VOL. XVIII JUNE, 1931 No. 6

THE BROWN BOVERI REVIEW

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

NEW GENERAL POST OFFICE (SIHLPOST) IN ZÜRICH.
62 charging stations for electric motor vans, fitted with the new Brown Boveri automatic charging equipment.

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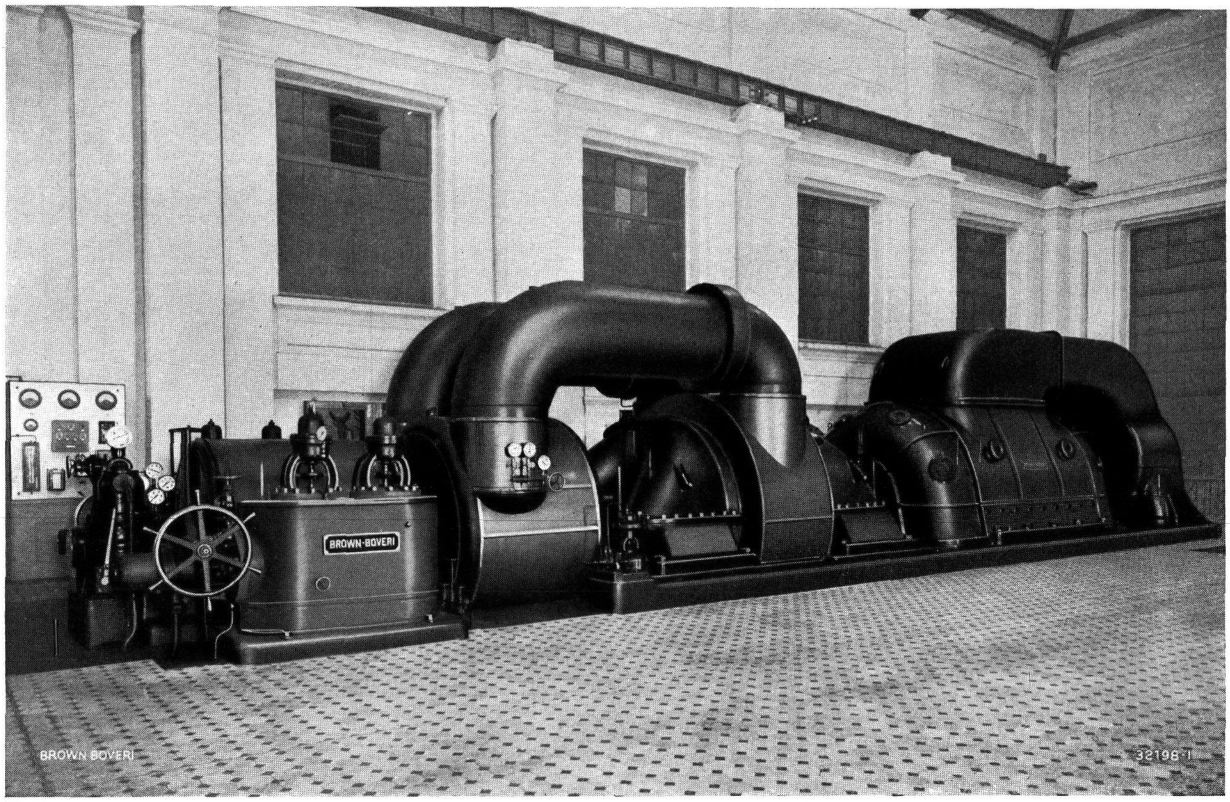
STEAM TURBINES



CHORZOW STATE NITROGEN WORKS, CHORZOW (POLAND).
Three-cylinder turbine, 25,000 kW, 14·5 kg/cm² abs, 340° C, coupled to a three-phase turbo-alternator, 34,600 kVA, 6300 V, 50 cycles, 3000 r. p. m.

LIVE-STEAM, BACK-PRESSURE, EXTRACTION AND MIXED-PRESSURE TURBINES FOR ALL CONDITIONS ENCOUNTERED IN PRACTICE

TURBINES FOR STEAM AT EXTRA HIGH PRESSURES AND SUPERHEATED TO THE HIGHEST TEMPERATURES AND FOR THE HIGHEST OUTPUTS

THE BROWN BOVERI REVIEW

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

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THREE-PHASE COMMUTATOR MOTORS FOR OUTPUTS UP TO 16·5 kW.

Decimal index 621. 313. 36.

THE increasing use of individual drives in industry, causing a growing demand for variable speed motors, has greatly promoted the use of a.-c. commutator motors. These motors can be connected directly to an a.-c. network such as exists in most industrial plants. They permit the speed to be varied between wide limits practically without losses, and therefore, as far as economy is concerned offer appreciable advantages over other variable speed drives.

These motors have always been used in especially large numbers in the textile industry for the variable speed individual drive of ring spinning and twisting frames. For many years Brown, Boveri & Co. have made a complete range of three-phase commutator motors intended for this purpose in the first instance. They have, however, also found many other fields of application by reason of their excellent qualities. Since its inception, this range of motors has undergone repeated improvements, to keep pace with the ever increasing service requirements, and, taking into account the experience gained in recent years, it was revised and enlarged. The new range of three-phase commutator motors thus formed will be described in greater detail in the following pages.

The design and connections of these motors (type P) can be seen from Fig. 3. The stator has a three-phase winding, the rotor being of the usual d.-c. type. The current is conducted to the commutator through carbon brushes; the stator and rotor are connected in series across a transformer arranged in the top of the motor casing. The transformer reduces the rated voltage to the most favourable value for commutation. The motor is series-wound, i. e., if the position of the brushes is fixed, the speed of the motor decreases when the torque is increased and vice versa. Since the speed can be adjusted between wide limits by shifting the carbon brushes without the efficiency being appreciably altered, this motor, as already mentioned, is specially suitable for drives where extensive and continuous speed regulation is required.

Of the many uses of these motors only some of the most important will be briefly mentioned here:

The drive of *spinning and twisting frames*, under certain circumstances in conjunction with a device for automatically regulating the speed according to the rate of cop winding.

The drive of *cloth printing machines*[1] which are particularly exacting as regards speed regulation of the motor.

The drive of *finishing machines* (stentering frames, mercerizing machines, etc.), a field which has recently been greatly developed.

The drive of *printing presses*. For drives of this kind, as also for driving cloth printing and finishing machines, remote control of the brushes is provided. The method of control is usually mechanical, but for printing presses electrical control operated by push-buttons is also arranged.

The drive of *fans, blowers, centrifugal pumps*, etc., i. e. of machines whose torque decreases rapidly with decreasing speed, and which are therefore specially suitable for driving by series motors.

(1) *Types.* — As will be seen from the above, the motors are usually placed either in very dusty or damp rooms. Accordingly, type P motors are either of the pipe-ventilated design, type PD (Figs. 1 and 2) or of the drip-proof design, type PR (Fig. 4). Both designs can be equipped with gears running in an oil bath, type PDZ and PRZ. These gears are placed in the end shield of the motor (Figs. 9 and 10). Such motors can be direct coupled to driving shafts which run at a moderate speed. The combination of a high-speed motor with favourable electrical properties and high quality gears gives a very economical drive, such as is unattainable with a slow running

[1] The Brown Boveri Review, 1929, No. 8, p. 219.

motor. The speed of the motor can also be stepped up. Usually the motors are constructed for only one direction of rotation; they can, however, be made suitable for both directions of rotation.

(2) *Stator.* — The pleasing outside appearance of the new motors is apparent from the illustrations. All corners and angles are avoided by the prismatic shape of the casing. The two disc-shaped end shields are in the centre of the casing and bolted on to it. The motor is closed in above by a thick sheet-metal hood.

The body of the stator consists of dynamo laminations. The rotor transformer and stator switch are arranged in readily accessible positions, under the metal hood. The three-pole stator switch has hammer contacts and consequently guarantees great reliability of action when the switch is frequently operated. Collection of dust in the switch, which might occur due to the cooling air not being quite free from dust, is avoided by a protecting cover of insulating material.

Two large openings, on the left and right at the commutator end of the casing, permit the brush holders to be conveniently overhauled and also allow the casing to be firmly bolted on to the baseplate. Further, small openings are arranged on the left and right of the driving side of the casing. The large openings are closed by easily removable covers, which, according to the type of ventilation, are made of plain or perforated sheet metal, while the small openings are permanently closed by sheet metal covers after the motor has been erected.

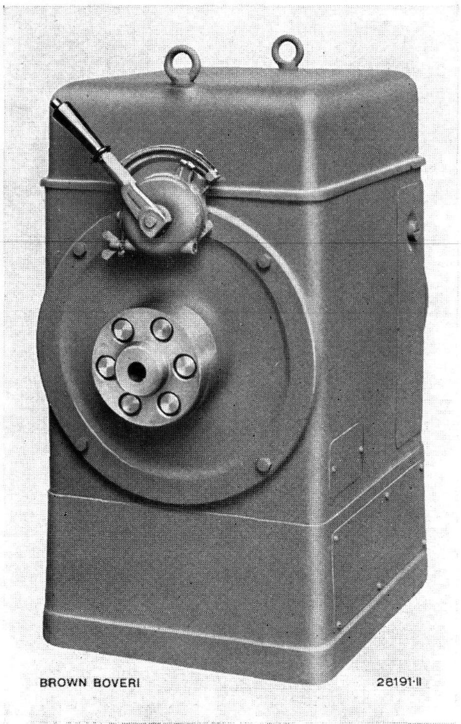

Fig. 1. — Three-phase commutator motor type PD with hand regulation (driving side).

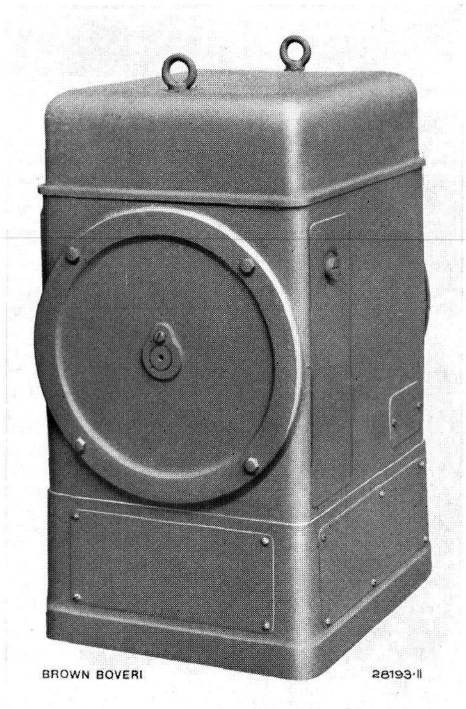

Fig. 2. — Three-phase commutator motor type PD on motor base (commutator side).

(3) *Terminals.* — The terminals are placed in the case on the right below the opening at the commutator end. They are protected by an insulated sheet metal cap from being touched when the carbon brushes are adjusted.

(4) *Bearings.* — In order to keep the frictional losses as small as possible, only ball bearings of well-known make are used. The bearings are grease lubricated. A single lubrication with suitable grease, according to the magnitude of the load, is sufficient for two years, which greatly decreases the amount of supervision required by the motors.

(5) *Rotor.*—The rotor consists of the shaft of best quality steel, the framework carrying the laminated core and the commutator. The latter is manufactured with the greatest care from hard drawn copper and is fitted with mica insulation.

(6) *Brush rocker.* The brush rocker is arranged so that it can be turned on the inside of the end shield, and to it are bolted the insulated brush-holder carriers. In order to avoid dismantling the end shield when changing the carbon brushes, the brush holders together with two carbon brushes each and compression springs, can easily be removed as a whole from the brush holder carrier by loosening a screw. In this way the maintenance and adjustment of the brushes are greatly simplified.

(7) *Brush control gear.* — The brush control gear is used for moving the brush rocker when starting and to vary the speed of the motor. The control

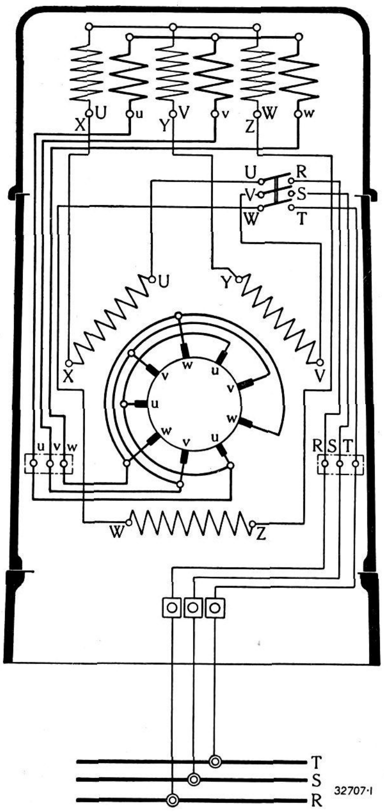

Fig. 3. — Diagram of connections of the motor with built-in switch and fuses.

gear is differently designed according to the purpose for which the motor is to be used.

(a) *Brush control gear for hand operation* (Fig. 1). — This includes the control lever, control shaft, the drive of the brush rocker by geared segments and of the stator switch by a lever from the control shaft. The control shaft lies on both sides of the stator casing between the stator core and the rotor transformer, above and parallel to the motor shaft.

A guide slot with stops for the zero and end positions of the control lever is screwed on to the end shield at the control side. On this guide slot there is a scale on which the displacement of the brushes can be read in electrical degrees. A cast iron cap is fixed to the slot; between these two the shaft carries a worm wheel with a ratchet riveted on; the control lever is pinned on to the end of the control shaft outside the cap. By means of the worm in the cap it is possible to make very fine adjustments of the position of the brushes. By the removal of the key required to adjust the brushes, unauthorized persons are prevented from displacing the brushes and thus causing additional changes of speed.

On starting, the control lever is pushed slowly from its zero position, when the rotor revolves in the same direction as that in which the control lever is moved. When the control lever reaches the notch on the notched lever, the plunger on the control lever is pressed by a spring into the notch and thus control lever and notched lever are mechanically united. On the control shaft inside the motor a strong spring is fixed, which forces the lever back into the zero position and switches off the motor immediately, if the control lever does not reach the notched position.

(b) *Brush control gear for automatic speed regulation* (Fig. 5). — In driving ring spinning frames this control gear is used for automatically regulating the speed according to the formation of the cops. It differs from that just described only in that the cap can be turned, and by means of a wire-rope or a rod is periodically turned forward by the automatic gear on the spinning frame. A spring keeps the wire-rope tight, and operates the backward movement of the movable cap and the control lever connected to it.

(c) *Bevel-wheel drive for mechanical remote control* (Fig. 6). — In this type of control gear the

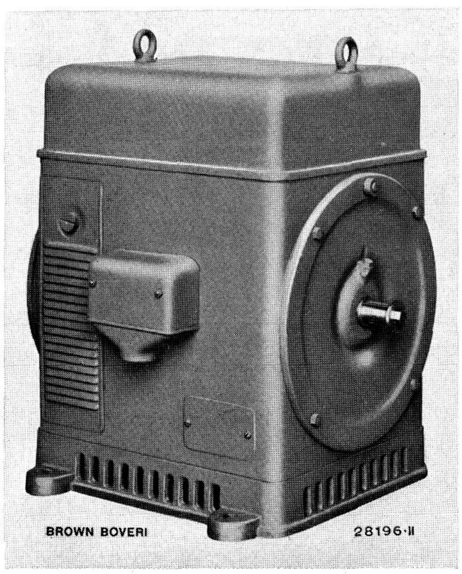

Fig. 4. — Three-phase commutator motor, type PR, with drip-proof protection.

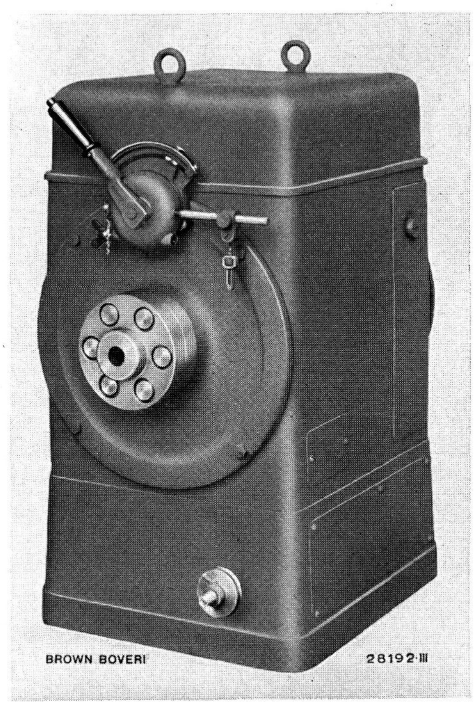

Fig. 5. — Three-phase commutator motor, type PD, with brush control for automatic regulation.

Fig. 6. — Three-phase commutator motor, type PR, with bevel gear control and sleeve for remote control.

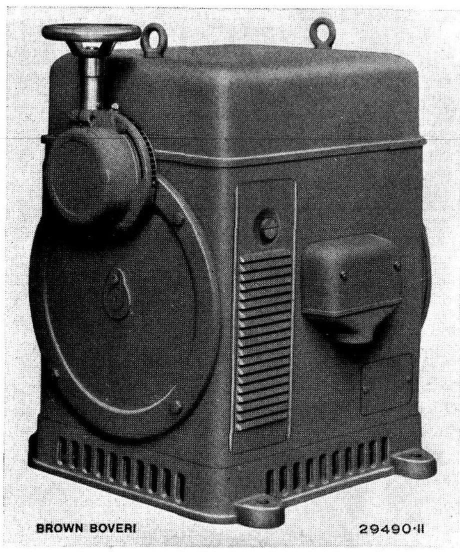

Fig. 7. — Three-phase commutator motor, type PR, with bevel gear control and handwheel.

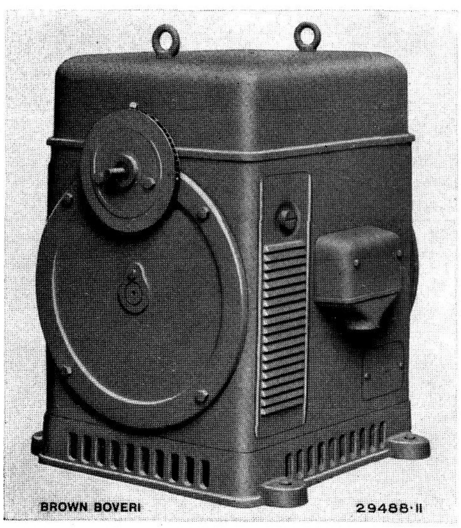

Fig. 8. — Three-phase commutator motor with end of control shaft free.

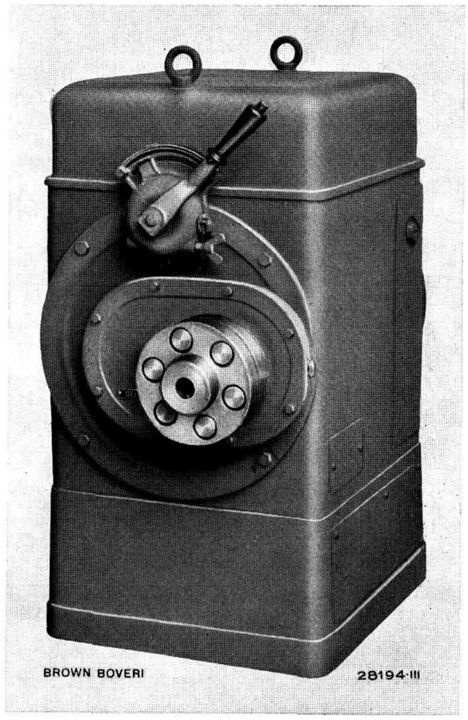

Fig. 9. — Three-phase commutator motor, type PDZ, with built-in gear control.

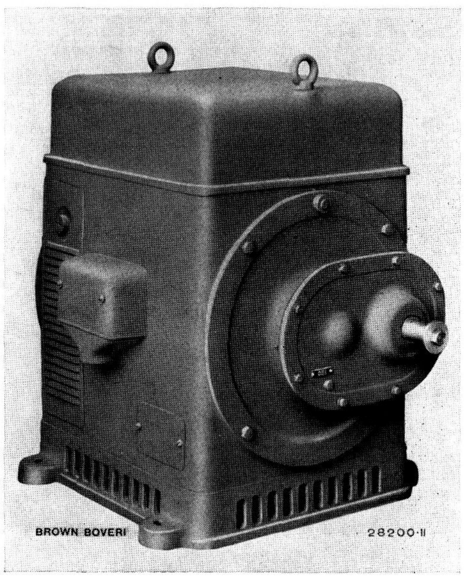

Fig. 10. — Three-phase commutator motor, type PRZ, with built-in gear control.

operating elements are placed at the commutator end of the motor. To the end shield, central to the projecting shaft, a guide slot is bolted, with stops for the zero and end positions, and on this a scale is fixed on which the displacement of the carbon brushes can be read in electrical degrees. A pointer firmly fixed on the shaft shows on the scale the magnitude of the brush displacement. The greatest possible angle through which the control shaft can turn is 90^0. The shaft of the smaller bevel wheel can be arranged at any desired angle, and carries a sleeve at the end of the rod. A contact screw prevents the control gear from moving automatically. For the largest possible displacement of the brushes the sleeve shaft must be turned through 310^0. In the case of motors of types PR or PRZ, the sense of rotation of the sleeve shaft can always be chosen only in one direction, either right or left, independent of the direction of rotation of the motor. A change of direction can be easily made.

(d) *Bevel-wheel drive for direct control* (Fig. 7). Instead of the sleeve a handwheel is fixed on the shaft, the control gear being otherwise as described under section (c).

Other arrangements of the control gear are also possible, in which the motor is built with the end of the control shaft free (Fig. 8), and on this suitable means of transmission, for example a chain wheel, can be fixed.

(8) *Baseplate and air duct.* — The casing is bolted on to a cast iron base-plate. Openings in the bottom of the casing and in the baseplate permit an uninterrupted flow of air. Since pipe ventilated motors are usually direct coupled, the height of the baseplate in each case is arranged according to the height of the shaft to be driven. In spite of this it is possible to change the motor easily, since the height of the shaft in the casing remains the same, and usually only the motor and casing require to be changed.

Under the baseplate of the pipe ventilated motor (Fig. 1) there are openings to connect up the air ducts in the bottom. The air is circulated by a fan fixed on the driving side of the rotor. The cooling air enters on the driving side, and, after effective cooling of all parts, including the rotor transformer, leaves the motor on the commutator side. The relatively high baseplate of pipe-ventilated motors usually allows fuses to be incorporated so that the motor can be connected to the mains without further switchgear being required.

Drip-proof type motors (Fig. 4) differ somewhat in design from the type described. The baseplate is kept low, and is provided with side openings for the passage of air in and out. The path followed by the air is similar to that through pipe-ventilated motors, except that the air also leaves the motor through the perforated casing at the commutator side. Because of the low baseplate, fuses cannot be fitted, and they must therefore be arranged separately. For connecting the leads a terminal box for steel conduit connection is arranged outside the casing.

(9) *Gearing.* — On the driving side of motors of types PDZ (Fig. 9) and PRZ (Fig. 10) there is an end shield arranged for gear drive and closed by a thick cover. The wheel and pinion run in oil and have helical teeth cut with the greatest possible accuracy on hobbing machines. The gear shaft, like the motor shaft, runs in amply dimensioned ball bearings. The pinion is of best quality steel, and the wheel of cast iron or steel. In the case of smaller motors the greatest gear ratio is 3·2 to 1, and in the case of larger ones, 3 to 1. The special advantages of practically noiseless running, high efficiency of about 98 to 99%, and great reliability should be emphasized.

(10) *Rotation in both directions.* — The motors are usually designed for only one direction of rotation. They can, however, also be supplied for running in both directions. In this case the mid-position of the brush shifting gear corresponds to the zero position of the brushes, and the movement of the gear to the one or the other side of the zero position causes the motor to rotate in one direction or the other. In order to reverse the motor field at the same time, so that it always rotates in the same direction as the

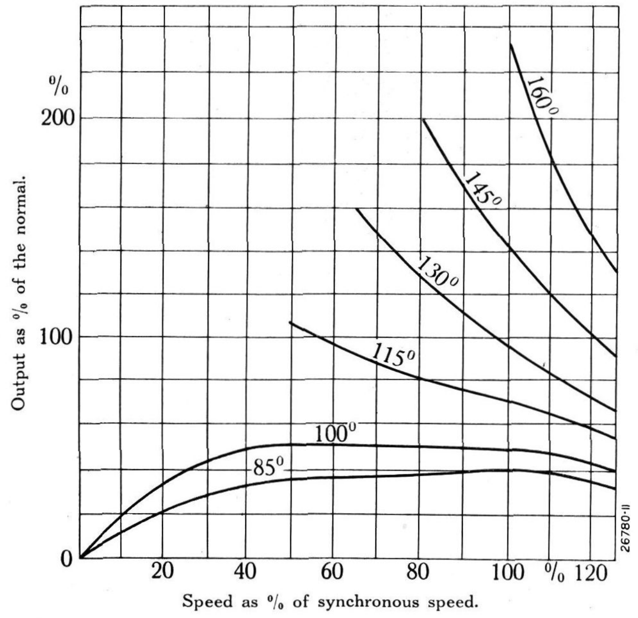

Fig. 11. — Variation of the output with the speed for various positions of the brushes.

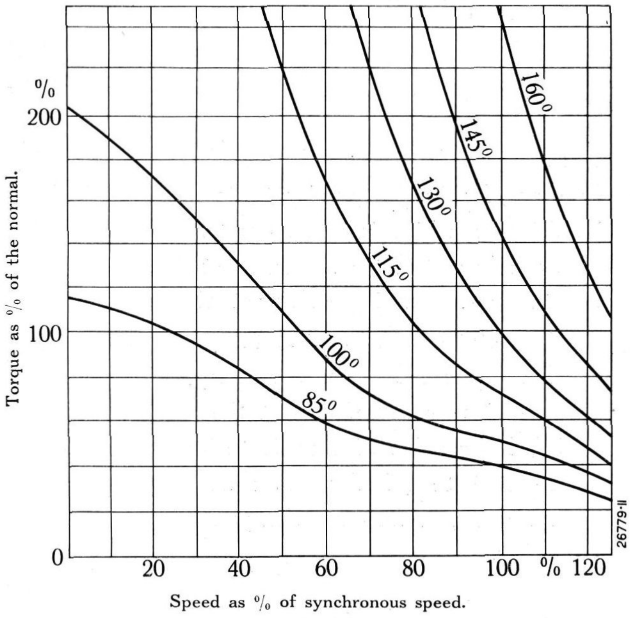

Fig. 12. — Variation of the torque with the speed for various positions of the brushes.

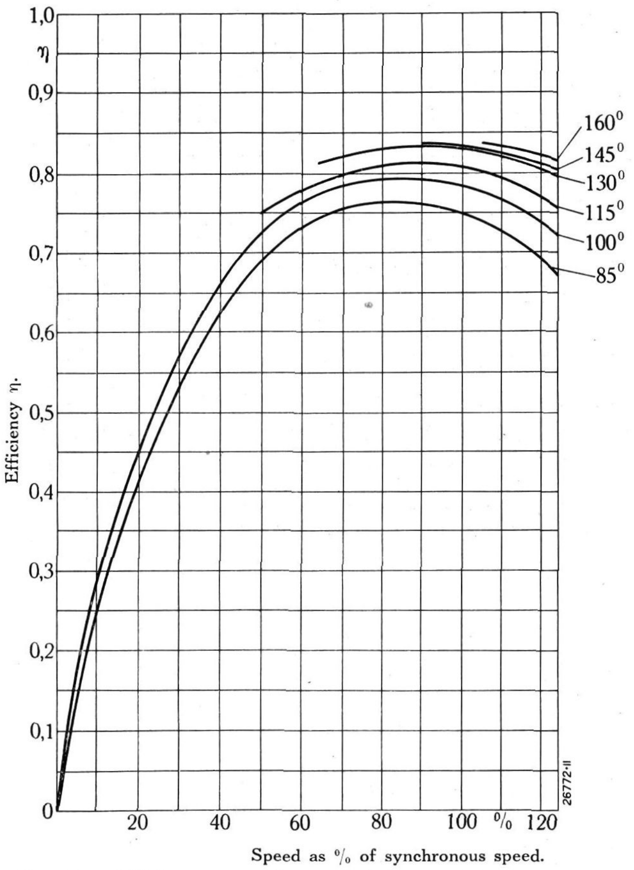

Fig. 13. — Efficiency η as a function of the speed for various positions of the brushes.

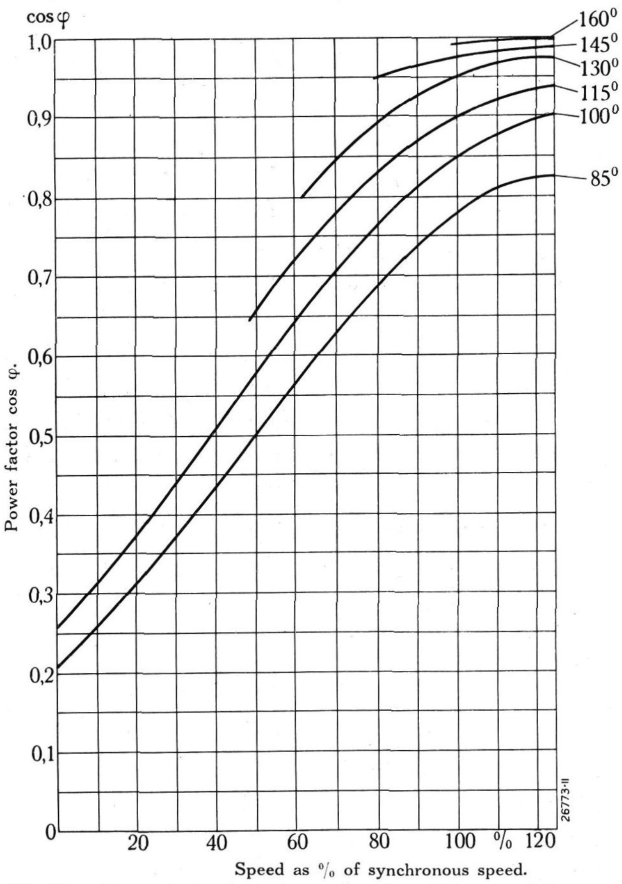

Fig. 14. — Power factor (cos φ) as a function of the speed for various positions of the brushes.

rotor, a three-pole change-over switch, like the stator switch, fitted with hammer contacts, is built in addition to the stator switch, and connected to the brush control shaft.

(11) *Output, pressure and speed.* — This set of motors includes ten sizes with outputs from 2·5 to 16·5 kW at 50 cycles and the usual pressures between 200 and 600 V. The possibility of obtaining a motor of suitable size for the power required by the driven machine is much greater because of the large number of motors of different sizes, than it was with the corresponding older set of motors.

The stator is connected to the mains pressure. The rotor pressure, on the contrary, is independent of the mains pressure, and at the commutator and brushes has a value of from 50 to 80 V when starting and from 8 to 26 V while running. The carbon brushes can therefore be changed while the motor is running.

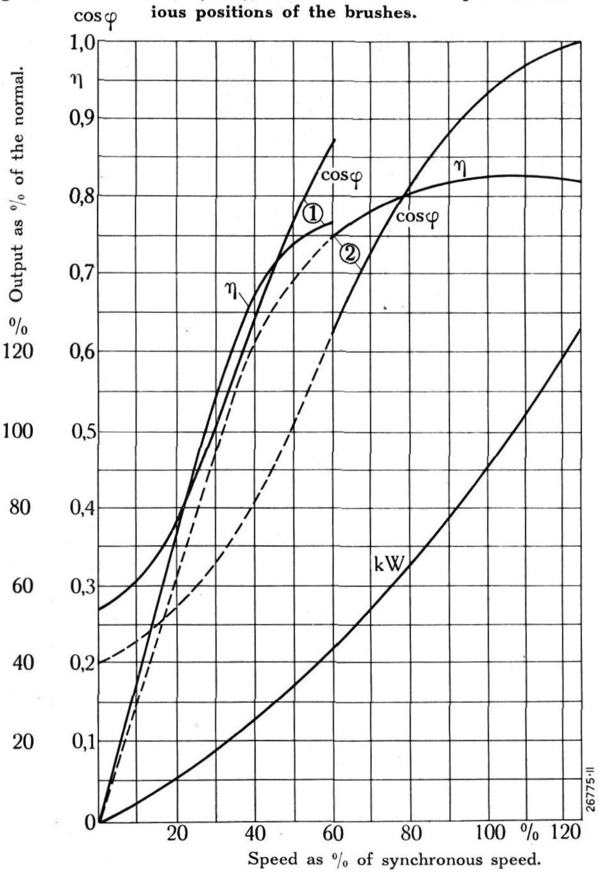

Fig. 15. — Output, efficiency and power factor as functions of the speed with approximately constant torque and change-over from delta to star connections.

The smaller types of motors have six poles, the larger four poles, and the speed can usually be regulated between 0·6 and 1·25 times the synchronous speed. The possibility of increasing the regulating range will be discussed later. The ratio between output, speed and brush displacement can be seen from the curves in Figs. 11 and 12. With the exception of type P 144, the motors can deliver their maximum output within the whole regulating range above synchronous speed without inadmissible heating, while within the regulating range below synchronous speed they are suitable for producing a constant torque. When the motor is fully unloaded its speed increases; the motor, however, does not run away, but reaches a limiting speed which is admissible without any damage taking place. Where the possibility exists of the load being thrown off in this way, it is therefore unnecessary to incorporate a centrifugal switch to safeguard the motor; nevertheless, under certain circumstances, having regard to the parts to be driven by the motor, this device may be required.

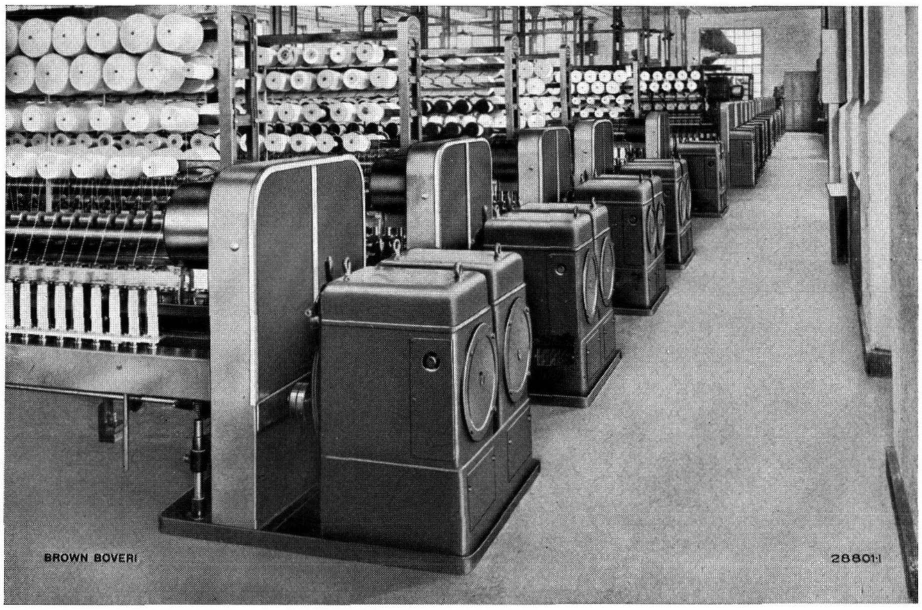

Fig. 17. — Drive of double sided cotton ring spinning frames by three-phase commutator motors.

Fig. 16. — Individual drive of double sided wool ring spinning frames by three-phase commutator motors type PD, with built-on delta-star change-over switch for wide range of regulation.

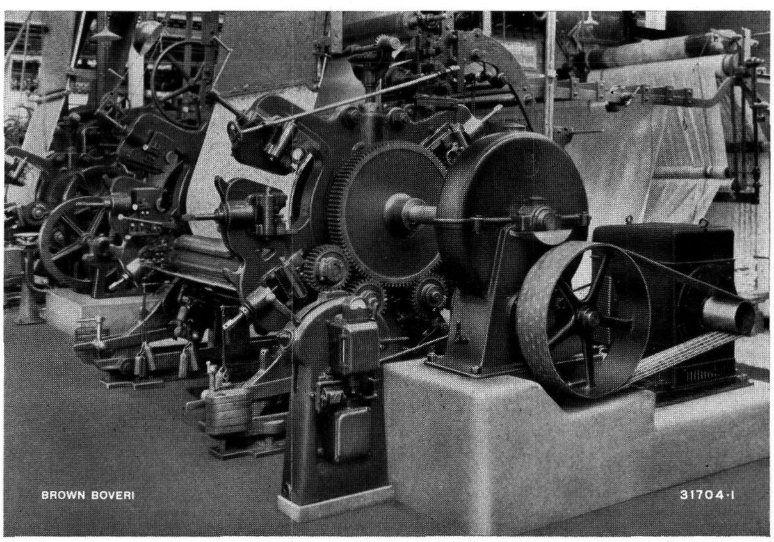

Fig. 18. — Drive of a cloth printing machine by a three-phase commutator motor, type PR 144 i, with control stand.

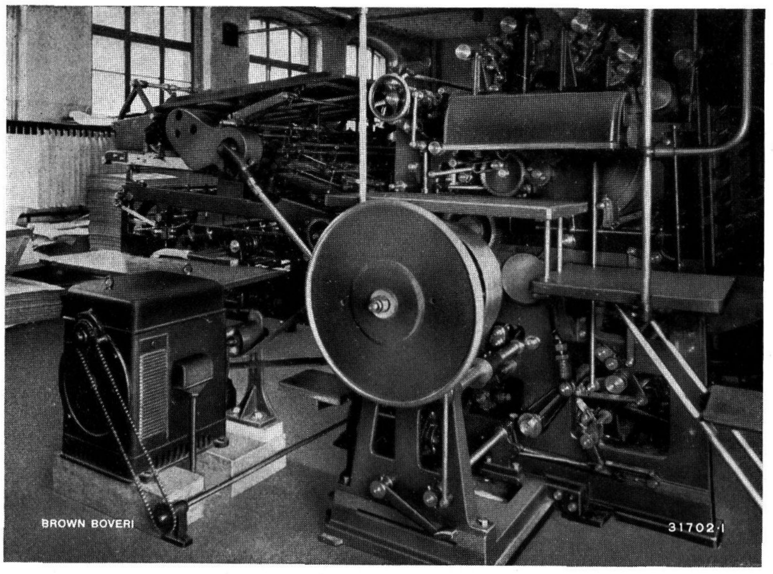

Fig. 19. — Drive of an offset printing machine by a three-phase commutator motor, type PR 126 i, with control rods.

(12) *Efficiency and power factor.* The three-phase commutator motor with series characteristic, compared with other kinds of commutator motors, is distinguished by a particularly high efficiency and power factor. The favourable values of the efficiency, which remains very high over a wide range, can be seen from the curve in Fig. 13. Fig. 14 shows the power factor, which approaches unity in the range above synchronous speed. Therefore when such motors of suitable power are used and operate with a large brush displacement, they produce a very favourable load on the mains. They also guarantee the greatest economy, both as regards the active current and the reactive current.

(13) *Starting and speed regulation.* — Further, with regard to starting conditions these motors have qualities which are very valuable for most applications. The starting torque is high and can rise to 2·5 times the torque at synchronous speed, while the starting current does not rise above a value 1·8 times the normal current at synchronous speed. Further, the complete operation of starting from rest up to the desired working speed is controlled by displacing the brushes, and according to the demands of the drive can be made as gentle as is required. This is frequently a great advantage, and shows the superiority of the series motor over motors with shunt characteristic. The starting from rest of the latter type, up to the lower limit of the range of speeds which are regulated by displacing the brushes,

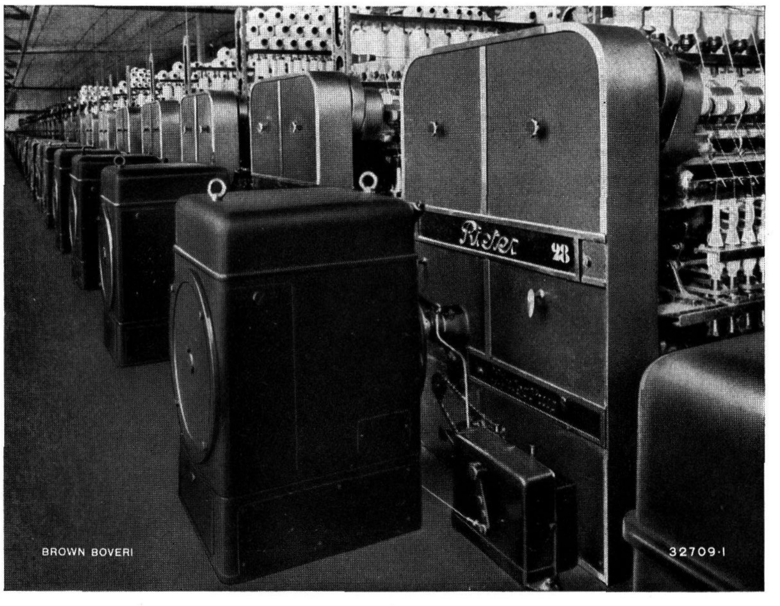

Fig. 20. — Drive of cotton ring spinning frames by three-phase commutator motors type PD 126.

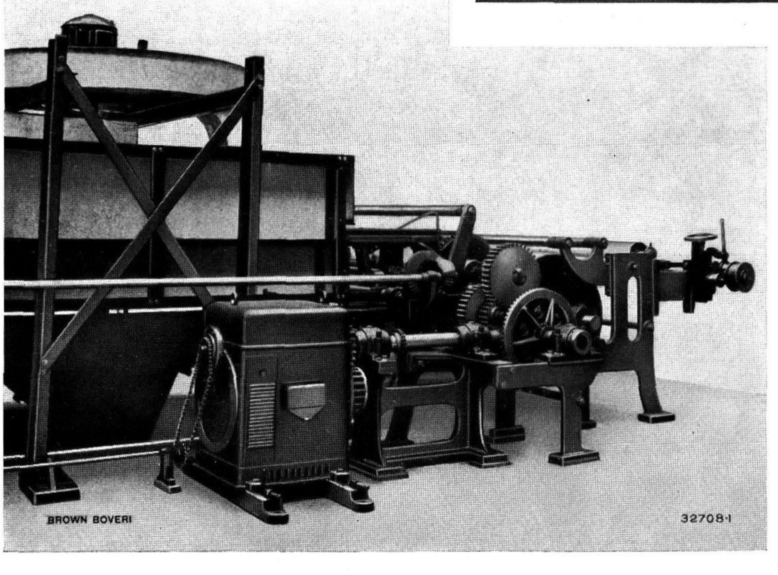

Fig. 21. — Drive of a stentering frame by a commutator motor type PR 116 with cast-iron pedestal and control.

is effected suddenly, as in the case of squirrel-cage motors, and can be controlled only by means of starting resistances.

If the brushes of the motors under consideration here are displaced from the zero position, the built-in stator switch is first of all compulsorily closed and the motor takes only a small current of a value about $^1/_4$ of the normal current. If the brushes are further displaced, the torque and current steadily increase and the motor is started. By further displacing the brushes from the zero position, the speed can be regulated gradually and without shocks up to its maximum value, about 25 % above the synchronous speed. By bringing the brushes nearer to the zero position the speed is again lowered. Continuous running is, however, possible only within certain limits, since the commutation imposes an upper limit, while a lower limit is imposed by the increased temperature rise caused by diminished ventilation. The speeds between these limits, viz., as already mentioned, usually between 0·6 and 1·25 times the synchronous speed, are described as the range of regulation of the motor.

Fig. 22. — Drive of cotton twisting frames by three-phase commutator motors, type PD 126.

(14) *Extension of the range of regulation.* It can be seen from Fig. 14 that for a large displacement of the brushes the power factor approaches unity, but sinks to a smaller value when the speed and required output are low, i.e., when the motor is operating with a small brush displacement. As can be further seen from Fig. 12 the torque changes with the brush displacement, but remains nearly constant over the lower range of speed with small brush displacement. Since the driving torque required by most machines does not noticeably alter with the speed, it may be difficult to keep the motor running at a constant speed with a small brush displacement, i. e., at low speeds and low outputs. If, therefore, motors are required to operate much below synchronous speed, it is advisable to arrange them for changing over from delta to star connections. At high speeds the motor runs with delta connections, and at lower speeds, i. e., with smaller brush displacement, it is switched over to star connections. In this way the output of the motor is lowered, and, in order to maintain a certain torque at a given speed, a larger brush displacement is required than before changing the connections. Thus the favourable relationship between driving and load torque is re-established, and at the same time a higher efficiency and considerably better power factor are attained for the motor. In this manner an extension of the range of regulation can be obtained down to 0·4 times the synchronous speed with sufficient speed stability and good power factor (Fig. 15). By this method of changing over the connections, it may be considered, to a certain extent, that two motors of different output are available. It is, however, necessary that the load should decrease sufficiently with the speed to render the weakening of the motor admissible.

The switching over may be effected while running, but only after the brushes have been brought back to the zero position, so that a large current rush is avoided. Brown, Boveri & Co. have protected by patent an arrangement where the change-over switch is fixed on a control stand, and compulsorily operated in combination with the brush control in such a manner that the change from delta to star connections is effected without change of speed.

To sum up, it may be said that the new motors, while retaining the excellent electrical features of the previous series, have undergone a number of constructional improvements, so that they can be operated more simply and require less attention. It is therefore to be expected that the new three-phase commutator motors, of which a large number are already in service, will be used for industrial purposes in still greater numbers than their predecessors.

(MS 649) *M. Mogensen. (R. O. P.)*

A PORTABLE RECTIFIER SUBSTATION FOR THE ITALIAN STATE RAILWAYS.

Decimal index 621. 316. 264:621. 33 (45).

THE description published in The Brown Boveri Review, 1930, No. 7, of the electrification of main and secondary railways in Italy with high-tension direct current, contains particulars of those sections of the Italian State Railways which have been electrified with this system, or the electrification of which has been decided upon and is already in hand.

The Italian State Railways electrified a number of sections in Northern Italy with three-phase current at $16^2/_3$ cycles, whereas in Southern Italy, direct current of 3000 V contact-wire pressure was chosen for the Benevento-Foggia line. The service results obtained on this trial section, which were favourable in every respect, provided an inducement to extend the electrification from Benevento to Naples with high-tension direct current. Electric traction will probably be introduced on the latter section of line during the course of this year. It remains to be mentioned that the Italian State Railways intend to electrify other important sections, where the traffic is heavy, with the same system. Among these are the main lines between Bologna and Florence as well as between Rome and Naples.

As was already mentioned in The Brown Boveri Review, 1930, No. 7, rectifiers will be used exclusively as converters for those sections of the Italian State Railways which are to be electrified with high-tension direct current. This is due to the satisfactory results obtained with rectifiers, and also because of the paramount advantages offered by this type of converter as compared with the rotary type. The rectifier substations are to be equipped with 2000-kW sets. The average distance between the substations, which are to be provided with from two to four rectifier sets, will be about 25 km. On the primary side the rectifier sets are fed with 60,000-V three-phase current.

For the three-phase electrified sections of line, the Italian State Railways possess a number of portable substations to increase the output of the converter sets installed in buildings along the railway or in the open. In the event of a disturbance they can also be used to replace the unit which is temporarily out of commission. These portable substations have given every satisfaction and have proved very suitable for railway service. It has therefore been possible to reduce the number of stand-by sets to a minimum by improving the load factor.

The output of a substation must be sufficient for the greatest traffic load even if this occurs only temporarily or rarely. The provision of portable sets enables the output of stationary converter substations to be raised, if the output of the substation should be insufficient at certain times. The peak outputs, which occur periodically or only in exceptional cases, are provided for by the portable substations. It is thus possible to construct smaller buildings for the stationary converter sets, and to reduce proportionately the cost of construction.

Because of the satisfactory results obtained with portable substations on the sections fed with three-phase current, the Italian State Railways have decided to provide portable substations for the railways already supplied with high-tension direct current and also for those still to be electrified with this system.

It might be mentioned here that only with the introduction of the rectifier as a converter for the electrification of railways was it possible to design and equip portable substations for large outputs. The equipment of such a plant with a motor generator (which alone comes into consideration for pressures of 3000 V) would have been possible only by the choice of a small output. The space required and the weight of a motor generator set of 2000 kW output, (which was the output chosen for all the sets), would not have permitted the construction of the portable substation. The installation of rectifier sets, on the contrary, simplified the solution of the problem.

Based on the portable substations already built by their associated company in Camden (two portable substations for the tramway service of the City of Calgary, Canada) and also on the numerous designs of rectifiers erected for different railways, Brown, Boveri & Co. put forward a proposal for a similar plant for the Italian State Railways. Intensive study was devoted to the solution of this problem. The results of the investigations were favourable, and the proposal was approved by the Italian State Railways, who recently placed an order with the Tecnomasio Italiano Brown Boveri, Milan, for the complete equipment of two portable rectifier substations.

The data of the rectifier substations to be delivered are as follows: —

Gauge	1445 mm
Length of truck over buffers . . .	16,900 mm
Maximum height (at the transformer) .	4280 mm
Maximum width	2990 mm
Distance between bogie pivots . . .	11,300 mm
Diameter of wheels	850 mm
Weight of truck without electric equipment, approx.	29 tons
Weight of electric equipment, approx.	45 tons
Axial load, approx.	15 tons

The electric equipment of the portable substation comprises a rectifier set consisting of:—

1 outdoor rectifier transformer of special design with natural cooling, for connection to 60 kV, 45 cycles.

1 rectifier type HA 612 c of special design:

Output	2000 kW
D.-C. pressure at full load	2900 V

Overload capacity: 20 % for 2 hours
50 % for 1 hour
100 % for 2 minutes.

1 combined closed-circuit cooling set, for cooling the rectifier and high-vacuum pump.

The high-tension apparatus and the rectifier transformer are of the outdoor type, while the rectifier, the closed-circuit cooling set and the d.-c. apparatus are arranged in the cabin on the truck. Since the primary pressure is very high (up to 66,000 V) and only limited space is available, the design of the high-tension apparatus and transformer was particularly difficult. By providing a three-pole oil switch of suitable design, by conveniently arranging the transformer terminals, and also by devoting considerable study to the erection of the transformer, it was possible to arrange the apparatus in the limited space available. The arrangement is shown in Fig. 1, so that a detailed description is unnecessary.

The rectifier was fitted with a preliminary and high-vacuum pump. Since the cylinder and pump form one unit, no leakages can occur into the vacuum pipes due to vibration during transport. It is thus possible to put the set at once into use, even after a long journey. The construction of the rectifier differs essentially from that of the normal equipment. An iron framework on the floor of the truck is supported on impregnated wood insulators. In order, as far as possible, to damp the vibration of the cylinder during transport, the cylinder is supported on springs which permit a certain amount of play in both vertical and horizontal directions. The spring support of special design is fixed on the iron framework already mentioned, and is shown in Fig. 2. All the connections between rectifier, transformer, d.-c. bus-bars and auxiliary apparatus are of cable or flexible copper wires, so that movement of individual parts of the apparatus in any direction is not interfered with. Rubber tubes were used to connect the rectifier to the closed-circuit cooling set. The ignition and excitation set is mounted beside the rectifier. The closed-circuit cooling set was provided, as usual, with two ribbed coolers, so that the rectifier and the high-vacuum mercury-vapour pump can be cooled separately. The water in both ribbed coolers is cooled by one fan. Louvred openings for the passage of air were constructed in the sides of the cabin.

The high-speed circuit breaker and all parts of the apparatus under d.-c. pressure (resistance for leakage indicator, contactors, relays, etc.) were arranged in an iron framework as shown in Fig. 1, elevation, plan and sectional elevation EE. An insulating bushing and a strain insulator on the roof of the cabin connect the substation to the contact wire.

At the d.-c. end of the truck there is a control room containing the switchboard with measuring instruments, control gear and switching apparatus for automatic operation. Section FF (Fig. 1) shows the operating switchboard.

The rectifier, the closed-circuit cooling set and the d.-c. apparatus are distributed in the available space on the truck, so that complete component parts of the plant are easily accessible for inspection. Since rectifier, closed-circuit cooling set, ignition and excitation device, etc., are under the full d.-c. pressure, the space in which they are erected is entirely separated from the control room. Visits of supervision and inspection should be made only when the apparatus is not under pressure.

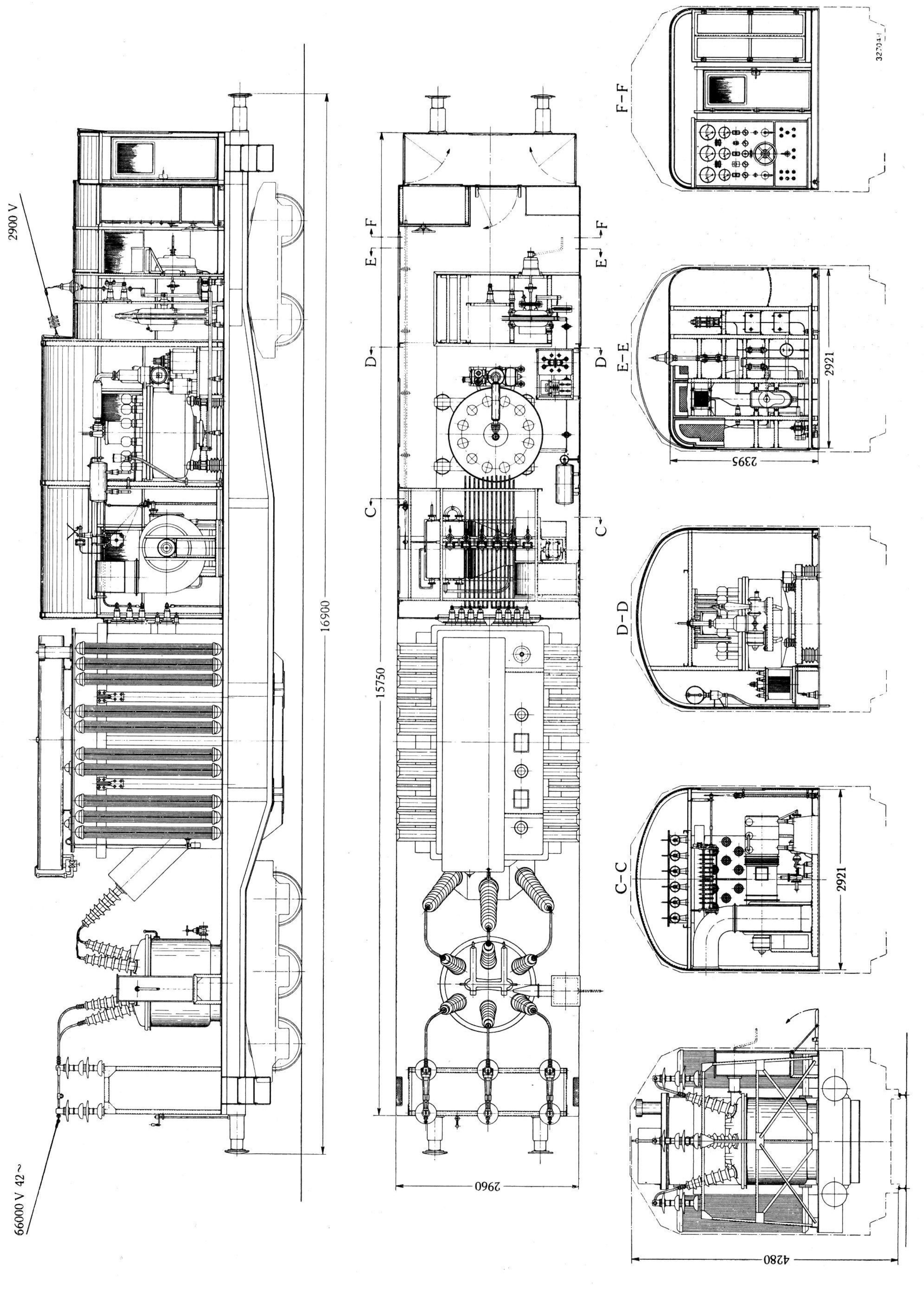

Fig. 1. — Plan, elevation and sectional elevations of the portable rectifier substation for the Italian State Railways.

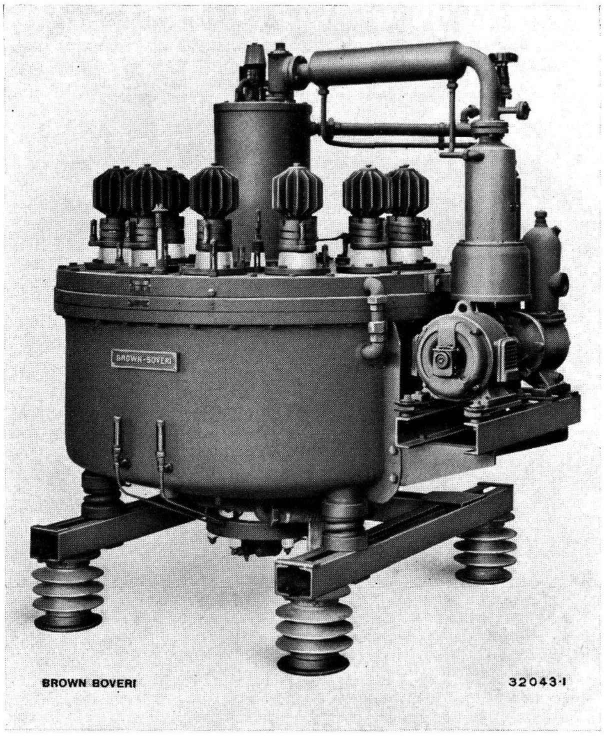

Fig. 2. — Rectifier type HA 612 c with built-on air pump set and spring support.

For protection purposes the rectifier was equipped on the primary side with a three-pole oil circuit breaker, and on the d.-c. side with a high-speed circuit breaker. The oil circuit breaker has a built-in current transformer which feeds the over-current relay. It is opened by a tripping coil when the over-current relay operates, the coil being fed by an accumulator battery. The cathode high-speed circuit breaker which, at the same time, acts as feeder switch, is fitted with an overcurrent relay. Should a short circuit occur in the network, only the high-speed circuit breaker trips, while the oil circuit breaker, on account of its somewhat longer tripping time, remains closed. On the d.-c. side a reverse current relay has also been provided, which operates under a reverse current of about 10 % of the normal current. By the installation of the reverse current relay, certain tripping is ensured in the case of an internal short circuit, even if the short-circuit current on the d.-c. side should be less than the normal current. Fig. 3 shows the diagram of connections of the over current and reverse current protective devices provided for this portable plant.

Fig. 3 also shows the simplified diagram of connections of the alarm device. The control apparatus for automatic operation is indicated by Nos. 10, 11 and 12. Alarm is given: —

(1) When the oil circuit breaker is locked out, should the attemped reclosing be unsuccessful (by control apparatus 10).

(2) When the high-speed circuit breaker is locked out, if the contact wire leakage indicator remains ineffective, or if the excitation does not function properly, when the rectifier set is put into operation (by control apparatus 11).

(3) When the substation is locked out because of an excessively high temperature on the rectifier or because of a poor vacuum (by control apparatus 10).

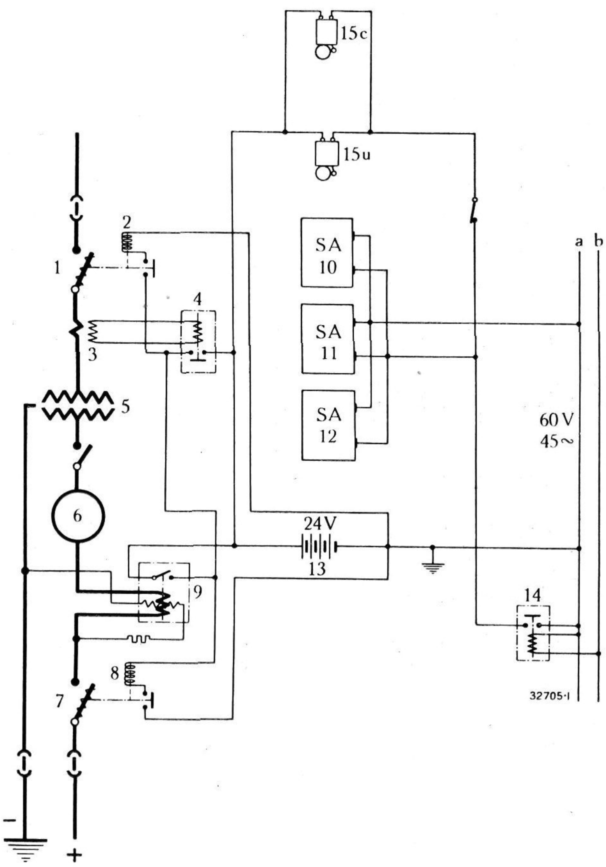

Fig. 3. — Diagram of connections of the over-current and reverse-current protective relays and the alarm device.

1. Three-pole oil circuit breaker.
2. Oil circuit breaker tripping coil.
3. Current transformer built into oil circuit breaker.
4. Over-current relay.
5. Outdoor rectifier transformer.
6. Rectifier type HA 612 c.
7. D.-C. high-speed circuit breaker with over-current release.
8. Tripping coil on the high-speed switch.
9. Polarized reverse-current relay.
10. Control gear for inserting the oil circuit breaker.
11. Control gear for testing for earth faults.
12. Control gear for the air pump set.
13. Battery.
14. No-volt relay.

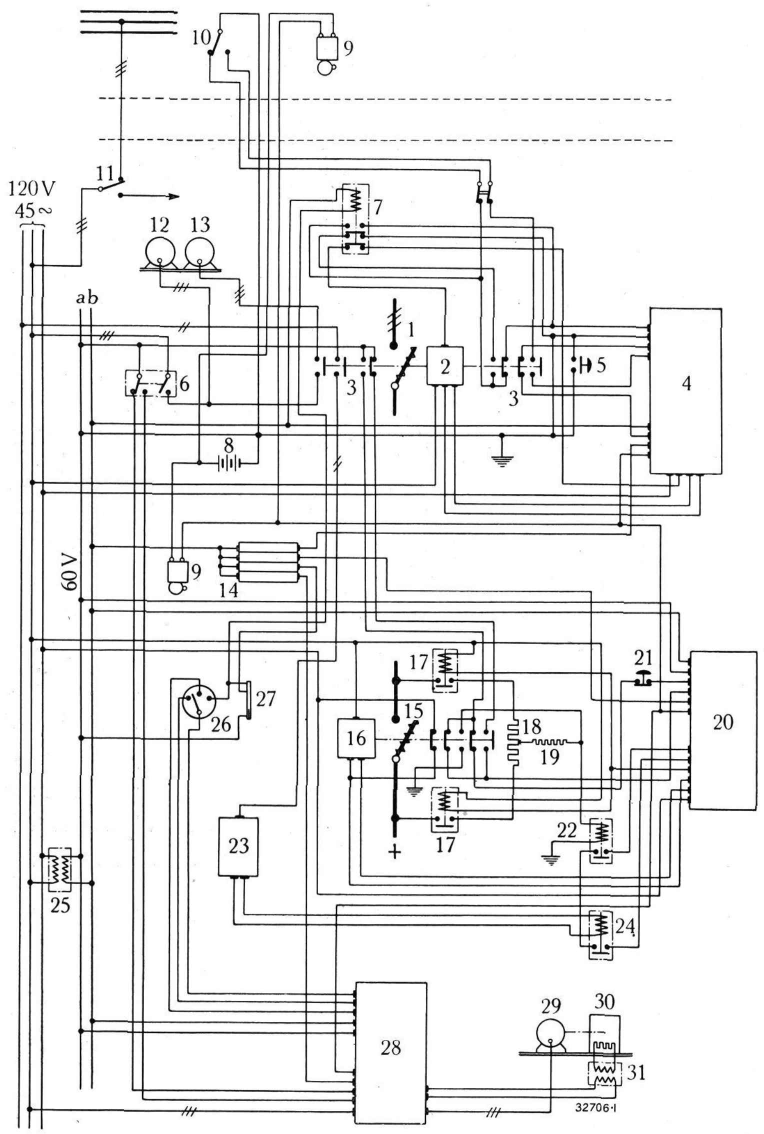

Fig. 4. — Simplified diagram of connections for automatic operation of the portable substation.

1. Three-pole oil circuit breaker.
2. Motor drive.
3. Drum-type switch.
4. Control gear type 10.
5. Tripping push-button.
6. Switchbox with thermal release.
7. Interlocking relay.
8. Battery.
9. Alarm bell.
10. Remote control switch.
11. Three-pole change-over switch.
12. Driving motor of pump of the closed-circuit cooling set.
13. Driving motor of fan of the closed-circuit cooling set.
14. Signalling panel.
15. D.-C. high-speed circuit breaker with over-current release.
16. Motor drive.
17. Leakage testing contactor.
18. Bridging resistance.
19. Bridging resistance.
20. Control gear type 11.
21. Tripping push-button.
22. Earth fault testing relay.
23. Ignition and excitation set.
24. Control relay.
25. Auxiliary transformer.
26. Vacuum gauge.
27. Contact thermometer on the rectifier.
28. Control gear type 12.
29. Driving motor for preliminary vacuum pump.
30. High-vacuum pump.
31. Insulating transformer.

(4) Should the current supply to the high-vacuum pump be interrupted, or the cooling become inoperative (by control apparatus 12).

(5) If the 60-V auxiliary pressure for feeding the different pieces of control apparatus fails (by no-volt relay 14).

One of the two alarm bells is installed in the control room from which the substation is remote controlled.

A three-phase auxiliary current supply of 120 V, 45 cycles, is available for feeding the various auxiliary appliances (ignition and excitation device, air pump plant, closed-circuit cooling set, etc.). Because of the high primary pressure and the space available, it was not possible to build an auxiliary transformer on the truck itself. The problem was solved in the following manner: If the portable plant is operating near a stationary substation, the auxiliary services are fed from this station. In this case the rectifier operates entirely automatically. If, on the contrary, the portable plant is set up where there is no substation, the auxiliary services are fed from the secondary side of the rectifier transformer. In this case, since no auxiliary pressure exists when opening the oil circuit breaker (except the d.-c. auxiliary pressure of the battery for alarm and tripping), the automatic operation of the rectifier set had to be confined to the d.-c. side. The breaker is closed by hand. By means of change-over switch 11 (Fig. 4) the 120-V *auxiliary* bus-bars of the substation can be connected, according to requirements, to the secondary side of the main transformer (auxiliary winding) or to the auxiliary supply of a substation in the neighbourhood.

Special control apparatus was used for the automatic operation of the rectifier set. The diagram of the automatic control gear is shown in Fig. 4. For controlling the oil circuit breaker, control gear type 10 (item 4) is used, that is, it carries out the closing and opening commands given to the rectifier set by

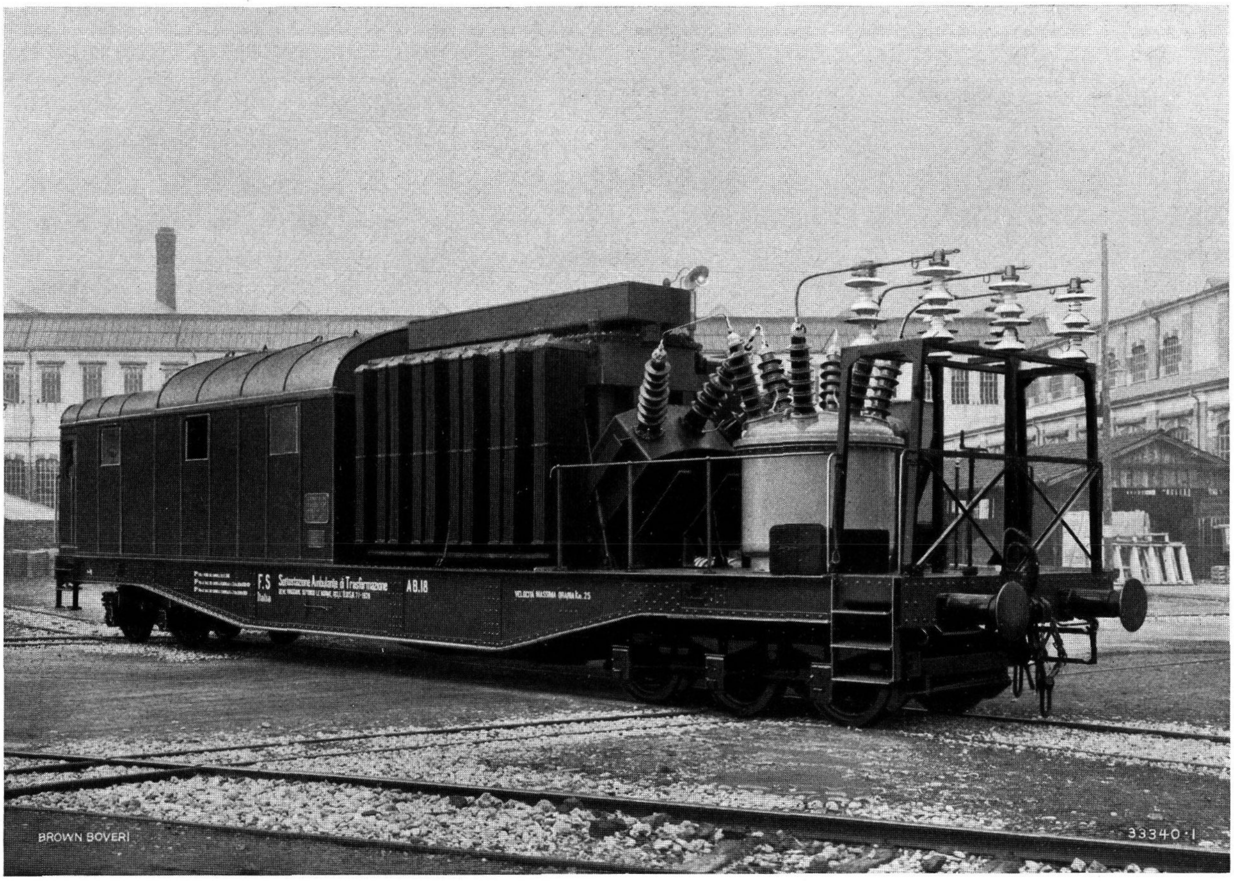

Fig. 5. — Portable rectifier substation for the Italian State Railways.

the control switch in the control room. If, after three trials, the closing command cannot be carried out, the switch is locked out and at the same time an alarm signal is given. Contacts on the drum-type switch 3, which is mechanically connected to the oil circuit breaker, effect the energizing of the ignition and excitation plant 23, when the rectifier set is switched in on the primary side. At the same time a closing command is transmitted to the high-speed circuit breaker. After the closing command has been given, control gear type 11 (item 20) is used to test whether the resistance in the network will permit the closing of the high-speed circuit breaker. If an earth fault prevails longer than a certain time, the high-speed circuit breaker is locked out after several unsuccessful trials. Resistances 18 and 19 and relay 22 are used to test the earth fault. Relay 24, the coil of which lies in the excitation circuit, prevents the d.-c. switch from being closed if the excitation is not working properly. The locking out of the rectifier set if the temperature at the anode plate becomes too high or the vacuum too bad, is effected by relay 7 which is provided with a locking device when in the attracted position. In this case, control gear 4 turns until it reaches the interlocking position, and thus causes both breakers to trip, at the same time signalling the disturbance. Control gear type 12 (item 28) controls the automatic operation of the air pump set. The motors of the closed circuit cooling set are protected by a switchbox with thermal release. The water circulating pump remains continuously in service, while the fan is switched in and out with the rectifier set. Auxiliary contacts on the switchbox cause the alarm to sound, by means of control apparatus 28, when the switch is tripped. Item 14 shows the signalling panel from which can be seen the nature of the disturbance causing the alarm.

The two portable substations for the Italian State Railways are to be put into operation in the first half of the current year. Full particulars of the results of operation will be given after they have been put into service.

(MS 652) *A. Greco. (R. O. P.)*

OVERSPEED TESTS ON THE POLE-WHEEL OF THE FIRST ALTERNATOR FOR RYBURG-SCHWÖRSTADT POWER STATION.

Decimal index 621. 313. 322. 0014.

BROWN, BOVERI & CO., jointly with Brown, Boveri & Co. A.-G., Mannheim, received the order for four vertical-shaft alternators for the Ryburg-Schwörstadt Power Station of the Kraftwerk Ryburg-Schwörstadt A.-G. Each alternator has a rating of 32,500 kVA at 10,500 V $\pm$ 6 %, 1790 A, a power factor of 0·7, 50 cycles, 75 r. p. m.[1]

Since, as regards size, weight and flywheel effect this is the largest slow running type three-phase alternator that has ever been built, it will be of interest to learn the details of the overspeed tests which were carried out on the double pole-wheel of this machine.

The alternators of this hydro-electric power station are direct-coupled to modern Kaplan turbines. The latter have a runaway speed which, from tests on models, is expected to be about 2·4 times the normal speed. The alternator pole-wheel, which, when working normally, runs at 75 r. p. m., had therefore to be tested at 185 r. p. m.

During the overspeed test the circumferential speed of the pole-wheel attains 91 m/sec. The pole-wheel has a flywheel effect of 12,500,000 kgm^2, and, at this speed, its kinetic energy is 60,000,000 mkg.

It is obvious that for carrying out the overspeed tests on this gigantic wheel extensive preparations and corresponding equipment were necessary.

The pole-wheel, 9400 mm in diameter and 2015 mm wide, was built and tested on the erection pit in the large erecting shop[2] (Fig. 1). The driving motor used was a 2$\times$2500-kW double armature d.-c. motor of the new regenerative set of the Brown Boveri rectifier testing department. The existing conditions, the possibility of using the above named motor, and simplification of the construction of the complete testing equipment made it necessary to arrange the pole-wheel horizontally. The latter was supported by horizontal bearings made purposely for these tests, and direct driven through an intermediate shaft with special coupling. In order to make it easier to start up the pole-wheel in these heavily loaded bearings, the shaft was floated on oil under a high pressure. A three-stage high-pressure pump for a maximum pressure of 300 kg/cm^2 delivered the oil at the required pressure. While running, special attention had to be given to the lubrication of these bearings. In order to ensure that oil would be supplied to the bearings under all circumstances, a system of lubrication independent of the pump was employed. From a reservoir containing over 5000 litres, oil flowed under static pressure to the bearings, which had no oil rings. From the bearings the oil flowed into a low lying reservoir on the bottom of the erection pit. After each test the oil was again pumped into the upper reservoir. The quantity of oil named would have been ample to allow the pole-wheel to run until it came to rest without braking, if for any reason it became impossible to use the brake. For safety's sake the bearings were fitted with water cooling, which, however, was not used in the over-speed tests. For checking the temperature of the bearings, thermo-elements were built at different places into the bearing shells. The temperature of the oil flowing to and from the bearings was measured in the same manner. The mechanical behaviour of the bearings, i. e., the amount of vibration, was recorded by a registering vibroscope. The speed was measured by means of a separately excited tachometer dynamo, and a specially adjusted precision voltmeter. All these measuring points could be supervised from the control point.

To reduce the air losses of the pole-wheel it was surrounded by a wooden casing. In order that this casing could sustain the air pressure, which was calculated and measured during the overspeed tests to be about 500 kg/m^2, it was supported by beams, rolled-steel sections and framework, and moreover, firmly fixed on all sides by strong tie-rods to prevent movement and vibration. Suitable openings in the casing kept the air constantly renewed, thus preventing it becoming hot enough to endanger the wooden casing. Fig. 2 shows the pole-wheel with casing and also the driving motor.

The connections of the electric drive are shown diagrammatically in Fig. 3. Motor 1 driving the pole-wheel was fed by the generators 2 on the Ward Leonard system. This method of drive permitted a delicate adjustment of the speed, and allowed a large amount of energy to be recuperated when braking

[1] See The Brown Boveri Review, 1929, No. 11, p. 311, for particulars of the design, the most important dimensions and data.

[2] See The Brown Boveri Review, 1930, No. 3, p. 120.

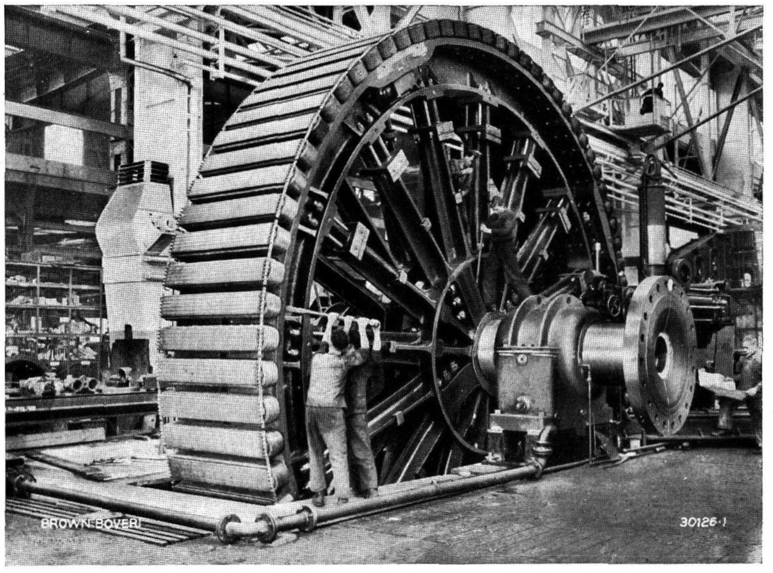

Fig. 1. — Pole-wheel on the erection pit during construction.

electrically. Both generators were driven by a synchronous motor, connected to an 8000-V network. Motor 1 and the generators 2 were excited by a separately arranged d.-c. machine 3. A change in the direction of rotation, as was necessary when balancing the pole-wheel, was effected by reversing the field of the generators 2 by means of the change-over switch 4.

Motor 1 was separately excited by a constant current. The main current delivered from the generators 2 was adjusted to the required value by regulating the pressure at the generators. In this manner the required adjustment of the speed of the pole-wheel was simply effected. If the pole-wheel were revolving at a certain speed, and it was desired to brake or to stop it, it was necessary only to reduce the excitation of the generator. In this way motor 1 became the feeding generator and the generators 2 worked back on to the 8000-V network through the synchronous motor.

The normal rating of the motor-generator set, viz. 2×900 kW, was much less than that of motor 1, viz. 2×2500 kW. In order, therefore, to protect the former from dangerous overloads and to ensure reliable operation, two polarized overcurrent relays 7 were installed in the main leads between motor and generators. One relay limited the current in the normal direction, the other the reverse current. Assuming a 100 % permissible overload for the generators, it followed that with an operating pressure of 600 V the relays had to trip a current of 6000 A. In the case of a short in the main circuit of the machines, or of a flash-over at the commutators, etc., these relays caused the no-volt relay 8 of the circuit-breaker 5 in the main excitation circuit to operate. In this way the main machines 1 and 2 were de-excited as quickly as possible. Moreover, by means of an emergency switch 6, de-excitation could be arbitrarily effected at any time. It was possible, besides, to separate the two sets of machines 1 and 2 by means of a remote controlled main current circuit breaker. This circuit breaker was also used for paralleling the generators and motor.

The quickest possible de-excitation had to be provided, especially for the following case. Suppose the pole-wheel had been run up to a given speed, and that a short circuit took place in generator 2, for example, due to flashing-over at the commutator. The output of the pole-wheel would then be concentrated at the fault in the set 2, if the excitation were not switched out as quickly as possible by the reverse current relay 7 or by the emergency switch 6.

Fig. 4 shows a part of the switching and measuring apparatus, where, along with the control of all machines, remote measurements are taken.

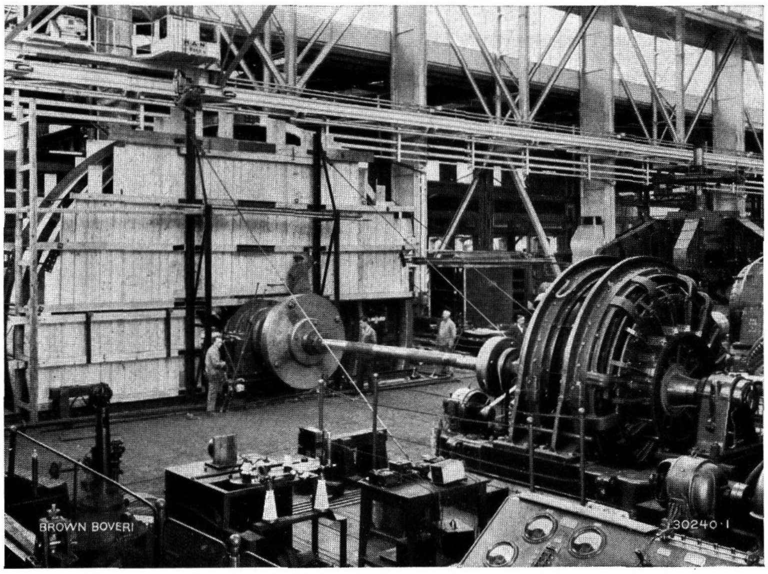

Fig. 2. — Encased pole-wheel with driving motor.

When balancing statically and dynamically a new method was employed, which will be described at some other time.

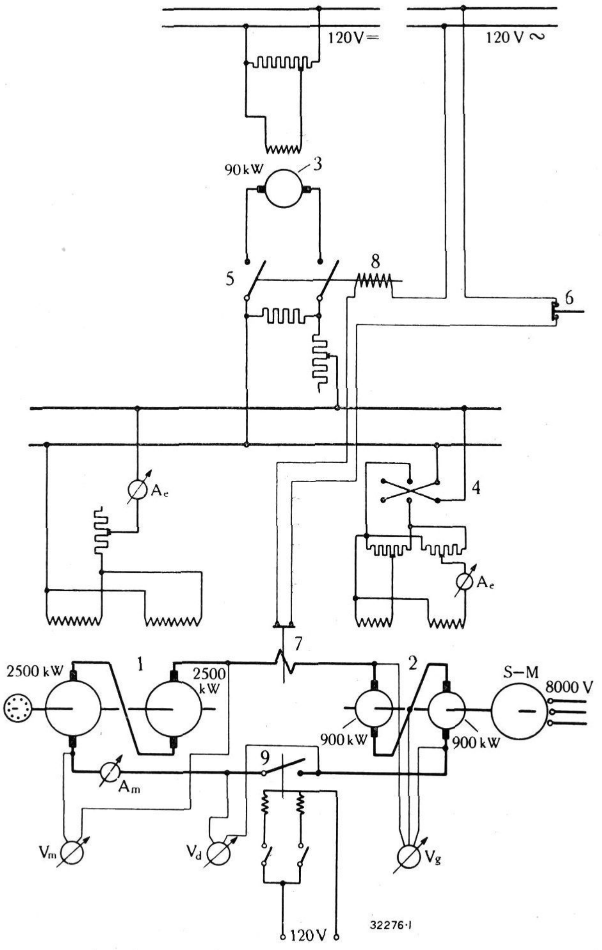

Fig. 3. — Arrangement of connections of the testing plant.

1. Double armature motor of 2×2500 kW.
2. Motor generator set of 2×900 kW.
3. Excitation generator of 90 kW.
4. Change-over switch for generator field.
5. Main switch for excitation current.
6. Emergency switch.
7. Polarized over-current relay.
8. No-volt relay.
9. Main circuit breaker.

The static and dynamic balancing having been carried out with the greatest care, the overspeed tests could then be commenced.

As with the overspeed tests of all pole-wheels made by Brown, Boveri & Co., a number of preliminary "steps" with gradually increasing speeds were also arranged in this case. With this pole-wheel the higher speed "steps" were chosen very near to one another, in order to produce only small increases of the stresses in the material. During the last five "steps", i. e., from 120 r. p. m. upwards, about 200 measurements were taken each time. The tightness of all important bolts and screws was also submitted to a careful test. The control measurements are intended to determine immediately even the smallest permanent deformations produced in the pole-wheel. These measurements refer to distances between fixed points on the following parts of the wheel-rims and hubs: the joints of the rims, which are in four parts; the joints of the parts of the hubs; in certain circumstances the play between hubs and shaft; axial distances between the hubs and the halves of the wheel; displacements of the damper windings and the connections between the coils, etc. A deformation remaining at any point on the wheel would have been discovered by these measurements. By these control measurements it was established with certainty that in no part of the wheel had the material experienced permanent deformation, either after the preliminary "steps" or after the final test which was carried out at the stipulated speed of 185 r. p. m.

These facts prove that the material had been at no point stressed beyond the elastic limit. They also offer a much better guarantee that when the machine is in service, the wheel will be able to stand the same overspeed a second and third time for a practically unlimited period, than would have been given by an overspeed test of proportionately longer duration, in which, however, the scrupulously exact measurements were omitted.

The method of overspeed testing by "steps" introduced by Brown, Boveri & Co. has proved to be very satisfactory in practice.

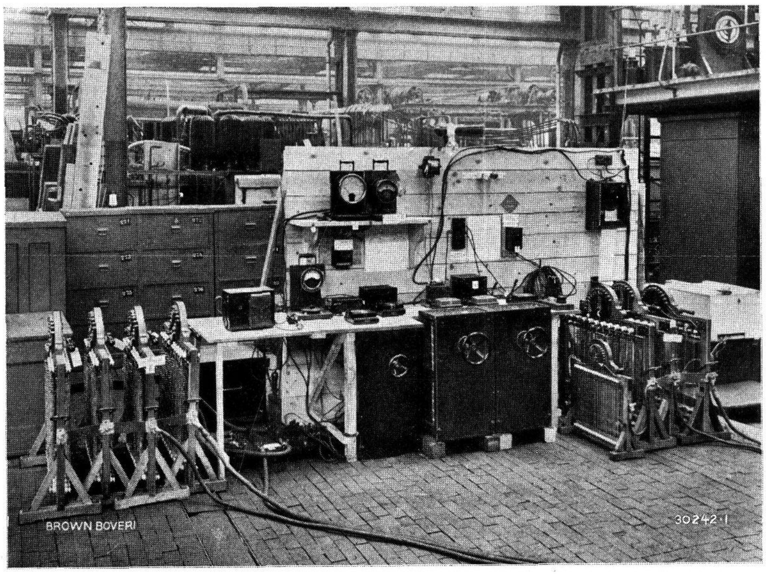

Fig. 4. — Switchgear and measuring apparatus of the overspeed testing plant.

It may be of interest to know that, at a steady speed of 185 r. p. m., the encased pole-wheel required a power of about 800 kW to drive it. If the pole-wheel had not been encased, a power about twice as great would have been required. The expensive casing thus made the driving and manœuvring of the pole-wheel much easier.

As a valuable subsidiary result of these overspeed tests, a range of experimental data was obtained, which constitute a welcome enrichment of the material at the disposal of the firm's design departments.

The tests described show that appreciable progress has recently been made in the design of large alternators, and that no special difficulties will stand in the way of further sound future developments. From what has been said, however, it can also be seen that the carrying out of works tests on large machines of such unusually great dimensions requires extensive testing apparatus and plant, such as possessed by Brown, Boveri & Co. since the completion of the new machine testing shop.

(MS 657) *K. Kupper. (R. O. P.)*

NOTES.

Motor generators for the French State Railways of Algeria.

Decimal index 621. 314. 521: 621. 33 (65).

THE Algerian Railway Administration, after exhaustive research and consideration of expert opinion on electrically-operated railways, such as the Paris-Orleans Railway, decided to electrify the Duvivier-Oued Keberid section, about 108 km in length. Direct current at 3000 V was adopted for feeding the railway network. The electrical energy is supplied from a private power station as high tension a. c. at 50 cycles, and is converted into d. c. in the railway substations of Souk-Ahras, Oued-Damous and Medjez-Sfa. For this purpose seven motor generators each with a continuous rating of 2500 kW (two-hour rating 3750 kW) were required, along with the requisite transformers and switching apparatus. Brown, Boveri & Co. obtained the order for these. The motor generators each consist of a three-phase synchronous motor and two d.-c. generators, each of 1250 kW at 1500 V. Since the railway line in the mountains reaches heights of 870 and 760 metres above sea level, the client required that the trains should be fitted with regenerative electric braking. The motor generators must therefore be capable of converting d.-c. into a.-c. The switchgear is arranged for automatic operation. The first unit of a substation is started up each day by means of a time switch adjusted according to the time table. The addition of further units, on the contrary, is effected according to the energy requirements of the network, i. e., according to the load on the motor generators already in operation.

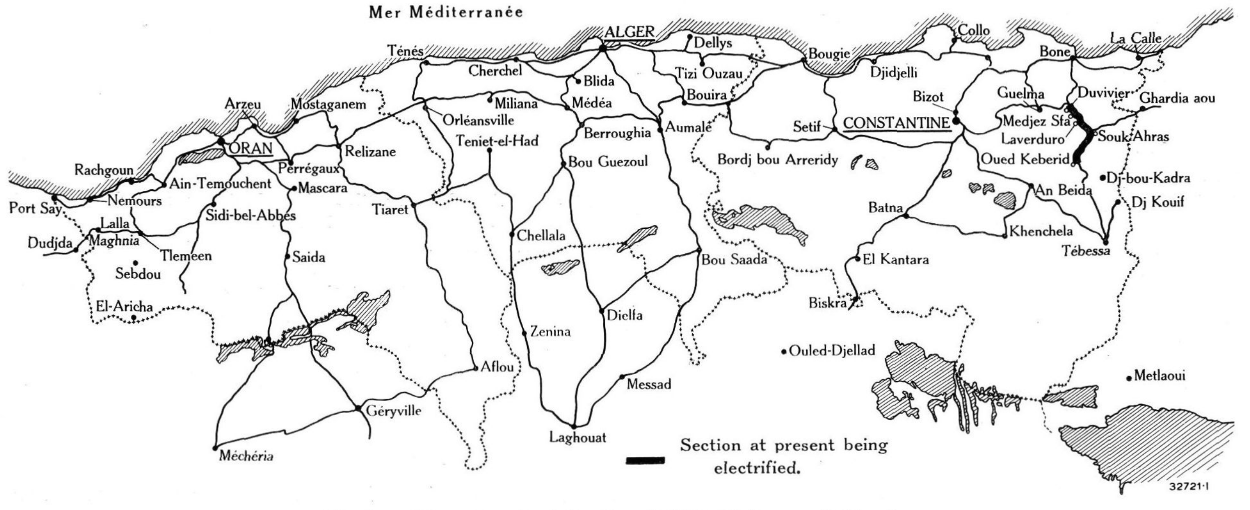

Fig. 1. — The network of the French State Railways of Algeria.

To excite the d.-c. generators and the corresponding three-phase synchronous motors, two exciters were arranged for each set of machines, one for the d.-c. generators, the other for the driving motor. In order to increase the torque of the synchronous motors when peak loads occur, the corresponding exciter is additionally excited by the current of the d.-c. network: on the other hand the exciter of the d.-c. generators is influenced by a current-limiting regulator so that the d.-c. voltage is diminished if a load of over 150 % occurs.

In designing the d.-c. machines great attention was paid to their being proof against short circuits, since they are required to feed a railway network in which repeated and heavy short circuits may occur. The short-circuit tests carried out on two motor generators already installed showed in a practical manner that the machines were short-circuit proof. Among others, 18 short-circuit tests were carried out on a motor generator with the voltage in the network rising from 2500 to 3000 V. The greatest short-circuit current at a network voltage of 3000 V indicated by an oscillograph, was about 25,000 A after about

0·02 second. In testing two motor generators connected in parallel, i. e., the equipment of a substation, a short-circuit current of 45,000 A (feeding current), at a network voltage of 3000 V, was measured after about 0·02 second. The tests carried out on the motor generators have shown that the machines delivered completely satisfy the most severe operating conditions.

(MS 672) *V. von Escher. (R. O. P.)*

Radiator batteries for large transformers.

Decimal index 621. 314. 21—714.

RADIATORS are used for cooling the oil of large transformers, but frequently, due to transport difficulties or lack of space on the transformer or erection site, they cannot be fixed to the tank and must be combined into one or two batteries. These are arranged opposite either the long or short side of the transformer, with which they are connected by suitable pipes.

Small radiator batteries are mounted directly on the tank, while large ones are mounted separately and often supported on concrete foundations as shown in Fig. 1. This arrangement has the disadvantage that the battery must be assembled and fitted on site, which necessitates special erection gear.

In other designs of large radiator batteries, the radiators are arranged on an iron framework provided with rollers. All the auxiliary equipment such as oil circulating pump with motor or, if forced air cooling is used, the fan with motor, the air conduits and switchbox can also be arranged on this framework. Fig. 2 shows a radiator battery of this description. These batteries are completely assembled in the works or in the erecting shop of the plant and brought up to the transformer on their own rollers. The height of the battery can be adjusted, by means of screws, to suit the pipe connections on the transformer tank. As a rule valves are fitted on both sides of the joints between the pipes connecting up the transformer and radiators, so that these can be separated without having to run off any oil. Expansion pieces in the connecting pipes prevent the material being too severely stressed.

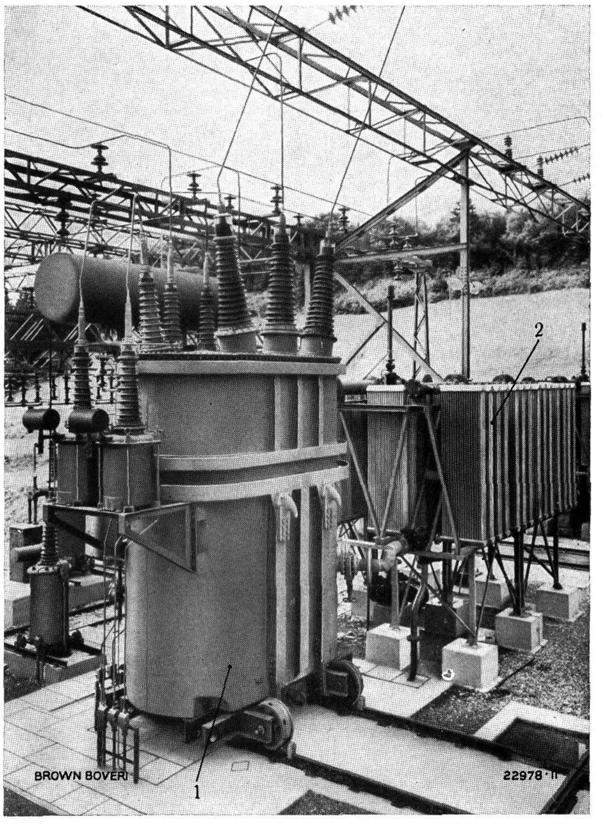

Fig. 1. — Transformer with radiator battery mounted on concrete blocks.
1. Transformer. 2. Radiator battery.

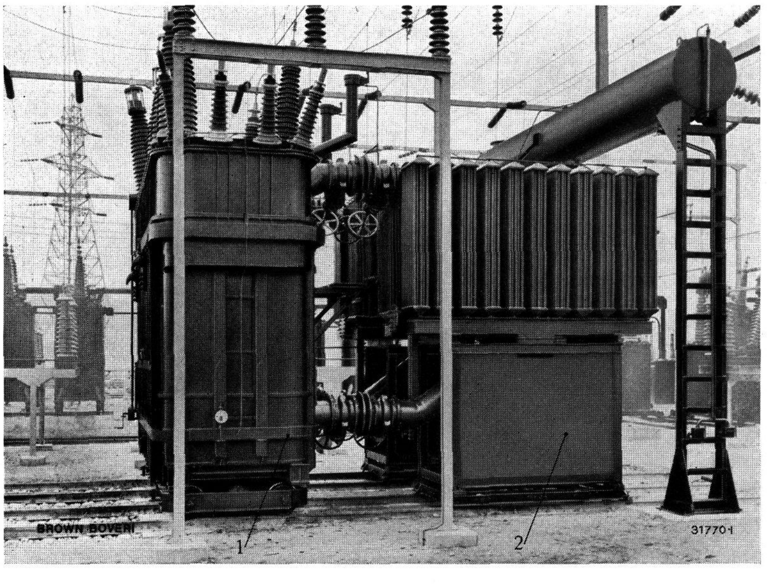

Fig. 2. — Transformer with portable radiator battery.
1. Transformer.
2. Radiator battery with forced air cooling. Fan, motor, switchbox, and air conduits mounted on portable frame.

It is advisable always to provide large transformers with two radiator batteries, whereby the following advantages are obtained:

(1) The transformer can be kept in operation on a reduced load even if one radiator battery is shut down for cleaning, etc.

(2) If the transformer is working on reduced load, the motor driving the oil circulating pump or, with forced air cooling, the fan and motor of one or both radiators can be switched off in order to save current.

The increased reliability of the transformer when equipped with a double radiator fully justifies the small additional cost. This is, moreover, quickly repaid by the saving in current.

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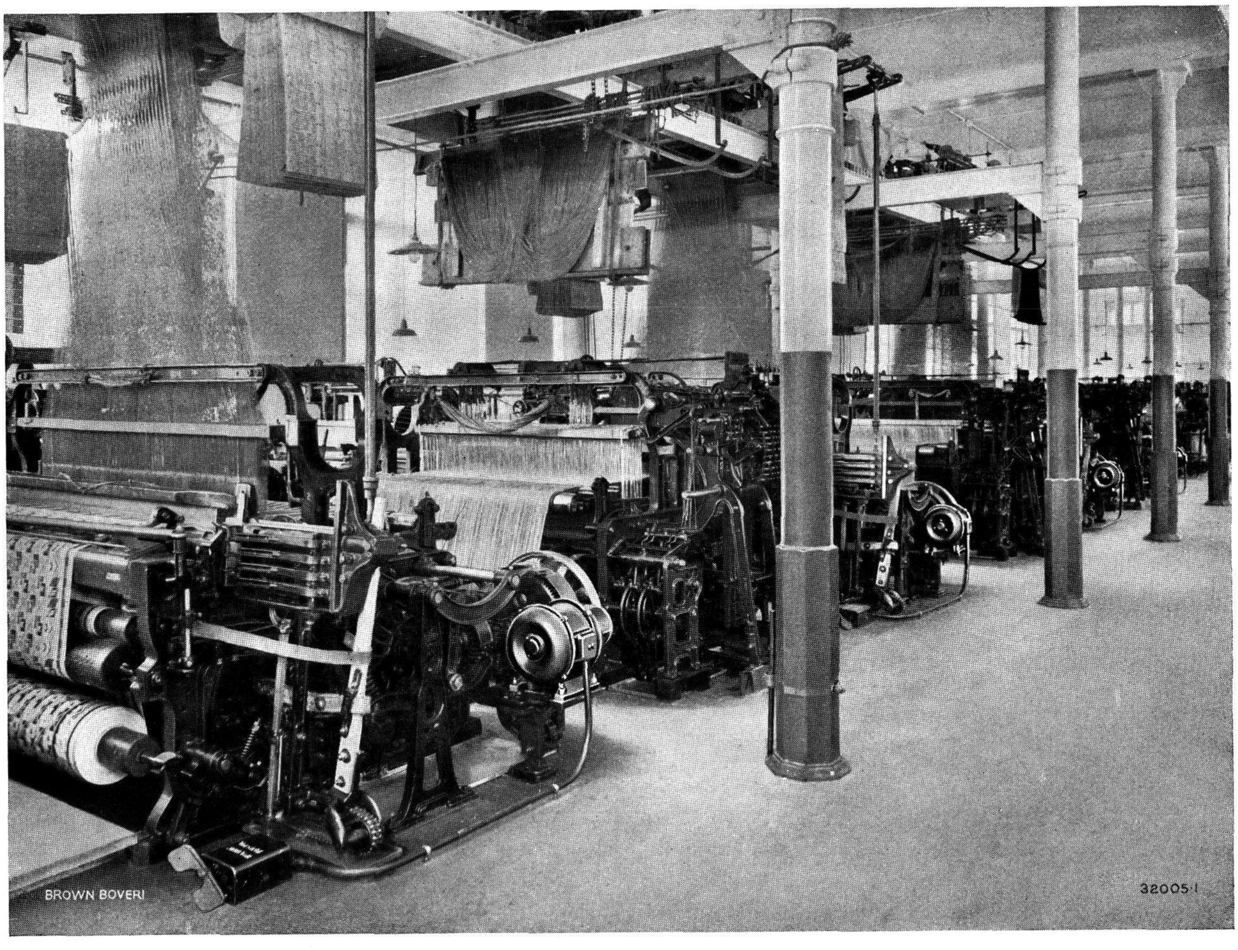
ELECTRIC DRIVES FOR INDUSTRIAL PLANTS



GEAR DRIVE OF HEAVY CLOTH LOOMS THROUGH CONTROLLED FRICTION COUPLINGS.

SPECIAL DRIVES FOR SPINNING AND TWISTING MACHINES

FLYER FRAMES - LOOMS - EMBROIDERING MACHINES

CALENDERS - FINISHING AND DYEING MACHINES