VOL. XII APRIL, 1925 No. 4

THE BROWN BOVERI REVIEW

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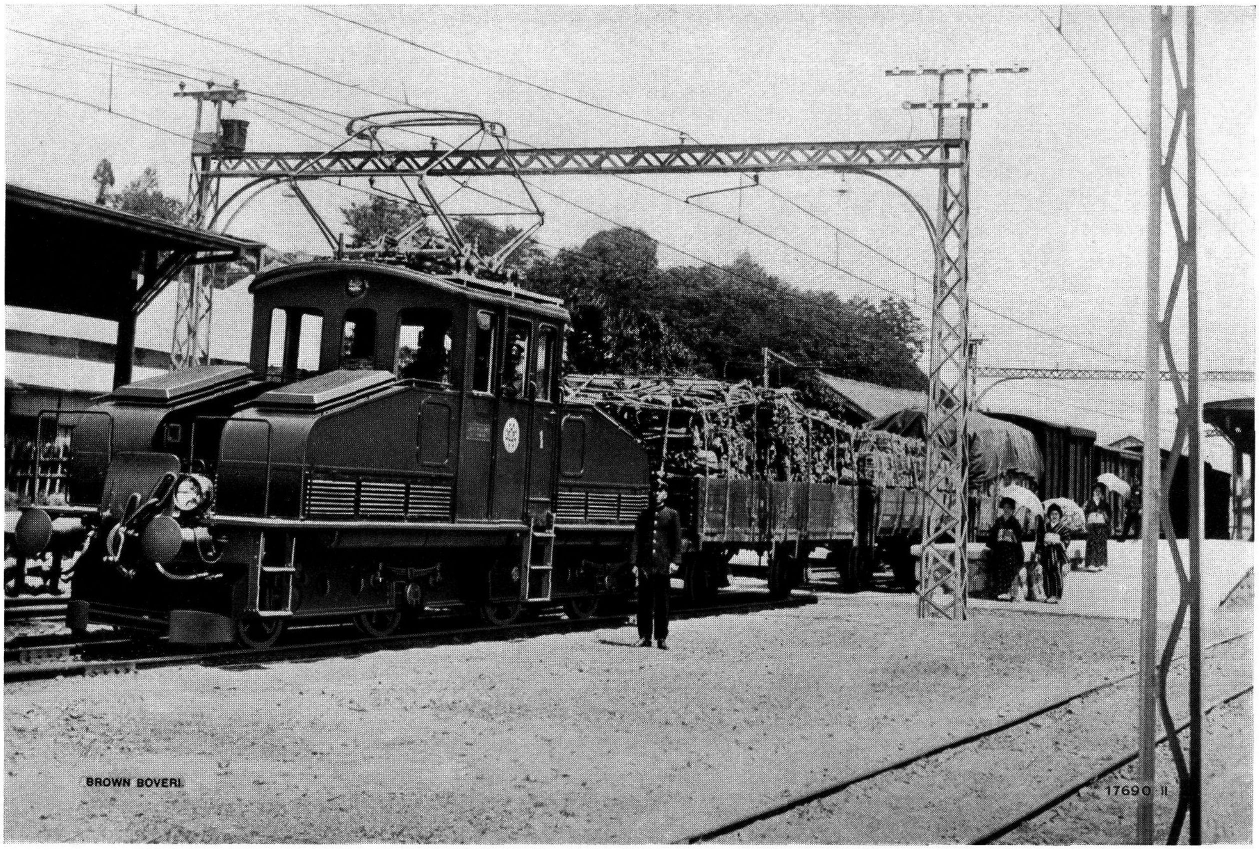
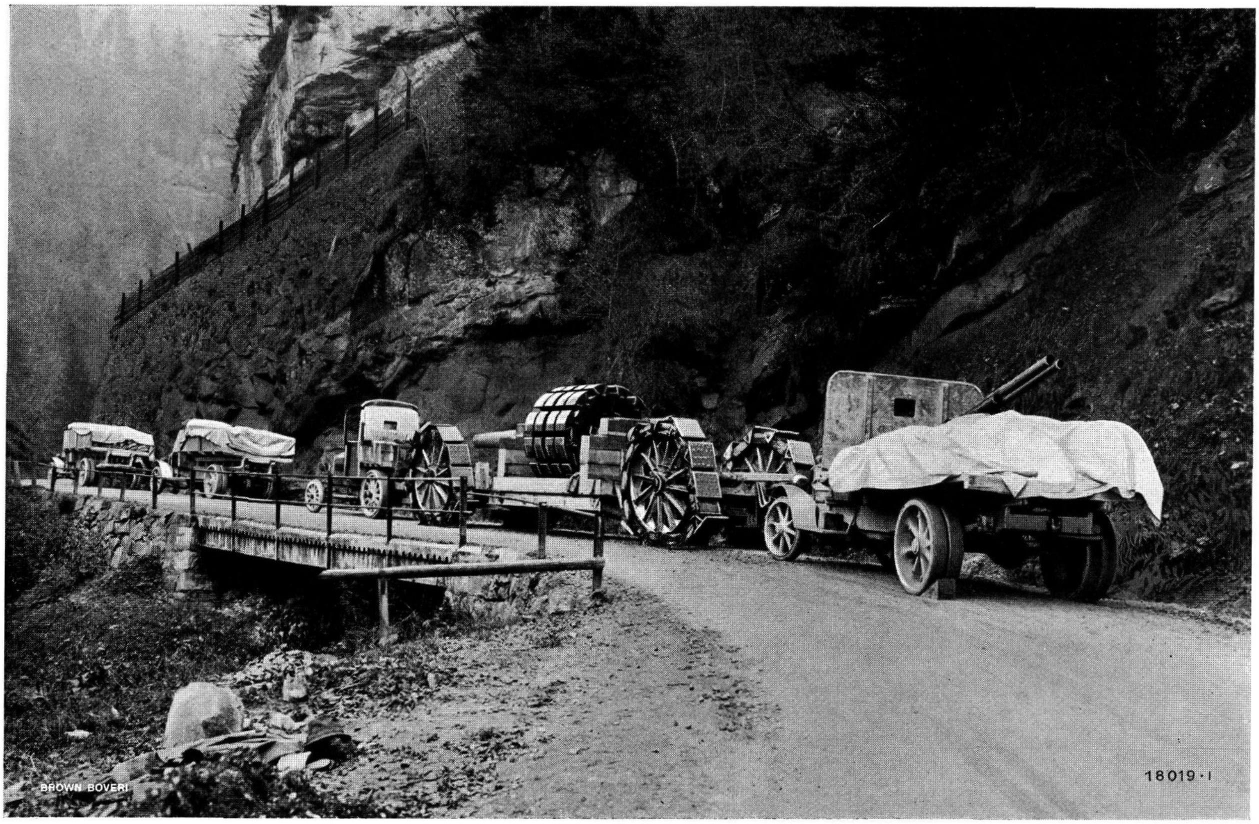


YOSHINO RAILWAY, JAPAN.
Goods train drawn by a B-B locomotive in Shimoichiguchi Station.

CONTENTS:

EQUIPMENT OF
ELECTRIC POWER STATIONS
OF ANY SIZE AND FOR ALL SYSTEMS OF SUPPLY



MACHINERY FOR THE WÄGGITAL POWER STATION, SWITZERLAND.
Transport of a rotor weighing 25 tons for one of the four three-phase alternators each 16,000 kVA, 8800 V, 0·7 power factor, 50 cycles, 500 r. p. m.

A.C. AND D.C. WATERWHEEL GENERATORS
FOR HIGH AND LOW-HEAD POWER STATIONS

THE BROWN BOVERI REVIEW

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

VOL. XII APRIL, 1925 No. 4

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THE BARBERINE POWER STATION OF THE SWISS FEDERAL RAILWAYS.

Decimal index 621. 312. 134:621. 331. 32 (49. 4).

I. INTRODUCTION.

SINCE their nationalisation, the Swiss Federal Railways have been occupied with a scheme for the electrification of the lines under their control. Owing to the lack of coal in Switzerland the maintenance of a steam train service is entirely dependent upon supplies of fuel obtained from other countries; the purchasing of coal for this purpose is a serious drawback and financial burden to the country. The rich water-power resources with which Switzerland is naturally provided are sufficient, if economically utilised, to generate the energy required for traction purposes, and Swiss manufacturing firms are in a position to construct all the necessary plant. The above circumstances, added to the well known advantages of an electrical service compared with steam operation, made the proposed electrification appear desirable from many points of view.

The first step towards the conversion was the electrification of the Simplon Railway in 1906. A special power station was erected for generating the low-frequency high-tension three-phase current used. Brown, Boveri & Co. supplied all of the electrical equipment of both the stationary plant and rolling stock (see Revue BBC 1920, No. 8, p. 199). The firm had already considerable experience with the three-phase system of traction, which had clearly shown its great value. Some of the railways previously equipped by Brown, Boveri & Co. were the Burgdorf-Thun Railway and the Stanstad-Engelberg Railway. The extremely good results attending these early electrification schemes and the experience which had been obtained pointed to the likelihood of a similar success attending the Simplon project.

The electrification of the comparatively short section of the Simplon Railway, for the most part in the tunnel, was of such a restricted character that it did not form a suitable example on which to base the development of electrification in Switzerland. Modern technical development has, in fact, progressed in other directions and the Simplon has—electrically speaking—remained isolated from the other distribution systems.

In the year 1913, the Swiss Federal Railways had already decided upon the electrification of a large part of their system. The project was of great significance both with regard to its influence on the finances of the Federal Railways, and particularly with respect to the reaction on the national economy. The decision was reached after a thorough investigation which extended over many years, the commission formed for the enquiry showing conclusively that a properly carried out electrification scheme would be advantageous. This commission investigated the technical problems involved as well as the economic considerations, and chose the single-phase system as the one which, promised to give the best results from every point of view.

From their investigations the commission found that the energy required should be generated in independent traction power station, and that it should be low-frequency single-phase alternating current.

The constructional work was commenced in 1916 and proceeded rapidly on the power stations at Ritom and Amsteg with five substations and the remaining electrical installation for the Gothard Railway. Descriptions of the work have been already published particularly in the Revue BBC, 1921, No. 9, p. 217.

Steam locomotives vanished long ago from the section 225 km in length between Chiasso and Lucerne. The electrification of this line has now been extended as far as Basle. This electrification is important from every point of view and has brought results which have become a centre of interest for the whole technical world; consequently a great deal is already known regarding these plants.

On the other hand, the electrification which has been carried out in the west of Switzerland is not so well known. This fact may arise because the section is small in comparison to the Gothard Railway, or because it is not of such pronounced international importance; the large stations in West Switzerland, however, show numerous interesting details. Many ideas relating to the erection of large stations have completely changed in recent times; for example, questions of over-voltage protection and earthing are treated entirely differently to-day compared with a few years ago. Particular attention has been paid to ensure that the plant in western Switzerland incorporates all recent improvements and in a description of the large power stations of the Swiss Federal Railways details should not be overlooked, and the provision for over-voltage protection in particular should be dealt with fully.

The preparatory work for the electrification of the western sections was commenced in 1918, soon after that for the Gothard Railway. The scheme being to introduce electrical operation from two points (Gothard and Valais), completing the work in such a manner that both distribution systems would meet and so unite to form a single network. The electrification scheme for West Switzerland started with the section from Brigue to Lausanne (146 km); of this, the sub-section between Brigue and Sion (54 km) had been equipped with three-phase current since 1918, in connection with the Simplon Tunnel. To establish uniformity, however, this part is to be converted to the single-phase system. The complete programme

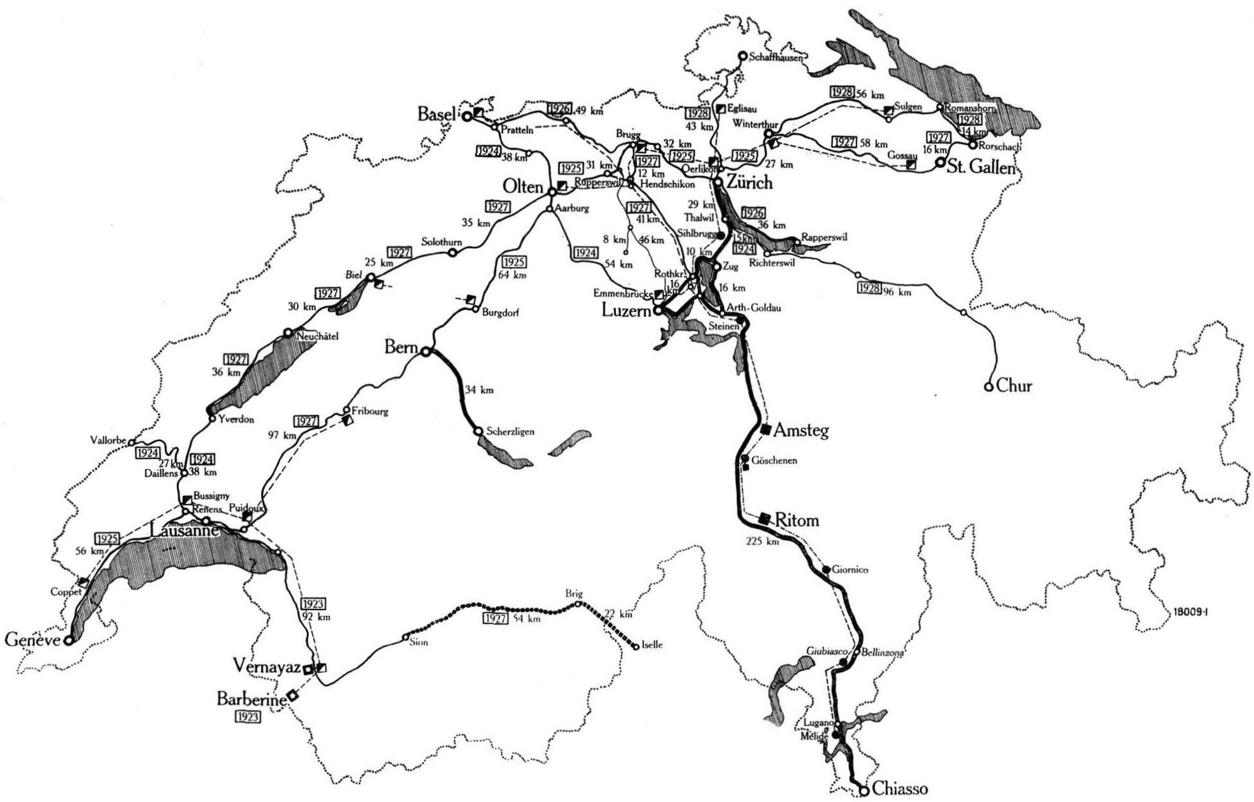


Fig. 1. — Map illustrating the accelerated electrification programme of the Swiss Federal Railways during the years 1923—1928.

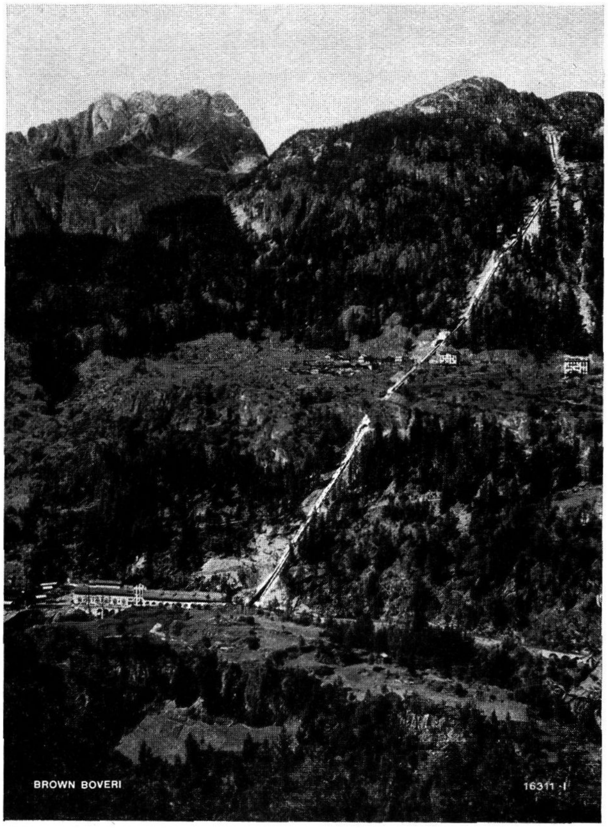


Fig. 2a. — General view of Barberine Power Station showing pipeline and funicular railway.

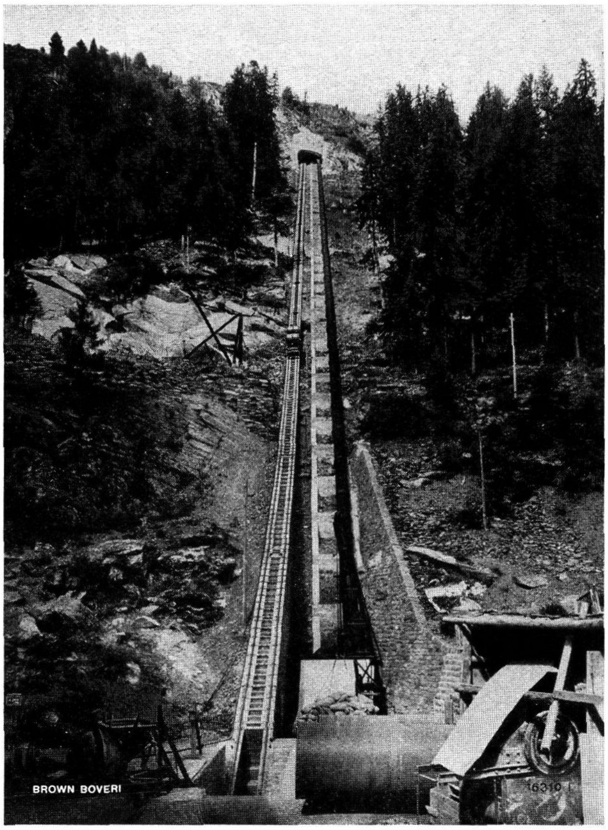


Fig. 2b. — Lower part of the pipeline and funicular railway.

for the extension of the distribution system has not yet been decided.

The tendencies are pointing towards a speedy completion of the work on the main sections. In 1923, the "Conseil Fédéral" decided upon the "Accelerated Electrification Programme" for the years 1923—1928, according to which the electrical service of the principal parts of Switzerland are to be completed by the year 1928. The map (Fig. 1) shows the lines already electrified and also those on which the conversion will soon take place.

Fig. 2c. — Head of the pipeline during construction.

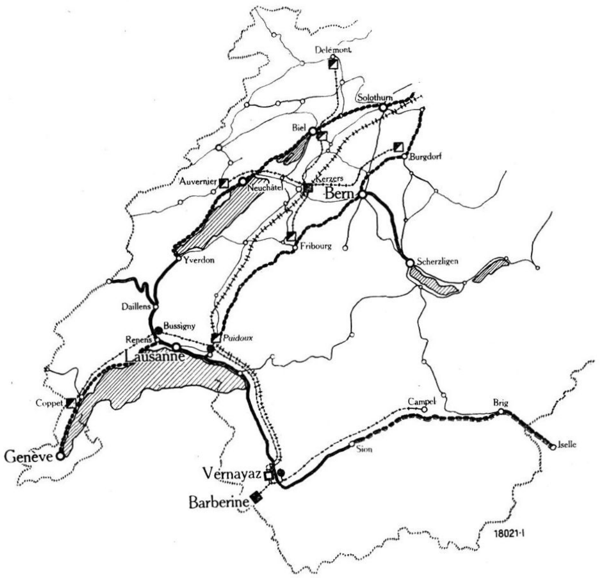


Fig. 3. — Map showing the western high-tension distribution system of the Swiss Federal Railways.

In each instance the probable year of completion and the length of the line in kilometres are given.

The energy required for the western sections is generated at two power stations, one at Barberine and the other at Vernayaz. Both of these power stations use the waters of the stream Eau Noire and also the falls of smaller streams. The flow of the high-mountain streams varies considerably during the year; to balance this variation an artificial lake was made by damming the valley. The dam, which is of concrete, is 77 m high, 264 m long, and its volume is 230,000 cubic metres. The quantity of water stored in this artificial lake is approximately 37,500,000 cubic metres, at a height above sea level of 1800 m. A gallery about 2300 m long conducts the water to the pipeline which leads to the power station, the fall amounting to about 760 m. The pipeline is designed

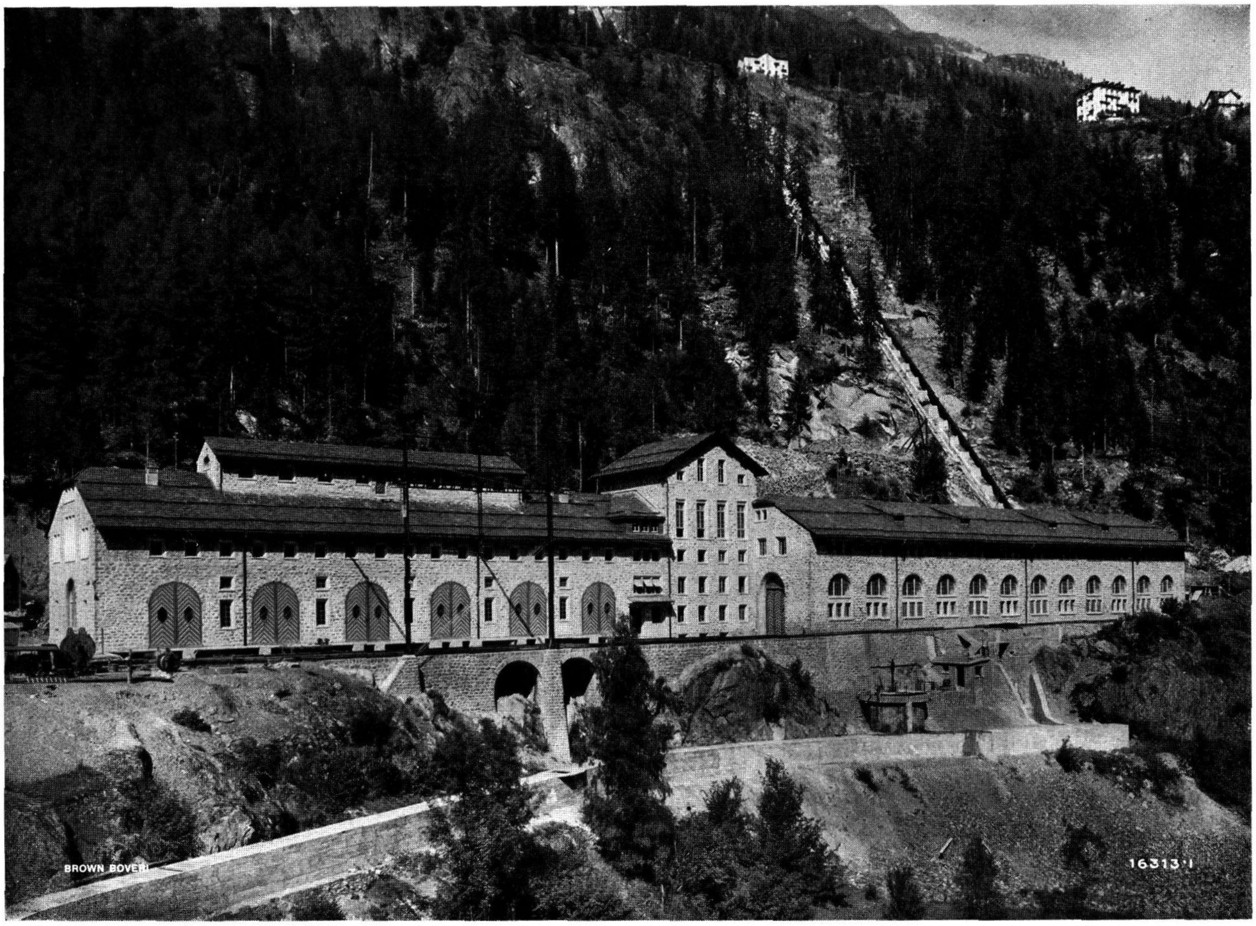


Fig. 4. — The power station buildings.

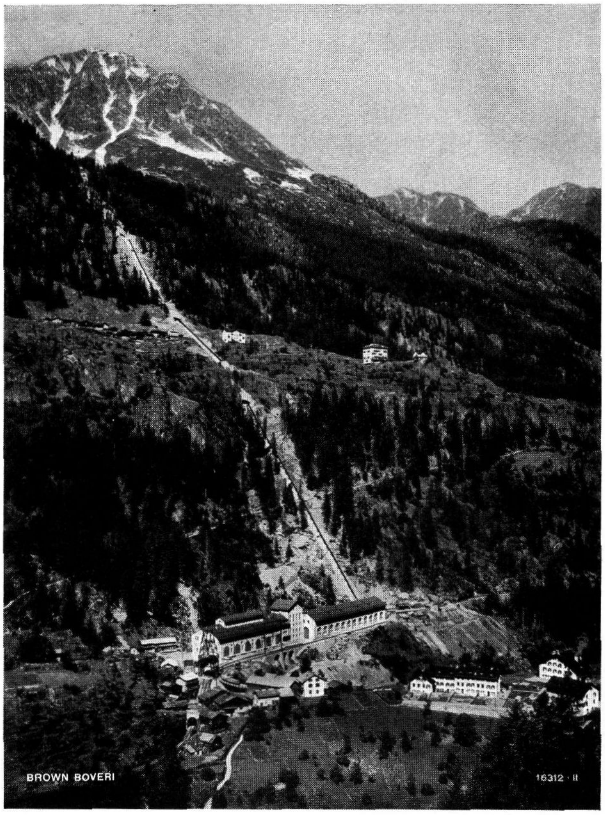


Fig. 5. — General view of the power station and pipeline.

for a maximum discharge of 4 cubic metres per second, whereas the average value for the whole year amounts to about 1·5 cubic metres per second. A special funicular railway, as shown in Fig. 2 was constructed to assist in laying the pipeline.

The second stage (Vernayaz) utilises a fall of approximately 630 m with a maximum flow of 14·0 cubic metres per second. The discharge from the first stage is increased by some streams which are tapped at the height of the Barberine machine house. As yet, only the first of the two power stations is in operation; the work on the plant at Vernayaz has been but recently commenced.

The energy is carried from the Barberine power station by four 66-kV lines, all supported by the same poles, to the Rhone Valley and is distributed as shown in Fig. 3. The chief branching point in the distribution system is the substation at Puidoux[1]. When the power station at Vernayaz is developed later the enlarged 66-kV system will be connected by a 135-kV transmission line to the East-Switzerland system.

[1] See the article "The Puidoux Substation of the Swiss Federal Railways" page 76.

II. THE POWER STATION.

The power station is built near the Châtelard-Village station of the Martigny-Châtelard Railway, it is bounded on one side by the railway line and on the other by the mountain slope. These conditions made it necessary to build the machine hall and switchgear house end-on, in the same straight line, as shown in Fig. 4. The insertion of a building, somewhat higher than those on either side, between the switchgear house and the machine hall maintains the good architectural appearance of the station, as shown in Fig. 5.

As described in The Brown-Boveri Review, 1923, No. 3, page 57, the greater part of the equipment of the Barberine Power Station consists of machines and apparatus manufactured by Brown, Boveri & Co.

III. THE GENERATORS.

The machine hall (Fig. 6) is designed to accommodate five generating sets, as yet, however, only three have been installed. The prime mover of each set is a Pelton turbine, which develops 17,000 H.P. at 333·3 r. p. m, with a head of 763 metres. Each turbine has a simple bucket wheel and is provided with one nozzle and a counter nozzle for braking; they are controlled by suitable automatic regulators and also a means of regulating by hand should this be desirable.

The sets each have three bearings, of which the centre one fitted to the generator has been designed to withstand half of the water pressure on the buckets as well as half of the turbine weight. The coupling between the shafts of the turbine and alternator is rigid.

The alternators (Fig. 7) are of the same type as the four supplied, by Brown, Boveri & Co., for the Ritom power station of the Swiss Federal Railways, a detailed description of these machines has already been published in the Revue BBC, 1921, No. 9, p. 217. The following table giving the chief characteristics and most interesting details will suffice in the present case:

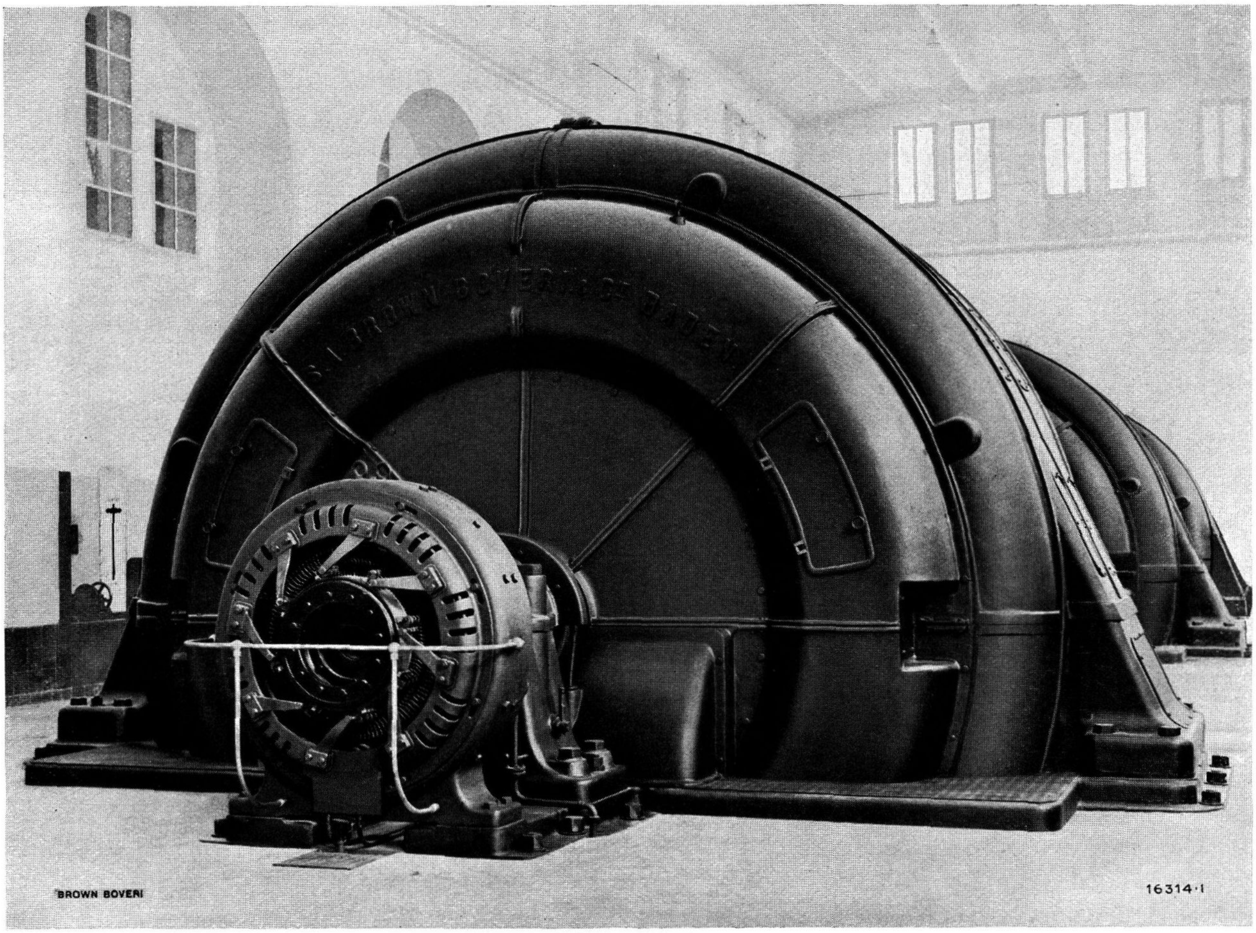


Fig. 6. — Three single-phase alternators each 10,000 kVA, 15,000 V, $16^{2}/_{3}$ cycles, 333·3 r. p. m.

Kind of current	single-phase
Continuous rating	10,000 kVA
Power factor	0·75
Terminal pressure	15,000 V
Frequency	$16^{2}/_{3}$ cycles
Normal speed	333·3 r. p. m.
Maximum voltage	55,000 V
Runaway speed	630 r. p. m.
Efficiency on full load with unity power factor	94·5 %
Efficiency on half load with unity power factor	91·0 %
Efficiency on full load with 0·75 power factor	93·8 %
No. of poles	6
Output of excitation machine	80 kW
Total weight	222 tons
Weight of rotor	80 tons
Moment of inertia	360,000 kg/m^2
Outside diameter	6 m approx.
Volume of cooling air	30 m^3/sec. approx.

The *cooling air* for the alternators is drawn in from the atmosphere through louvred windows as shown in Fig. 4. During the winter the air can be obtained from the machine room by suitable arrangement of the ventilators and shutters. After circulating round the machines, the air which has become warmed, collects on the far side of the machine room in a longitudinal channel also serving as a cable duct, and flows to the pipeline house. In winter the air flows also into the heating channels for the switchgear.

IV. THE SWITCHGEAR.

1. General. The principle condition influencing the general layout of the switchgear was that the whole of the energy was to be taken from the power station by two (subsequently four) high-tension lines, no medium or low-tension lines being present. For this reason, a transformer is connected to each alternator, and the alternator-transformer sets so established operate on the 66-kV busbars without the intermediate connection of low-tension busbars. This arrangement is to be found in many central stations which have been equipped by Brown, Boveri & Co., and embodies the general practice followed by the firm for many years. The advantages of this arrangement are, among others: a decrease in purchasing and building costs owing to the reduction in the number of switches and the omission of the low-tension busbars; an increase in the reliability of operation resulting from the simplification of the plant and of the attention required.

With respect to the dangers arising from excessive voltages occurring as a result of atmospheric discharges or flashovers to earth, no short low-tension lines or lines at the potential of the generators should pass outside the station if it can possibly be avoided. Such an arrangement, however, is not always practicable particularly in the case of railway work. In Barberine, the conditions compared favourably with those in other plants, so that the full advantages of combining the alternators and transformers as individual sets were self-evident.

The general diagram, Fig. 8, shows how each group can be connected as required to one or other of

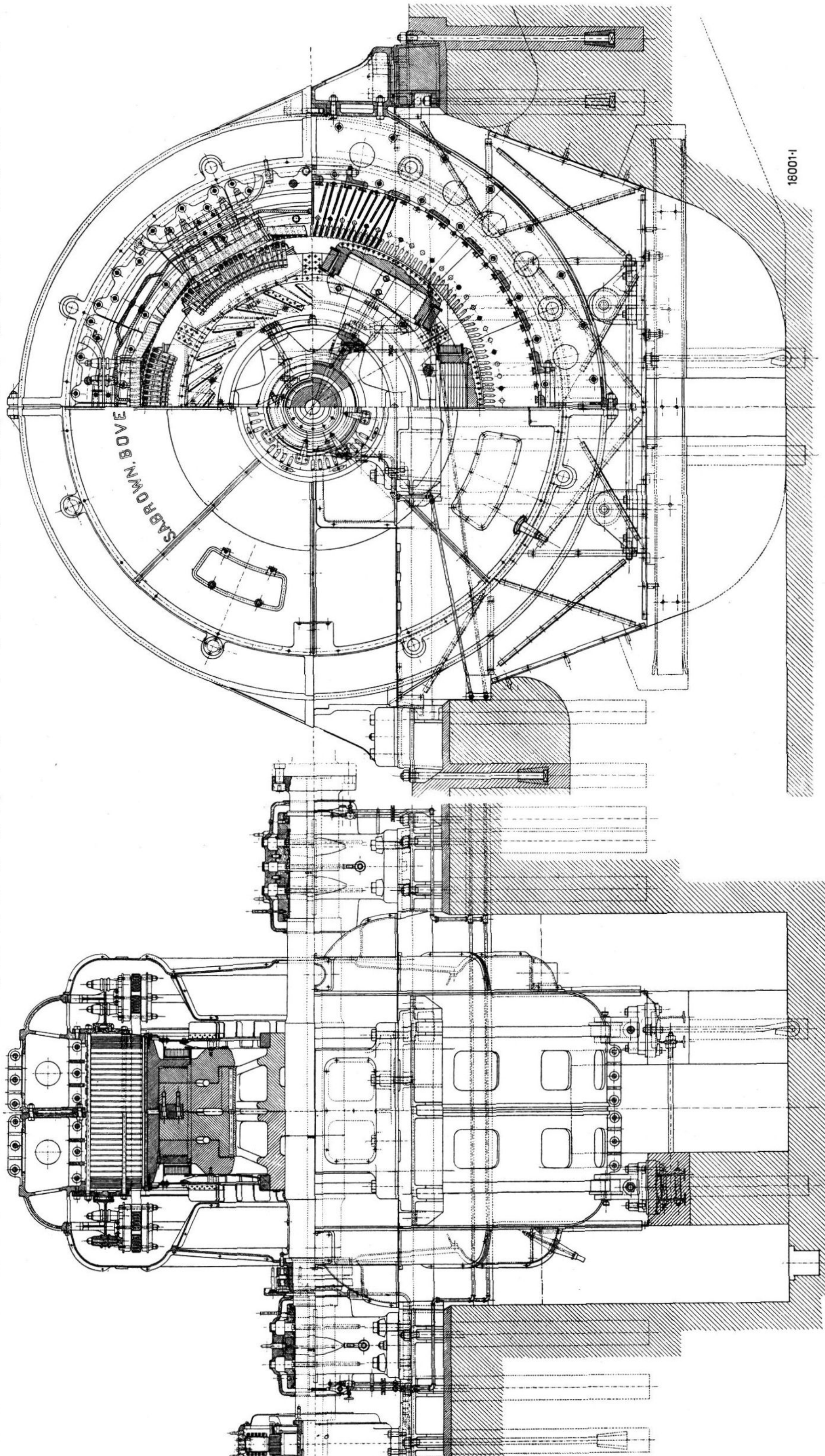


Fig. 7. — Single-phase alternator 10,000 kVA, 15,000 V, $16^2/_3$ cycles, 333·3 r. p. m.

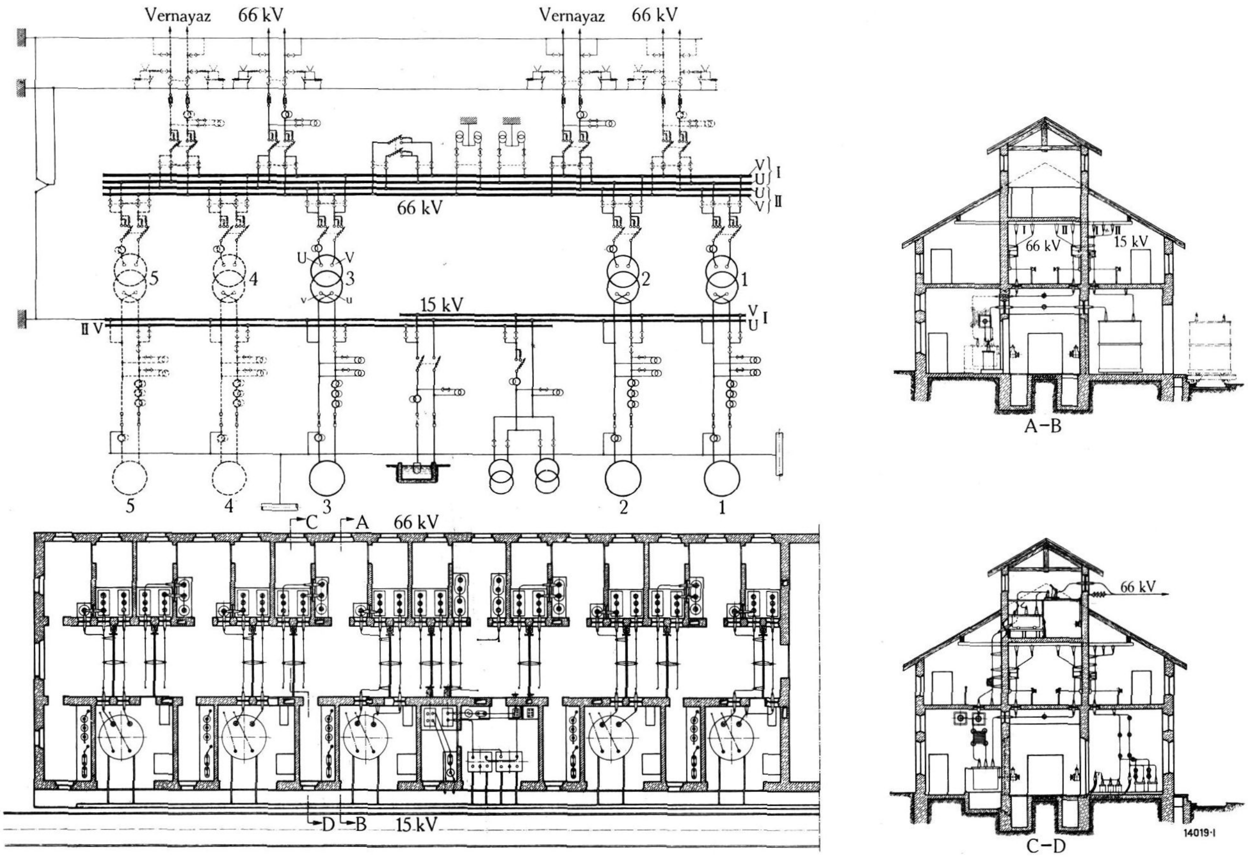


Fig. 8. — Diagram of principal connections.
Scale 1 = 550.

the two 66-kV busbars, which can be coupled together, and also, that the outgoing lines can be supplied from both sets of busbars. Direct current, partly at a pressure of 220 V and partly at 14 V is required to supply the auxiliary apparatus of the station, such as the signalling devices. The plant supplying the needs of the station itself transforms, converts, and stores the electrical energy taken from the 15-kV busbars. Although by employing station transformers with the 66-kV high-tension busbars the auxiliary busbars could have been omitted, they were found to be necessary to enable any particular alternator to be connected to any of the transformers in the event of repairs, and on account of the necessity for providing permanent busbars for testing purposes.

The station is completed by the inclusion of a water resistance, with a capacity of 10,000 kW for testing purposes. This resistance is also connected to the 15-kV busbars.

Fig. 9 shows the plan and elevation of the buildings. In the basement are situated the channels for the alternator and control cables and also a place for the earth connections. These channels also conduct the warm air from the generators, which is used for heating in winter. No further space was provided in the basement as the expensive blasting operations in the rocks on which the switchgear house is built had to be reduced to a minimum.

All equipment difficult to remove oving to its great weight, or which could cause a fire or explosion on account of its oil content, is installed in two rows of cells arranged along both sides of the ground floor of the building. Each cell is enclosed and separated from the adjoining ones by thick walls but the windows of these cells are relatively weak, so that, if an explosion should occur they would be immediately broken and a dangerous rise of pressure avoided. With this arrangement the explosion shutters, recently

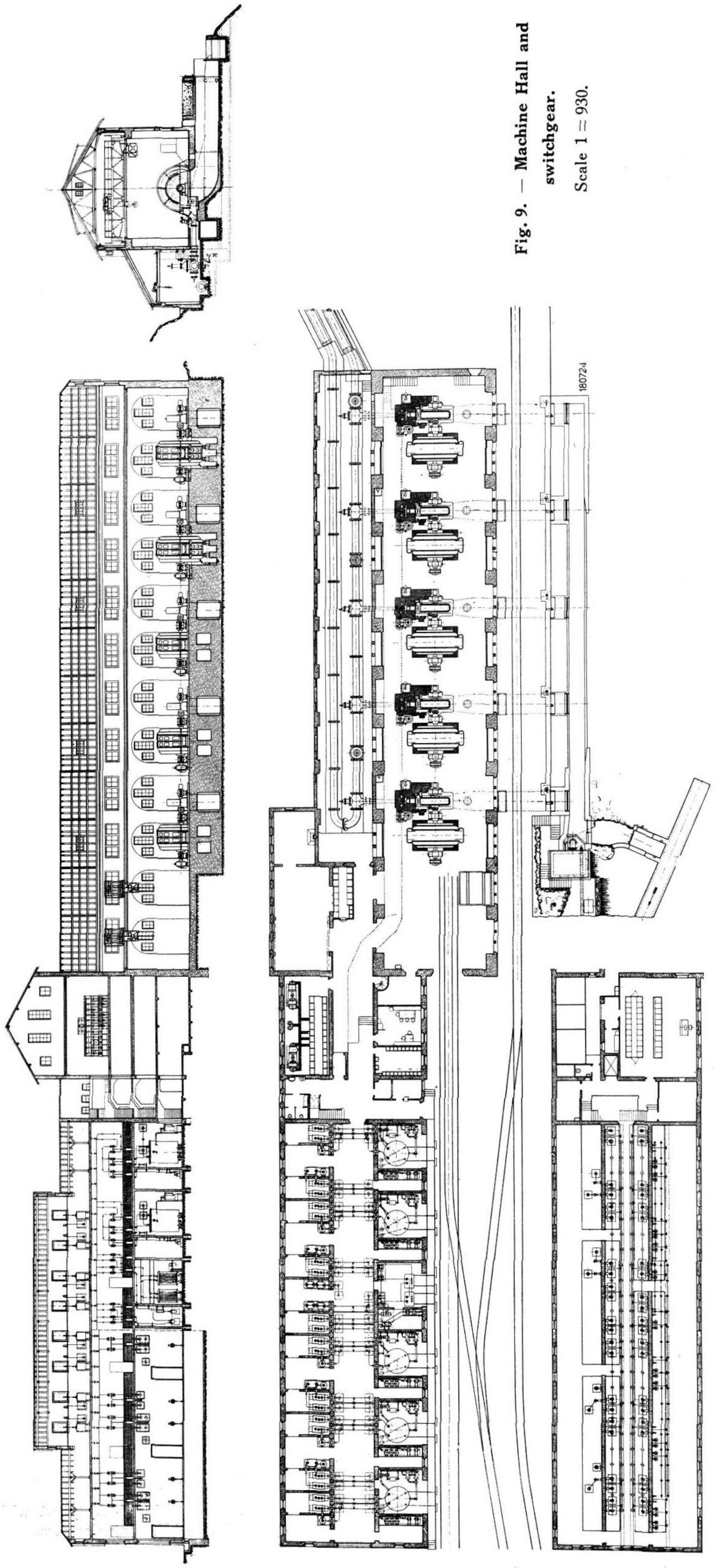


Fig. 9. — Machine Hall and switchgear.
Scale 1 : 930.

used for the same purpose in certain other stations, are not necessary; the plant is therefore cheaper without prejudice to the safety. By this means, any outbreak which may occur would be completely localised and the fire could not spread by jumping the dividing walls of the cells.

Each group of cells is accessible through a large opening which is used at the same time to illuminate the central portion of the ground floor. Each group contains all the interdependent apparatus such as the transformer switches and differential-protection current transformers or line switches and the potential and current transformers of an outgoing line.

All the controls of the oil switches are situated in the centre of the building. If it is required to operate a switch by hand, there is no need for the attendant to enter the cell since the control is accessible from without. The switch cells should not be entered for the purpose of operating the switches contained but only for examination, which is seldom necessary.

The upper storey of the building is divided longitudinally into three rooms. In one of the outer rooms the 15-kV busbars are fitted, and in the middle one, the 66-kV main busbars. Beneath the busbars, all isolating switches of the plant not connected with the over-voltage protection or the outgoing lines are installed. In this manner, ease of supervision is ensured, which is the chief condition for reliability of operation in a station. The room facing the mountain side contains the leads from the line switches to the outgoing lines and protective choke-coils.

The raised central portion of the roof is used for the installation of the bushings and insulators of the outgoing lines, together with apparatus and isolating switches for earthing and over-voltage protection.

(MS 314) *C. Cohen. (J. R. L.)*

(To be concluded.)

THE PUIDOUX SUBSTATION OF THE SWISS FEDERAL RAILWAYS.

Decimal index 621. 312. 63 (49. 4) : 611. 331. 32 (49. 4).

I. GENERAL.

THE Puidoux substation of the Swiss Federal Railways is situated about 500 metres S.W. of the Puidoux-Chexbres railway station, in the angle formed by the lines separating at Puidoux-Chexbres, one to Lausanne the other to Vevey.

This substation is a combined transformer and high-tension switching station. In the former capacity, it supplies current to the neighbouring trolley-line sections of Lausanne-Palézieux and Puidoux-Vevey as well as to the St. Maurice-Lausanne section. In the latter capacity, it distributes power to the substations

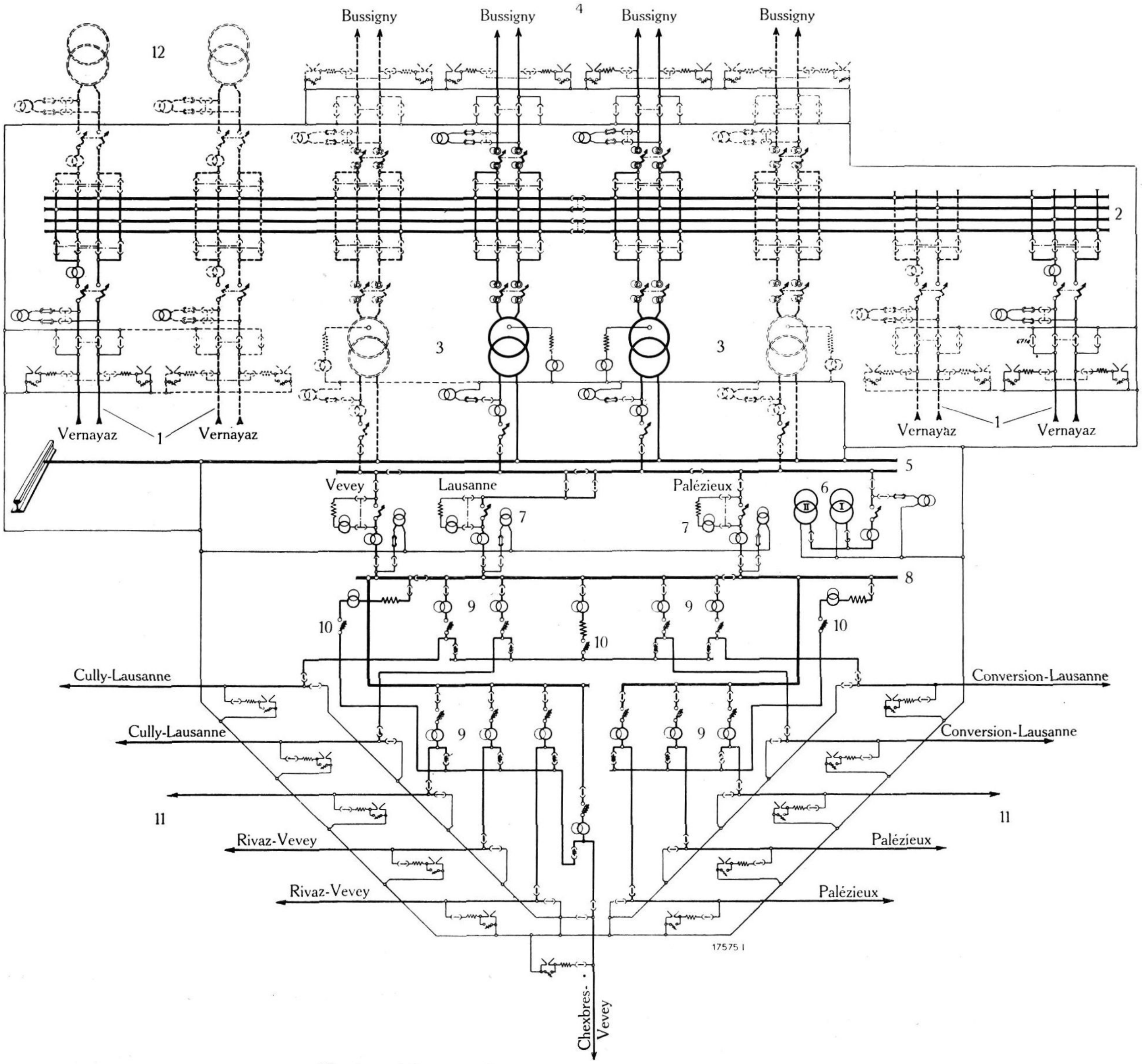


Fig. 1. — Diagram of connections of the Puidoux substation.

1. Incoming 66-kV lines.
2. 66-kV busbars.
3. 5000-kVA transformers. 66/15 kV, $16^2/_3$ cycles.
4. Outgoing 66-kV lines.
5. 15-kV busbars.
6. Station service transformers, 100 kVA, 15,000/220 V.
7. Feeder switches, with automatic release and shunted by testing resistance.
8. Busbars for trolley line.
9. Feeder switches, with remote control.
10. Testing equipment for trolley line.
11. Outgoing 15-kV lines.
12. Suggested 132-kV plant with 11,000 kVA transformers.

situated in West Switzerland and belonging to the Swiss Federal Railways.

Power generated in the Barberine power station (Canton Valais) is carried by four 66,000-V overhead lines to the Puidoux substation. At present these lines from Barberine are carried through the substation at Vernayaz but, later on they will pass through the Vernayaz power station, at present being built.

The power required for supplying the trolley lines is stepped down, in the Puidoux substation, from 66,000 V to 15,000 V, the frequency being $16^2/_3$ cycles.

When completed, the substation will comprise: four incoming and four outgoing 66,000-V overhead lines, the latter going to the Bussigny substation. There will also be 11 outgoing 15,000-V feeders for the trolley lines which are: two to Lausanne via Cully, two to Vevey via Rivaz, two to Lausanne via Conversion, two to Palézieux, one to Vevey via Chexbres, and two to the station of Puidoux itself. There will be

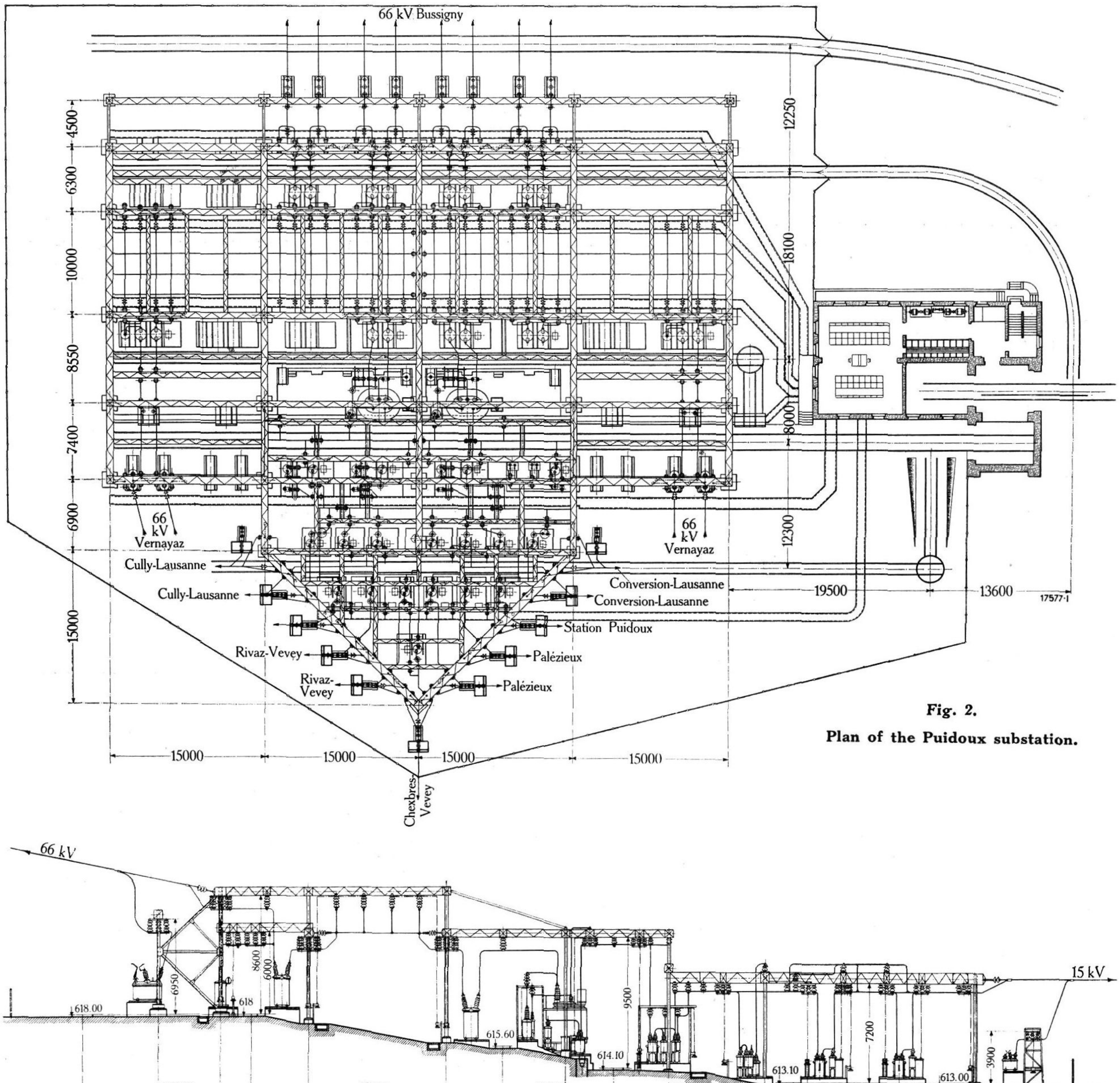


Fig. 2.
Plan of the Puidoux substation.

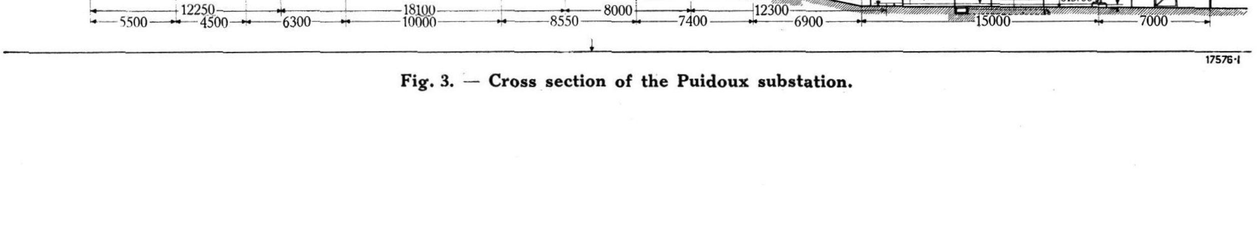


Fig. 3. — Cross section of the Puidoux substation.

four 5000-kVA step-down transformers 66/15 kV. Of these, two only are at present, installed.

Since it was first planned, a further duty has been added to those of the Puidoux substation by the building of the Vernayaz power station. The transmission line, of the Barberine-Vernayaz power stations, is provided with energy at 120,000—132,000 V. Another overhead line to carry the energy at this tension will be built, mounted on separate masts and parallel to the existing 66,000-V lines, and two big step-down transformers for 120,000/66,000 V, with the corresponding switchgear will be added to the Puidoux equipment. Puidoux, like several of the other substations built for the electrification of the Swiss Federal Railways, is designed as an outdoor station combined with a switch house containing the control equipment (Fig. 2). This arrangement presents the great advantage inherent to outdoor stations of allowing extensions which were not foreseen when the plant was first built.

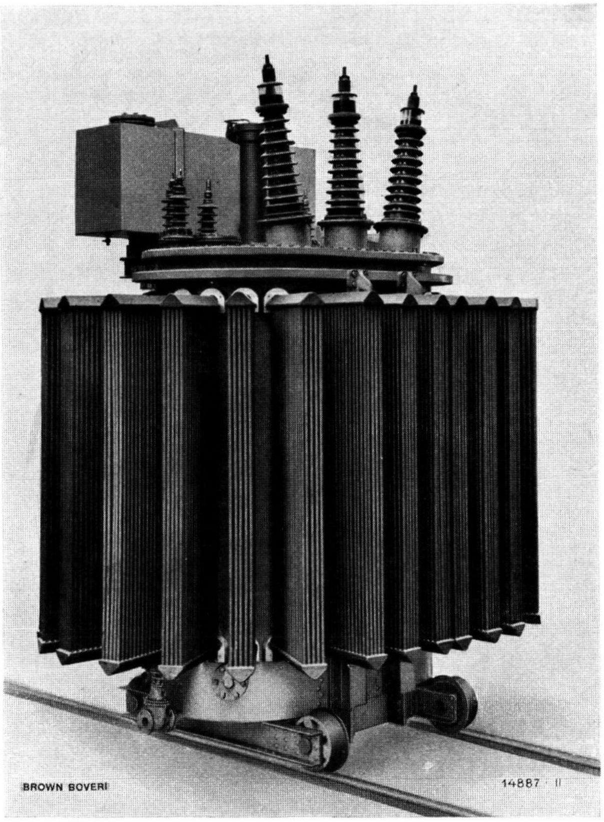


Fig. 4. — Single-phase transformer with natural cooling, 5000 kVA, 66,000/15,000 V, 16²/₃ cycles.

The layout of the station was drawn up by the Federal Railways themselves, in accordance with the character of the site chosen. The diagram of connections given in Fig. 1 shows the position of the transformers, the busbars, and the incoming and outgoing lines. The cross section (Fig. 3) shows how the layout was made to suit the site, the result being satisfactory both technically and as regards general appearance. On this subject we would say that, today, it has been proved possible to design outdoor stations so that they do not stand out and disfigure the countryside. Further, by using insulators of a suitable colour and by painting the steelwork so that it harmonises with its surroundings, all startling contrasts are avoided. This being so, it is generally difficult to justify any longer the attacks made on outdoor installations from an æsthetic point of view.

A description is given further on of the way in which the work of erection was carried out. Owing to the division of the station into terraces, the greatest difficulty encountered was to get the equipment into position.

The plan, view of the plant (Fig. 2) shows the steelwork, the conductors, the railway lines, and the switch house.

The Puidoux plant is extremely easy to supervise, an advantage it shares with outdoor stations in general. This is a very valuable asset for a railway substation, easy surveillance and quick service being essential. The whole of the Puidoux substation equipment, with the exception of that for the use of the station itself, was ordered from Brown, Boveri & Co. Some data on the principal items of the equipment are given below.

II. THE 5000-kVA TRANSFORMERS.

These units step-down the pressure from 66,000 to 15,000 V at $16^2/_3$ cycles and are constructed as regards insulation and bushings to 80,000 and 25,000-V standards. They have natural cooling. When used at 50 cycles and under standard rules, their output corresponds to about 13,500 kVA each. They should, therefore, be the largest single-phase transformers with natural cooling and for the above pressures built in Europe up to date. Fig. 4 shows one of these transformers delivered and ready for service. Owing to the heavy short-circuit currents which will have to be dealt with, the transformers have been calculated for a big, inductive pressure drop and a short-circuit pressure of approximately 10 %. The windings are composed of circular coils, because this is the best shape to withstand the tendency to deformation caused by short circuits; they are of the simple concentric type. The windings are supported by pressure rings which are held in position by heavy springs — a device patented by Brown, Boveri & Co. The coils nearest to the terminals are protected against excess pressures by very heavy insulation and the whole windings are especially well insulated. This enabled protective choke coils, which are usually placed on the high and low-tension sides, to be dispensed with and made a considerable saving in the cost of the plant. There are slots between the coils throughout the windings, and each separate conductor of both high and low-tension windings comes into direct contact with the oil. The tank is air-tight and provided with horizontal and vertical stiffeners so that it shall be able to withstand atmospheric pressure in the tank when the oil is being dried out under vacuum. The tank is fitted with an oil conservator, the duty of which is to reduce the oxidation of the oil filling to a minimum and to prevent the ingress of damp.

This conservator consists of an expansion chamber which takes up differences in the volume of oil resulting from fluctuations of temperature. A manometer and distance thermometer give the momentary values of oil pressure and temperature. In order to maintain equilibrium between the air pressure outside and inside the transformer tank, that is to say to allow of the "breathing" of the transformer, a device is provided consisting of a drying chamber placed below the conservator to which it is connected by a pipe. The air enters this chamber, passing through a perforated box containing calcium chloride and a layer of cotton wool, and thence through the pipe to the conservator, the calcium chloride having absorbed all the moisture.

As the transformer is made absolutely air-tight and as the cover is bolted firmly to the tank, it was necessary to provide a safety valve to guard against excess pressures in the interior resulting from the sudden formation of gases. This valve has a cover which is hinged and sealed by oil so that no water can penetrate through it into the tank. The valve is connected by a pipe to the air chamber of the conservator. Small quantities of gas find their way through this pipe to the conservator and thence to the outer air while large quantities of gas suddenly generated cause the cover of the safety valve to lift so that the gas escapes direct to the outer air. The porcelain terminal bushings are oil-tight and can be removed after the conservator has been emptied, which can be effected by means of a cock specially provided for the purpose. These bushings are themselves filled with oil, the oil filling of the low-tension bushings being connected to the oil in the main tank, while that on the high-tension side is independent. The latter have their own conservators. A gauge placed at the upper end of the insulator shows the oil level in the bushing.

In order to attain the necessary cooling surface, the tank is provided with vertical radiator pipes. These vertical pipes open into bigger collecting pipes above and below, which radiate horizontally from the tank. By means of welding, the points between collecting and radiating pipes are made absolutely oil-tight.

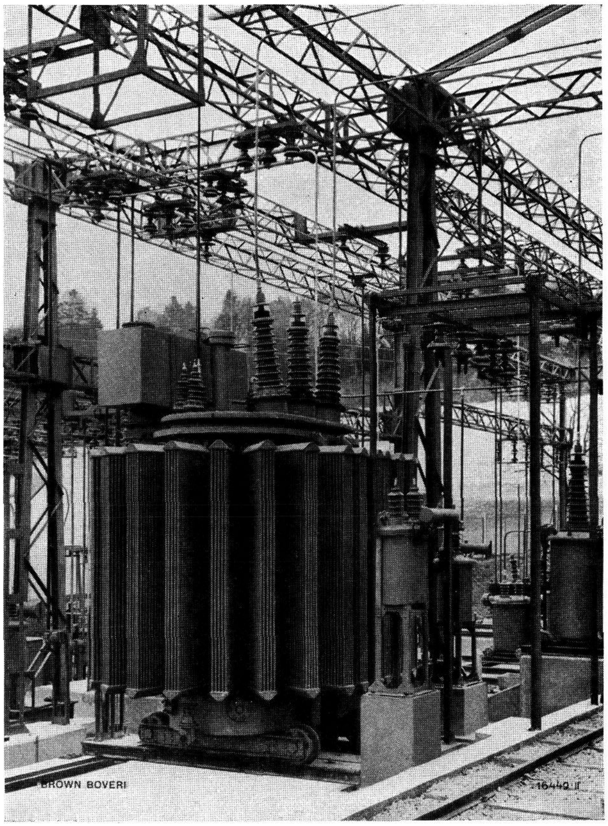


Fig. 5. — One of the 5000-kVA transformers in position.

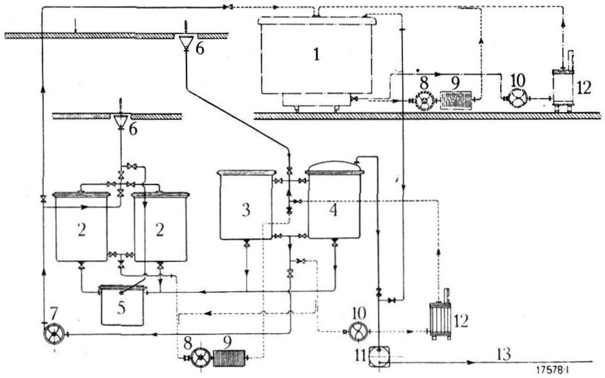


Fig. 6. — Oil-cleaning and drying-out equipment.

1. Transformer.
2. Reservoir for drained-off oil.
3. Reservoir for clean oil.
4. Vacuum tank.
5. Reservoir for dirty oil.
6. Filling funnel.
7. Oil pump.
8. Portable filter pump.
9. Portable filter press.
10. Vacuum oil pump.
11. Vacuum pump.
12. Oil heater.
13. Exhaust pipe.

The separate cooling units, composed of an upper and lower collecting pipe and a number of vertical radiator pipes connected to them, are bolted to the tank, the collecting pipes having flanges for that purpose. Suitable packing is placed between the flanges and the tank. The transformers are mounted on wheels and are held in their respective positions by buffers (Fig. 5).

III. OIL-CLEANING AND DRYING EQUIPMENT.

Although the transformers were completely dried out and tested before despatch, it was considered necessary to equip the substation from the first with a very complete plant for reconditioning the oil and for drying out the oil and transformers.

This equipment was also supplied by Brown, Boveri & Co., and is situated in the basement of the switch house. It comprises a vacuum tank, three reservoirs for clean and drained-off oil, and one for dirty oil. Oil pumps, vacuum pumps, portable filter presses, oil circulation pumps, and oil-heating boilers, together with the necessary fixed pipe-work with sluice valves and flexible piping were also provided. Fig. 6 is a diagrammatic drawing of the equipment.

The 5000-kVA transformers, when completely epuipped for service, were too big for transporting whole. It was necessary to remove the bushings and radiators and to send them separately, together with a certain amount of the oil. Thus, when the transformers were assembled on site, it was necessary to dry them out again. Under ordinary conditions, the radiators with which each of these transformers is equipped, carry off a quantity of heat corresponding to 200 kW, when once the transformer in question has been brought to the temperature required for the drying-out process. This caused the Federal Railways to provide an insulating chamber to complete the drying out equipment. The first transformer without its radiators required 36 kW to heat it to the temperature requisite for drying out, while the second transformer took the same energy with the radiators in position, when placed in the insulating chamber.

IV. THE APPARATUS AND ITS ERECTION.

On both the high-tension and low-tension sides, the conductors and the isolating switches are carried by the suspension method. This has the advantage over the supporting method that the conductors and steelwork do not cross, and also the connections from the conductors to the apparatus at ground level are

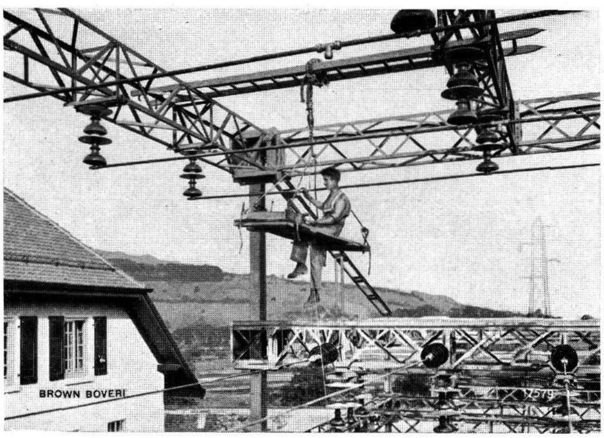


Fig. 7. — Erection of busbars.

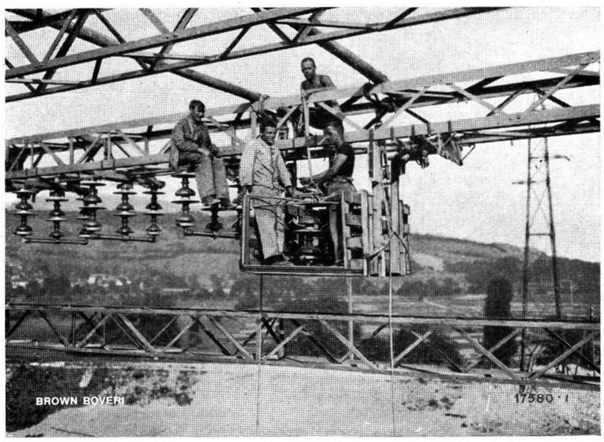


Fig. 8. — Erection of isolating switches.

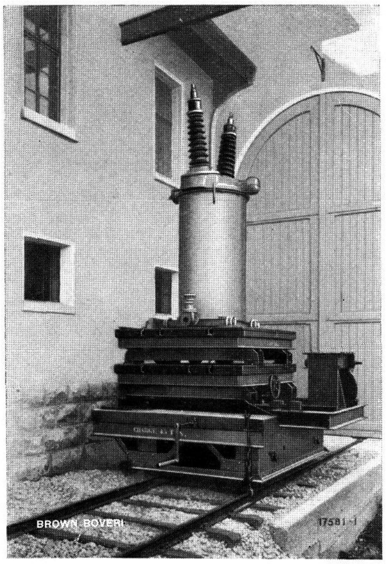


Fig. 9. — Oil switch mounted on truck at the height of its final position.

shortened. The suspension and strain insulators secured to the steelwork as well as the isolating switches are all clamped and therefore easily changed; further, it is unnecessary to drill holes in the steel frame. The devices required for the erection of outdoor installations differ considerably from those used with indoor plants. The simplest expedients were found to give the best results, as shown in the following figures. A crate cover with a pulley block, by means of which the erector pulled himself up, was used, to assist in securing the conductors as shown in Fig. 7. Heavy parts, such as isolating switches were loaded onto a kind of rough crate and then raised by two pulley blocks and secured. As Fig. 8 shows, it was very easy to clamp the isolating switches once they had been raised by the method described.

The plant is laid out in terrace formation and the problem of placing the heavy gear in position was solved by using trucks of various heights and designs. Fig. 9 shows three of these trucks placed one above the other which enabled the terrace step on which the oil circuit breakers are located to be reached. When brought opposite a terrace step, the lowest truck was clamped to the rails to prevent it upsetting while the upper one carrying the apparatus was pushed off and onto the terrace rails; it was then rotated on a turn-table and guided on to the oil-switch rails. A similar process was used to put the instrument transformers in position.

V. STATION TRANSFORMERS.

These provide current for the power, heating, and lighting circuits in the station and the dwellings of the operators, as well as for remote control of apparatus, signalling devices and the automatically indicating station layout in the switch house. The single-phase current, tapped from the station 15-kV busbars for this purpose, is stepped down in two 100-kVA transformers to 220 V and thus used partly for power and heat and partly converted to direct current at 220 V for supplying motors, lighting, and remote control. There is a storage battery as reserve. Fig. 10 shows both of these transformers ready for service. They are of air-tight design with oil conservators and safety valves, similar to the 5000-kVA units.

Fig. 10. — View of part of the Puidoux plant with station transformers.

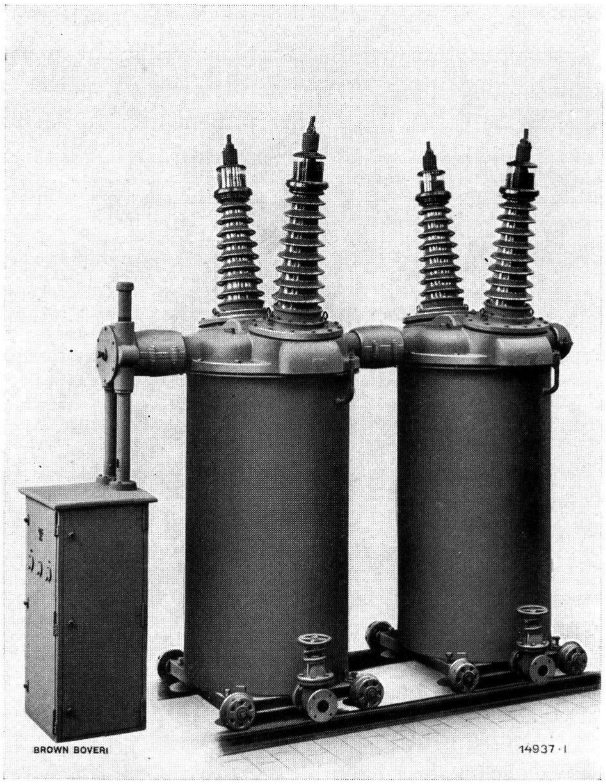


Fig. 11. — Two-pole, 80-kV outdoor switch group with control pillar.

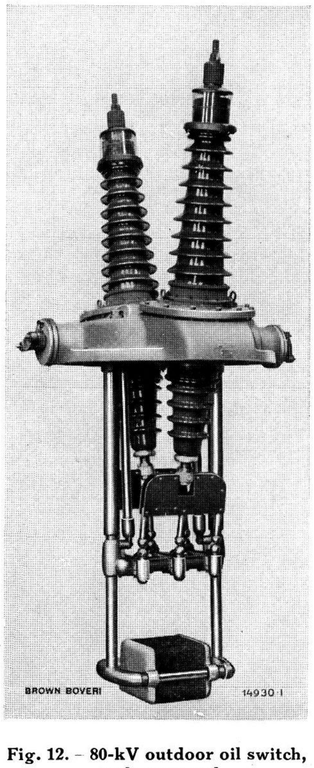


Fig. 12. – 80-kV outdoor oil switch, tank removed.

The 80-kV and 24-kV oil circuit breakers are cylindrical and of single-pole type. The former have oil-filled bushings and the latter compound-filled bushings. The switch cover is of cast iron with two apertures in which the bushings are lodged, being secured by flanges with appropriate packing. Two flange bearings guide the oil-switch shaft, which projects on both sides. These bearings also support the terminals of the auxiliary conductors brought out of the switch. For coupling and controlling several circuit breakers together, a link coupling with sufficient play to allow for erection is used. Sleeves in two parts are used to cover couplings and terminals and to protect them from damage or rain. The cover carries projections with openings which allow some air circulation in order to maintain the equilibrium of air pressure inside and outside the switch, as well as the escape of any gas which may form in the tank. Fig. 11 shows a complete two-pole circuit-breaker group with control pillar, while Fig. 12 shows the design of the breaker and Fig. 13 the motor remote control. Fig. 14 is a part view of the circuit-breaker groups installed ready for service.

The chief parts of the circuit breaker are the fixed and movable contacts, which are spherical and pressed together by means of springs when it is closed. The fixed contacts are secured to the bushings and the movable ones on an insulating transverse piece.

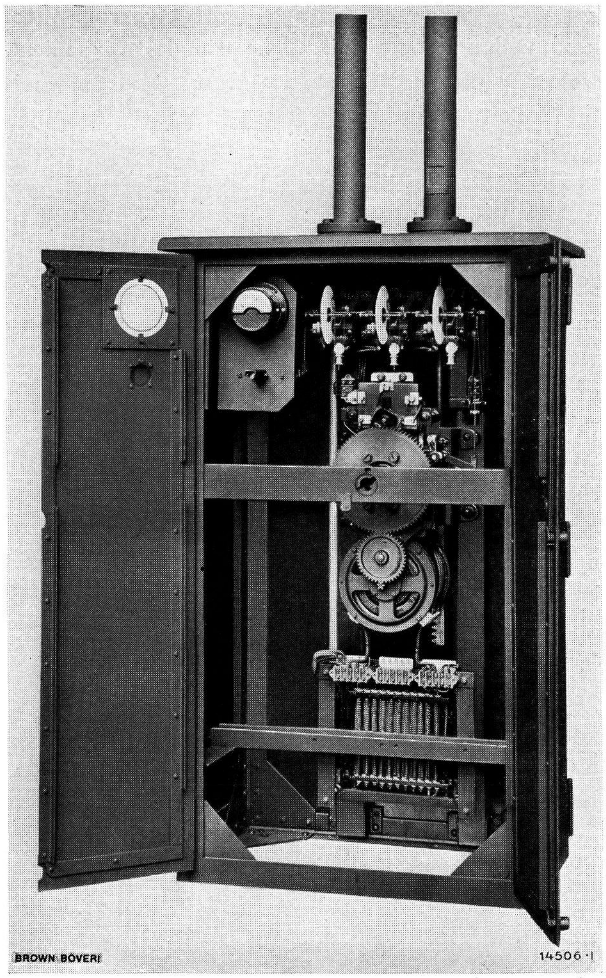


Fig. 13. — Motor remote control gear of an outdoor switch.

The movement of the latter is controlled by cranks and rods from the control shaft. The multi-gap principal is applied in these switches, the arc being broken at a number of points, a design which allows of inserting protective and rupturing resistances. The latter are situated in the tank below the switch proper.

The tanks of the circuit breakers are autogenously welded and the upper end reinforced by rolled steel stiffeners. The welded butt joints are not located where the metal is bent at the bottom of the tank, but somewhat higher. The cover fitting on the tank is watertight. Insulating cylinders protect the switch from flashovers to the tank sides when the circuit is broken. There is an ohmic resistance of grid shape secured to these insulating cylinders, which is used to warm the oil when the surrounding temperature is lower than — 15° C.

Fig. 14. — View of part of the Puidoux plant showing 80-kV oil switches.

Fig. 13 shows the control pillar. These gears are all of the remote-control type; the automatic release is effected by the action of current transformers lodged in the bushings. The circuit breakers on the low-tension side have separate current transformers. Above the control gear, can be seen three

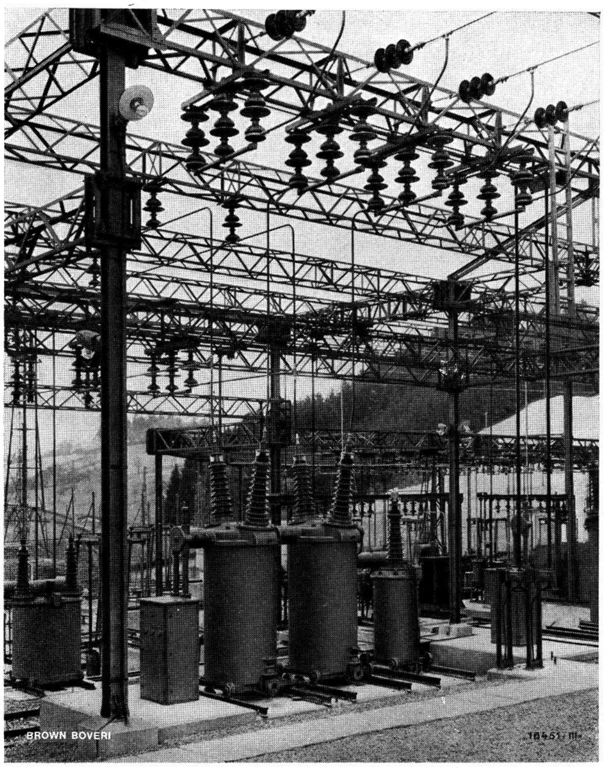


Fig. 15. — View of part of the Puidoux plant showing current and potential transformers of the 80-kV type.

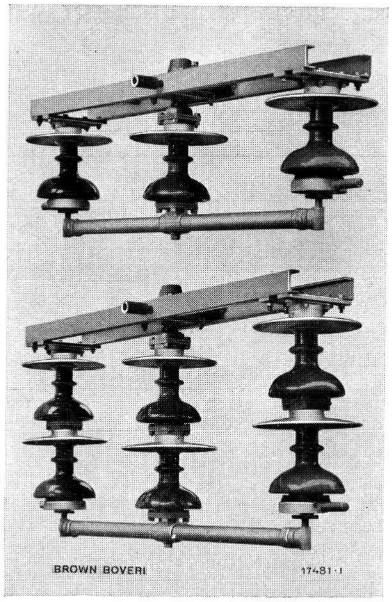


Fig. 16. — Rotary isolating switches with insulators of single and double type for 50 kV and 90 kV.

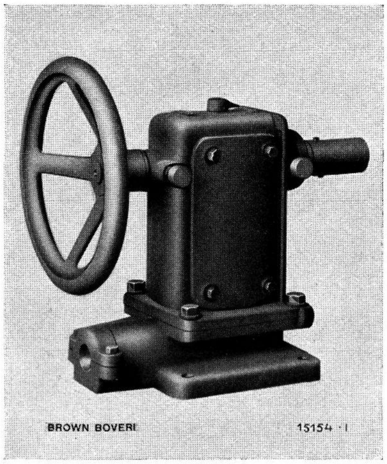


Fig. 17. — Control gear of rotary isolating switch.

Type-A relays; these produce the mechanical tripping of the breaker and are intended for use in plants having no auxiliary source of current. In the Puidoux substation, however, a storage battery has been provided and relays of Type H 2/1 for electrical tripping of the breaker from the switchboard are used. The torque required to close the breaker is transmitted to it through a rack. If desired, switching in and out can also be effected at each control pillar by hand. In order to make the control gear and the whole mechanism accessible, the columns which carry the driving gear have doors on three sides. Further, the design of these columns is sufficiently water-tight and at the same time allows plenty of ventilation, so that any danger of condensation is avoided.

Fig. 15 shows *current and potential transformers* of the 80-kV type, and Fig. 5 shows similar apparatus of the 24-kV type. All these instrument transformers are *air-tight* and have both safety valves and oil conservators. The bushings are of the same type as used on the corresponding oil switches and main transformers. The secondary conductors are brought out of the tank to special bosses cast on the cover forming terminal boxes, to which the ends of the leads are secured.

Apparatus, similar to the transformers, is also provided with neutral-point earthing resistances and test-

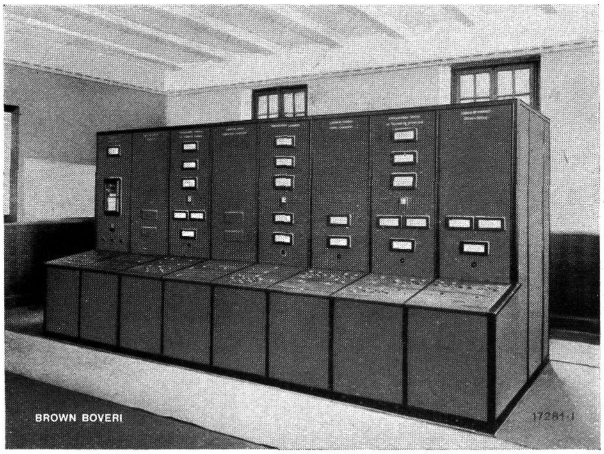


Fig. 18. — ***One of the two control desks.***

ing resistances. These resistances are oil immersed, as the apparatus is of outdoor type.

Thermo-contact signalling devices are fitted, giving the alarm if the temperature rises too high.

VI. ISOLATING SWITCHES.

The design of the isolating switches, shown in Fig. 16, is a Brown Boveri patent. The two outer insulators are bolted fast to the frame, while the middle insulator, which carries the contact bridge, can be rotated by a worm drive. The drive is so

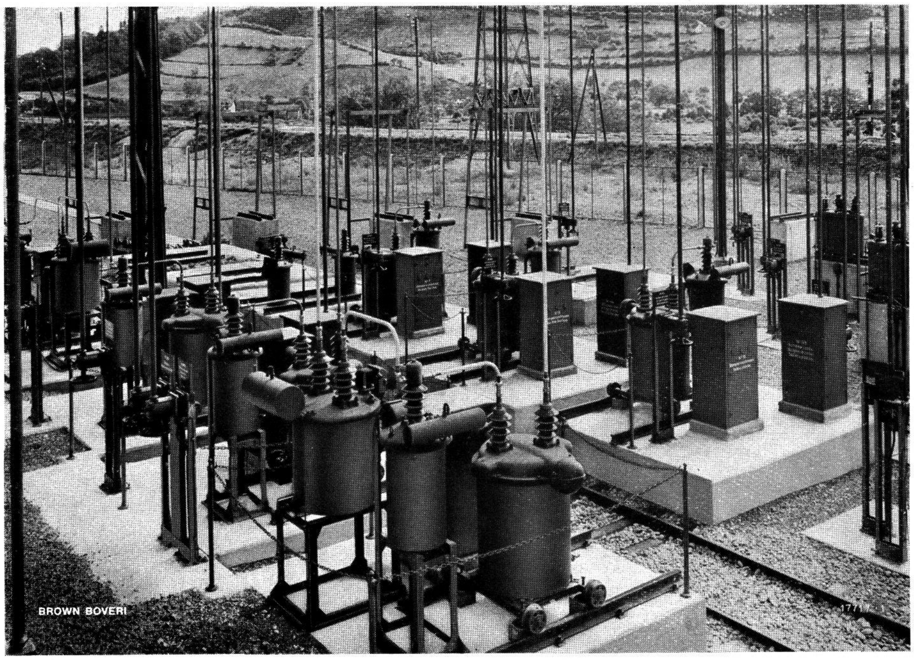


Fig. 19. — 15-kV switchgear of the Puidoux substation.

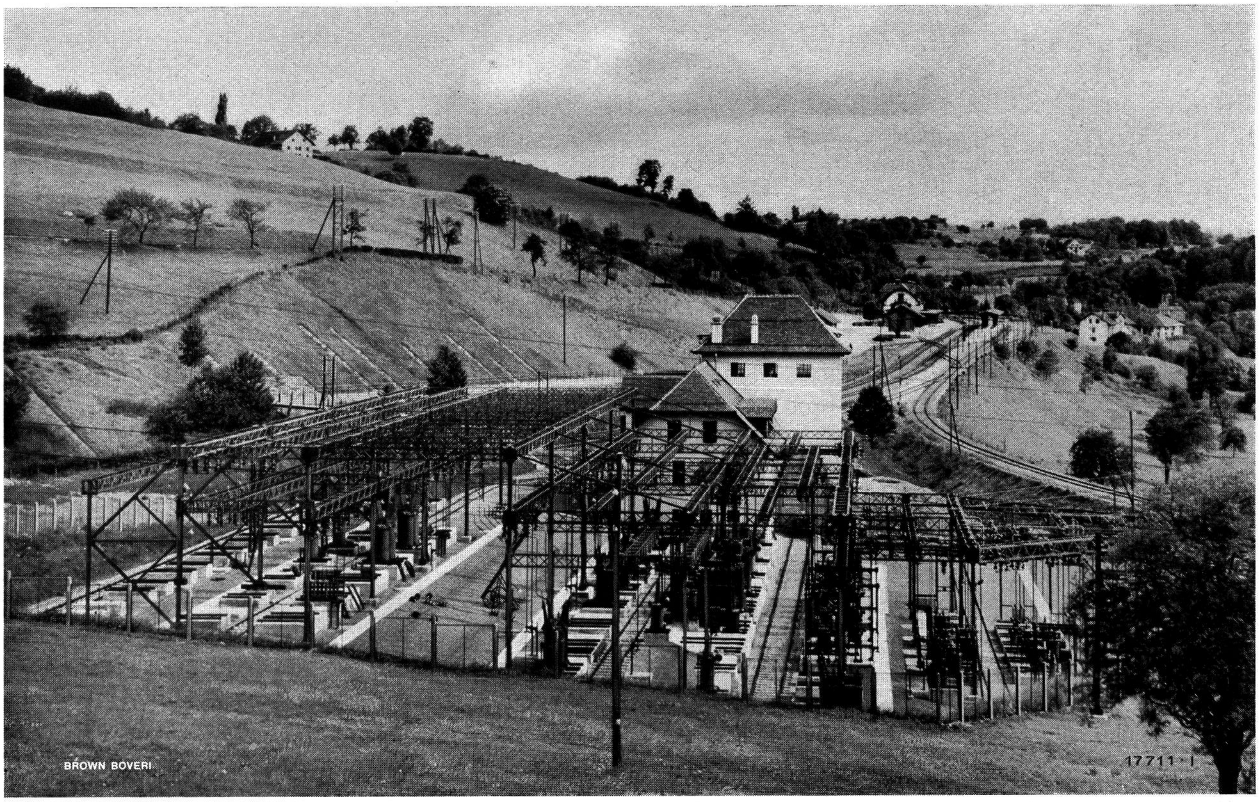


Fig. 20. — General view of Puidoux outdoor substation.

designed that when the switch is to be opened, the middle insulator first sinks by a few millimetres and then rotates through an angle of 90^0. By applying this principle, the insulators are completely saved from torsion or bending moments and the torque to be applied to the driving shaft is very small despite large contact surfaces and contact pressures. The contacts are protected against the weather by a sheet-metal cap. The Brown Boveri three-pole rotary isolating switch is designed to be either suspended or supported and is built for all voltages. The switches differ, from one type to another, only by the clearance between the insulators and the number of insulator units rigidly connected together.

Fig. 17 shows the construction of the control mechanism. In addition to the handwheel which controls the switch directly, there is a mechanical indicating device and a remote signalling device. The base plate is designed to form a cable-end box. The connection between the control and the switch is through hollow shafts and bevel wheels. The isolating switch used for testing purposes in the station is the only one having motor remote control. It is interlocked with the testing circuit-breaker group.

VII. CONTROL ROOM.

The position of the control board in the switch house is such that the whole outdoor station can be easily supervised. There are two switch desks parallel and facing one another which contain the controls and remote signalling equipment of all outgoing and incoming lines and of the 5000-kVA transformers. One of these desks is shown in Fig. 18. A single-pole automatically indicating station layout on the control desk cover gives the exact position of all switches and allows of prompt intervention in case of trouble.

The boards of the vertical and desk type switchboards are of sheet steel and of extremely simple but pleasing design. All the instrument leads and those of the remote control are laid openly and are easy to follow. The distribution and arrangement of the various incoming cables are effected in a special chamber situated directly under the control room. Adjacent to the latter, is a room containing a board with vertical panels for the service of the station proper. These panels can be supervised by the operator in the main control room.

VIII. SERVICE CONDITIONS.

Erection was begun in June 1923 and was practically completed by October of the same year. The mechanical and electrical drive of the switches fully came up to expectations. Mention should be made here of the remote-controlled isolating switch for testing, and its interlocking with the corresponding circuit-breaker group. When short circuits occur, or when lines are being tested, the isolating switch is first closed from the control room, the circuit-breaker group and its 2000-ohm testing resistance in series are then switched in automatically, and an ammeter indicates whether the line is open or short circuited. When switching out, the oil circuit breakers are the first to open and then the isolating switch. The Brown Boveri isolating switch is particularly suitable for this purpose.

Insulation tests are easily carried out and require no special description, the 15-kV side being tested at 50 kV and the 66-kV side at 120 kV.

The Puidoux substation was put under pressure for the first time in December 1923, when the Barberine power station started service. Since then, one 5000-kVA transformer and the auxiliary plant have been working continuously. It was only after the St. Maurice-Lausanne railway section was electrified for the first time in May 1924, however, that the Puidoux substation began to operate under the conditions for which it was designed. Fig. 20 shows a general view of the substation completed.

(MS 319) *W. Holliger. (C. M.)*

Train of the German State Railway on Freilassing-Berchtesgaden section drawn by B-B locomotive built by Brown, Boveri & Co.

NOTES.

Direct-current locomotives for the Yoshino Railway, Japan.

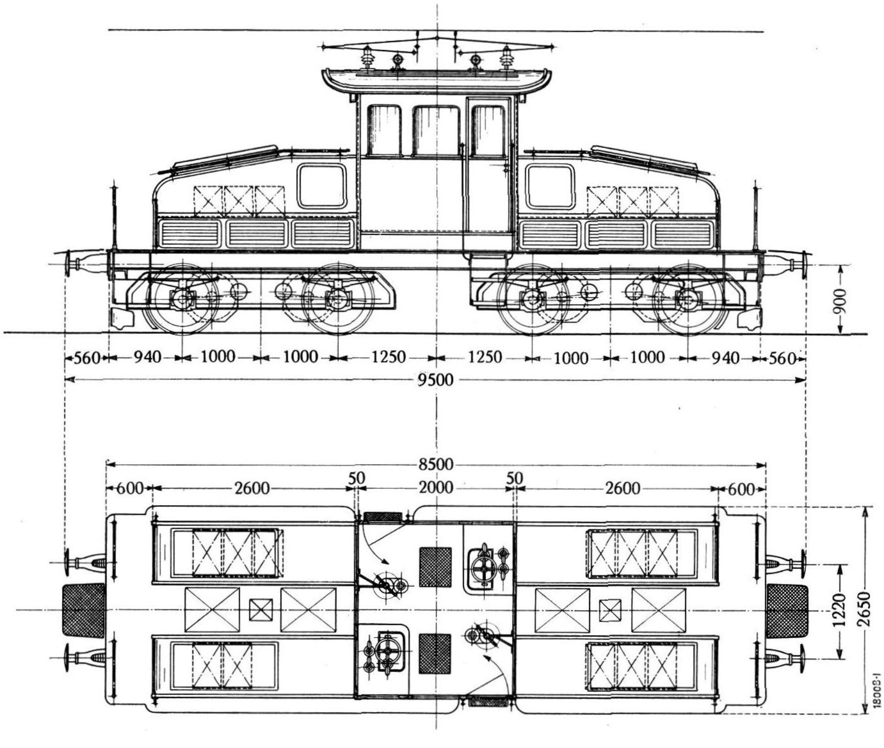
Decimal index 621. 334. 2 : 621. 331. 34 (52).

AT the end of 1923, Brown, Boveri & Co. delivered to the Yoshino Railway Company of Japan a four-axle goods locomotive. Its performance under working conditions so pleased the purchasers that in May 1924 two more similar locomotives were ordered, which were delivered some time ago.

The track of the Yoshino Railway is situated in the mountainous country to the south-east of Osaka, and is famous throughout Japan for the magnificient orchards of cherry trees through which it passes. Every year, at the blossom time, groups of excursionists, including many pilgrims, visit the numerous temples and shrines found in the vicinity of Yoshino. The hills and mountain slopes near the railway are covered with thick woods; hence the transport of timber forms a considerable proportion of the traffic on this line.

The Yoshino Railway runs from Yoshino to Yoshinoguchi, where it connects with the Japanese Government Railways. The rails are laid throughout on their own separate track. The length of track is 11·6 km, and the gauge 1067 mm ($3^1/_2$ feet), which is the same as that used almost exclusively in Japan, especially on the Government Railways. The maximum gradient on this line is 2 %; the smallest radius of curvature on the open track is 160 m, and 120 m where points occur; the admissible axle pressure is 8 tons per axle. A new line from Yoshinoguchi to Unebi, which is 13 km in length, and includes short inclines of 3·3 %, is under consideration and will later be joined to the Yoshino Railway.

The Yoshino Railway was previously steam operated and was only electrified in 1922-3. The system of supply selected was 1500-V direct current; this is furnished by a substation, the mean trolley-wire pressure amounting to 1400 V. The trolley wire is suspended throughout from a single messenger wire, which in turn is supported by steel lattice poles fitted with cross members, the construction of which varies according to the span; the height of the trolley wire above the upper surface of the rails is 4·1—5·2 m.



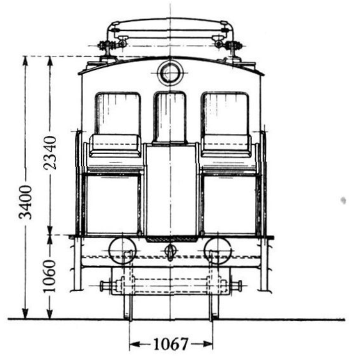


Fig. 1.
Plan, elevation, and end elevation of a B-B goods locomotive, for the Yoshino Railway.

The goods locomotives referred to were intended primarily for the transport of timber, but also for passenger traffic should it be necessary. The purchaser's stipulated performance was, that when loaded with 150 tons, the locomotive should be capable of attaining a speed of 19 km per hour on a 2 % incline and a maximum speed, on the level, of 40 km per hour. To fulfill these conditions, the locomotives were designed for a continuous rating of

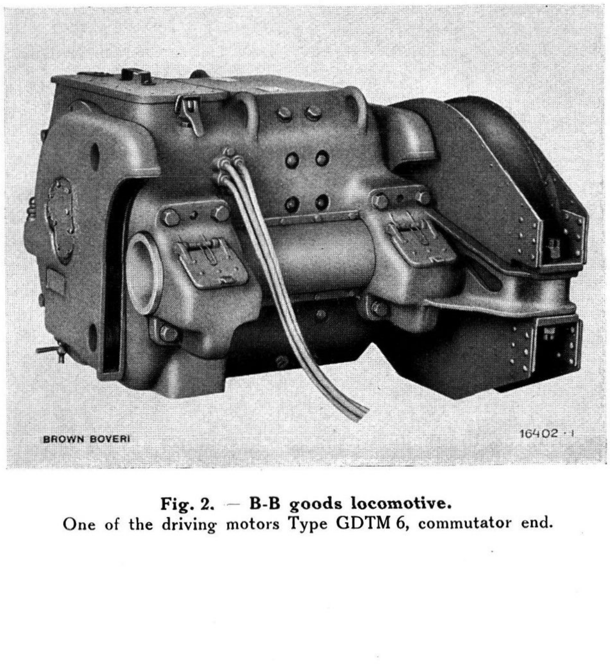


Fig. 2. — B-B goods locomotive.
One of the driving motors Type GDTM 6, commutator end.

240 H.P. at the shafts, to be developed by the driving motors running at 750 r.p.m. with a trolley-wire pressure of 1400 V. The chief particulars are given in the following table:—

Length over buffers	9500 mm
Length of frame	8380 mm
Maximum width of body	2300 mm
Maximum height of roof above rails	3400 mm
Diameter of driving wheels	860 mm
Wheel base of bogies	2000 mm
Distance between bogie centres	4500 mm
Weight of mechanical portion	15·4 tons
Weight of electrical portion	8·7 tons
Total weight of locomotive	24·1 tons
No. of motors	4
Type	direct-current, series-wound
1-hour rating per motor at tread	75 H.P.
Continuous rating per motor at tread	60 H.P.
Terminal voltage across each pair of motors	1400 V
Gear ratio	4·93 : 1

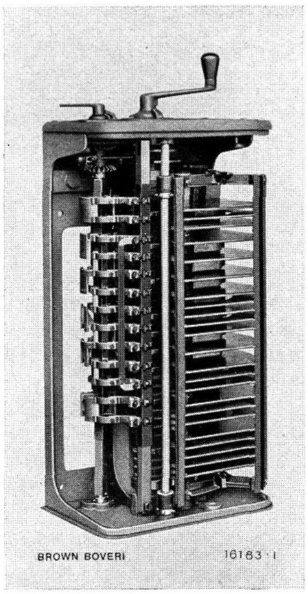


Fig. 3. — Cam controller with casing removed.

Fig. 1 gives a general idea of the design and dimensions of the locomotive while the frontispiece of this number shows a locomotive attached to a goods train.

The mechanical part consists chiefly of two two-axle bogies and a rolled-steel frame upon which is built the small body of the locomotive and the two extensions or end casings. The central portion comprises the driver's cab which is fitted with two complete driver's stations situated in each case to the left hand looking in the direction of travel. This arrangement is contrary to the usual practice of providing a single central driver's station. The cab is constructed of steel and wood, with a double wooden roof to protect the driver from the heat of the sun. Three windows, one of which is moveable, are provided on every side of the cab, and two doors are fitted.

On each of the end walls of the driver's cab a control desk is provided, which contains a controller, control valves for the current collector, and for the main switch, also the compressor motor and an air-brake valve. The steel end casings at the front and rear of the cab contain the starting resistances, the main switch, the air compressor, the lighting battery and various fuses. As shown in the frontispiece, each of these casings is made in two parts with a clear gangway between them. A means of inspecting the enclosed apparatus is provided by inspection covers, partly interlocked with the actuating valve for the current collector, fitted in the control desk, the walls of the cab and the end casings. Certain inspection covers including those of the driving motors can be opened from the above-mentioned gangways between the two parts of the casing. Each end casing has louvred openings and an air intake for cooling the resistances and for supplying air to the compressor.

The underframe of the body is made of rolled steel sections. In accordance with the standard practice of the Japanese Government Railways central draw-gear and double buffers are fitted. Both bogies are constructed of sheet steel and rolled steel sections. Simple laminated springs are employed which are supported on the axle-boxes; these are fitted with pad-lubricated journal bearings of the usual type. The eight brake blocks of the locomotive can be applied by hand, from either of the driving positions, or by a direct-acting Westinghouse compressed-air brake equipment which works on the same linkwork as the hand brake. The mechanical parts of the locomotive have been constructed by the Swiss Coach Works, Schlieren, near Zurich.

The electrical equipment is as follows: — Each axle is driven by a self-ventilated D. C. series motor Type GDTM 6, as used for tramways (Fig. 2). These motors have a one-piece casing and in general construction resemble the machines described in the Revue BBC, 1919, No. 10, page 203. They

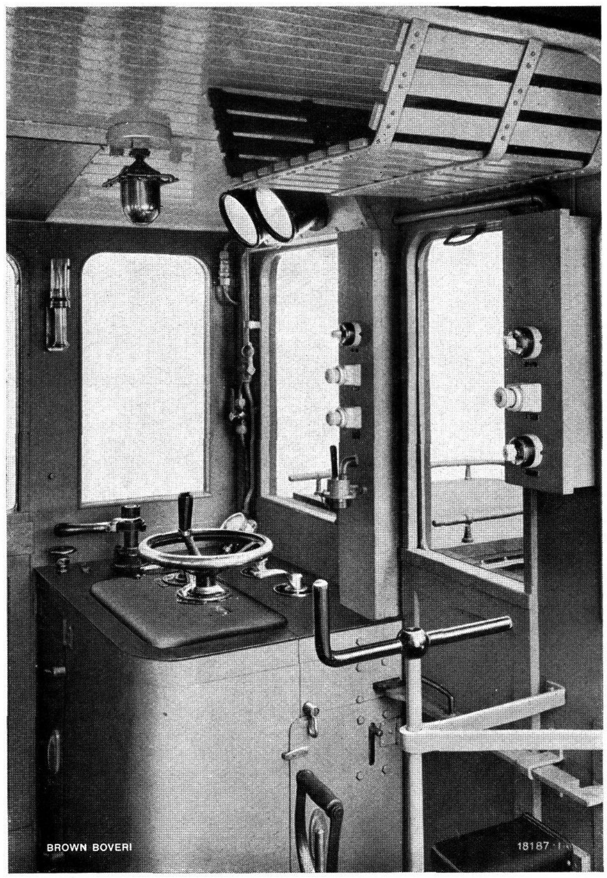


Fig. 4. — Interior of driver's cab showing one of the control desks.

Fig. 5. — Locomotive ready for transit.

can be used easily in a metre-gauge locomotive so that the field of application of this type is considerably widened. The motors in each bogie are permanently connected in series, but the two groups so formed are arranged for series-parallel control. Contrary to the practice hitherto general for pressures in excess of 1000 V, a controller with remote control from the control desk is not employed in this case, but each desk has incorporated in it a vertical hand-operated controller externally resembling those used on tramcars. These differ from tram controllers, however, in that they do not make and break the circuits by means of contact segments and contact fingers mounted on a drum, but, as with the larger electric motor coaches and locomotives on high-tension railways, the main drum is replaced by a number of contactors controlled from a cam shaft and provided with electro-magnetic blow-out coils to ensure reliable interruption of the arcs formed. The controller is arranged for series-parallel control of the two pairs of motors, it is provided with six series and four parallel running positions and, on rotating the cam shaft in the reverse direction, resistance braking is obtained for seven positions of the control lever. By means of a second drum the direction of the locomotive can be reversed, or either pair of motors can be disconnected should a defect develop (Fig. 3).

The starting and braking resistances consist of cast-iron elements assembled in frames situated under the end casings of the locomotive. The automatic main-switch and the pantograph current collector are operated pneumatically from the control desk. A motor-compressor set Type GC2 supplies the compressed air for the above apparatus and also for the Westinghouse brake equipment. This set which is supplied with current at trolley-wire pressure, compresses 590 litres of free air per minute to a pressure of 4·5—6 kg per sq. cm. The current for lighting the locomotive is supplied by a small 12 V accumulator battery which is periodically recharged at a charging station. The driver's cab is heated by two heating elements and two electrically heated foot-plates, all connected in series and supplied with current from the trolley wire.

The electrical equipment was constructed by Brown, Boveri & Co. in their works at Baden and Münchenstein.

(MS 325) *A. Brodbeck (J. R. L.)*

The determination of rapid pressure impulses.

Decimal index 621. 197. 7.

IN both electrical and mechanical work it is often necessary to examine the manner in which rapid variations of pressure take place and to determine the magnitude of such variations experimentally. The production of a gauge for this purpose presented considerable difficulties since the natural frequency of the instrument must be high, from 500 to 1000 vibrations per second often being required. A pressure gauge, to fulfill this purpose has been patented by Brown, Boveri & Co. and is described briefly below.

Fig. 1 shows a section through the pressure gauge while in Fig. 2 the original form of the instrument is shown. A screw connection a in Fig. 1, is used to support the gauge and to connect it with the inside of the tank. The pressure impulse is measured electrically. The metal tube b acts as a spring and lies in contact with a curved resistance strip c, through which current flows, and which can be put into circuit or short-circuited according to the position of the tube. The curved resistance is fastened to an insulating block d by two terminal screws e and e' to which a battery and a galvanometer or ammeter are connected in series.

The instrument operates as follows:—

In a state of rest the metal tube b, which is soldered or welded into the screw connection a, lies in contact with the resistance c, fastened to the insulated block d. The resistance is short-circuited by the tube, so that when a source of current f is applied to the terminals e, e', there is no voltage drop between the two points. When a certain internal pressure is reached the end of the tube b is slightly straightened, this portion lifting itself away from the resistance c. A fall of potential proportional to the free length is set up in the resistance strip. This change of potential, which corresponds to the pressure fluctuation is read by

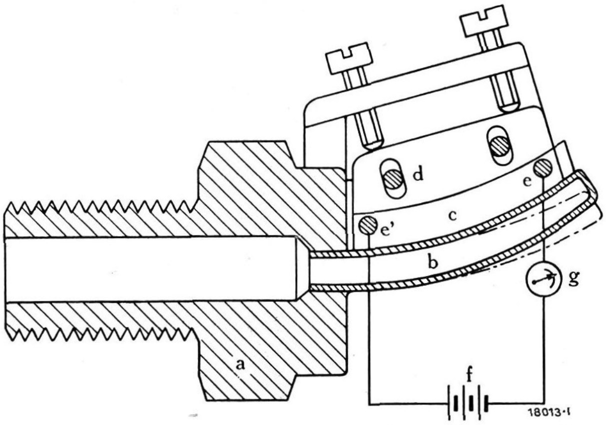


Fig. 1. — Section through pressure gauge for rapid pressure fluctuation.

a. Screw connection.
b. Metal gauge-tube.
c. Resistance strip.
d. Insulating block.
e. Terminal screw.
f. Battery.
g. Galvanometer.

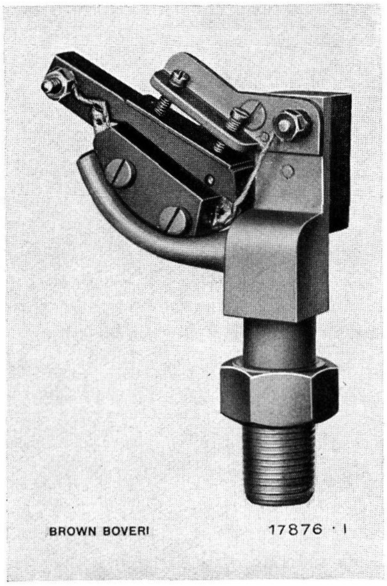


Fig. 2. — Original form of pressure gauge.

means of extremely sensitive electrical instruments or recorded by an oscillograph.

Fig. 3 shows an oscillographic record taken by means of this pressure gauge. In a closed tank, where an electrical circuit is interrupted, it is frequently necessary to find the pressure impulse as well as the arc-current and voltage during the arcing period.

The field of application for pressure gauges of this kind is very large. It can be used in all cases where rapid pressure impulses occur whether in a positive or negative sense; further this gauge can be employed to count or record such variations. Some examples of its use are, in connection with boilers, tanks under pressure or vacuum, gasometers, oil switches and transformers, and the indicating of pressure in high-speed steam engines, internal combustion engines, blowers, pumps, etc.

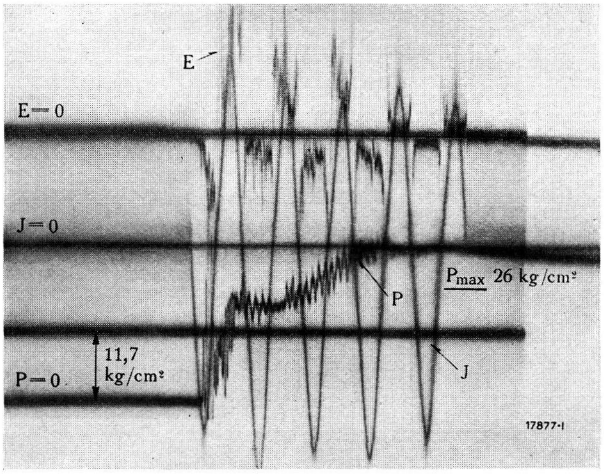
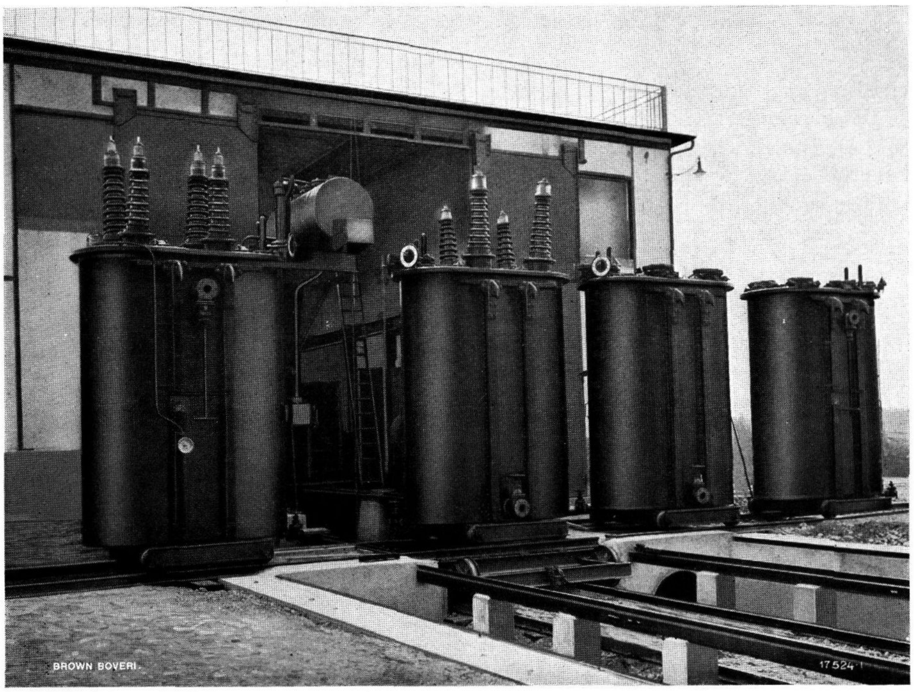


Fig. 3. — Oscillographic record taken on breaking a 50 cycle alternating-current circuit in a tank under pressure.

E. Arc voltage. 1 mm. 112·9 V effective.
J. Arc current. 1 mm. 14·09 A.
P. Pressure variation due to breaking the circuit. 1 mm. 1·292 kgm/cm².

Since pressure and temperature are connected by definite laws, the pressure gauge referred to above may be employed to indicate temperature, i. e., as a distance thermometer. Further, it can be employed in a similar manner to serve as a thermostat.

(MS 326) *E. Lienhard. (J. R. L.)*



Swiss Power Transmission Company, Berne.

Gösgen outdoor substation, four transformers each for 4330 kVA, 78,000/50,600 V, 50 cycles, on the rails of the substation immediately after delivery.

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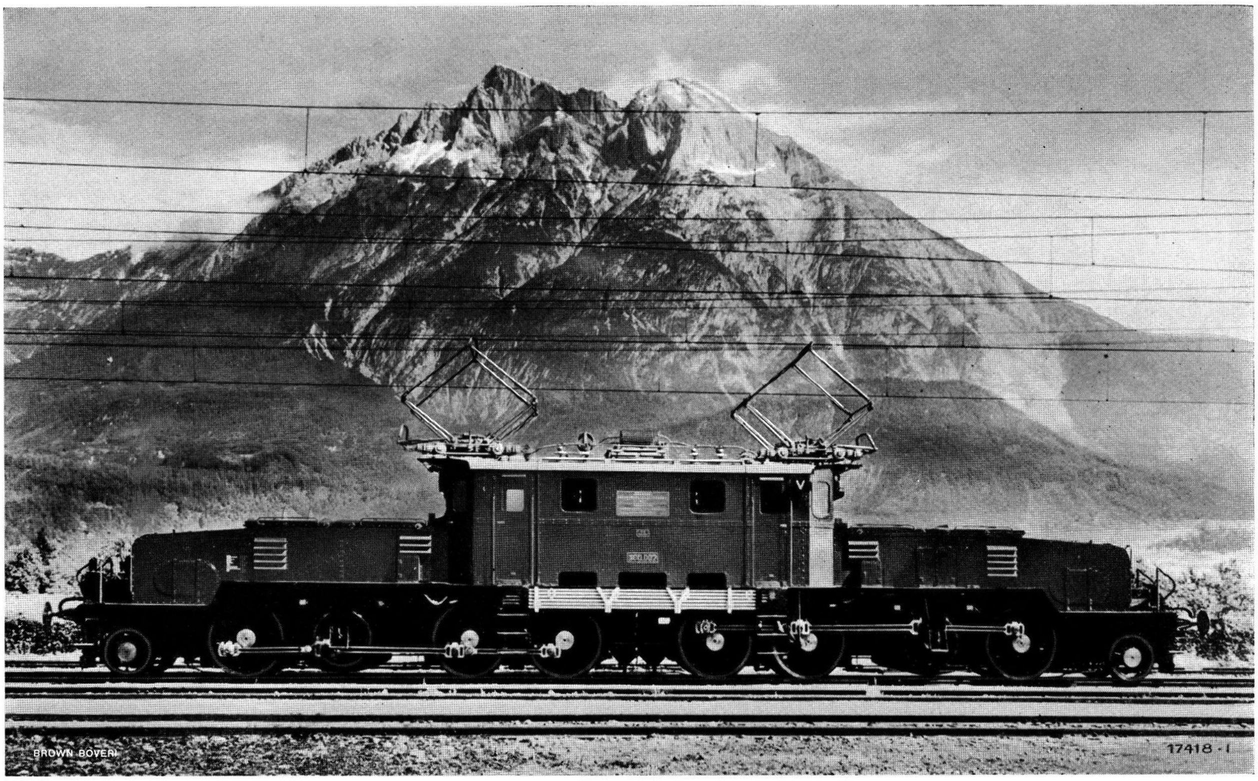
EQUIPMENT OF RAILWAYS

FOR ALL CURRENT SYSTEMS, PRESSURES, AND FREQUENCIES



AUSTRIAN STATE RAILWAYS (ARLBERG LINE).
Single-phase express locomotive for use on mountain sections, Type 1 C - C 1, 15,000 V, $16^2/_3$ cycles.

LOCAL AND INTERURBAN RAILWAYS
TRAMWAYS - MOUNTAIN RAILWAYS
AERIAL ROPEWAYS AND FUNICULARS