated permanent magnet mounted on a beam reflector.

Centimetre waves obey the laws of geometrical optics: With a reflector they can be focussed into the form of a beam like light.

Brown Boveri micro-wave oscillators will play an important part in communications equipment of the future.

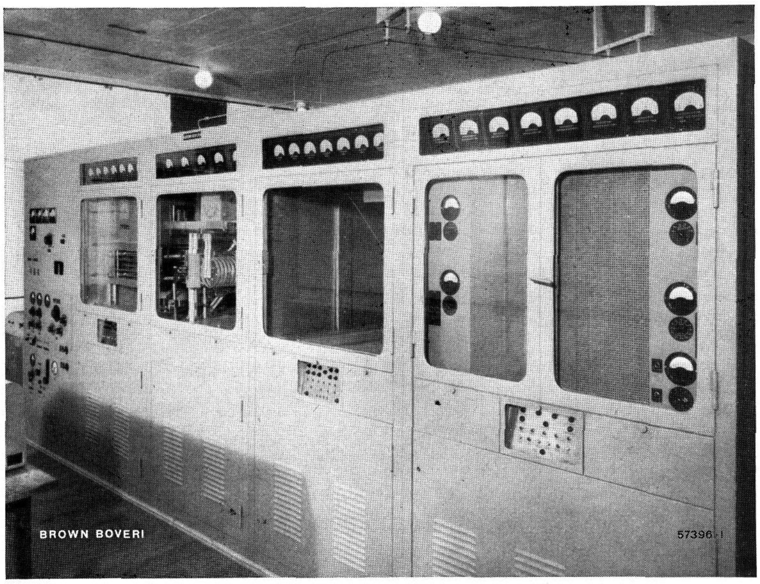


Fig. 113. — 10 kW short-wave transmitter for broadcasting stations and overseas telephone traffic.

Outstanding features of the transmitter are: compact design, therefore small space requirements; unit construction of transmitter stages, therefore shortest possible installation time; rapid change of wave-length, excellent transmission quality, large wave range (10—90 m), semi-automatic control, and fault indicator to simplify operation.

In the illustration the high-frequency panels are visible on the left and the two low-frequency panels on the right. The power plant entails five further panels which, however, are not shown.

used for communication and aviation purposes upon the return of normal conditions.

Decimetre-wave sets have also recently been developed. Decimetre waves are suitable for communication over distances up to 200 km where topographical conditions are favourable. Our sets permit reliable two-way wireless telephony and can thus be used instead, or as an extension, of a telephone line where for economic or technical reasons no wires can be run or cables laid. By interposing relay stations comprising two complete decimetre-wave sets it is possible to surmount topographical obstacles and thus substantially increase the range of transmission. Transmitter and receiver have single-knob tuning with spiral scale directly calibrated in mega-cycles. Special features incorporated in the tank circuits result in a very stable frequency and extensively offset the influence of temperature changes. The quality of transmission is excellent and the possibility of faults extremely slight. Like our mobile ultra-short-wave stations for police forces the new sets operate with frequency modulation. The transmitting power is much higher than has been normal practice for portable decimetre-wave sets hitherto, thus enhancing reliability.

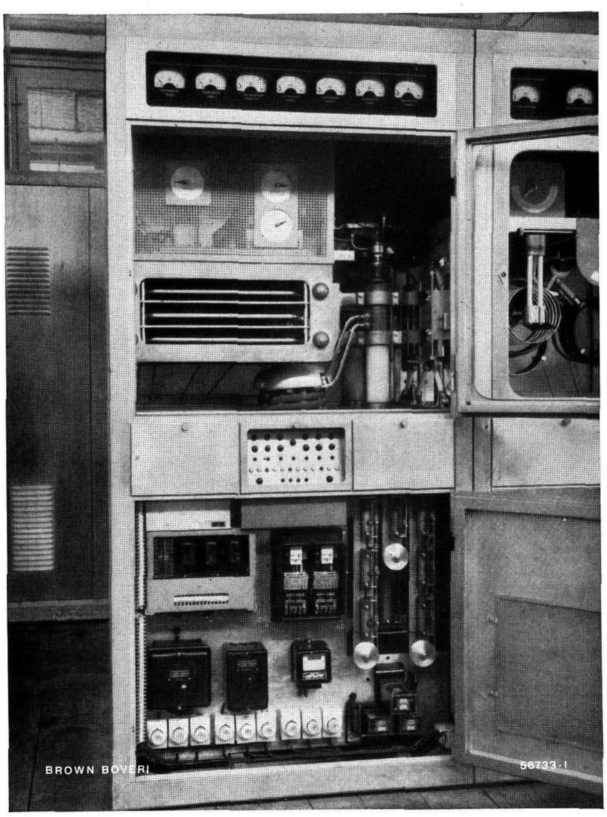


Fig. 114. — 10 kW short-wave transmitter for broadcasting stations and overseas telephone traffic.

The illustration shows the compact construction of the valve cubicle of the high-frequency *output stage. In the top left-hand corner*: Wave-range indicator and grid circuit tuner, underneath condenser in anode tank circuit. On right: Brown Boveri water-cooled transmitter valves. In centre: Control board with pilot lamps. Below: Control gear and fuses.

As already stated in the above-mentioned special number of the Brown Boveri Review for December, 1941, apparatus for *automatically preserving the secrecy of telephonic and telegraphic communications* on different principles have been developed. In the interim this work has been continued on a wider basis to meet numerous requirements. By thoroughly investigating the various deciphering possibilities under the assumption that the key is unknown the foundation has been laid for sets with an extremely high degree of privacy. Very exacting demands are made on various components, such as modulators, audio-frequency oscillators, filters, magnetic delaying devices, etc. The development of these components is now practically concluded, so that apparatus for preserving the secrecy of telephonic and telegraphic communications can now be supplied for specified conditions without lengthy preliminary work.

The development and design work in connection with the construction of *medium-wave broadcasting transmitters* and *short-wave transmitters for overseas traffic* was continued during the year under review. By sub-dividing transmitters of up to 10 kW carrier-wave power into readily portable units, both the time necessary for dispatch and erection are considerably shortened. Moreover, space requirements have been kept down to a minimum, notwithstanding the good accessibility. These 10 kW transmitters can also be used as preliminary stage in large transmitting stations.

Our semi-automatic 10 kW short-wave transmitter with a wave-range of 10—90 m (Figs. 113 and 114) deserves special mention. Ten adjustable frequencies within the foregoing range can be selected by means of push-buttons on the control desk. Moreover, the wave-length of this transmitter can be varied over pilot wires from a remote station. The operation and supervision of the transmitter are very simple. Automatic fault indicating gear enables faults to be immediately located and eliminated. These short-wave transmitters are suitable for both broadcasting purposes and overseas telephony. The rapid change of wave-length possible enables such installations to be utilized to a maximum. For telegraphy similar remote-controlled units of 2 and 20 kW power (c. w.) have also been developed.

Suitable and reliable *studio equipment* is necessary if a broadcasting station is to keep to its scheduled programme. Such equipments, which take into account the practical requirements of broadcasting stations, have recently been developed.

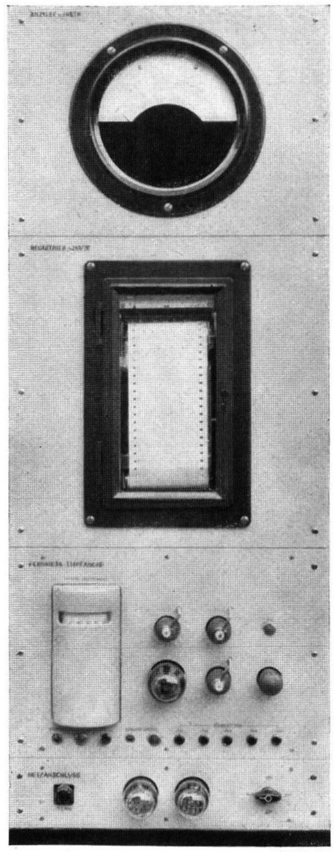


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Fig. 115. — Brown Boveri remote metering receiver for the connection of indicating and recording instruments of any size and for any method of mounting.

Our remote metering equipments are independent of the valve data and of voltage fluctuations to a high degree, an important factor where reliability is concerned.

Work in the *supervisory control field,* i. e., *carrier-current telephony and supervisory control installations on different principles for electricity*

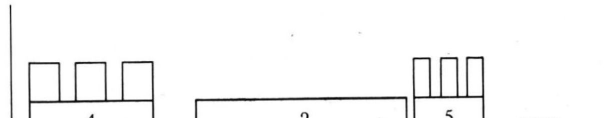
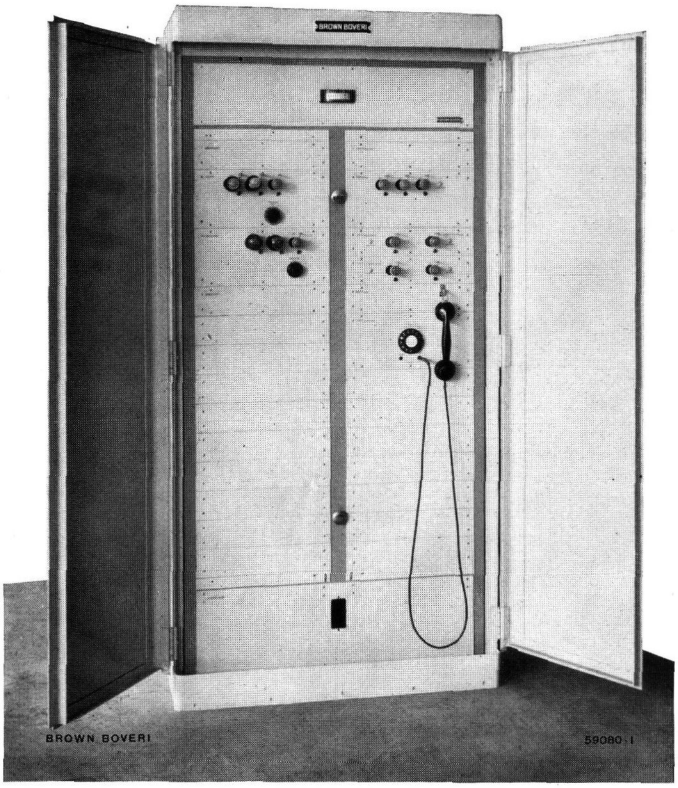


Fig. 116. — Diagrammatic illustration of frequency distribution of three audio frequency bands.

The telephony band 2 covers the frequency range from 300 to 2400 cycles. Three remote control channels are provided in the frequency band 4 between 60 and 200 cycles, below the frequencies employed for telephony. In the frequency band 5 between 2500 and 5000 cycles are lodged three remote metering channels.

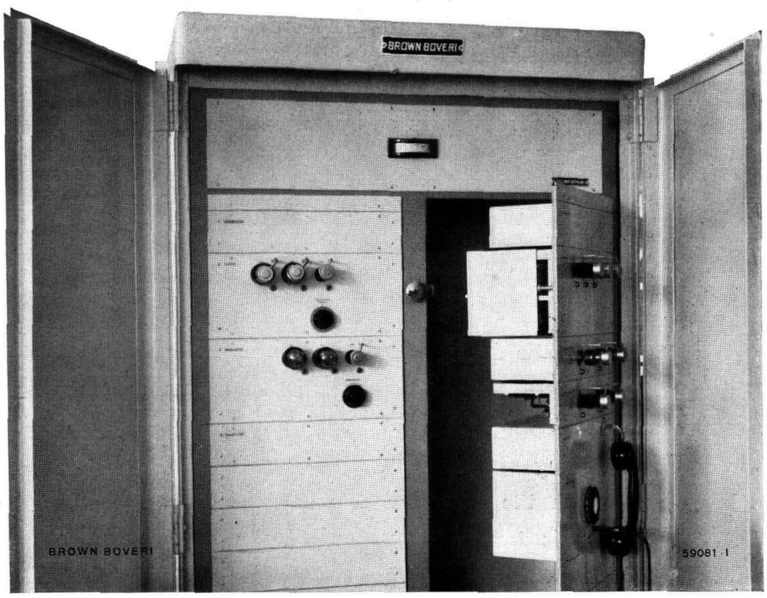


equipments have already been supplied or are in hand for Swiss electricity supply undertakings. For some time past a carrier-current telephony and line protection installation incorporating high-speed distance relay equipment has been in operation in the Olten-Gösgen and Laufenburg Power Stations (Switzerland). Another installation of this type is in hand for the Rhonewerke A. G. (Switzerland) where a 73 kV transmission line is also employed for communication purposes. In this case our carrier-current telephony installation will be adapted to the official telephone. With our specially-designed and patented supervisory control systems we attain a very high accuracy and virtually instantaneous transmission for power, current, voltage, and power factor metering or for imparting remote control or regulating impulses (Figs. 115—117a).

In those cases where no power or communication lines are available we employ short-wave transmitting and receiving sets. We already have practical experience in this field and just recently received a further order for a *radio supervisory control installation* where

Figs. 117 and 117a. — Carrier-current telephony equipment for the Rhonewerke A.-G. (Switzerland).

The carrier-current and audio-frequency equipment is split up into separate, readily changeable standard panels which can be assembled as required. The internal part of the cubicle can be swung out. All panels are readily accessible.



Carrier-current telephony and supervisory control installations facilitate supervision and operation of electricity works. Our carrier-current equipment is characterized by its adaptability.

supply undertakings, railways, and industrial applications, has recently been greatly extended.

For supervisory control purposes (telephony and remote metering, control, and regulation) there are several possible methods of transmission depending on requirements and local conditions.

For the supervision of modern power stations *carrier-current installations* are the most reliable. Such

the temperature and level of the water in a reservoir and pumping station had to be measured and the pumping plant controlled by wireless over a distance of 5 km. For a foreign customer we also have a water-level remote metering equipment in hand with which the water turbine likewise has to be automatically governed from a distance over existing communication lines.

Three supervisory control installations working on different systems are worthy of special mention.

The line combination system was successfully employed for a tramway substation of the Zurich Municipal Electricity Supply (Fig. 118). The "Promenade" substation with three mutators and twenty-four feeders is controlled and supervised from a remote attended station over six pilot wires and two selector switches. In this case fifty impulses and signals are possible. The line combination system is particularly suitable for moderate numbers of impulses, i. e., for 8—50 impulses, the larger number being achieved with six pilot wires.

One of our frequency-selection supervisory control systems is also employed for the supervision and control of a local-railway mutator station from an attended station 5 km away. For the transmission of the supervisory control impulses a telephone line belonging to the railway is employed; telephone

Fig. 118. — Remote control equipment on the line combination principal in the "Promenade" Substation of the Zurich Municipal Electricity Supply. Controlled station with switchboard.

The first panel contains the apparatus for the remote control of three mutator sets and twenty-four feeders. The equipment permits up to fifty operating or position indicating impulses to be transmitted.

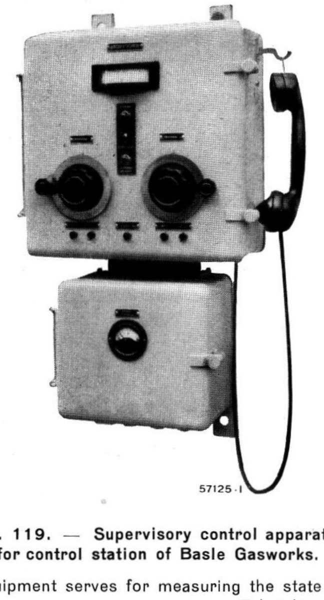


Fig. 119. — Supervisory control apparatus for control station of Basle Gasworks.

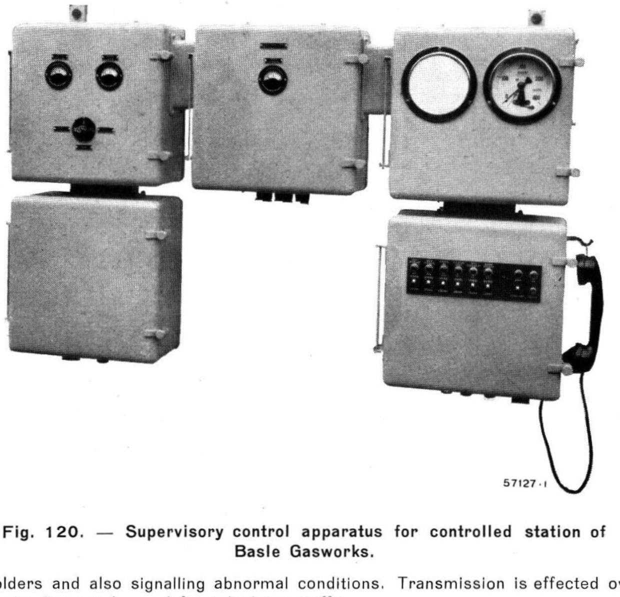


Fig. 120. — Supervisory control apparatus for controlled station of Basle Gasworks.

The equipment serves for measuring the state of charge of two gas-holders and also signalling abnormal conditions. Transmission is effected over a 7 km long telephone line which is simultaneously used for telephone traffic.

operation is not interfered with. The frequency-selection system is of advantage when a small number of switching operations have to be controlled over a pair of telephone lines. By employing the so-termed simultaneous connection telephone communication can be maintained simultaneously with, and independently of, the remote control. Currents of different frequency, in phase with or opposed in phase to that in the power supply system common to both stations, are switched on to the transmission lines. Selection is effected with special phase and frequency relays.

An interesting example of supervisory control is afforded by the installation at the Basle Gasworks (Figs. 119 and 120). Here the greatly fluctuating state of charge of two gas-holders situated in the suburbs is signalled to, and controlled from, the works office. A large number of valve positions, pressure conditions, the state of the gas-holders, etc., have to be separately indicated and transmitted to the works office in the form of a warning signal. The pair of wires employed here is also used for telephone communications.

From the above examples it will be seen that supervisory control problems can be solved in various ways. The solution adopted must not only be the best technically, but should also be the most economical. In the case of remote control gear for electricity supply undertakings reliability is an extremely important factor. This application calls for wide experience in both power and communications engineering. The requirements of power engineering bodies have been specially considered in the development of our supervisory control equipment and in many cases we are now in a position to supply remote control gear as an integral part of the power plant.

VI. MARINE EQUIPMENT.

A special number of the Review was devoted to marine equipment last year[1] and a series of articles were published which dealt with the following subjects, so that we need refer to them here only briefly.

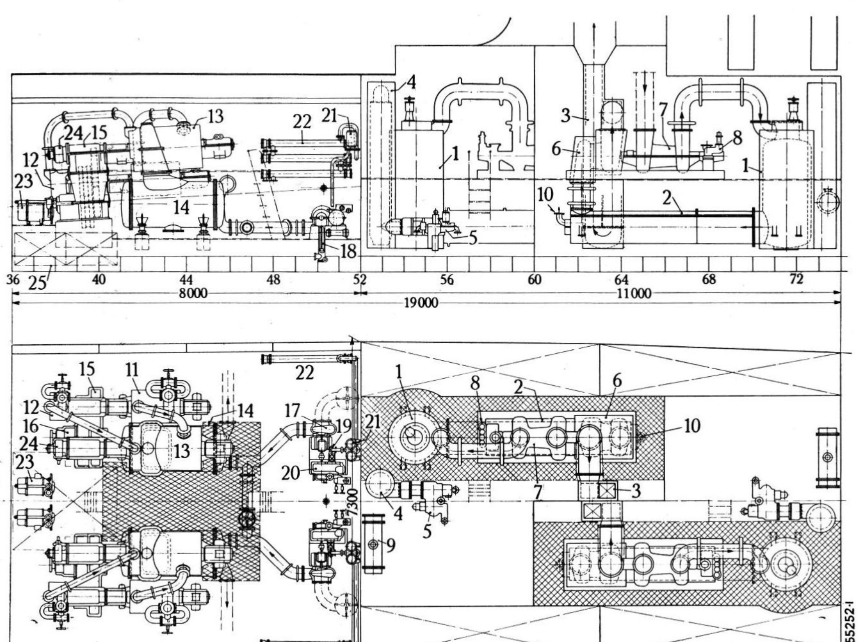
A. VELOX STEAM GENERATORS FOR SHIPS.

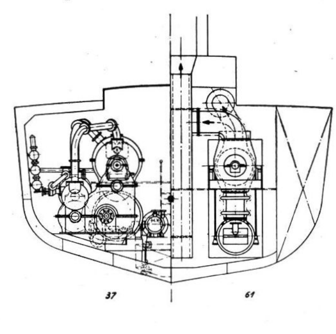
The new design for Velox steam generators for ships was described in detail in the special marine number of the Brown Boveri Review, pages 251—255, which also gives all important data in relation to space requirements and weights. We would only like to mention here that tests made with a boiler of this design, which we built for general test purposes, gave very satisfactory results. Although the trials cannot yet be regarded as completed, — the shortage of fuel oil has made it impossible to carry out prolonged service tests — it may, however, safely be said that the horizontally arranged evaporator tubes and the water tube screening walls which also act as evaporator elements, operate as well, and with as high a degree of safety, as the hitherto vertically arranged evaporator elements. A special advantage of the new arrangement is the relatively large sections for the passage of the gases, which will presumably enable the boiler to be operated also with fuel oils containing ash. An excellent feature is the accessibility and easy dismantling and replaceability of the heating surfaces. Even though it is seldom necessary to make use of these advantages in service, they remain very valuable.

[1] The Brown Boveri Review 1942, No. 9/10.

An example of an installation is shown in Fig. 121 which illustrates the accommodation of two steam generators, each for an output of 12 tons/h in a small naval craft.

The same space has here been allowed for the installation of the Velox steam generators as would have been required for the usual marine boilers. In the case of the Velox installation, this space is not, however, filled, so that there is still plenty of room available in which auxiliary machinery may be installed, thereby liberating valuable space elsewhere for other





1. Combustion chamber.
2. Evaporator and superheater.
3. Economiser.
4. Water separator.
5. Circulating, feed, and fuel pump set with steam turbine drive.
6. Gas turbine.
7. Blower.
8. Starting and regulating machine (steam turbine).
9. Feed-water economizer.
10. Live-steam connection.
11. High-pressure turbine.
12. High-pressure astern turbine.
13. Low-pressure turbine with astern stage.
14. Condenser.
15. Double reduction gear.
16. Propeller shaft thrust bearing.
17. Circulating water pump.
18. Condensate pump.
19. Main oil pump.
20. Auxiliary turbine with gear.
21. Oil filter.
22. Oil cooler.
23. Turbo-dynamo (20 kW output).
24. Shaft turning device.
25. Oil tank.

Fig. 121. — Two Velox steam generators each for an output of 12 t/h installed in a small naval vessel.

Note the small space requirements. When Velox boilers are installed in spaces such as are required for boilers of usual design, much room remains free. This may be used for mounting auxiliary machines. Note also the absence of the smoke uptakes. Even in forced operation the efficiency of such boilers is still of the order of 90%. The weight of a 12 t/h marine boiler of the type illustrated, inclusive of water and oil, is about 14 t.

purposes. The saving in space with boilers of larger outputs is proportionately still greater. It should be especially noticed that with Velox boilers the structures for the usual gas uptakes are done away with.

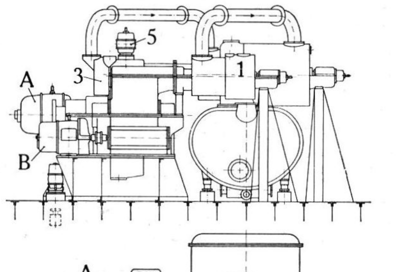
B. STEAM TURBINES FOR SHIP'S PROPULSION.

The steam turbine with gear drive is employed for a constantly increasing proportion of ships' drives at the cost of the steam engine. Whereas formerly it was employed mainly for large outputs, to-day its reliability as well as its simple attendance and greater economy of operation with the modern steam conditions, should enable the steam turbine to encroach still more on the field of medium outputs hitherto reserved to the reciprocating engine. In actual fact the geared steam turbine for high pressures and temperatures such as now demanded and installed by progressive ship builders, is superior to the steam engine already from outputs of 1500 H.P. onward, even when the latter is provided with an exhaust-steam turbine, in order fully to utilize the vacuum in the same way as a geared turbine. The disadvantage of the reciprocating engine is that it cannot be operated with highly superheated steam because of the necessity of lubricating the cylinders. If a steam turbine is interposed between it and the boiler in order to enable the use of higher superheat temperatures, or if a turbine is added after the engine in order to utilize the vacuum fully, the simplicity of the installation has disappeared and the initial costs are too high.

The above facts seem to be contradicted by the relatively wide application of reciprocating steam engines during the past year. The reason here is, however, that the existing gear-cutting machines are at present not able to cope with the number of gears which would be required for turbine drive. Taking into consideration this difficulty of gear manufacture, it might be expected that direct-connected steam turbines would be used for coupling to such steam engines or else the output of the exhaust turbines electrically transmitted to the propeller shaft. Compared with other makes, our exhaust-steam turbines possess a number of characteristics which are to be valued as considerable advantages, for instance, the spring coupling between the gear and the exhaust-steam turbine and the propeller shaft or the steam engine. In spite of the elastic connection, this coupling enables the fluctuations of the torque of the steam engine during a revolution to be reduced by the inertia of the turbine to such an extent that it is not necessary to stiffen the shaft for transmitting the additional output of the turbine. Moreover, it prevents the engine and the turbine from running away when the propeller comes out of the water during heavy seas.

A notable improvement is the combination of all auxiliaries into a single set which is then electrically driven. The required current is furnished by a generator which is driven from the gear of the turbine. During manœuvring, or when steaming at slow speed, the auxiliary set is driven by the steam turbine which automatically comes into operation when the speed falls below a certain minimum value.

The steam turbine drive for ships results in very favourable arrangements if a Velox boiler is used as a steam generator, especially in regard to weight and



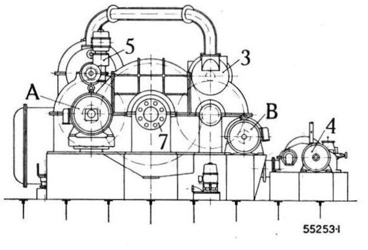
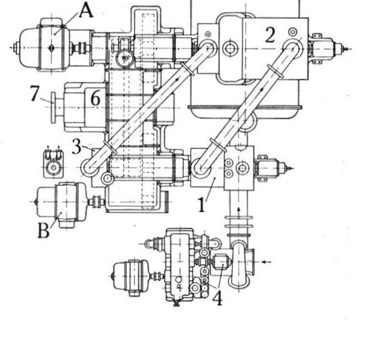


Fig. 122. — Standard geared turbine unit of 2500—6000 S. H. P. with electrical auxiliary drive for merchant vessels.



The special features of this unit are the two electrical machines coupled to the propeller shaft. The machine A, is the so-called Helux generator, which supplies the electrical energy for various purposes including the power requirements of the condensing auxiliaries. The machine B is on the other hand an electric motor, which receives current from the separately driven auxiliary generator always provided, and serves for driving the ship when the latter steams at a speed below about 30 % of normal. Such low speeds may be required during fog, when negotiating difficult entries to and exits from ports, etc. During operation of the auxiliary motor, the main machinery runs light. When the auxiliary motor is out of service, it is disengaged. The numbers on the drawing denote:

1. High-pressure turbine.
2. Low-pressure turbine.
3. Astern turbine.
4. Condenser pump set.
5. Shaft turning device.
6. Propeller shaft thrust bearing.
7. Propeller shaft flange.

A. Helux generator.
B. Auxiliary driving motor.

space requirements. We would refer the reader here to the data given in the special marine number of the Brown Boveri Review of 1942, and in particular to page 254.

If a ship has frequently to steam for a long time at a very reduced speed, as for instance is the case in fog, it is then convenient to shut down the main engines and to employ for this purpose an auxiliary engine. According to our suggestion, the auxiliary may consist of a direct-current motor which drives the propeller shaft through the medium of a clutch-type coupling and a special pinion on the main gear. A power of 3—4 % on the propeller shaft is then sufficient to maintain a speed of about $^1/_3$ of the normal value. The current for this auxiliary drive can be supplied from the electrical auxiliary sets usually provided, or use may be made of the auxiliary unit which furnishes the power requirements of the ship when in port. To protect the motor against excessive speed, the clutch-type coupling is provided with an interlocking device which prevents the opening of the stop valve on the main driving engine as long as the coupling is engaged. The auxiliary drive just described can, of course, serve not only for slow speed operation, but also for driving the ship in an emergency, if for any reason the main engine is out of service (Fig. 122).

C. GAS TURBINES FOR SHIP'S PROPULSION.

Since our first publications on the gas turbine, considerable interest is shown in the application of gas turbines to ships. We have in the meantime worked out many projects which have repeatedly shown that already to-day, because of its great simplicity, its low weight and space requirements, and simple attendance, the gas turbine deserves serious consideration. Allowing for the fact that under normal market conditions, ordinary fuel oil is almost always considerably cheaper than Diesel-engine oil, the fuel costs of the gas turbine are in spite of its lower efficiency not higher than those of a Diesel engine drive, for which an appreciable outlay for lubricating oils has also to be reckoned with. With large heat exchangers or with compression and combustion in several stages, the efficiency of the gas turbine may, however, be raised to such an extent that even with small differences in fuel-oil prices the gas-turbine drive is less costly than one with Diesel engines and may even compete with steam engine and turbine installations.

D. MARINE AUXILIARIES.

Sales of marine auxiliaries were again satisfactory, our monobloc lighting turbo-sets with ratings of 0·5

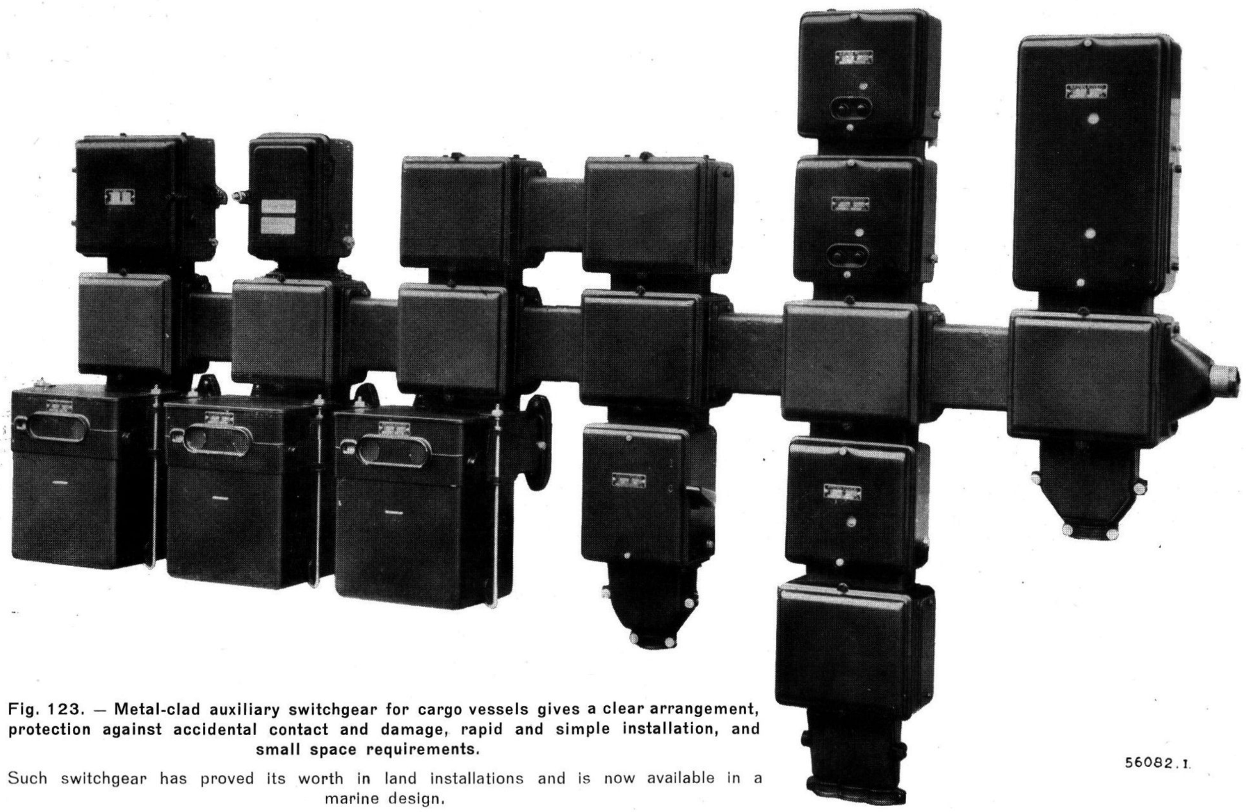


Fig. 123. — Metal-clad auxiliary switchgear for cargo vessels gives a clear arrangement, protection against accidental contact and damage, rapid and simple installation, and small space requirements.

Such switchgear has proved its worth in land installations and is now available in a marine design.

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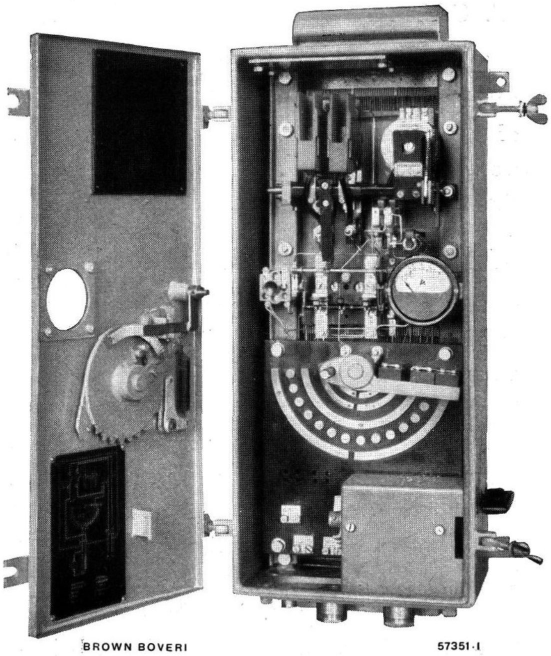

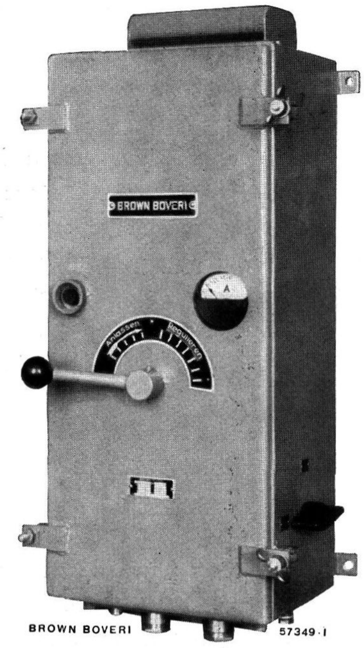

Figs. 124 and 125. — Marine-type face-plate starter, splash-proof pattern, with current ratings up to 75 A d. c.
Isolating switch in separate box in bottom right-hand corner. The starters have over-current and low-voltage releases. The design protects both the operator and the motor and renders faulty operation impossible.

to 20 kW in particular proving very popular. Improvements to the steam inlet and guide ducts have brought a reduction in steam consumption of 10—15 %. The series of our small turbines with ball and roller bearings and mechanical governor, described earlier, has been extended to include a type rated 400 kW. These small turbines, which are intended for the drive of pumps, fans and the like, also arouse great interest in marine circles.

During the past year the complete auxiliary equipment has been supplied for a large number of cargo vessels. The proportion of d. c. turbo or Diesel-generators and d. c. motors was still greater than that of a. c. machines, but that there is a definite tendency increasingly to employ a. c. is proved by the orders received. In the case of low-power drives direct-on-started squirrel-cage motors were exclusively provided, while for high powers squirrel-cage motors with star-delta switches were employed. These switches are changed over automatically from the star to delta connection, thus rendering the starting of large motors extremely simple and precluding mistakes in operation such as waiting too long in the star position, too rapid or too slow change-over from one connection to the other, etc. They also have thermal releases, which are connected in the phase to neutral circuit so that the motor is also protected during the starting process. For rooms with several auxiliary motors, totally-enclosed switchgear, such as has been the practice in land installations for many years past, is preferably employed (Fig. 123).

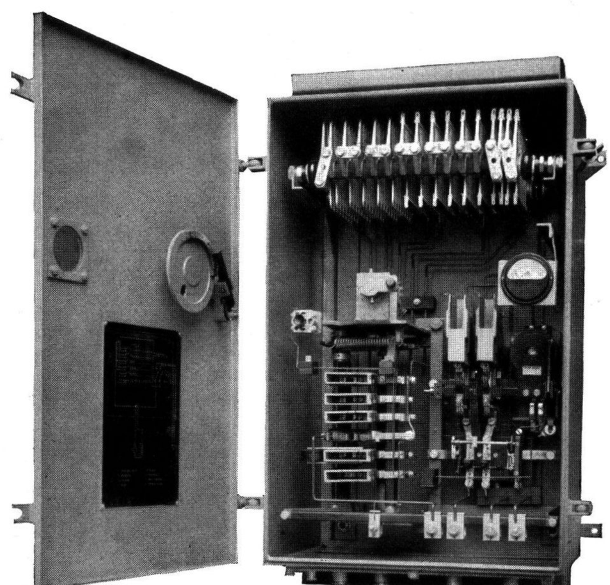

Fig. 126. — Marine-type direct-current cam-operated starter with current ratings up to 400 A and over-current and low-voltage release.

For drives requiring speed variation, pole-changing squirrel-cage motors are supplied, while for cases entailing fine, progressive speed regulation we have now developed a high-speed shunt commutator motor, thus enabling the gearing between the motor and machine to be dispensed with. The price and space requirements of these three-phase commutator motor drives are much less than in the case of the slow-speed commutator motors employed hitherto, so that this method of drive should find wide application on ships with a. c. auxiliary supply systems in future.

For d. c. motor drives up to 70 H. P. we put new *marine starters* on the market during the year. One hundred and fifty of these have already been ordered. The starters are of the splash-proof type and disconnect the motor from the supply on both poles. Over-current and low-voltage releases and an interlocking device for preventing the starter being

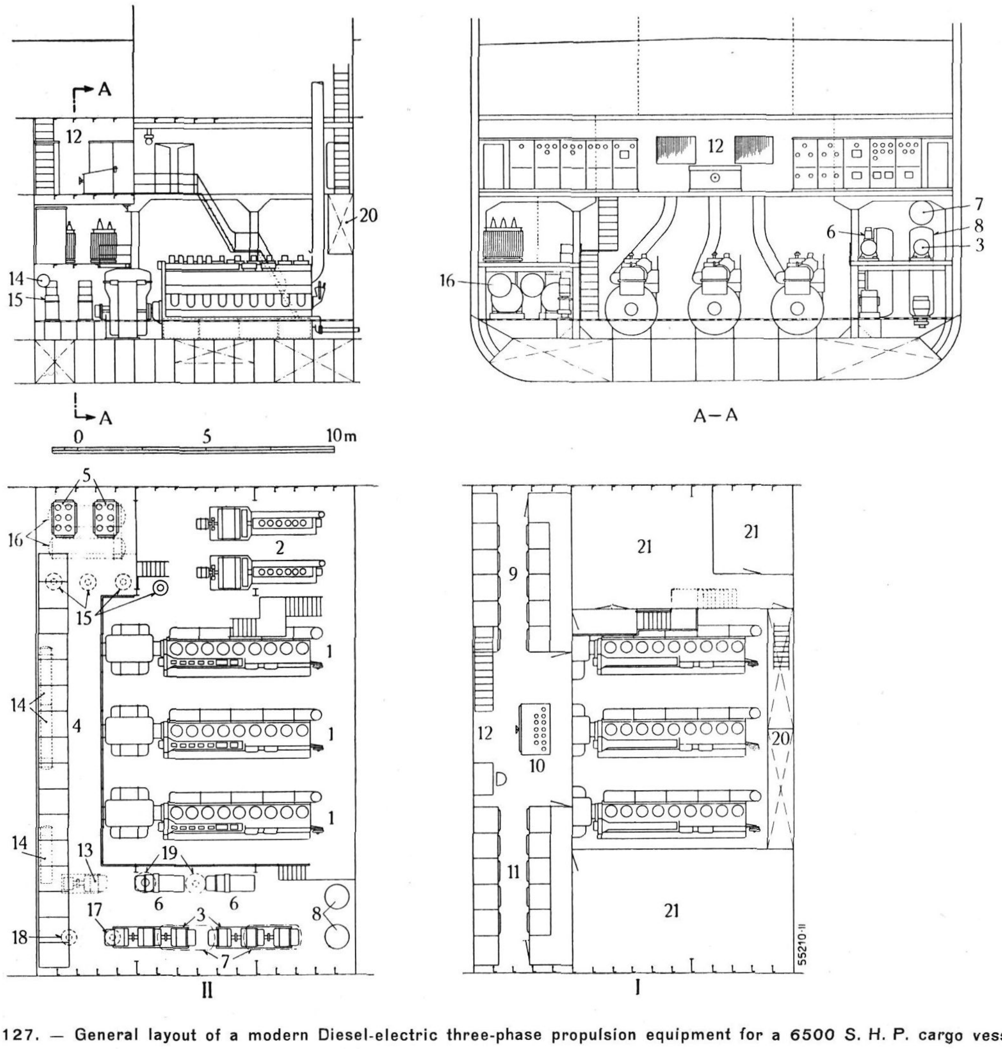

Fig. 127. — General layout of a modern Diesel-electric three-phase propulsion equipment for a 6500 S. H. P. cargo vessel.

I. Deck I.
II. Engine room.
1. Main Diesel-alternator sets.
2. Auxiliary Diesel-alternator sets.
3. Exciter sets.
4. High-voltage switchgear for main generators, propeller motor, and transformers.
5. Transformers.
6. Compressors.
7. Compressed-air receivers for switchgear.
8. Compressed-air receivers for starting Diesel engines.
9. Switchboards for main alternators, propeller motor and transformers.
10. Control desk.
11. Switchboards for auxiliary Diesel-alternators, exciter sets, and low-voltage distribution system.
12. Control room.
13. Standby oil pump.
14. Oil cooler.
15. Fresh and sea-water pumps.
16. Fresh water cooler.
17. Ballast pump.
18. Bilge pump.
19. Sanitary and fire-fighting pump.
20. Fuel tanks.
21. Space for various auxiliaries, workshop, stores, etc.

Space requirements and weight are less than with other forms of Diesel propulsion. The engine room is only about 13 m long and the weight of the equipment is at least 140 t less than with direct Diesel drive. The economy of a vessel can thus be substantially improved by employing electrical transmission with parallel-operating three-phase alternators. The control room with control desk and switchboards for the main electrical machines is completely separated from the engine room. Owing to the freedom from noise and oil vapour, conditions in the control room are much more pleasant for the staff entrusted with manœuvres.

left on the starting steps extensively protect both motor and starter (Figs. 124—126). The switch components are neatly arranged in the front of the box and can thus be readily inspected upon the door being opened. Together with the starting and regulating resistors they are mounted on an iron frame which can be readily removed from the box for inspection after four screws have been removed.

A new sphere of application for our *Helux ship's lighting equipments* has been opened up through the conversion of internal combustion engines for operation with non-liquid fuels, which tendency is particularly pronounced in inland navigation applications for tugs, ferry-boats, etc. A condition of such conversion schemes is practically invariably that no liquid fuel may be used for the auxiliary power plant either. The small auxiliary Diesel-driven generating set usually employed for providing such vessels with an electricity supply is therefore no longer possible. In the majority of cases it is replaced by a Helux equipment comprising a d. c. generator driven from the propeller shaft, a battery, and a voltage and charging regulator which automatically regulates the generator voltage and supervises the charging of the battery throughout a propeller speed range of approximately 50—100 % of the maximum value. Our lengthy experience in this field — over 800 automatic charging and voltage regulators have already been supplied for ship's lighting plants or auxiliary power stations — enables us to furnish the correct lighting equipment for every running schedule.

E. ELECTRIC PROPULSION OF SHIPS.

In the field of the electric propulsion of ships exhaustive studies were made, particularly concerning the Diesel-electric three-phase drive with alternator sets operating in parallel, as constructed for the first time in 1936 by Brown, Boveri & Cie., A.-G., Mannheim, for the 6000 S. H. P. cargo vessel "Wuppertal" of the Hamburg-America Line. For the first plants constructed the alternators were driven by either four-stroke-cycle Diesel engines with Brown Boveri exhaust turbo-chargers or single-acting two-stroke Diesel engines with outputs between 2000 and 3600 B. H. P. at speeds of 250—235 r. p. m. The high-speed engines developed by leading Diesel engine-builders in the meantime with outputs of 1600—3000 B. H. P. at 750—360 r. p. m. now permit Diesel-electric three-phase drives to be constructed which on the score of weight, space requirements, and price have the advantage over direct drive by Diesel engine with or without gearing. Taking the example of a 6500 S. H. P. cargo ship with three 1850 kVA, 360 r. p. m. Diesel-alternator sets for the generation of the entire electrical power required at sea a reduction in weight of approximately 140 t is achieved, compared to direct Diesel drive. The corresponding diminution in relation to geared Diesel drive with 320 r. p. m. engines is of the order of 36 t. Fig. 127 shows that the space requirements of the installation are relatively small. The engine room proper is only about thirteen metres long in the case of a vessel of the power under consideration and is also lower than with direct Diesel drive. The shafting tunnel through the holds aft involved by the latter form of propulsion, is eliminated, the propeller motor being placed right aft in a location having little value as cargo space. Diesel-electric three-phase propulsion is therefore not only warranted on ships for special applications, but also for high-power vessels in general, and will doubtless play a big part in the rebuilding of merchant fleets upon the return of normal conditions.

The advantages of three-phase propulsion are set out, partly from a new point of view, in the recent special marine number of this journal (September/ October, 1942, pp. 240—250).

K. Sachs / W. G. Noack.
(MS 930) *(E. G. W. / Hv.)*

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