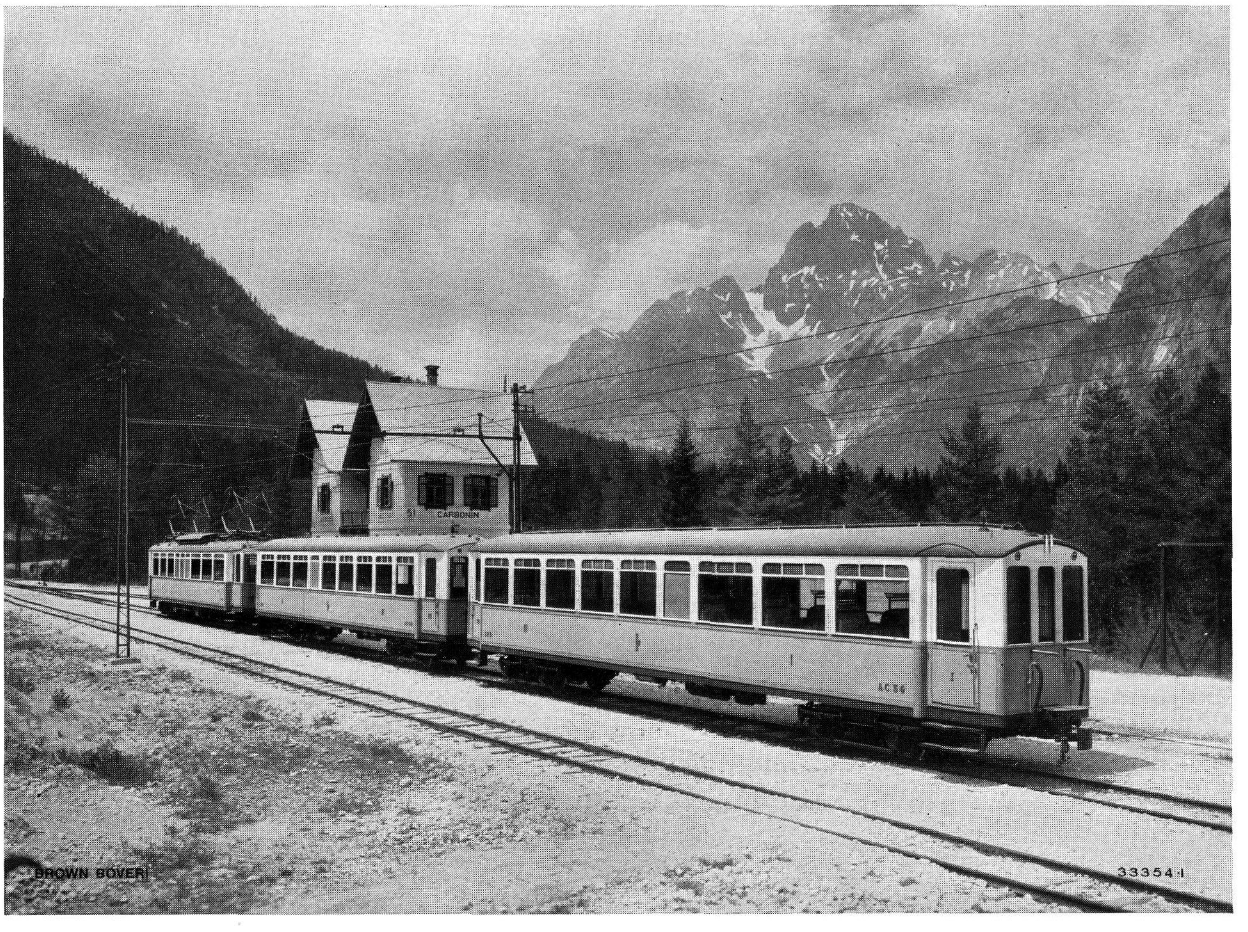
VOL. XVIII OCTOBER, 1931 No. 10

THE BROWN BOVERI REVIEW

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



THE DOLOMITES RAILWAY. PASSENGER TRAIN IN CARBONIN-MISURINA STATION (SCHLUDERBACH).

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WORKSHOPS IN BADEN, 1891.

On the 7th October, 1891,

the firm

BROWN, BOVERI & COMPANY

was entered as a joint-stock company in the commercial register of Canton Aargau.

BROWN, BOVERI & COMPANY, LIMITED

which emerged from the original firm, can therefore look back upon an existence of 40 years duration.

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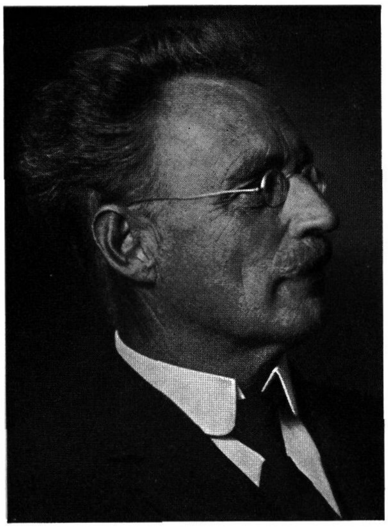

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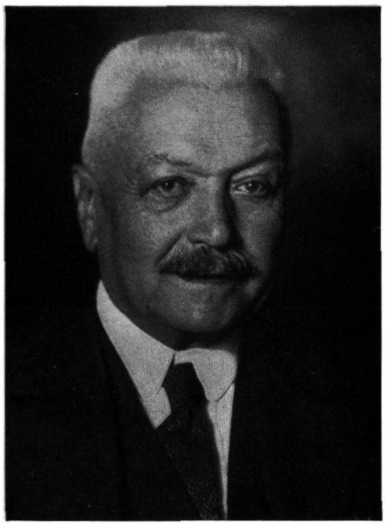

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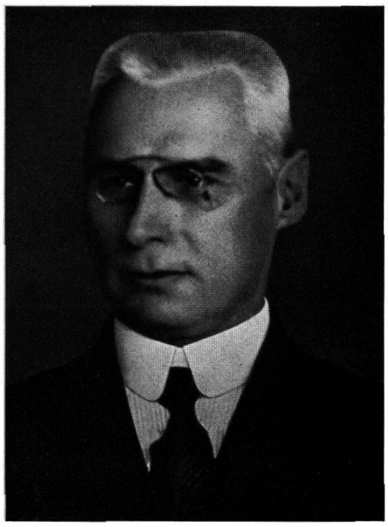

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THE BROWN BOVERI REVIEW

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

VOL. XVIII OCTOBER, 1931 No. 10

THE SWITCHGEAR OF NORE POWER STATION No. 1.

Decimal index 621.316.311:621.311 (481).

THE Norwegian Government has many waterfalls at its disposal, which can be developed at a reasonable cost, but it was only in the last few years that the Government began to deliver power for the general electricity supply of the country. Among the latest plants built for this purpose by the government authority — the Norges Vassdrags-og Elektrisitetsvesen — Nore power station No. 1, put into service in the summer of 1928, is the first large power plant.

Besides giving a short general survey, in the present article it is intended to describe some interesting details of the switchgear by which the suppliers were confronted before delivery, and which required new solutions to be found.

I. THE POWER STATION.

Nore power station No. 1 utilizes a portion — about 360 m — of the fall between Tunhövd storage dam and the Norefjord so that the tailrace of the plant forms the headrace of a plant Nore II which will be constructed later, and which will utilize the remainder of the fall — about 100 m — to the Norefjord. The regulated flow of water in the first stage amounts to about 25 m^3 per second, and by further regulation of the mountain lakes may be raised to 66 m^3 per second. This corresponds to about 240,000 H.P. turbine rating for the complete installation of Nore No. 1. This rating is divided between eight units, one of which is a spare.

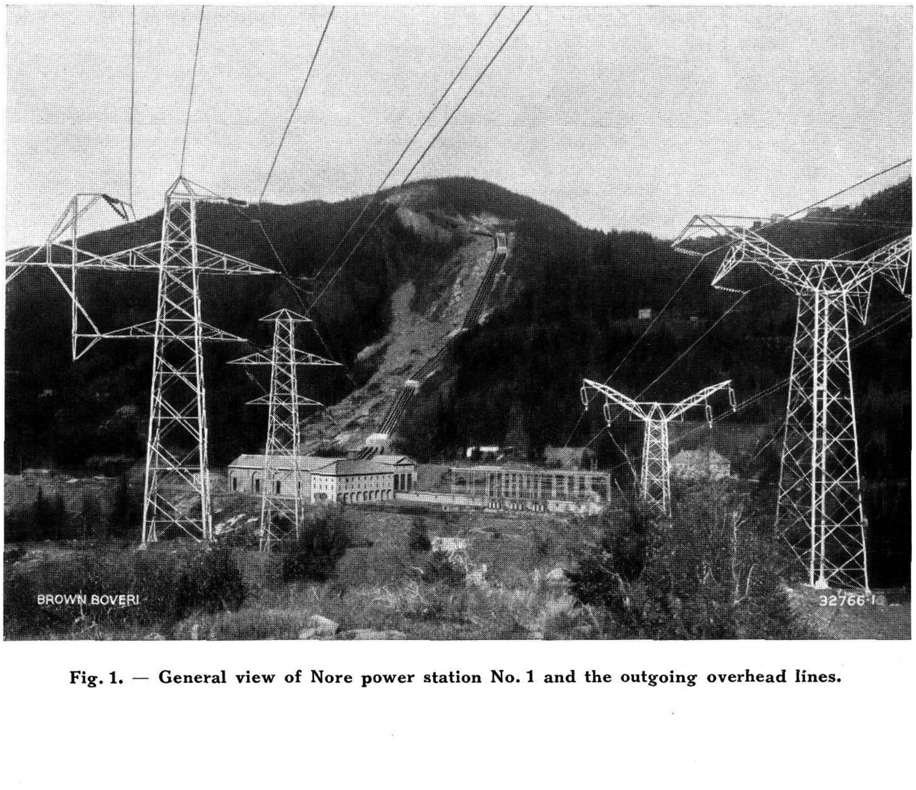


Fig. 1. — General view of Nore power station No. 1 and the outgoing overhead lines.

The first section of Nore No. 1 comprises four horizontal three-phase alternators each of 25,400 kVA, capable of an overload up to 29,000 kVA, 10—12,000 V, 50 cycles, power factor = 0·9, 300 r. p. m. By means of three-phase outdoor transformers, the pressure is stepped up to 132,000 V, and transmitted by two long distance lines, 120 and 140 km long respectively, to the substations at Smestad near Oslo and Flesaker and Slagen near Tönsberg. Smestad and Flesaker substations are interconnected by 60,000 V long distance lines. A ring is thus formed which, however, for the present is opened in Nore No. 1 power station.

II. THE SWITCHGEAR.

In planning the switchgear it was assumed that the *station auxiliaries should be fed directly from* any main alternator. This was rendered more difficult since the alternators must operate with a very variable voltage (about ± 15 %) because of the long power transmission lines, while a constant voltage was required for the auxiliaries. Further, there should be no oil circuit-breaker between alternator and transformer but, in spite of this, complete flexibility of interconnection and over-current safety of the alternators and auxiliaries had to be ensured. It is thus self-evident that the correct arrangement of the switchgear must be of decisive importance for the reliable operation of the power station.

(1) *The connections of the 12,000 V main indoor switchgear.*—As can be seen from Fig. 2, each alternator, with its corresponding transformer, forms one unit which is connected to the network through the 132,000-V oil circuit breaker. By means of a 12,000 V transfer bus-bar it is possible, should a defect occur in any alternator, to connect it to any desired transformer. Only isolating switches are provided for this switching over.

The omission of the oil circuit breaker on the alternator side arose principally from the desire to treat as a single unit the alternator-transformer set thus formed, which would be disconnected from the network by the high-tension side oil circuit breaker under simultaneous de-excitation of the alternator, should an internal defect occur. Some importance was also attributed to the consideration that defects in indoor high-capacity oil circuit breakers of medium voltage might be fatal under certain circumstances. The operation of the isolating switch is, however, rendered more difficult by the fact that it can be effected only when all the alternators concerned are de-excited.

Experience in plants with similar connections has shown that in such cases one must not depend entirely on the attentiveness of the switchboard attendant, even when using an illuminated dummy board. The switchgear suppliers, therefore, were faced with the problem of designing a reliable interlocking system.

Let it be further stated that this plant was designed in 1925—26, at a time, therefore, when the Brown Boveri automatic selective safety switching supervisor had not yet been introduced. This new type of interlocking connection, full details of which are given elsewhere, is intended, by optical or electro-mechanical stops which are controlled compulsorily, to free only those connections which are ready for service.

Now, in the first place the problem is simplified by limiting the number of independent isolating switch positions to the least number required for operation, by mechanical interlocking of the isolating switch operating rods. In consideration of the fact that the transfer bus-bar is destined also for the artificial loading of an alternator on the water resistance, Fig. 3 shows the fundamental connections of the isolating switches of two alternators.

From this it follows that:

(a) Isolating switches 12 and 15 should never be closed at the same time (in the same manner this applies to 22 and 25, 32 and 35, etc.).

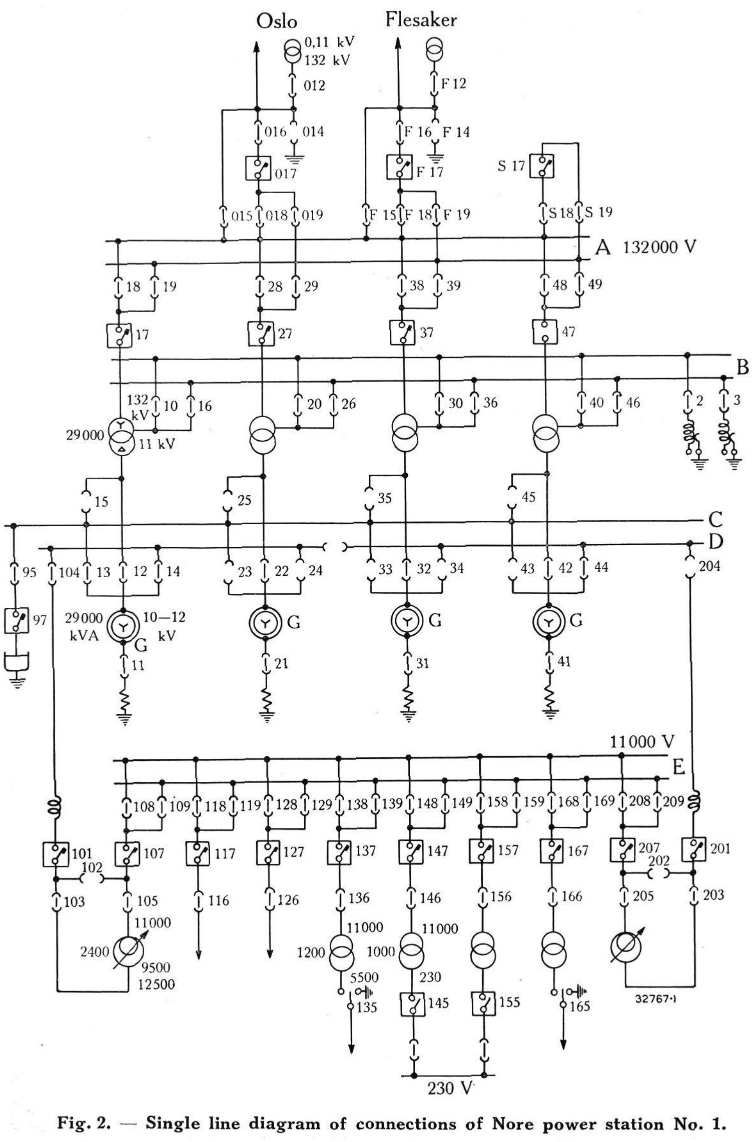


Fig. 2. — Single line diagram of connections of Nore power station No. 1.

A. 132,000 V bus-bar. B. Neutral point bus-bars. C. Transfer bus-bar. D. Auxiliary bus-bar. E. 11,000 V distribution bar.

(b) Of the isolating switches 95, 15, 25, 35 and 45, only one can be closed at a time.

(c) Only one of the isolating switches 13, 23, 33 and 43 can be inserted at the same time.

Condition (a) is already fulfilled by mutual mechanical interlocking of the isolating switch operating levers, and conditions (b) and (c) may be completely realized by using two unchangeable, portable handles, which can be removed only when the isolating switch is open.

As can be easily seen, these precautions mechanically prevent two alternators being connected in parallel to the 12,000 V transfer bus-bar. Nevertheless, fatal faulty switching operations can occur if the load or charging current of a transformer is interrupted by opening a wrong isolating switch. It would have been technically possible to prevent this by means of interlocking magnets controlled by the position of the field switch. This idea was abandoned, however, because of the fear of these magnets failing just when they were required. Further considerations led to the formation of two interlocking systems quite independent of each other, one of which, by lighting a lamp at the isolating switch to be operated, intimates its readiness for service, as soon as the required conditions have been fulfilled. The other system, by means of tripping current circuits already provided, compulsorily produces just these conditions, if it is incorrectly attempted to operate the isolating switch regardless of the lamp signal.

To this end the oil circuit breaker on the high tension side, the alternator field switch and the oil circuit breaker of the water resistance are provided with auxiliary contacts connected to signal lamps on the adjacent isolating switches. They are connected in such a way that the lamps can light up only when the oil circuit breaker or the field switch is open (Fig. 4). Further, to the transfer bus-bar a no-volt relay is connected, the contacts of which interrupt the lamp circuit of the adjacent isolating switches as soon as the bus-bar is put under voltage. As can be seen from the diagram of connections in Fig. 4, the lighting of the lamps (12, 13, 15, 95, etc.) indicates whether the isolating switch may be operated or not.

The development of the second interlocking system (Fig. 5) is simplified by the fact that because of the transfer facility of the alternator, the tripping coil of the high tension side oil circuit breaker

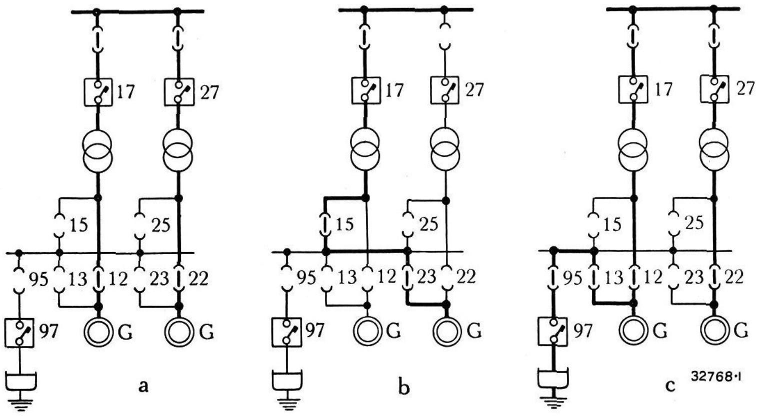


Fig. 3. — Possible methods of connecting the power station alternators.
a. Direct operation. b. Crosswise operation.
c. Load on water resistance and direct operation.

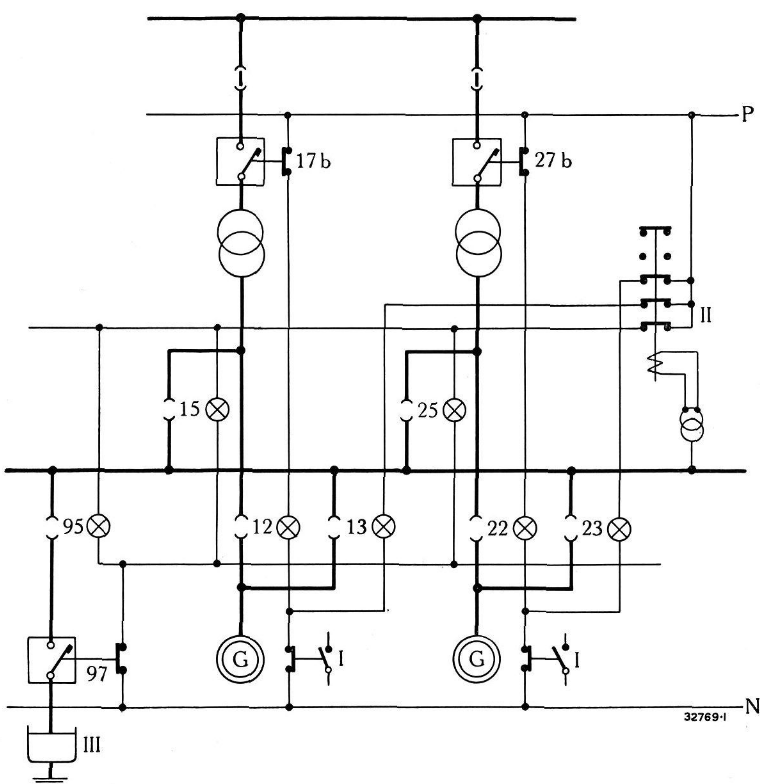


Fig. 4. — Diagram of connections of the signalling system of the main plant isolating switch.
I. Field switch. II. No-volt relay. III. Water resistance.
N, P. D.-C. bus-bars.

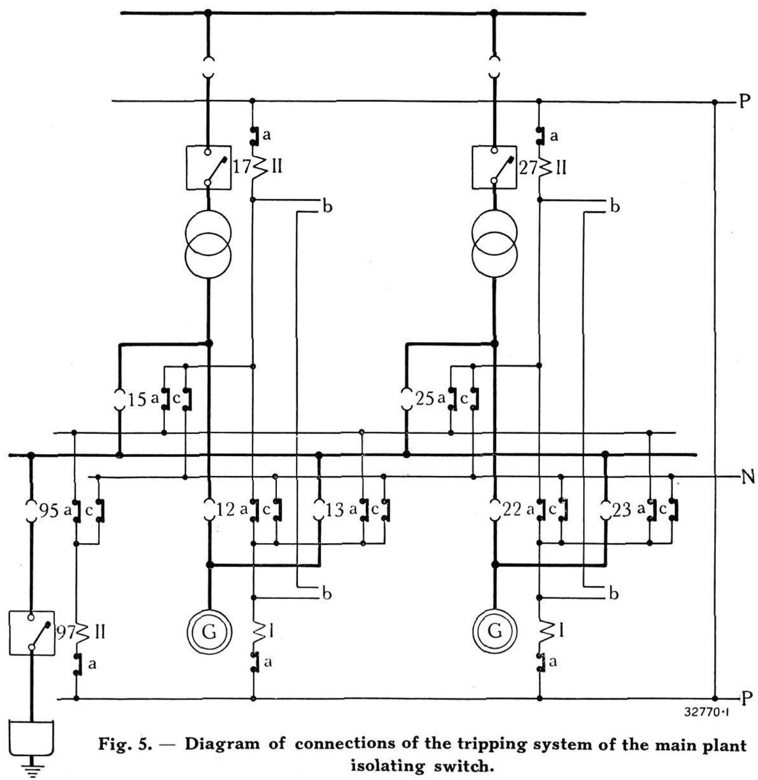


Fig. 5. — Diagram of connections of the tripping system of the main plant isolating switch.

I. Field switch tripping coil.
II. Oil circuit breaker tripping coil.
a. Contact closed when switch closed.
b. To relay.
c. Contact closed when switch thrown over.

had to be connected to that of the field switch over auxiliary contacts of the isolating switches (12, 13, 15, etc.), so that when the oil circuit breaker is tripped, the correct alternator is de-excited at the same time. This joint tripping circuit is now utilized to trip the oil circuit breaker and the field switch, if the attendant, without noticing the lamp signal, proceeds to operate an isolating switch. To this end the auxiliary switch drum of the three-pole isolating switch, besides having contacts for the lamp signals for in or out position (for the sake of brevity designated a and b contacts), is also fitted with a c contact, which is open in both end positions of the isolating switch but closes while the latter is moving. Moreover, it is important that the arrangement of the operating levers should allow the c contact to close as soon as an operation is started, i. e. before contact is made when closing, or broken when opening the isolating switch.

The method of operation of the interlocking system can be most easily explained by means of Fig. 5 and a concrete example. Let it be assumed that alternators 3 and 4 are operating directly, alternator 1 together with transformer 2, while alternator 2 and transformer 1 are out of service. Isolating switches 23, 33, 43, 15, 35, 45 and 95 cannot be operated because the loose handles are in the closed position on switches 13 and 25; 22 cannot be closed because it is mechanically interlocked with 25. Switch 12 remains. This can be operated, but only on condition that lamp 12 is lighted, showing that circuit breaker 17 is open and that alternator 1 is not excited. If it were attempted to operate the isolating switch 12 while the lamp was unlit, then the c contact would trip both circuit breakers 17 and 27 and the field switch of alternator 1 before the position of the isolating switches had changed. The c contact thus tests the connections of the plant and places them as required for the intended position of the isolating switches.

Fig. 6 shows the operating levers of the main plant isolating switches, which are arranged near one another so that they can be easily supervised.

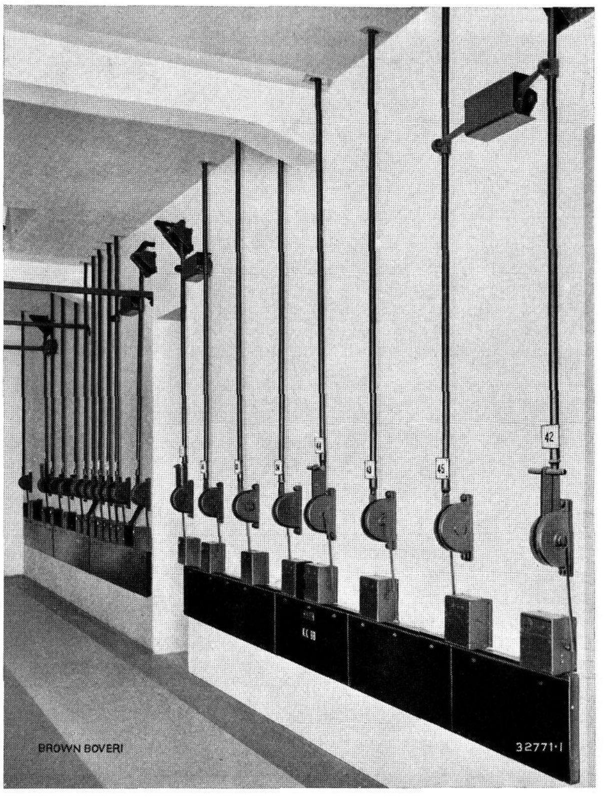


Fig. 6. — Control room of the main plant isolating switch.

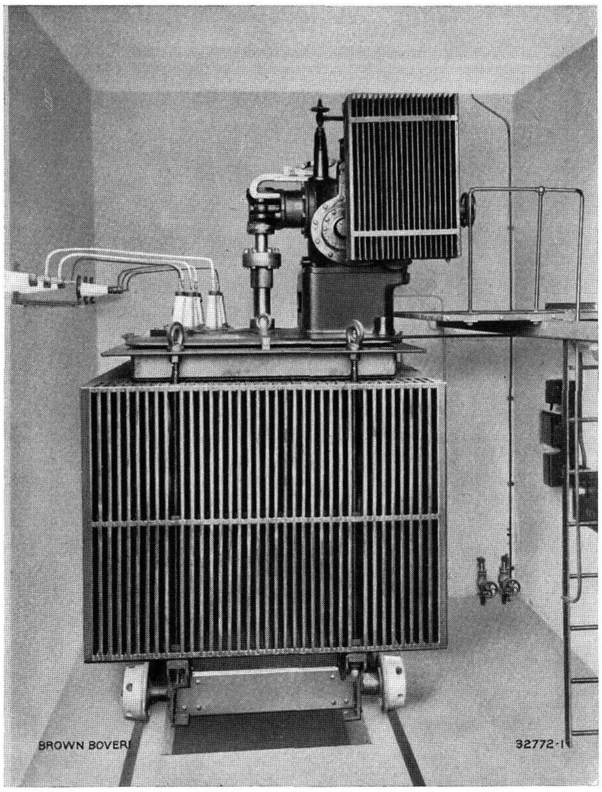


Fig. 7. — Induction voltage regulator of 2400 kVA power transmitted, 11,000 ± 1500 V, with automatic oil-pressure control.

(2) *The connections of the 11,000-V auxiliary indoor switchgear.* — The current for all the auxiliaries and for the immediate surroundings of the power station, is supplied by two three-phase transformers of 1000 kVA, 11,000/230 V, and two three-phase transformers of 1200 kVA, 11,000/5500 V. One of these is always in reserve. The transformers can be fed from any main alternator. The voltage of the 11,000-V distribution bus-bars is automatically kept constant at 11,000 V by two three-phase induction voltage regulators of 2400 kVA, 11,000 ± 1500 V. In order to lower the short-circuit stresses of these regulators, air-core current limiting reactors were connected in series.

As can be seen from Fig. 2, regulator 1 is fed direct from alternator 1 or 2 over an auxiliary bus-bar, and regulator 2 over another auxiliary bus-bar from alternator 3 or 4. The alternators, however, must not be connected to the same auxiliary bus-bar at the same time. This is prevented by an arrangement whereby switches 14 and 24 can be operated only by a joint portable handle A, and switches 34 and 44 only by a different handle B. Now, in order that the regulator 1 may be fed from either alternator 3 or 4, a connecting isolating switch 94 is arranged, which can then be operated by the available handle A. Similarly, by means of handle B in switch 94, regulator 2 can be connected to alternator 1 or 2. Since the handles can be removed only in the open position, in this manner an extensive transfer facility is obtained, without danger, for the two alternators being directly connected.

Since here an oil circuit breaker (101 or 201) always lies in the path of the current lead, all that is required for the safe operation of these isolating switches is that the adjacent oil circuit breaker should be open. As in the main plant, two independent interlocking systems were also installed here, one of which trips the correct oil circuit breaker if the lamp signal is disregarded, before the manipulation of the switch has caused the isolating switch contacts to be opened or closed.

Figs. 9 and 10 show both protection systems of the auxiliary switchgear, the method of operation of which is easily understood after what has been already said. It might just be mentioned that isolating switch 94 is equipped with two signal lamps and two auxiliary switches corresponding to handles A and B.

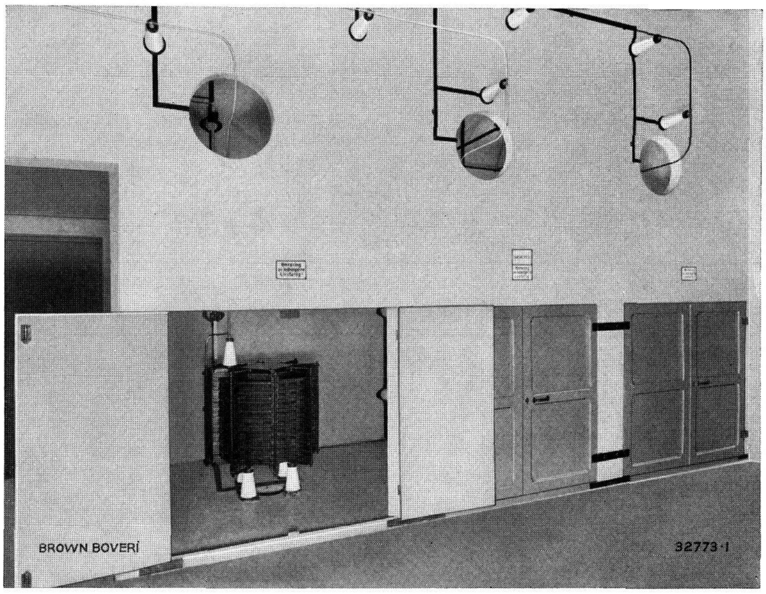


Fig. 8. — Air-core current limiting reactors.

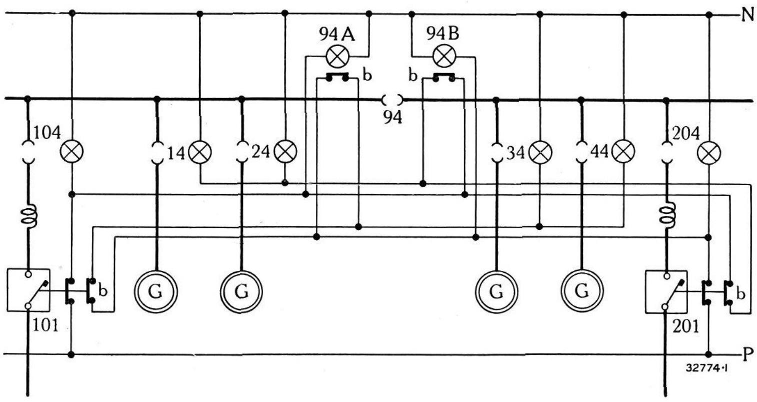


Fig. 9. — Diagram of connections of the signalling system of the auxiliary plant isolating switch.

94 A. Lamp and auxiliary switch of operating handle A, which is also used for 14 and 24.
94 B. Lamp and auxiliary switch of operating handle B, which is also used for 34 and 44.
b. Contact closed when switch open.

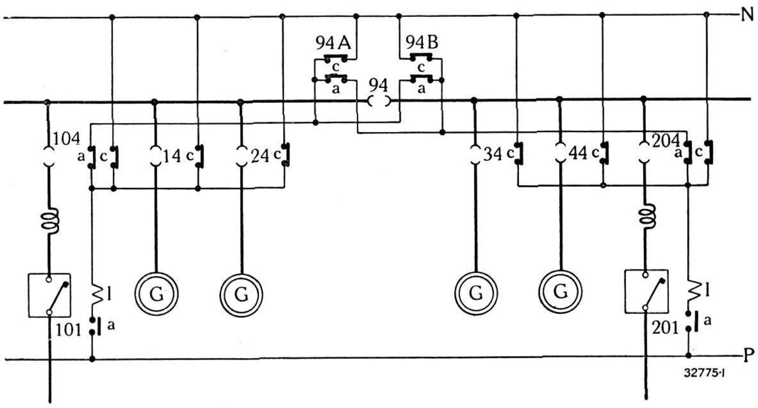


Fig. 10. — Diagram of connections of the tripping system of the auxiliary plant isolating switch.

a. Contact closed when switch closed. c. Contact closed when switch thrown over.
I. Oil circuit breaker tripping coil.

By correctly operating isolating switches 14, 44 and 94 it is possible to switch the auxiliaries from one induction voltage regulator to the other, or from one alternator to any other as desired, without interrupting the service. In effecting this under certain circumstances, two alternators must be connected in parallel through the reactors. This is only permissible provided that the phase lag is the same, as will be further referred to below.

(3) *Synchronization.* — All the oil circuit breakers, including those of the auxiliary plant, are provided with a synchronizing plug, through which the remote control closing current is conducted. Before closing any oil circuit breaker, therefore, the synchronizing instruments are compulsorily switched on. This accustoms the switchboard attendant always to observe the indication of the phase voltmeter before closing an oil circuit breaker. An example will be given later of the importance of strict adherence to this rule.

The connections for synchronization were so arranged that the voltages on both sides of the oil circuit breaker concerned are compared. Since no voltage transformers are provided on the 132,000-V bus-bars, this comparison of voltage is obtained by an arrangement of connections as shown in Fig. 11. In order to take account of the voltage drop in the main transformers, a choke coil II, which is also influenced by the alternator current, is connected in series. Since this current when the power factor = 1 leads the line voltage utilized for synchronization by 30°, the impedance Z_K of the choke coil must lag 30° behind the impedance Z_T of the main transformers (Fig. 12). The resultant voltage e_T will then, at every load, be equivalent to the real high tension E_T, apart from the 30° displacement. This is absolutely necessary in order to obtain an auxiliary bus-bar according to the diagram in Fig. 11.

The station transformers of 11,000/230 V are equipped on both sides with oil circuit breakers. Since, however, only the 11,000 V circuit breaker has remote control and a synchronization plug, the voltage is only connected to this plug if the 230 V oil circuit breaker is closed. In a similar manner the oil circuit breakers 101 and 107 or 201 and 207 are electrically interlocked with each other. Assuming that regulator 1 is connected to alternator 1, and that it is desired to transfer the auxiliaries to regulator 2 supplied by alternator 3, connected in parallel on the high tension side to alternator 1. Oil circuit breaker 201 is first closed provided that 207 is open. Regulator 2 adjusts its regulated voltage to 11,000 V exactly as regulator 1. If, however, the voltage of alternators 1 and 3 were not the same, the two positions of the rotor of the regulator would not be identical. Between the contacts of the oil circuit breaker there may be a difference of voltage up to 2×1500 V according to the case. This is indicated by the phase voltmeter.

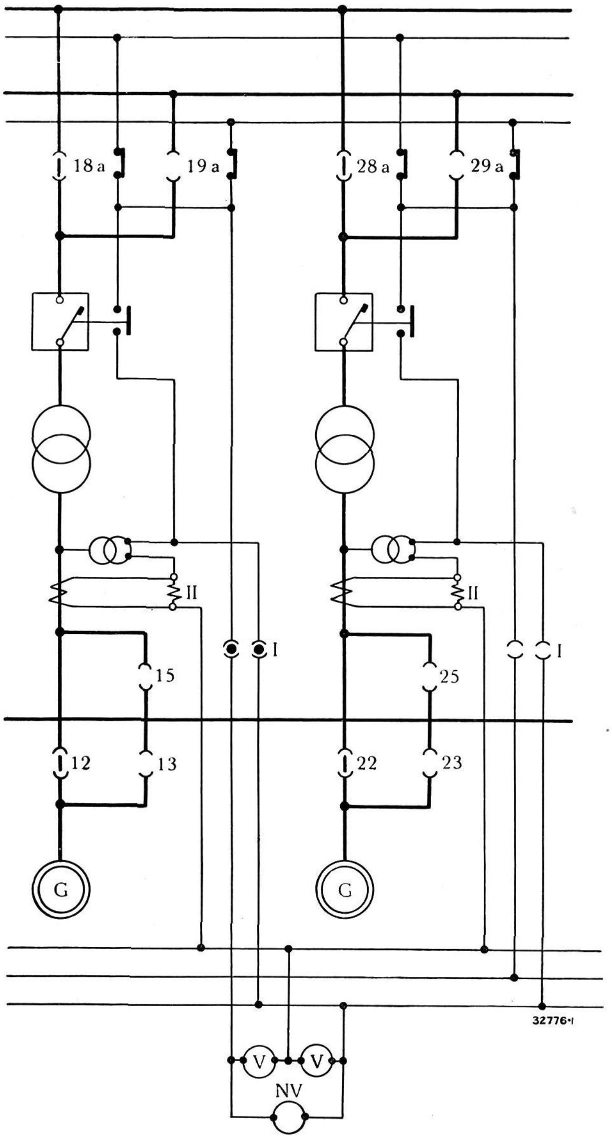


Fig. 11. — Simplified diagram of connections for synchronization.
I. Synchronizing plug. II. Choke coil with resistance.
NV. Phase voltmeter.

It is thus not permissible to close the oil circuit breaker before the alternator voltage has been equalized by changing the excitation of the alternator, and the boosting voltage of both induction voltage regulators has assumed the same value.

The paralleling is usually effected by using a Brown Boveri parallel switching device acting through auxiliary relays on the remote control apparatus. It can, however, also be done by hand.

(4) *Voltage regulation.* — The alternators are provided with Brown Boveri over-current and voltage regulators with static characteristic, which are particularly suitable for the parallel operation of long distance power plants. The voltage can be adjusted within the limits 9500 to 12,500 V by means of separate adjusting rheostats as required.

The voltage of the distribution bus-bars is kept constant by a Brown Boveri regulator along with a pressure oil servo-motor on the induction voltage regulator. This method of regulation which operates very quickly as compared with motor control, has proved to be entirely satisfactory in service. Because of the astatic character of the voltage regulators these have to be stabilized in service. Stabilization is effected in a simple manner, as in the case of synchronous alternators operating in parallel, by current transformers in polygon connection.

(5) *The protection of alternators.* — As a protection against internal winding shorts and earth faults, each alternator is provided with three single pole differential current relays, the neutral point of the alternator being connected to earth through a resistance of 20 ohms. The differential relays are so designed that they protect about 80 % of the winding, and yet for a short time can stand the current which would occur if an earth fault should take place at one terminal of the alternator and at the same time the neutral point resistance should flash over. The choice of the value of the resistance was decided on the one hand by the consideration that with class F current trans-

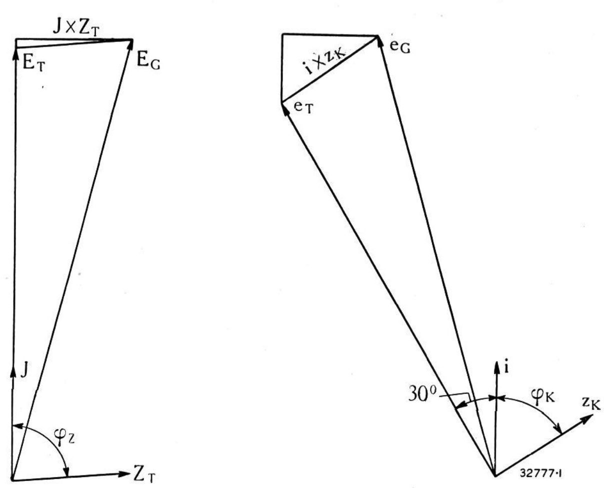


Fig. 12. — Synchronization vector diagram.

$E_{G.}$ Star voltage of the 12,000 V alternator.
$E_{T.}$ Star voltage of the loaded transformer, referred to the alternator.
$Z_{T.}$ Transformer impedance referred to the alternator.
J. Alternator current.
$e_{G.}$ Alternator line voltage, 110 V, measured at the voltage transformer.
$e_{T.}$ Compensated voltage for synchronization.
$z_{K.}$ Impedance of choke coil.
i. Alternator current, measured at the current transformer.

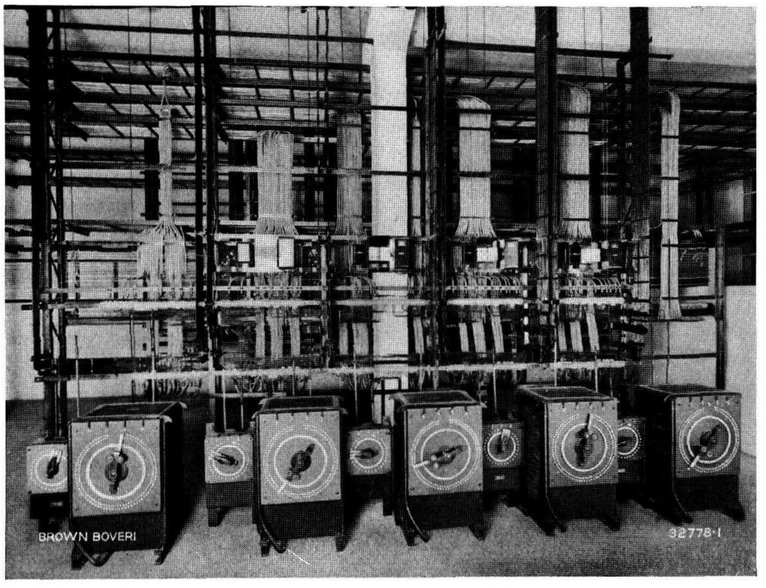


Fig. 13. — Distribution room for the measuring and control circuits below the control room.

formers the permissible error in transformer ratio should not lower the operating limit to such an extent that undesirable tripping might occur if a short circuit took place across the alternator terminals. Such a result would have led at once to the protecting device being dispensed with. On the other hand it was desired to obtain the automatic tripping of an earth fault in the auxiliary switchgear by the overcurrent time-limit relay arranged there. The earth fault current must therefore be larger than the highest relay setting of the induction voltage regulator oil circuit breaker.

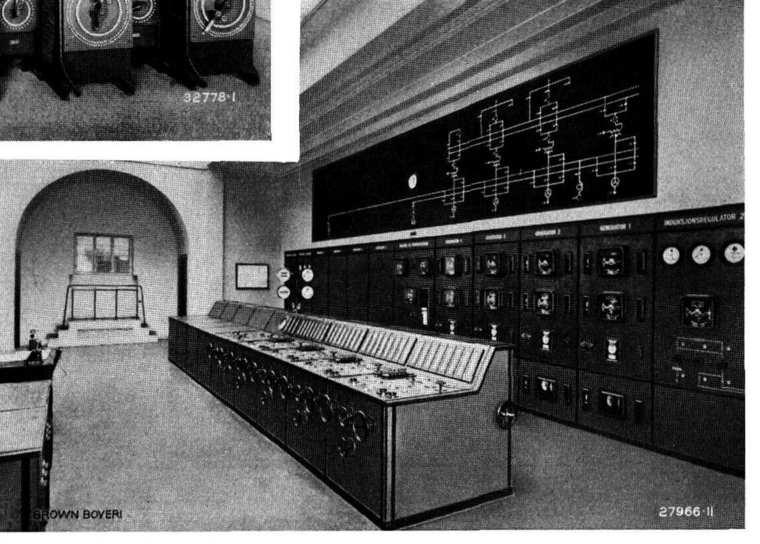


Fig. 15. — Control room of Nore power station No. 1.

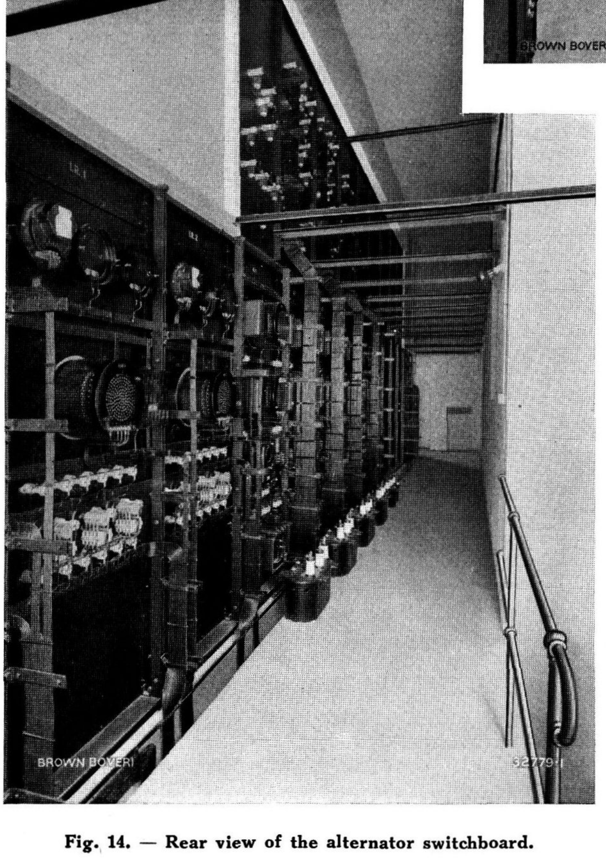


Fig. 14. — Rear view of the alternator switchboard.

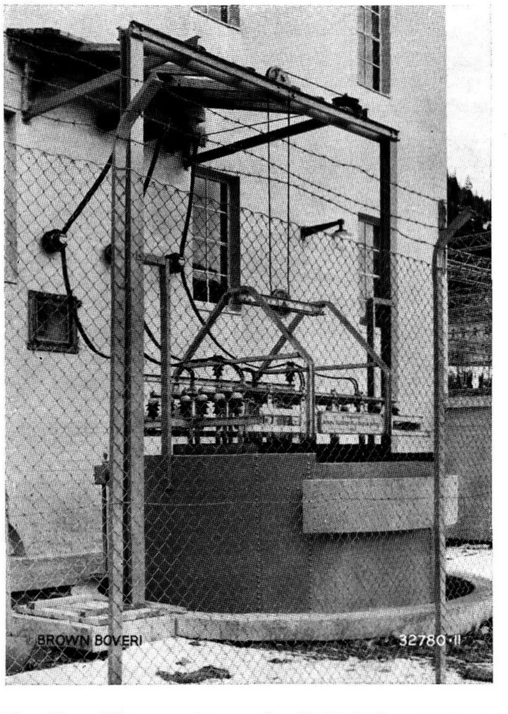


Fig. 16. — Water resistance for 30,000 kW at 12,000 V.

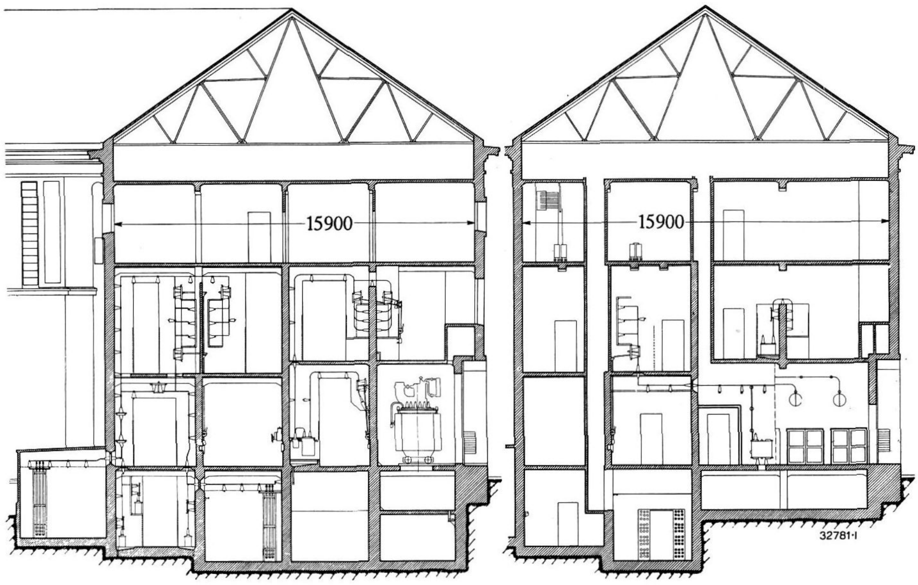


Fig. 17. — Cross-sections through the indoor switchgear.

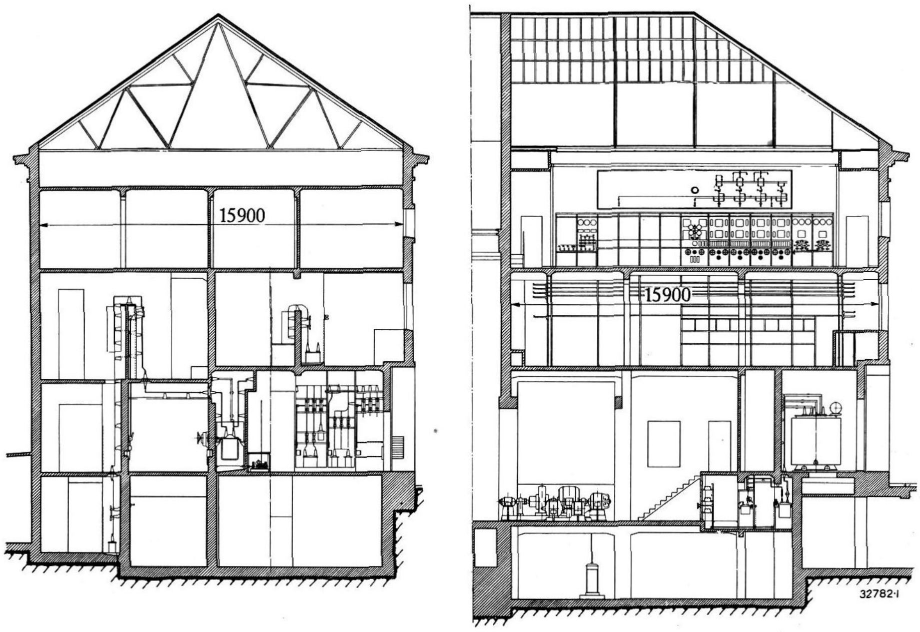


Fig. 18. — Cross-sections through the indoor switchgear.

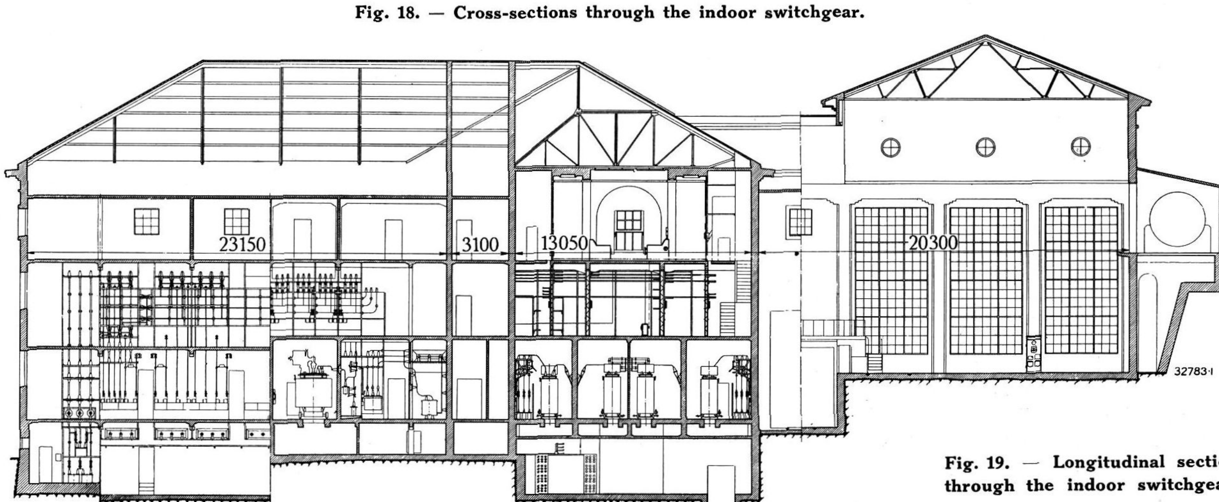


Fig. 19. — Longitudinal section through the indoor switchgear.

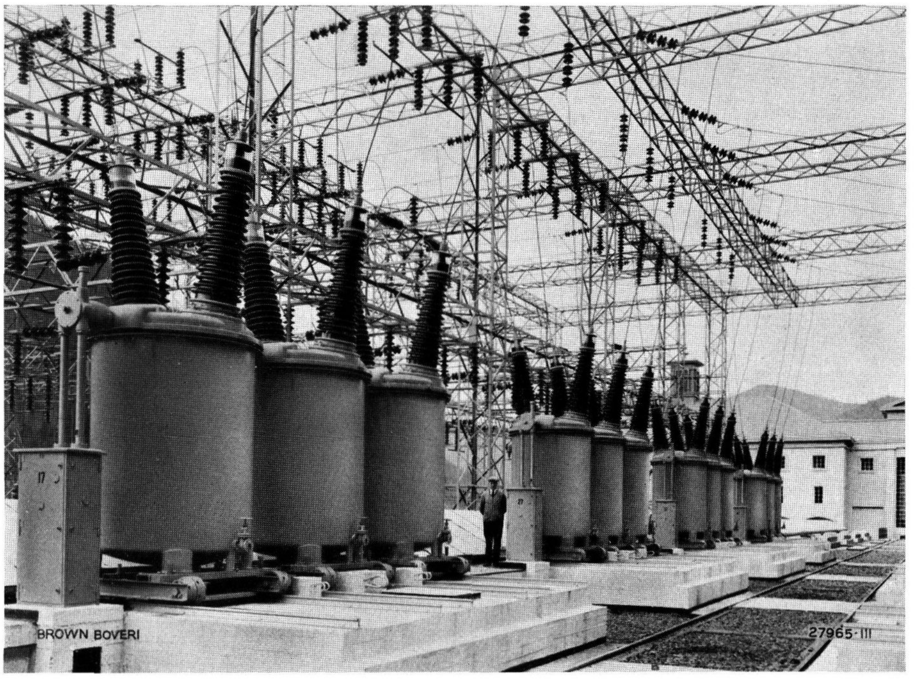


Fig. 20. — View of the outdoor switchgear. In the foreground 132,000-V transformer oil circuit breakers.

By the operation of the differential relay the alternator-transformer unit is separated from the network and de-excited, and the carbon dioxide fire extinguishing plant put into operation.

It might happen that an earth fault occurred outside the operating range of the differential protection but in front of the nearest oil circuit breaker of the auxiliary switchgear. In this case the earth fault current through the neutral point resistance will remain in existence. It must be rendered harmless by a current time-limit relay arranged in the neutral point, this relay disconnecting and de-exciting the unit.

(6) *Laying the measuring circuits.*—Great importance was laid on the arrangement of the measuring circuits so that they could be easily inspected. From outside the high tension cells rubber lead covered cables are run in fibre ducts to the circuit distribution room below the control room. From here solid rubber insulated wires on insulated supports lead to the control desks and switchboards. Terminal boards at a convenient working height form the transition (Fig. 13).

Such a method of laying the measuring circuits necessitated that the wiring diagram should be practically completed before the constructional work was taken in hand, in order to ensure that the ducts should have the required capacity. The work expended on this, however, is amply rewarded, because it enables the space available to be adapted to the measuring circuits. These can thus be arranged where they can be easily inspected, which is of great importance for the safe operation of a somewhat complicated plant.

(7) *The water resistance.*—For artificially loading the alternators during acceptance tests and the like, a water regulating resistance is arranged directly outside the switchhouse. The electrodes consist of parallel iron plates insulated from each other and suspended in an electrode frame. The input is adjusted by raising and lowering the electrodes, while the height of the water surface in the tank is kept unchanged. The resistance is dimensioned for a continuous load of 30,000 kW (Fig. 16).

The electrodes are moved by an earthed motor driven rope hoist, remote controlled from the control room, from which the cooling water temperature can also be easily read by means of a remote thermometer.

(8) *The arrangement of the indoor switchgear.* The division of the switchgear into a main and an auxiliary plant is also noticeable in the structural arrangement of the building. In Fig. 17 the left half of the picture shows the main part with cables and bus-bars, while the right half comprises the induction regulators, oil circuit breakers and bus-bars of the auxiliary part. All the levers of the main plant isolating switches are suitably and visibly arranged on a wall on the ground floor, while the main bus-bars themselves are arranged on the first floor. Here are also the distribution bus-bars, while the oil circuit breakers and other oil-filled, heavy apparatus and transformers are located on the ground floor.

Because of this separation in location of the oil circuit breakers and isolating switches of the auxiliary plant, an indication of the position of the isolating switch is of great importance for the safe inspection of an oil circuit breaker cell. Such an indication is provided, not only for all oil circuit breaker cells, but also for the transformer and induction regulator compartments, by the lighting of a green lamp as soon as the cell is no longer under voltage, i. e., as soon as the isolating switches are opened on both sides.

All auxiliary plant isolating switches are three-pole. As in the case of the main plant, the operating mechanism is fitted with a signal lamp which, by lighting up, shows that the corresponding oil circuit breaker is open. In this manner, in spite of the separation in location, correct operation of the isolating switches is always guaranteed.

(9) *The outdoor switchgear.*—The 132,000 V bus-bars are erected in two tiers, one above the other, an arrangement which had to be chosen here because of considerations of space. As conductors, copper cables of 185 mm^2 cross-section are employed, strained on suspension insulators, motor system. Copper tubing on pedestal type insulators is used in isolated cases only, in stationary bows, and where it cannot be avoided, for example in the bus-bars.

The transmission line oil circuit breakers may be short-circuited by an air-break switch, thus making possible an inspection of the oil circuit breaker without interrupting the service. This is an advantage not to be underestimated, especially here, where the transmission lines are operated for the present as single lines, with no reserve provided for under normal working conditions.

Nore power station No. 1 was put into service in the summer of 1928. During the past three years of service, it has fulfilled all requirements placed upon it. Especially the switch arrangements, including the isolating switches, which were frequently subjected to severe trials during the acceptance tests, have been particularly satisfactory.

(MS 665) *E. Styff. (R. O. P.)*

"Jalomița" Societate anonimă Română pentru Forță și Lumină Electrică. Dobresti Plant (Roumania).
Four three-phase alternators, each 5000 kW, 5500 V, 50 cycles, 750 r. p. m.

THE ELECTRIC EQUIPMENT OF THE DOLOMITES RAILWAY.

Decimal index 621. 331 (45).

THE narrow gauge Dolomites railway lies in the Dolomites district north of Venice, famed for its natural beauties. The railway joins Calalzo in the Piave valley to Dobbiaco in the Puster valley, and connects districts specially favoured by tourists, such as Cortina d'Ampezzo, Pieve di Cadore, etc., to the international main lines, since both termini are on the Italian State Railways. The frontispiece of this number and Fig. 1 give a good idea of the beauty of this mountainous region.

The railway is 65 km long. Like all mountain railways it has steep gradients and curves of small radius. From Calalzo (altitude 806 m) it climbs for 49 km to Cimabanche (altitude 1528 m) and falls again to Dobbiaco (formation level at the station 1210 m). The gauge is 950 mm, generally used in Italy for narrow gauge railways; the steepest gradient is 3·5 % and the smallest radius of curvature 60 m. The track is composed of Vignole rails weighing 22·1 kg/m.

Fig. 1. — The Dolomites railway. Passenger train on Cortina d'Ampezzo viaduct.

The benefits of electric operation, viz. travel in clean carriages without annoyance from smoke and steam, are of particular importance on such railways of a scenic character, and contribute to the full enjoyment of the journey. Therefore, it can be understood that electric operation for lines of this type is becoming more and more common, and was also chosen in the present case, the more so since electric energy was available in the form of three-phase current at 18,000 V and 42 cycles from the network of the Società Idroelettrica Bartolomeo Toffoli at Calalzo. For operating the railway, direct current of 2700 V average pressure was adopted, permitting the traffic requirements to be fulfilled by a single substation fairly evenly loaded, while maintaining the contact wire voltage within admissible limits. This substation is situated near Cortina

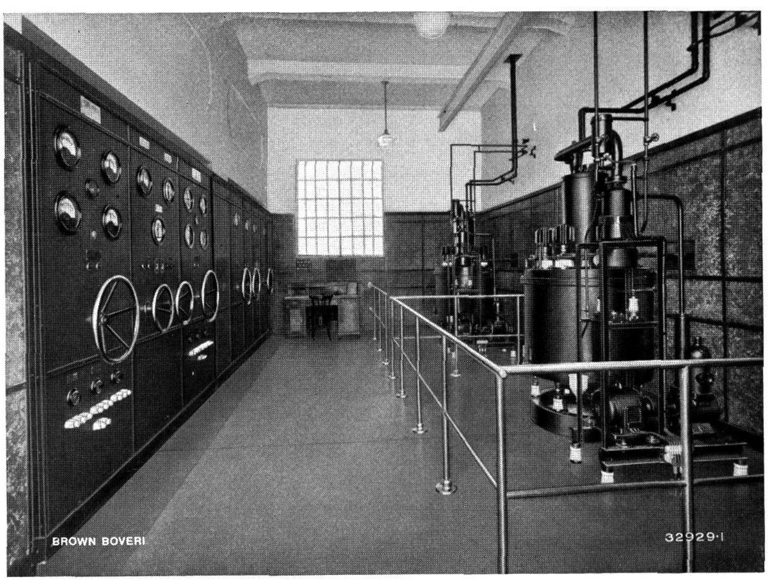


Fig. 2. — Rectifier room in Cortina d'Ampezzo converter station.

d'Ampezzo station, distant about 36 km from Calalzo and 29 km from Dobbiaco. Fig. 2 shows the substation rectifier room, which is equipped with two mercury-arc rectifiers, each of 1100 kW continuous rating at 3000 V d.-c. pressure, and with the corresponding transformers, auxiliary machines and apparatus. The rectifier sets can sustain a 25 % overload for half an hour, 100 % overload for five minutes, and a momentary overload of 200 %. In recent times rectifiers have been more and more employed in railway plants such as that under consideration. They are particularly advantageous in such cases, since the space required, because of the comparatively small currents, becomes correspondingly small, and the efficiency particularly high. For the rectifier alone in this case it is 99·1 % over a large range of output.

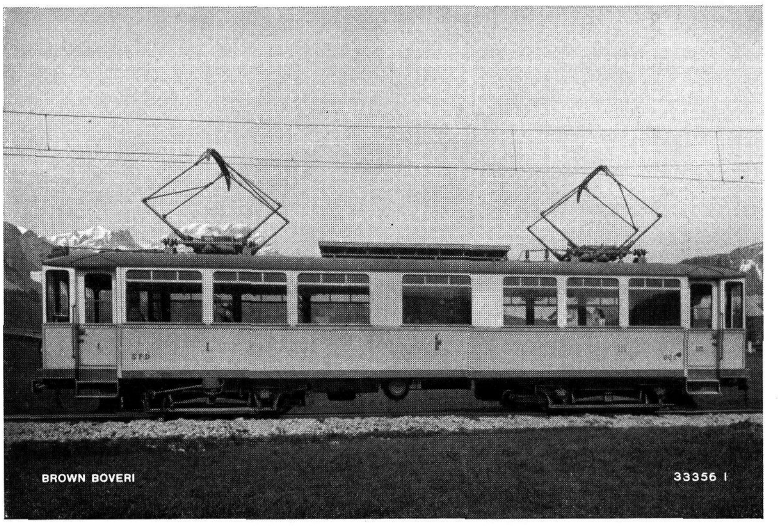


Fig. 3. — Four-axle motor coach.

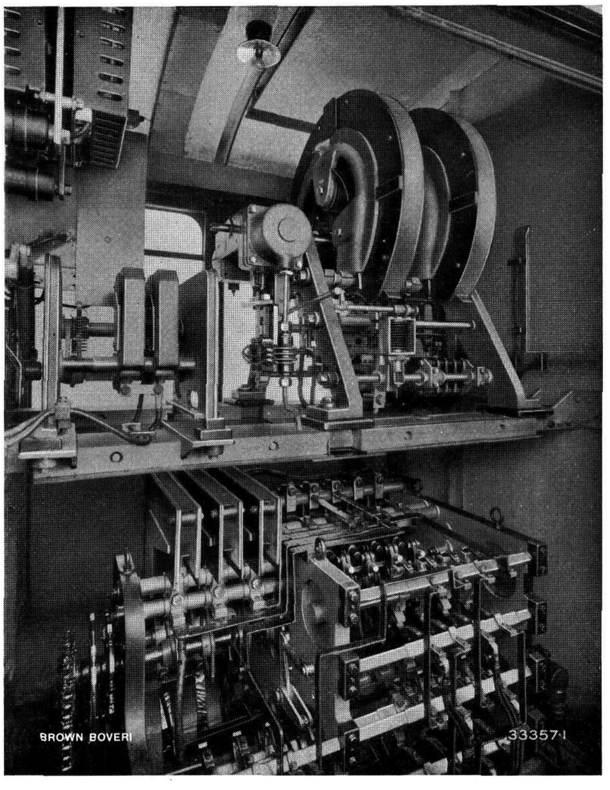


Fig. 4. — High-tension room of a motor coach.

For passenger and goods traffic, the railway company possesses six four-axle motor coaches, two four-axle locomotives, and ten new four-axle trailers as well as various older coaches and goods wagons.

The principal features of the motor coaches and locomotives may be briefly summarized as follows:—

	Motor coaches	Locomotives
Length over buffers	16,110 mm	12,280 mm
Length of body	15,030 mm	11,200 mm
Width of body	2,400 mm	2,400 mm
Height of body	3,395 mm	3,395 mm
Bogie wheelbase	2,260 mm	2,330 mm
Distance between bogie pivots	8,500 mm	6,200 mm
Weight empty	35·0 t	35·5 t
No. of 1st class seats	18	—
No. of 3rd class seats	23	—
Standing room for	100 persons	—
Net load	4 t	3 t
Diameter of driving wheels	900 mm	1,030 mm
Traction motors	4 motors, type GDTM 081 a 4, each of 73·5 kW (100 H. P.) one-hour rating at the shaft at 600 r.p.m. and 2700/2 V; and of 56 kW (67 H.P.) continuous rating at the shaft at 670 r. p. m. and 2700/2 V terminal pressure.	4 motors, type GDTM 091 c 6, each of 96 kW (130 H. P.) one-hour rating at the shaft at 730 r.p.m. and 2700/2 V; and of 73·5 kW (100 H. P.) continuous rating at the shaft at 815 r. p. m. and 2700/2 V terminal pressure.
Gear transmission ratio	1:3·95 (19:75 teeth)	1:5·11 (18:92 teeth)
Tractive effort at wheel tread at one-hour rating	4,000 kg	4,800 kg
at continuous rating	2,700 kg	3,300 kg
Speed at one-hour rating	approx. 26 km/h	approx. 28 km/h
at continuous rating	„ 29 km/h	„ 31 km/h
Highest speed	45 km/h	45 km/h
Total weight of train (normal)	73 t	approx. 150 t
(maximum)	85 t	—

Fig. 3 shows the outside of one of the attractive motor coaches. Each of these coaches is divided into a 1st and 3rd class passenger compartment with large windows and very tastefully furnished. Between these compartments are the high tension room (Fig. 4) and the lavatory. At each end of the body of the coach there is an enclosed driver's cab.

In the locomotives (Fig. 5) all the space between the driver's cabs, except the enclosed part used to install the high tension apparatus, is available for luggage.

Both types of vehicle are fitted with Westinghouse air brakes and hand brakes. In addition, on down grades, and within certain limits of speed, they can be electrically held back by rheostatic (short circuit) braking.

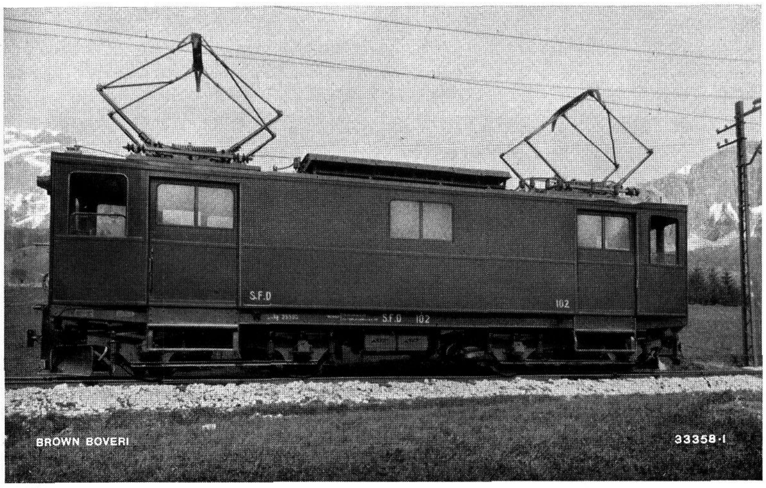


Fig. 5. — Four-axle goods locomotive.

The electric equipment of the locomotives is different from that of the motor coaches only in so far as is required by the difference in the motor output and in the service conditions to be fulfilled by these vehicles.

The main control apparatus consists of a Brown Boveri cam controller placed in the high tension room, and which has seven series and five parallel running positions as well as seven resistance braking positions. In accordance with the proved Brown Boveri design for vehicles not operated by multiple unit control, this cam shaft is driven from the control desks in the driver's cabs by means of mechanical transmission. In addition to the individual contactors operated by cams, the controller comprises a pneumatically operated reversing drum and a drum for cutting out a group of motors should they become inoperative. The main switch operated by compressed air is also situated in the high tension room.

The starting and braking resistances are placed between the two pneumatically operated pantograph current collectors on the roof of the vehicle.

As can be seen from the above, the main apparatus, when not controlled mechanically, is directly operated pneumatically by means of control valves fitted in the driver's desks. The compressed air required for this purpose and for the air brake system is delivered by a motor compressor, type GC 3/2, the motor of which is connected to the contact wire pressure of 2700 V. This motor has a one-hour rating of 4·5 kW and a speed of 750 r.p.m. At this speed the compressor supplies about 560 litres of free air per minute. A regulator maintains the pressure in the reservoir between 5 and 7 kg/cm^2.

The motor coaches and locomotives are fitted with the Brown Boveri safety device which, after a certain distance, trips the main switch and applies the brakes, if the driver is suddenly taken ill.

The arrangement chosen here for supplying the lighting circuit is worthy of special mention. This was the only purpose for which low tension current was necessary, since, although it would have been technically possible to connect this circuit to the contact wire voltage, this was avoided because of the danger to the staff and passengers. A motor-generator set for the small output under consideration would have been very expensive. There was no opportunity, however, for the usual drive of a train dynamo, since all the space between the driving wheels was taken up by the traction motors equipped as nose-suspended geared motors of ordinary design. The bogies were therefore widened so that sufficient space was available between the frame and driving wheels to install a chain drive for a train dynamo (Fig. 6). This dynamo operates in parallel with a battery of accumulators of 155 Ah capacity when discharged in ten hours. The dynamo and battery are large enough to supply lighting current to the whole train. A Brown Boveri train lighting regulator ensures reliable operation in parallel and prevents voltage variations in the lighting circuit.

The carriage heaters are supplied from the contact wire, and are connected in series in sets of six. The heating current is conducted through rod couplings to the trailers.

The electric equipment of the substation and that of the motor coaches, locomotives and trailers was supplied by the Tecnomasio Italiano Brown Boveri, Milan. This firm also supplied the bogies for the motor coaches and trailers, the motor coach and locomotive bodies being made by the S. A. Officine della Stanga, Padua.

Regular electric operation of the railway was begun in July, 1929. The results obtained have completely fulfilled all expectations. It may be mentioned that during exceptionally heavy falls of snow, the traction motors of both types of vehicle, by making use of the special closing arrangement provided, have worked completely surrounded by snow as totally enclosed motors. No water entered the motors, nor, in spite of considerable overloading in snow clearing operations, did they suffer any damage.

(MS 679) *A. Brodbeck. (R. O. P.)*

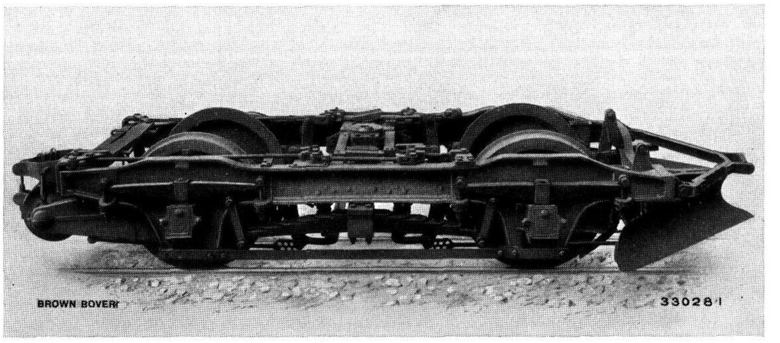
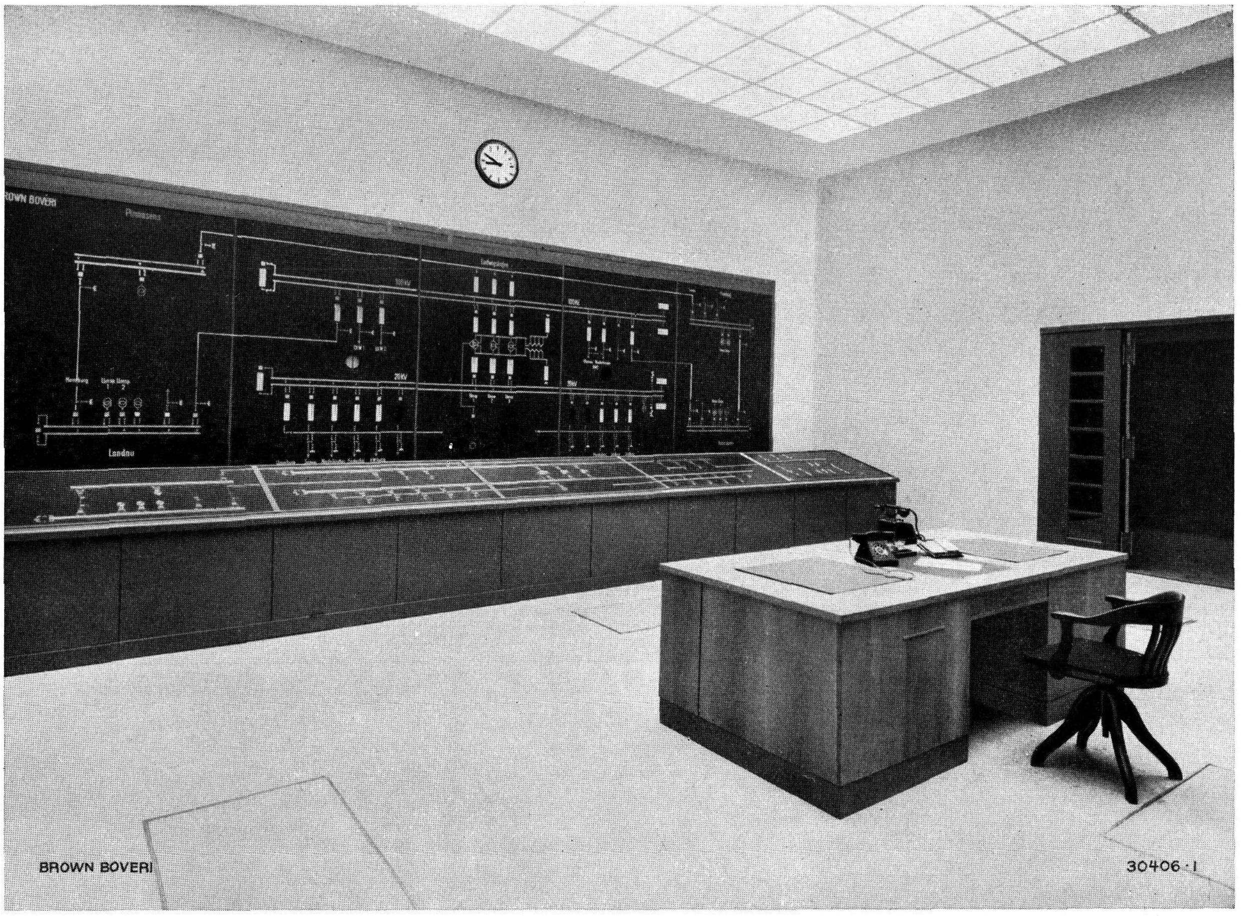


Fig. 6. — Bogie of a motor coach, without driving motors, but with built-in train dynamo with enclosed chain drive (to the left in front).



Control room with light diagram and block-signalling system in Mundenheim Substation (Ludwigshafen) of the Pfalzwerke A.-G.

THE ECONOMIC IMPORTANCE OF STEAM TURBINES FOR INDUSTRIAL PURPOSES.

Decimal index 621.165.0031.

STEAM turbines may be divided into two classes:

(1) Turbines for producing electrical energy in thermal power stations, and

(2) those which, in addition to producing power, are employed for other specific industrial purposes (such as supplying steam for heating, or the utilization of exhaust steam).

Modern industrial development is leading more and more to the centralized bulk production of electrical energy under state control or that of private corporations. The districts supplied by these large organizations are continually increasing in size and the basic load on the power stations is growing, causing a corresponding increase in the rating of individual machines. As the machines become more powerful, the live steam conditions are in general improved and in addition the design of the machines themselves is perfected. The large power stations are therefore in a position to supply energy so cheaply that there is no longer any advantage to consumers in building a small power station adapted to their needs. Large power stations are therefore slowly displacing smaller industrial power plants using condensing turbines.

It is, however, entirely different in the case of steam turbines of special design, part of whose steam is used for industrial purposes. These turbines must either supply steam to other machines or they are supplied with steam which has already been used in other machines or processes. In this case the price of the unit of electrical energy is generally reduced to such an extent that the large power stations can no longer compete, in spite of larger individual machines and more favourable live steam conditions. These turbines of special design will therefore never be displaced but, on the contrary, their economic importance will increase from year to year.

Turbines for industrial purposes can be subdivided as follows:—

(1) Back-pressure turbines for delivering low-pressure steam;

(2) Extraction back-pressure turbines for delivering low-pressure steam at two different pressures;

(3) Exhaust steam turbines for utilizing low-pressure steam obtained as a by-product of manufacture or exhausted from non-condensing engines.

All types of turbines for special purposes, along with the advantage mentioned, viz. low cost price of current, have the disadvantage that their output depends entirely on the quantity of steam required or available. The output and the time during which it is available are known, and only rarely coincide in magnitude and duration with the output required.

The simplest method of overcoming this difficulty is to arrange a contract with a supply company stipulating that the latter shall supply electric energy when the output of the turbine is no longer sufficient, the quantity of steam available being too small. On the other hand any excess of energy produced will be taken by the company. By suitably arranging the production operations in one industry, it is often possible to adjust the time when extra current is required to coincide with the time when a surplus of current is generated by another industry. These conditions, and the establishing of a method to provide all parties with power, can be the more easily realized the greater the difference in the nature of the industries to be supplied. By means of a suitable arrangement, the basic load on the power station is raised and current peaks lowered, i.e., the power station will operate more economically. The economic importance of such a collaboration is so great that its realization may be considered as one of the most important problems to be solved by the power stations.

If it is impossible to arrange a contract with a power supply company, or when there is no such station near, in order to supply the extra power for these special turbines, either low pressure stages together with condensing equipment are provided, or extra high pressure stages are arranged. This portion is often of little importance as compared with the remainder of the blading, because in most industries the quantity of steam available corresponds, to a certain extent, to the energy required. Naturally, the first condition to be realized in operation is as nearly as possible the equalization of the energy produced and that required during the process of manufacture. With these special types of turbine, electric energy can be

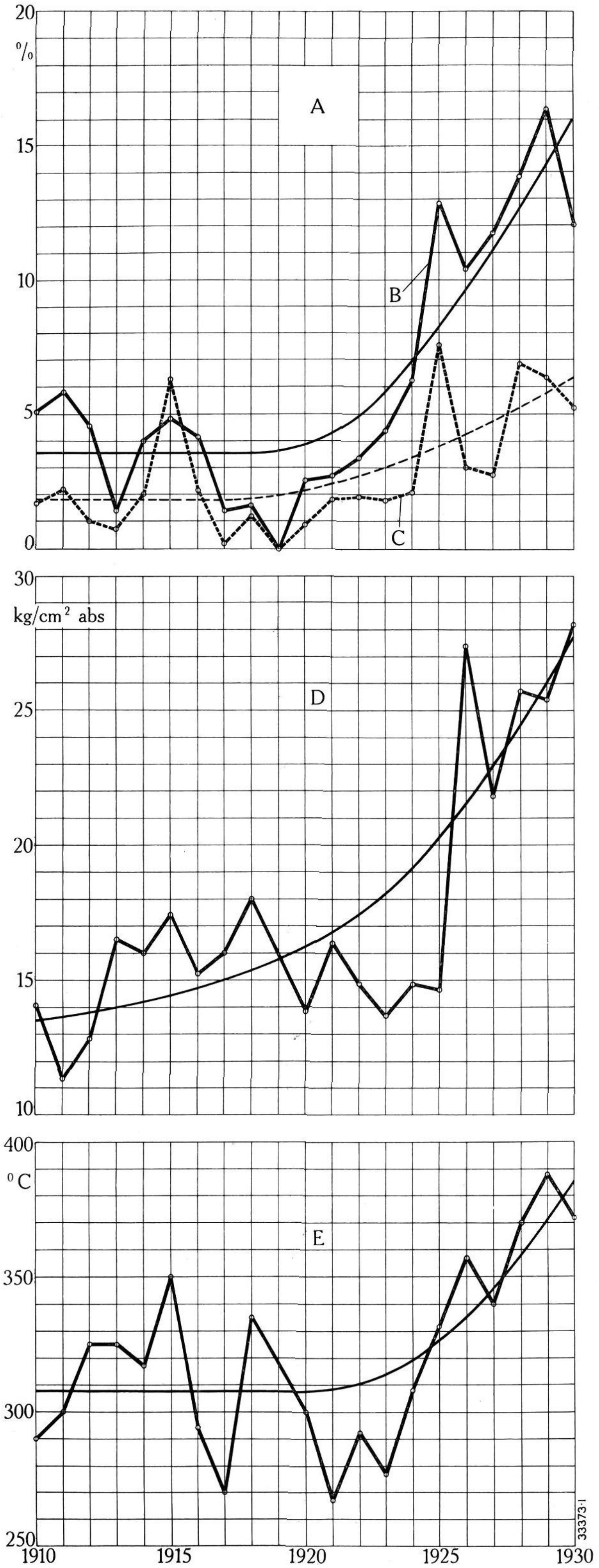


Fig. 1. — Back pressure and extraction back-pressure turbines.

A. Percentages per annum with reference to the total number of turbines delivered.

B. Number in percentages.

C. Output in percentages.

D. Live-steam pressure.

E. Live-steam temperature.

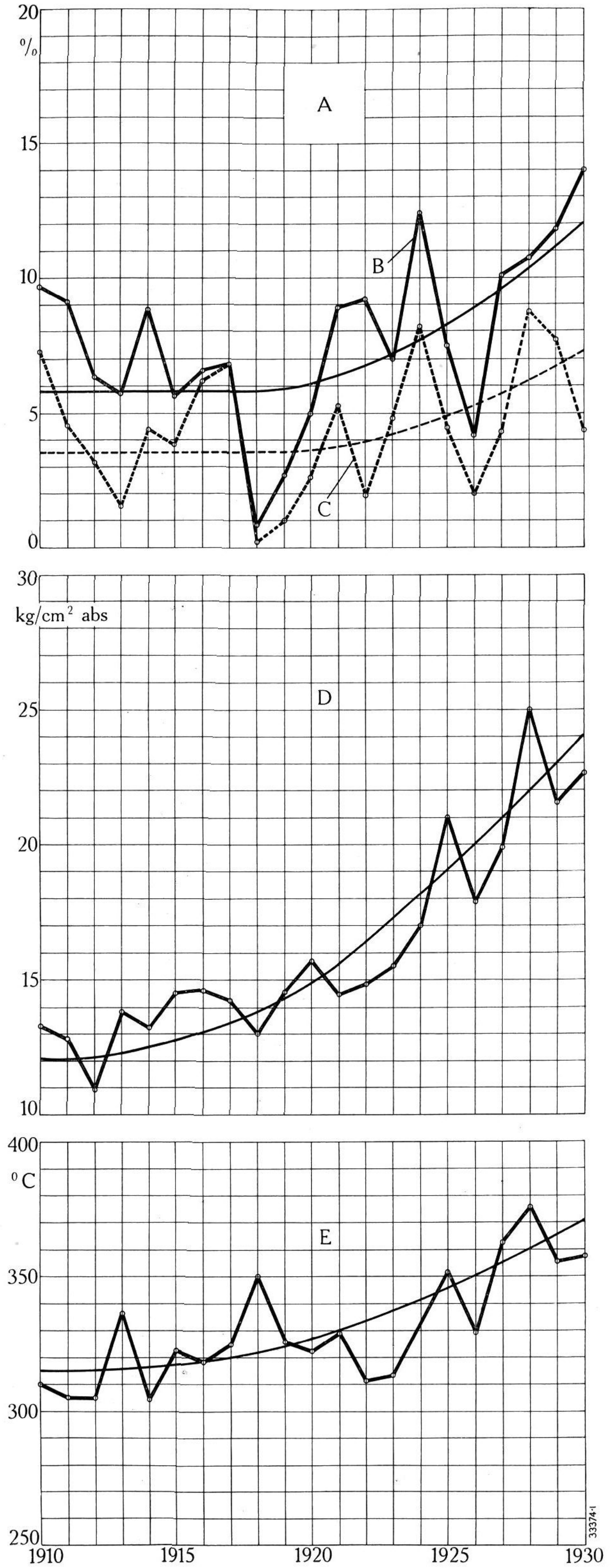


Fig. 2. — Single and double extraction condensing turbines.

A. Percentages per annum with reference to the total number of turbines delivered.

B. Number in percentages.

C. Output in percentages.

D. Live-steam pressure.

E. Live-steam temperature.

supplied almost as cheaply as by the three types previously mentioned. These special types of turbine may be denoted as:—

(4) Single extraction condensing turbines;
(5) Double extraction condensing turbines;
(6) Mixed-pressure turbines.

The great advantages of special steam turbines have been more and more recognized in recent years. This can be seen from the following diagrams in which is shown the percentage increase, during the last 20 years, of steam turbines for special purposes.

The graphs in Figs. 1 and 2, Fig. 1 for back-pressure and extraction back-pressure turbines, Fig. 2 for single and double extraction condensing turbines, show clearly the rapid increase in the use of these turbines. A corresponding graph for exhaust and mixed-pressure turbines has not been given, because these two types rarely occur in practice and are not often ordered.

The upper portion of both diagrams shows the number of special turbines made per annum as a percentage of the total number of turbines ordered from the Brown Boveri concern. The figures are taken at the end of each year. Further, the average value curve is also shown. For example, in Fig. 1 from 1910 to 1920 the average fraction of power corresponding to back-pressure turbines is about 2% of the total power of land turbines over 200 kW ordered, while with respect to the number it is about 4%. From this time the average value curve rises very quickly to 6% and 16% for 1930. Therefore, in ten years the power per annum has tripled and the number per annum even quadrupled. At the same time it should be mentioned that the total number of turbines delivered by the Brown Boveri organization from 1920 to 1930 increased very rapidly, as can be seen from Fig. 3 showing the total number and output of the turbines delivered. From 1920 to 1930, according to the average curves, the number of turbines delivered has increased from 75 to 190 per annum, i.e. about 2·5 times, while the total annual output has risen from 290,000 to 1,200,000 kW, i.e. about four times.

If therefore, during these years, the *percentage* figure corresponding to back-pressure turbines has *quadrupled as regards number* and *tripled with respect to power,* the *total* number of turbines of all types delivered having increased, during the same period, in a proportion of *1 to 2·5 for the number* and *1 to 4 for output,* this represents a total annual increase in production for both types of turbine, of *1 to 10 in number* and *1 to 12 with respect to output.*

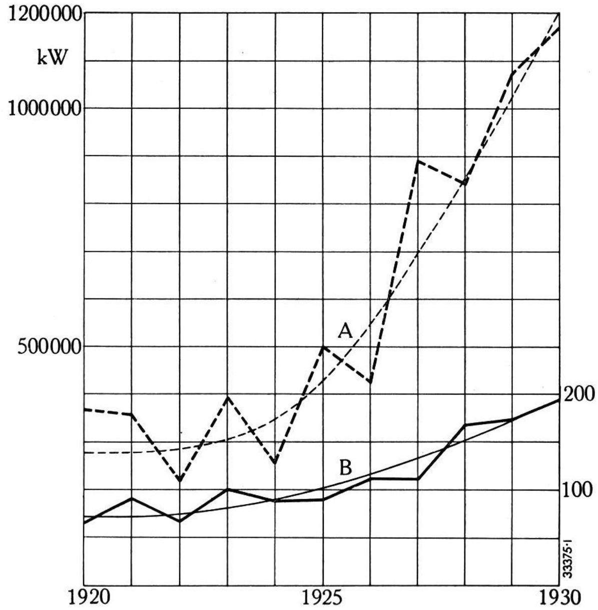


Fig. 3. — Total output and number of steam turbines delivered per annum by Brown, Boveri & Co.
A. Output. B. Number

Moreover, the lower curves in Figs. 1 and 2 represent the average live-steam pressure and temperature. In these, the development of recent years can again be recognized. Thus, in the case of back-pressure turbines, the average live-steam pressure at the end of 1910 was 13·5 kg/cm² abs, in 1920 already 16 kg/cm² abs, and at the end of 1930 it had reached 27·5 kg/cm² abs. In other words, in 20 years the average pressure has approximately doubled. There was a similar increase in the live-steam temperature, which at the end of 1930 was, on the average, nearly 400° C. This development, i. e. the increasing use of high pressure high superheated steam, is the result of recognition of the fact that for a given back-pressure one kg of steam can produce a greater output, the higher the pressure and temperature of the steam and the higher the back-pressure. Certainly the amount of heat per kilogram of steam is also greater, but this is more than offset by the still greater percentage increase in output.

In many cases to-day it is possible to supply the client with all the electrical energy required simply by increasing the live-steam pressure and temperature. A back-pressure turbine will often suffice instead of an extraction condensing turbine, causing a great simplification and considerable cheapening of the installation. This explains the more rapid increase of back-pressure and extraction back-pressure turbines as compared with single and double-extraction condensing turbines.

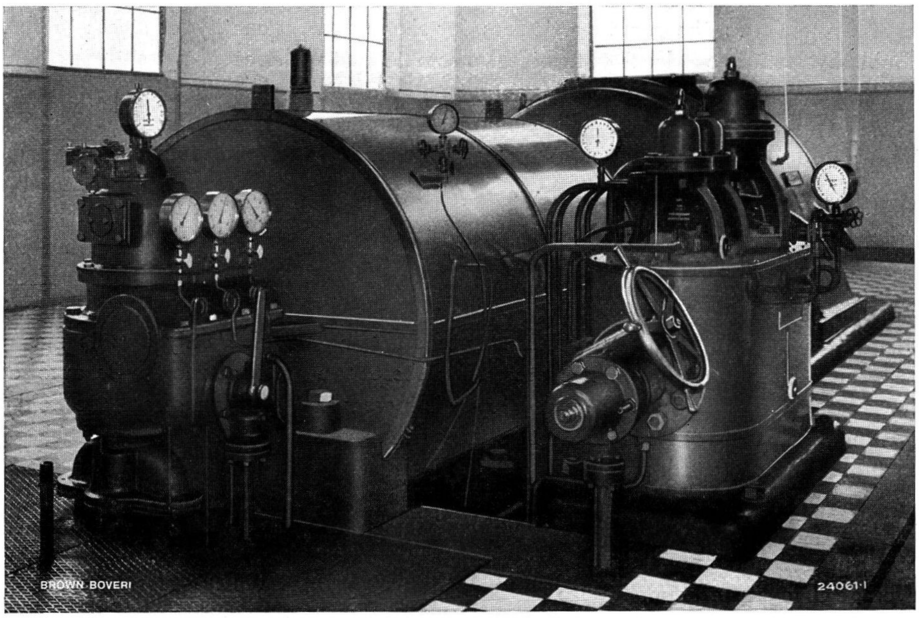


Fig. 4. — Back-pressure turbine of 2800 kW, 3000 r. p. m., designed for 37 kg/cm² abs, 400° C, 4 kg/cm² abs back-pressure.

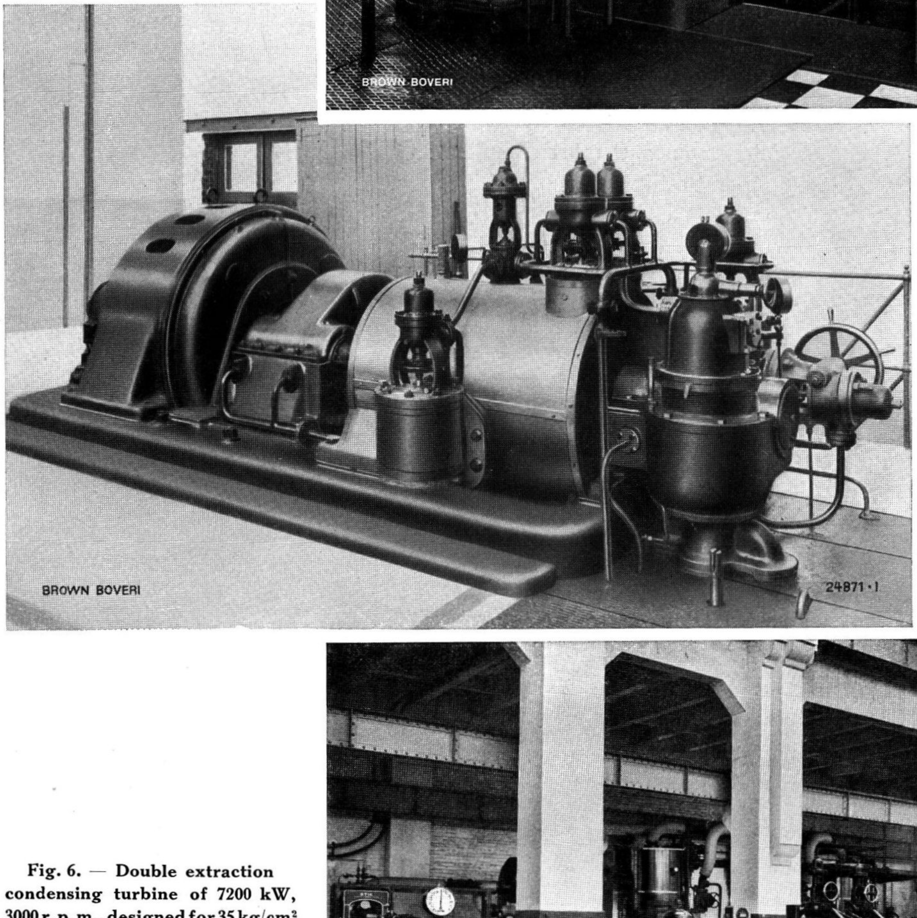


Fig. 5. — Extraction back-pressure turbine of 1800 kW, 3000 r. p. m., designed for 15 kg/cm² abs, 350° C, 5 kg/cm² abs extraction pressure, 1·1 kg/cm² abs back-pressure. Maximum extraction 16,000 kg/h.

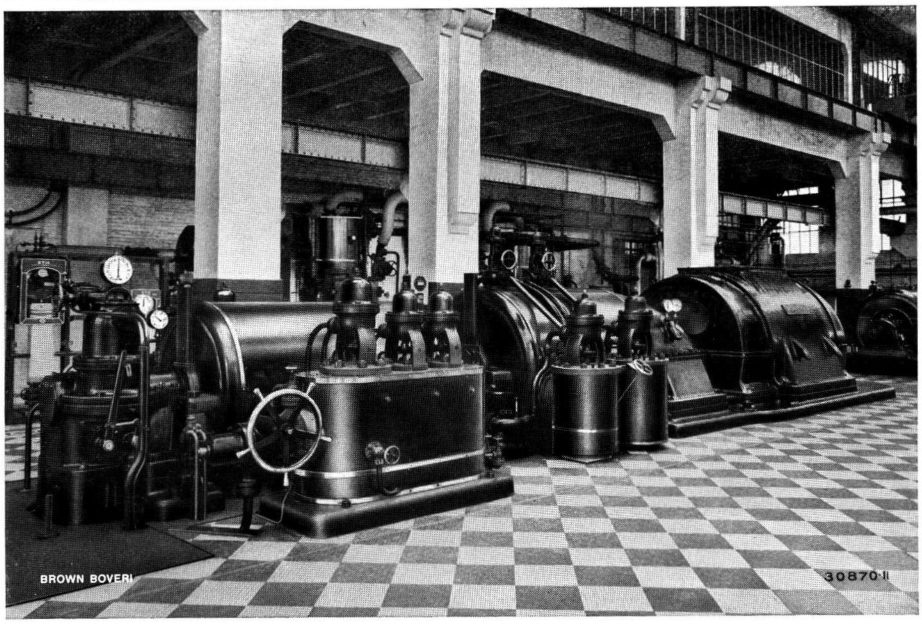


Fig. 6. — Double extraction condensing turbine of 7200 kW, 3000 r. p. m., designed for 35 kg/cm² abs, 400° C, extraction pressures 7 and 3·5 kg/cm² abs, maximum extractions 25,000 and 12,600 kg/h.

Fig. 2 shows the same particulars for single and double-extraction condensing turbines. From 1910 to 1920, on the average, 3·5 % in output and 6 % in number of the turbines made per annum were of these two types. The corresponding figures at the end of 1930 were 7 % and 12 %. In other words, during the last ten years, the percentage increase of extraction turbines as compared with the total turbines above 200 kW delivered, was 100 % both as regards power and number of units. The increase is therefore considerably less than for back-pressure turbines.

The conditions of the live steam for these two types of turbines have also tended towards increased pressures and temperatures, but not to the same extent as in the case of back-pressure turbines. In 1910 the average live steam pressure was only 12 kg/cm^2 abs, in 1920 already 15 kg/cm^2 abs, and at the end of 1930 it reached the value of 24 kg/cm^2 abs. The average live steam temperature at the end of 1930 was 370 °C.

In the case of extraction condensing turbines, therefore, an increase of pressure and temperature is not so important, because the low pressure part can generally undertake overloads. In any case the condensing plant is continually in service, and whether the quantity of steam to be condensed is larger or smaller does not greatly matter.

To sum up, the statistics possessed by Brown, Boveri & Co. show clearly the percentage increase of steam turbines for special purposes compared with the total number produced. These types of turbines are continually required by industry and still greater numbers will be required in future. The importance and advantage of suitably combining the production of electric energy and heat is becoming more and more recognized, since only in this manner can the highest efficiency be attained. Because of the increased use of high-pressure steam, the field of application of back-pressure and extraction back-pressure turbines has greatly increased.

Brown, Boveri & Co. recognized these facts a long time ago and have produced such designs even for the highest pressures, thus acquiring a wealth of experience. The well-known oil-pressure governor without link transmission ensures reliable operation even in the most complicated cases. Figs. 4 to 6 show three special steam turbine plants, viz. a back-pressure turbine, an extraction back-pressure turbine and a double extraction condensing turbine.

(MS 686) *W. R. Felix. (R. O. P.)*

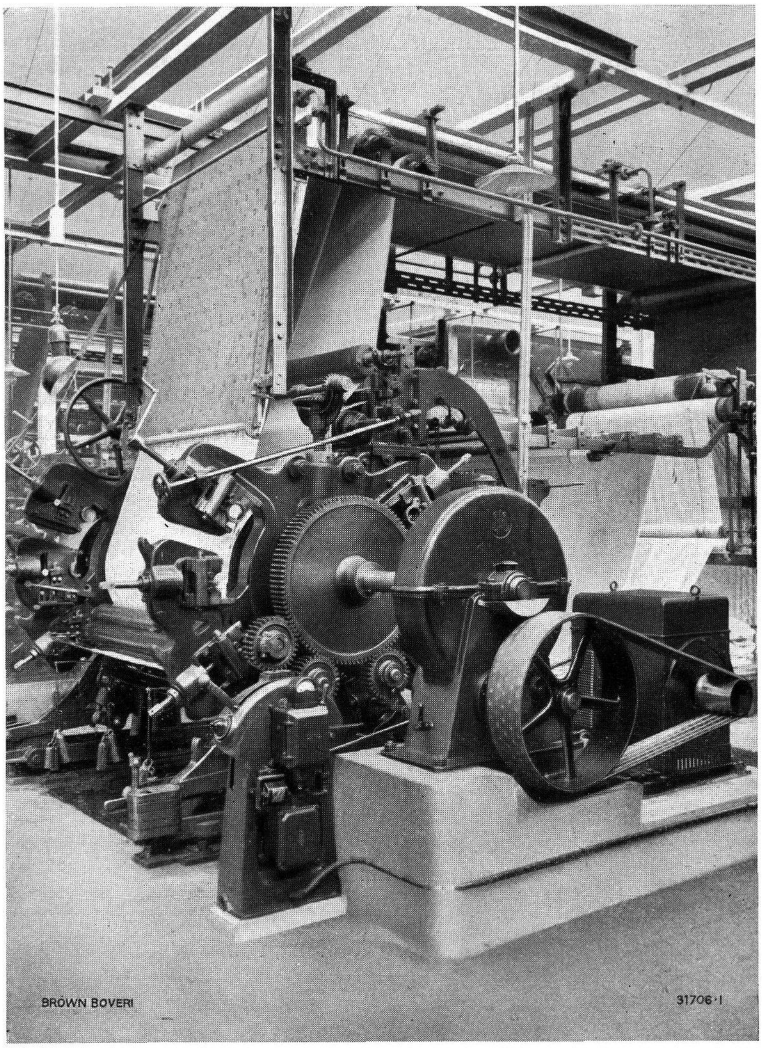
Swiss Federal Railways. Express passenger locomotive type 2 Do 1 with Brown Boveri individual axle drive.

Published by BROWN, BOVERI & COMPANY, LIMITED, BADEN (Switzerland). Printed by Kreis & Co., Basle, Switzerland.

WORKSHOPS IN BADEN, 1931.

BROWN, BOVERI & COMPANY
LIMITED
BADEN (SWITZERLAND)

WORKS: BADEN AND MUNCHENSTEIN (SWITZERLAND)



INDIVIDUAL DRIVE OF AN EIGHT-COLOUR CLOTH PRINTING MACHINE BY THREE-PHASE COMMUTATOR MOTOR AND CONTROL STAND.

DRIVES
FOR
CLOTH PRINTING MACHINES