VOL. XVI OCTOBER, 1929 No. 10

THE BROWN BOVERI REVIEW

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

STANSSTAD-ENGELBERG RAILWAY. VIEW OF THE LINE NEAR ENGELBERG.
Three-phase current, 850 V, 33 cycles.

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"FESTSCHRIFT ZUM 70. GEBURTSTAG VON PROFESSOR Dr. A. STODOLA."

PUBLISHED BY ORELL FÜSSLI, ZÜRICH.

This work was presented to Professor Stodola by his friends and scholars to commemorate the occasion of his 70th birthday. A number of interesting articles in the book were written by our employees and co-workers, as follows:—

W. G. NOACK:

BIOGRAPHY OF PROFESSOR Dr. A. STODOLA.

G. DARRIEUS:

CONTRIBUTION AU TRACÉ DES AUBES RADIALES DES TURBINES.

Long radial turbine blades should be given a certain twist in order to adapt them to the increasing reaction with the distance from the shaft; in practice this is seldom done. This inequality in the degree of reaction is absent in ordinary turbines, due to the increase in the axial velocity of the steam towards the periphery of the rotor, but at the expense of a reduction in the power developed at the blade tips of the first wheels and a corresponding loss at exit from the last wheel. These losses can be avoided by inclining the guide blades in the direction of the plane of the wheel.

Dr. J. VON FREUDENREICH:

UNTERSUCHUNG DER STABILITÄT VON REGELVORRICHTUNGEN.

A description of a device for mechanically testing the stability of governors, with the governing system of an extraction turbine explained by way of example. The device integrates linear differential equations of any order with constant or variable coefficients.

Dr. E. HONEGGER:

ÜBER EIGENSPANNUNGEN.

After a general discussion of internal stresses and heat stresses, the additional stresses liable to be produced in suddenly heated spheres and cylinders are calculated, and also the time which elapses before they occur.

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C. SEIPPEL:

WÄRMESTRÖMUNG IM SCHAUFELFUSS VON GASTURBINEN.

The article describes the method of determining the temperature of the blades and rotors of gas turbines and illustrates how the calculation can be verified by simple experiments.

THE BROWN BOVERI REVIEW

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

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THE GRÜNEWALD METHOD OF BRIGHT-ANNEALING.

Decimal index 621. 39 : 669. 8.

DURING the present century very big improvements have been made in every branch of the metal industry. The sizes of rolling and drawing mills have increased and a much higher degree of accuracy is now worked to. Only the intermediate and final stages in these two processes of rolling and drawing, viz., annealing, have not kept pace with the general development. More than 90% of all the products in the metal industry are still annealed by the same clumsy and inaccurate methods in general use over fifty years ago.

The advent of the electric furnace opened the way to new possibilities, particularly as regards the maintenance of a more uniform temperature, but the problem of preventing the oxidation of the goods to be annealed, however, still proved insoluble.

With the old methods of bright-annealing, such as filling the annealing pot with cast-iron chips, the cost of electrical heating proved prohibitive; and filling the muffle or furnace with inert, though, nevertheless, generally explosive gas, introduced so many inconveniences and additional costs that a wider use of this latter method was naturally out of the question.

Comparatively early on it was found by experience that in order to obtain a bright surface of the annealed goods it is actually only necessary to provide protection against oxidation while the charge is cooling down. The Vitry method, for instance, depends on this fact, but since it involves the use of an inert gas, it has not been adopted very extensively.

The Grünewald method of bright-annealing also depends on this fact. Instead, however, of using inert gas to prevent air from reaching the goods, the annealing pot is rendered air-tight when the maximum temperature is reached, the principle being similar to that used for preserving fruit and other food-stuffs.

Constructionally, the Grünewald pot differs from all previously used types in that it does not stand on the bottom of the furnace but is suspended inside it from the rim at the top. Also, the charge is not laid directly in the pot but on a special tray suspended from the cover by means of rods, the cover also serving to close the furnace. These new features allow of the following:—

(1) Since the annealing pot is only stressed due to its own weight when heated, it does not need to be made so strong and therefore its weight can be very appreciably reduced.

(2) The seal of the annealing pot is not in contact with the source of heat, and therefore an absolutely air-tight joint can be made in the simplest manner.

(3) Part of the heat stored in the charge and in the pots can be recuperated without the use of expensive installations.

The economic advantages are obvious. Instead of making the pots 20 to 30 mm thick out of cast steel or special plates, for temperatures up to 750 °C the casings can be made of 6 to 8-mm boiler plate. The reduction in the dead weight to be heated alone enables a saving in the current consumption of 15 to 20% to be effected. The thin walls also offer much less resistance to the passage of heat, so that the productive capacity of the furnace is very appreciably increased. In general, the annealing pots used in electric furnaces have a longer average life than those used in other types of furnaces; the life of the Grünewald pot is still further increased due to the fact that it can be used until it becomes so thin as to be no longer air-tight (three to four millimetres). Even then it is only necessary to replace that part of the casing which is exposed to the heat of the furnace (and therefore subject to oxidation), while the cover lasts indefinitely so that the cost of repairing a Grünewald pot is barely one quarter of the cost of repairing a cast-steel pot which is placed wholly inside the heating chamber.

As already mentioned, Grünewald annealing pots with very thin walls can be used. This enables the part of the pot exposed to the heat to be made of special heat-resisting alloy steel without rendering the cost too high. The thin walls, low weight, and the fact that the surfaces of the annealing pot are always free from oxide, allow the charge to be heated up and also cooled down in a much shorter time. Thus the number of annealing pots required for a given production is much smaller. Fewer furnaces are also required so that, neglecting the saving in floor space, the total cost of the furnace plant complete with annealing pots is less than that of any other annealing plant for the same production even if the walls of the former are made of the more expensive non-oxidizable metal.

The annealing pots themselves are sealed similarly to preserving glasses for fruit, by means of a rubber ring placed between the rim of the pot and the cover. The rubber ring is cooled by water circulated in a groove and is thus prevented from becoming too hot, enabling it to be used hundreds of times.

Other features of the annealing pot can be seen in Fig. 1. The process of bright-annealing wire and hoop iron is as follows:—

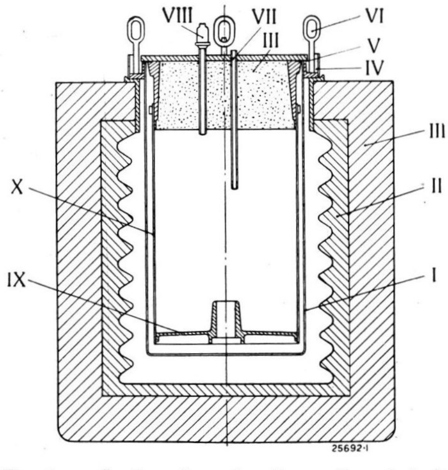


Fig. 1. — Section through a Brown Boveri shaft furnace with Grünewald annealing pot suspended inside it.

I. Annealing pot.
II. Fire-brick lining.
III. Lagging.
IV. Cooling water groove.
V. Rubber packing ring.
VI. Lifting rings.
VII. Tube for pyrometer.
VIII. Valve.
IX. Supporting tray.
X. Suspension rods.

The goods are first laid on the supporting tray (Figs. 1 and 2). The cover with suspension rods (Figs. 3 and 4) is brought over the supporting tray by the crane, and the rods are attached to the tray (Fig. 5). The cover is now lifted, together with

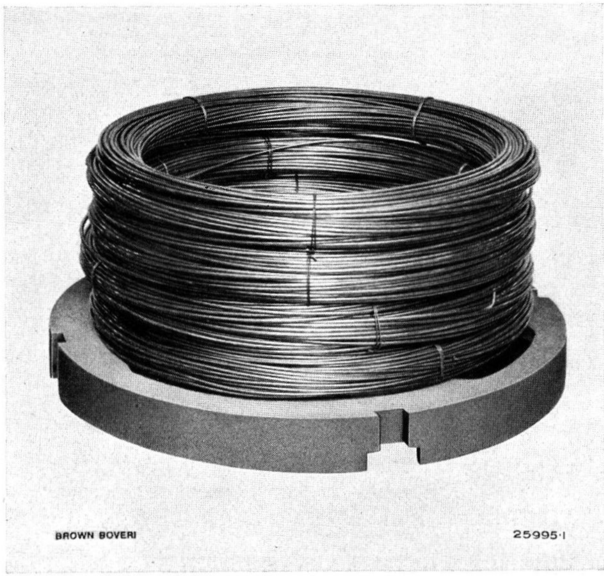


Fig. 2. — Supporting tray partly loaded with coils of wire.

the charged tray, carried to the pot, and lowered into it. Before bringing the pot together with the cover to the furnace, the cover is tightly clamped to the pot. By this means an absolutely uniform pressure is exerted on the whole of the rubber ring, and an air-tight joint made between pot and cover from the beginning. The clamps are not shown in the figure. The cooling-water groove is filled up with water before bringing the pot to the furnace. The pot (Fig. 6)

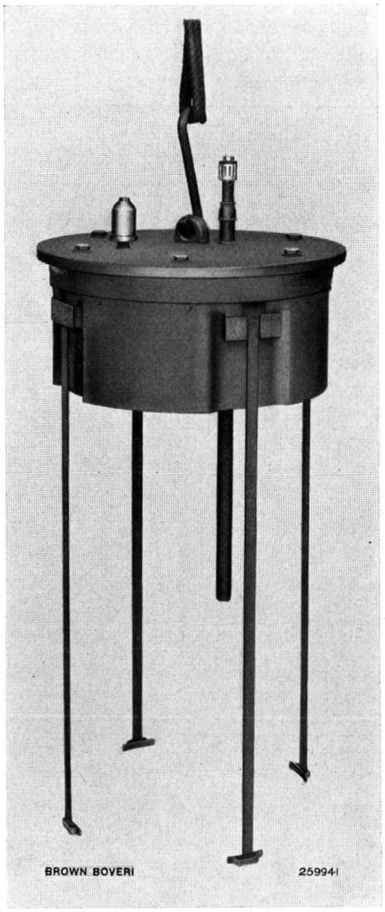


Fig. 3. — Cover of annealing pot with suspension rods, lagging, valve, and pyrometer.

Fig. 4. — Charge of wire coils on supporting tray. Fixing the suspension rods.

Fig. 5. — Charge of hoop iron on supporting tray. Fixing the suspension rods.

can now be lowered into the furnace and heated up (Fig. 7).

A large part of the air is expelled through the valve due to the expansion caused by the rise in temperature and also due to the vaporization of oil and grease which has adhered to the charge. The oxygen in the remaining air is used up in burning part of the oil vapour, so that the annealing pot is entirely free from oxygen long before the oxidation temperature of the charge is reached. The pressure in the pot drops towards the end of the process and the valve then closes automatically. For safety, the valve can be screwed down tight when moving the pot. When the desired annealing temperature has been reached, the pot is lifted out of the furnace by the crane and hung in a cooling pit, where it cools in 12 to 20 hours. The good fit of the cover and of the valve prevents any air from entering during the cooling process, so that a vacuum up to 400 mm of mercury can be attained inside the pot. The valve

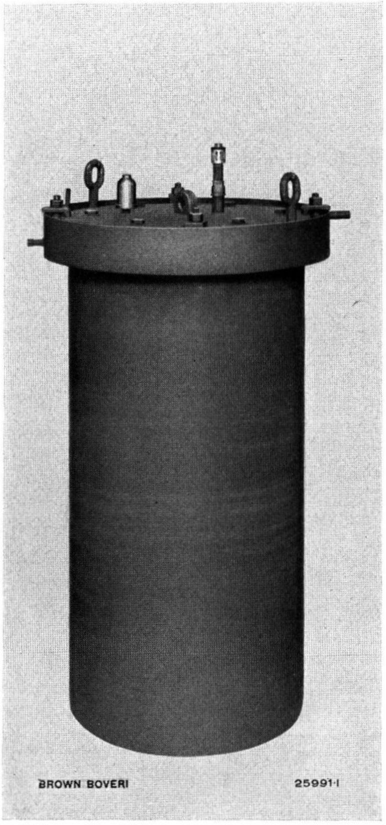


Fig. 6. — Annealing pot completely assembled and ready for suspending in the furnace.

is opened at the end of the cooling process, i. e., when the temperature has dropped to the value required for bright, blue or black dull annealing, whichever is desired, and the charge, suspended from the cover, is lifted out of the annealing pot. The supporting tray is now placed on the floor and the suspension rods are removed and immediately fitted to another tray, ready loaded with a fresh charge.

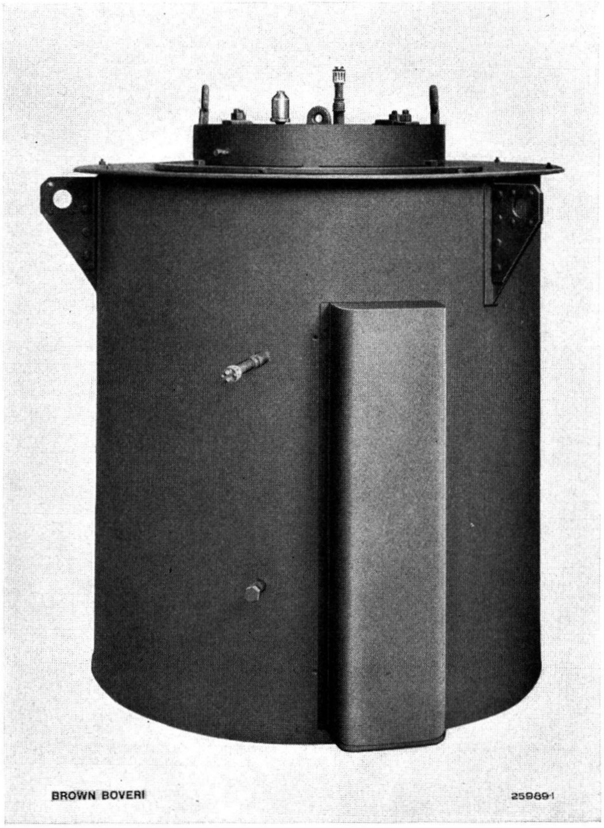


Fig. 7. — Brown Boveri shaft furnace with Grünewald annealing pot suspended inside it.

Not only iron and steel, but any kind of metal can be bright-annealed in the Grünewald pot. When treating metals which oxidize at a very low temperature, it is necessary to remove all oxygen from the pot before this temperature is attained. The simplest way of doing this is to introduce a small quantity of red-hot charcoal into the pot just before sealing it.

Fig. 11 shows the arrangement of a cooling plant in which the heat from the pots which are cooling down is used for warming up the freshly-charged pots. The power saved by using such

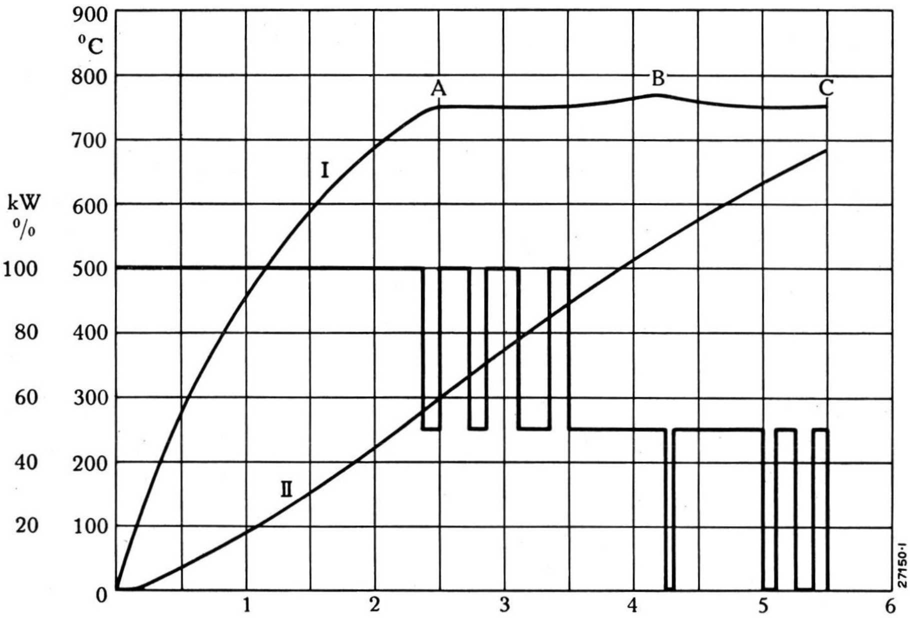


Fig. 8. — Temperature characteristics and power consumption when annealing a 2000-kg charge.

Ordinates: Temperature in °C and percentage load.
Abscissae: Time in hours.
Curve I. Temperature at exterior of annealing pot.
Curve II. Temperature of charge.
O—A. Full power consumption = 100%.
A—B. Power consumption between 50 and 100%.
B—C. Power consumption between 0 and 50%.
C. End of annealing process.

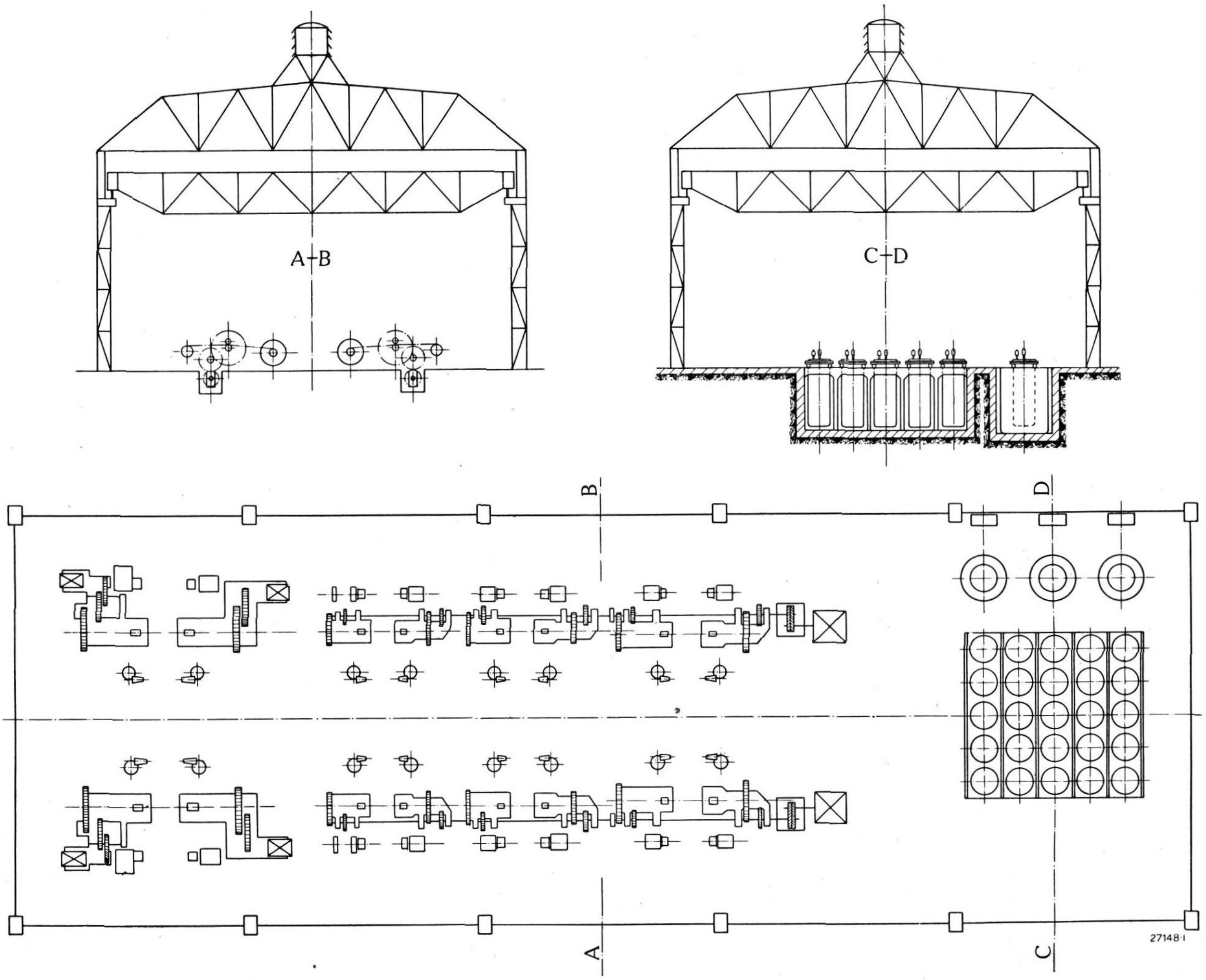
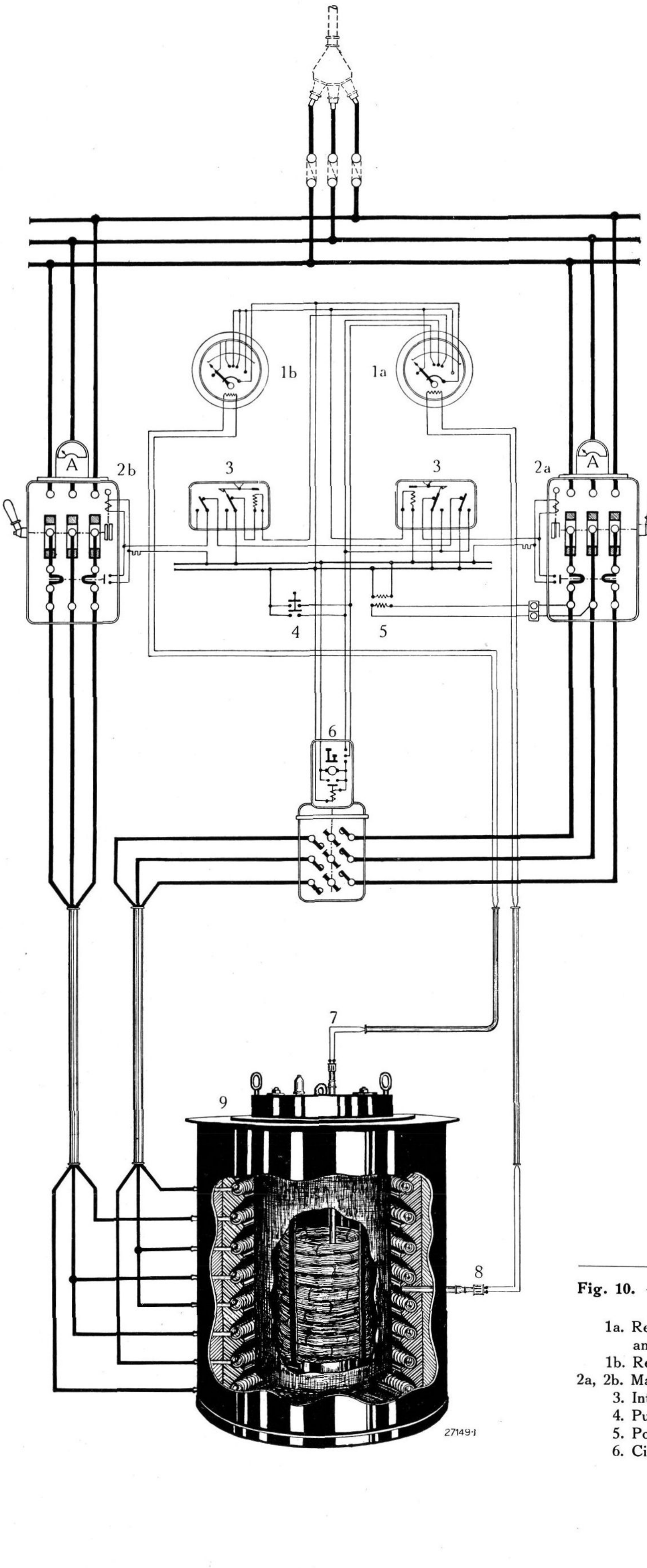


Fig. 9. — Plan and cross-sections of a cold rolling mill for hoop iron, with annealing plant *in the same shop*.
Production up to 500 tons per month.

a plant is anything up to 40 %. The number of pots placed in the pit to cool down together is varied according to the cooling speed required by the charge. The pots which have been brought up to the correct annealing temperature in the furnaces are suspended at I from small flat carriages provided with rollers running on rails along the top of the cooling pit. As each fresh pot is run into the pit, the whole row is moved up towards point II. The freshy-charged pots move in the opposite direction towards the furnace in a pit immediately adjoining. The cold pots are always run into the pit at III and the warm pots removed at IV and placed in the furnaces.

A current of air enters the pit at II and flows through it in a direction opposed to that in which the pots move. It cools the hot pots, thus heating itself, enters the warming pit at IV, flows over the cold pots, and leaves at III at a much lower temperature. The draught can be produced naturally by connecting up the plant with a chimney, or artificially by means of an aspirator. In the latter case the draught can naturally be regulated as desired, and it is then also possible to use the warm air for heating purposes in winter.

A plan and two cross-sections of a modern hoop-iron rolling mill plant are shown in Fig. 9. Note that the annealing furnaces are arranged in the same shop as the rolling mills. Compared with older plants in which the rolling mills and annealing furnaces were in separate shops, this arrangement enables a big reduction in transport costs to be effected. It can obviously only be adopted when electrically-heated



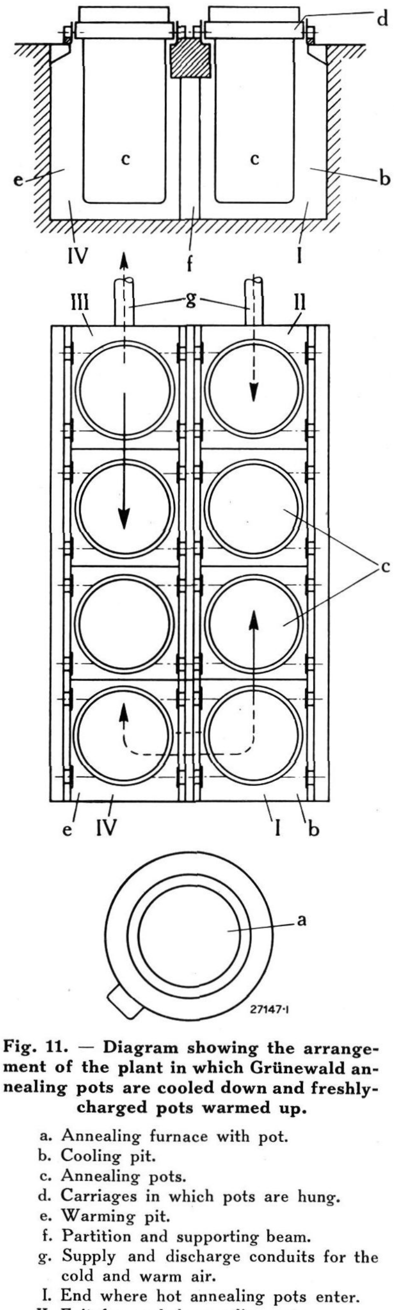


Fig. 11. — Diagram showing the arrangement of the plant in which Grünewald annealing pots are cooled down and freshly-charged pots warmed up.

a. Annealing furnace with pot.
b. Cooling pit.
c. Annealing pots.
d. Carriages in which pots are hung.
e. Warming pit.
f. Partition and supporting beam.
g. Supply and discharge conduits for the cold and warm air.
I. End where hot annealing pots enter.
II. Exit for cooled annealing pots.
III. Entrance for cold annealing pots.
IV. Exit for warm annealing pots.
——➤ Direction in which the annealing pots move.
----➤ Direction of flow of cooling air.

Fig. 10. — General diagram of connections of a Brown Boveri annealing installation.

1a. Regulator and indicator for the temperature at the exterior of the annealing pot.
1b. Regulator and indicator for the temperature at the charge itself.
2a, 2b. Main switchboxes.
3. Intermediate relays.
4. Push-button switch.
5. Potential transformer.
6. Circuit breaker.
7. Pyrometer for measuring the temperature of the charge.
8. Pyrometer outside annealing pot.
9. Annealing furnace.

annealing furnaces are employed, this being also the only case in which it is possible to realize fully the big advantages of the Grünewald annealing pot.

Brown Boveri shaft furnaces, which are specially designed for using in conjunction with the type of annealing pots under consideration, are characterized by an extremely low current consumption and very good temperature control. The heating elements are divided into two or three sets according to the size of the furnace, and the current is regulated by the temperature regulators and automatic switches so that the required temperature is attained in the shortest possible time and is not exceeded at any point of the furnace.

Fig. 10 shows the principal diagram of connections of an annealing furnace with two sets of heating elements. One set is connected to the 500-V three-phase mains through the main switch 2a and the automatic circuit breaker 6, and the other set directly through the main switch 2b. Both main switches have over-current releases and are tripped by the relays 3 through remote control. The two temperature regulators 1a and 1b, which also indicate the temperature of the furnace, control the power consumption by means of the relays 3 and the circuit breaker 6. The regulator 1a is operated by the thermo-element 8 which measures the temperature at the exterior of the annealing pot. When the temperature to which the regulator has been adjusted by means of the three central contacts is reached, the power consumption of the furnace is regulated by the automatic device 6 to between 100 and 50 % of its maximum value (see point A in Fig. 8). When the annealing process is so far advanced that 50 % of the furnace rating is too great for maintaining the desired temperature at the exterior of the annealing pot, the main switch 2b is tripped by an intermediate relay (point B in Fig. 8) and from then on the power is regulated to between 0 and 50 % until at point C the temperature of the charge reaches the required limit. The main switch 2a is now tripped by the temperature regulator 1b and the attendants are notified by an optical or acoustic signal. Thus the whole annealing process needs no supervision whatever, all that is required being to charge the annealing pots and convey them to and from the furnaces and cooling pits. Fig. 11 illustrates the typical procedure when annealing a charge of hoop iron weighing 2000 kg, the charge not being preheated. The heating elements are switched in and out entirely automatically, with an accuracy of $\pm$ 5° C. Throughout the process the furnace is heated absolutely uniformly along its whole height and circumference.

A metal which has been uniformly and completely bright annealed at the theoretically correct temperature can obviously be machined better and with greater accuracy, and it is only then that all the advantages of the new methods of rolling and drawing can be fully utilized and the work of these departments made as economical as possible.

(MS 566) *G. Keller. (E. J. B.)*

DIRECT-READING VACUUM GAUGE FOR MERCURY-ARC RECTIFIERS.

Decimal index 533. 82 : 621. 313. 73.

A description of the direct-reading vacuum gauge introduced by Brown, Boveri & Co. in 1924 has already been published in this journal.[1] The type for connecting up to a.-c. supplies is being used at the present time in many hundreds of rectifier plants, where it performs a very important service. In fact, it is indispensable for automatic plants. The degree of accuracy demanded of measuring instruments of all types is continually increasing and, as a consequence, certain improvements and simplifications had to be made to the Brown Boveri vacuum gauge. The improved design now meets all requirements regarding accuracy, simplicity, and reliability. A description of the instrument (Fig. 1) as now used for power rectifiers is given in the following pages. The primary windings of the saturated and unsaturated cores of the transformer 6 are connected to the auxiliary current supply through a series resistance 1 and the fuses 7. The secondaries of the two transformers are in series with a resistance 3, the field winding of the ferro-dynamical galvanometer 4, and the hot-wire vacuum gauge 5. The coil of the galvanometer is connected

[1] The Brown Boveri Review, 1924, No. 8, p. 160; 1926, No. 9, p. 224.

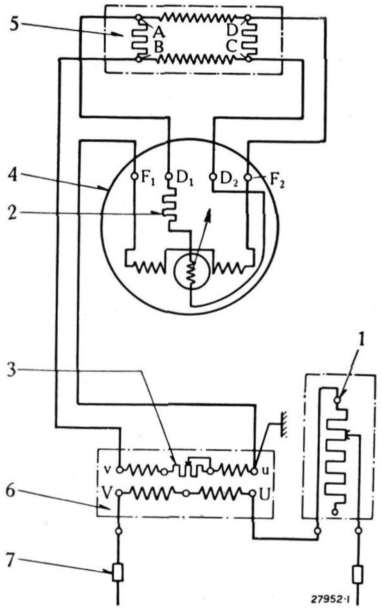


Fig. 1. — Diagram of connections of a direct-reading vacuum measuring instrument with hot-wire vacuum gauge for connecting to an alternating-current supply with transformer.

1. Series resistance in auxiliary circuit.
2. Series resistance in moving-coil circuit.
3. Series resistance in field circuit.
4. Ferro-dynamical galvanometer.
5. Hot-wire vacuum gauge.
6. Transformer.
7. Fuses.

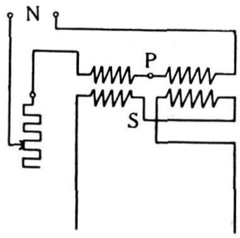
through a built-in series resistance 2 to the points A and C of the hot-wire vacuum gauge 5.

In order to keep the measuring current of the vacuum gauge constant even with variable network pressure, iron resistances in the form of hydrogen-filled lamps were originally used. These proved unsatisfactory, because in time their resistance increased, causing a diminution in the measuring current. In addition, the life of these resistances is too short for plants which operate continuously. They were therefore replaced by current regulators, each consisting of a saturated and unsaturated transformer connected in parallel, thus also enabling the insulating transformer to be dispensed with. With voltage fluctuations in the network up to $\pm$ 10 %, this arrangement keeps the measuring current constant to such a degree that the pointer of the vacuum meter does not oscillate visibly.

The principle on which the gauge works will be seen from Fig. 2. The primaries of the saturated and unsaturated transformers are in series and are traversed by a current which is kept at a constant mean value by a series resistance. Fluctuations in the network pressure also cause this primary current to fluctuate, and, therefore, the magnetic force in the laminations of the transformers. The overlapping of the secondary pressures of the two transformers, which, for the same frequency, are proportional to the lines of force, produces a constant resultant secondary pressure, independent of the primary current within very wide limits. The series resistance 1 in the auxiliary circuit has an important effect on the regulation, and, furthermore, enables the same transformer to be used for all frequencies between 25 and 65 cycles.

The vacuum gauge was further improved and at the same time considerably simplified by choosing a value for the exciting current of the ferro-dynamical galvanometer which was also suitable for the heating current of the vacuum gauge. Since the Wheatstone Bridge of the vacuum gauge is connected directly in series with the exciting coil of the galvanometer, the heating current for the vacuum gauge can be maintained constant at practically all static pressures. The increase of the resistance between the points B and D of the bridge as the pressure drops is negligible, because the reactance of the whole circuit is several hundred ohms. On the other hand, by supplying the bridge from a shunt, the heating current changes with variations in pressure in the vacuum gauge, even if the total current is kept constant. In order to understand this last improvement better, the characteristics of the hot-wire vacuum gauge should be briefly described.

When a constant heating current flows through the vacuum gauge, the energy converted into heat in



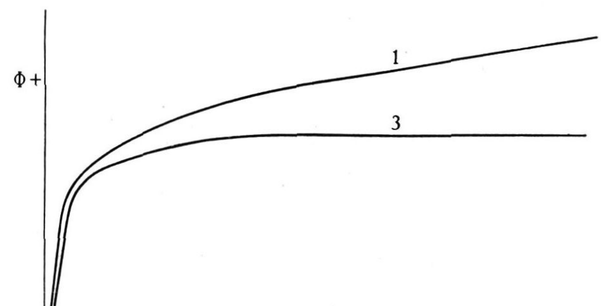


Fig. 2. — Characteristics of the transformer.

1. Magnetic flux of the saturated transformer.
2. Magnetic flux of the unsaturated transformer.
3. Resultant power flux.

AW/cm = Ampere-turns per centimetre.

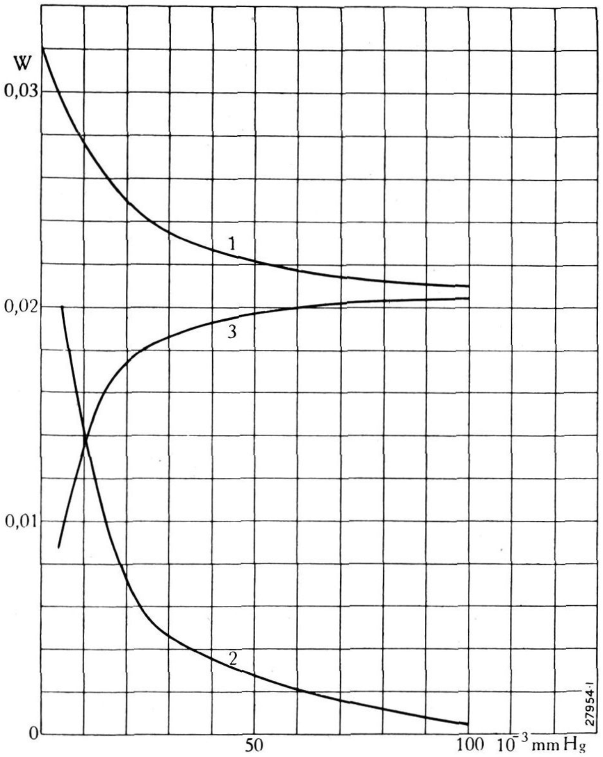


Fig. 3. — **Variation of the electrical energy in an internal branch of the hot-wire vacuum gauge.**

1. Electrical energy supplied (in watts).
2. Energy (in watts) dissipated by radiation.
3. Energy (in watts) dissipated by convection.

an internal branch, e. g., AB in Fig. 1, varies as the pressure, because the temperature of the platinum wire, and therefore its resistance, increases as the pressure drops.

To determine the energy balance of an internal branch of the hot-wire vacuum gauge for the simplified diagram shown in Fig. 1, the following terms are used:

I_H. Heating current in amperes of the vacuum gauge.

Q. Heat in watt-seconds developed per minute in an internal branch.

r_0. Resistance in ohms of an internal branch at temperature t_0 in degrees C.

t_1. Temperature of an internal branch at a pressure of p millimetres of mercury.

T_1, T_0. Absolute temperatures of an internal branch, i. e., of its surroundings.

d, l. Diameter and length of an internal branch in millimetres and metres, respectively.

α. Temperature coefficient for the electrical resistance of platinum.

s. Coefficient of heat radiation of the black body.

γ, φ. Coefficients of heat radiation for bright platinum.

q_k. Heat lost by convection.

q_s. Heat lost by radiation.

q_1. Heat lost through the ends of the wires by conduction.

$Q = q_k + q_s + q_1$.

When the vacuum is good, q_1, the heat lost through the ends of the wires by conduction, is only equal to a small part of the energy supplied to the instrument; it may be neglected for pressures greater than 5×10^{-3} mm Hg.

The energy supplied to an internal branch is given by:

$$Q = \frac{I^2_H}{4} \cdot r_0 \left[1 + \alpha (t_1 - t_0)\right]$$

The heat lost per second by radiation is:

$$q_s = \pi \cdot d \cdot l \cdot s \cdot \gamma \cdot T_1^{\varphi} \left[T_1^4 - T_0^4\right]$$

Therefore the heat lost per second by convection at gas pressures greater than 5×10^{-3} mm Hg is given by:

$$q_k = Q - q_s.$$

i. e., $q_k =$

$$\frac{I^2_H}{4} \cdot r_0 \left[1 + \alpha (t_1 - t_0)\right] - \pi \cdot d \cdot l \cdot s \cdot \gamma \cdot T_1^{\varphi} \left[T_1^4 - T_0^4\right]$$

Substituting numerical quantities in these equations and employing the coefficients of radiation given by

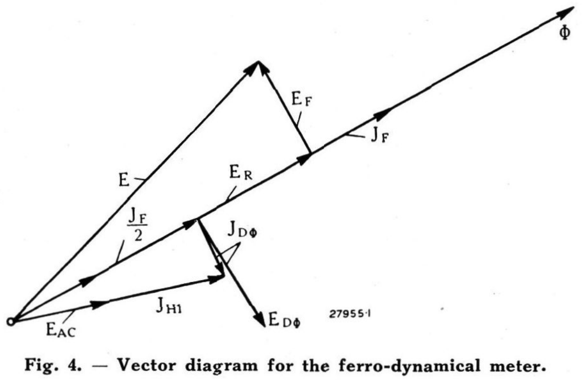


Fig. 4. — **Vector diagram for the ferro-dynamical meter.**

E. Network voltage.
J_f. Exciting current.
E_f. Exciting voltage.
Ø. Magnetic flux.
$\frac{J_f}{2}$ Current in internal branch.
J_{H_1}. Heating current in an internal branch.
$E_{DØ}$. Induced voltage in moving coil.
$J_{DØ}$. Induced current in moving coil.
E_{AC}. Voltage in bridge.

W. Geiss,[1] for bright platinum, the variation of energy shown in Fig. 3 is obtained. The increase in the energy supplied to the instrument with decreasing pressure has a very big influence on the sensitivity of the vacuum meter within a pressure range of 0 to 20×10^{-3} mm Hg, because simultaneously with the increasing movement of the ferro-dynamometer of the vacuum gauge a current is induced at the points A and C, which produces the torque in the coil. The heating effect of this current in the moving coil is reduced to a certain extent by an auxiliary current, with a phase displacement of about 93°, produced by the voltage induced in the moving coil by the alternating-current field of the instrument. The electrical characteristics will be seen most clearly from Fig. 4. The dial of the ferro-dynamical instrument is illustrated in Fig. 5. The zero position is on the right-hand side so that the indications can be marked off from the left as usual.

In automatic rectifier plants the vacuum gauge performs the important duty of maintaining the correct vacuum in the rectifier cylinder. According to the position of the pointer of the indicating instrument, the drop stirrup mechanism starts up or shuts down the pump set by means of a special switch.[2] Fig. 6 shows the diagram of connections for automatic plants.

[1] "Physica": Nederlandsch Tijdschrift voor Natuurkunde, Vol. 5, 1925, pp. 203—207.

[2] Bulletin S. E. V., 1927, p. 484. The Brown Boveri Review, 1926, No. 10, p. 246.

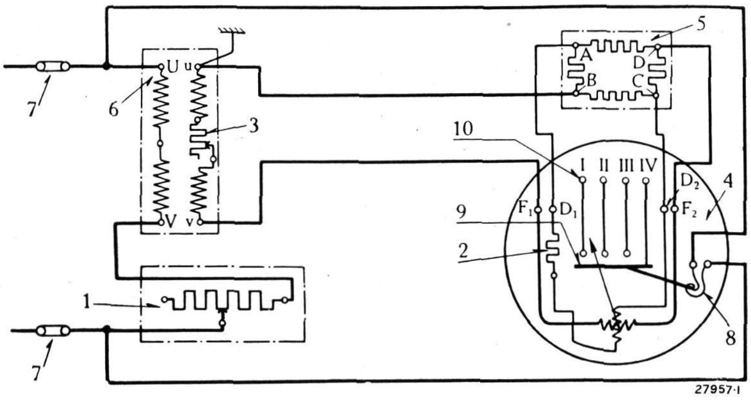


Fig. 6. — Diagram of connections for automatic plants.

1. Series resistance in auxiliary circuit.
2. Series resistance in moving-coil circuit.
3. Series resistance in field circuit.
4. Ferro-dynamical galvanometer.
5. Hot-wire vacuum gauge.
6. Transformer.
7. Fuses.
8. Bi-metal motive system.
9. Drop-stirrup.
10. Contacts.

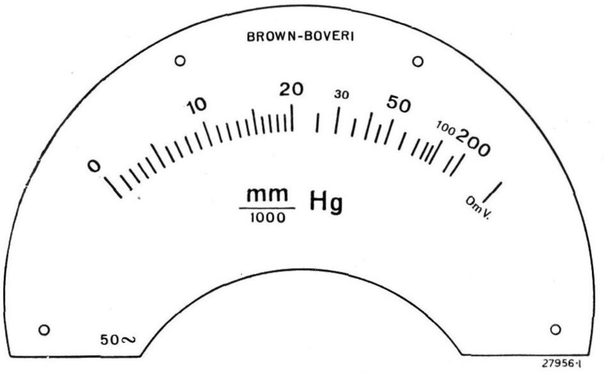


Fig. 5. — Dial, with scale, of a hot-wire vacuum gauge with ferro-dynamical indicating instrument.

Like every measuring instrument, the accuracy of the hot-wire vacuum gauge depends to a certain extent on the temperature. Due to radiation phenomena, the temperature of the internal branch of the vacuum meter varies less than that of the external branch as the ambient temperature changes. If the pressure and heating current are constant, the voltage in E_{AC} decreases with increasing external temperature, and thus the movement of the galvanometer diminishes. The total resistance of the moving-coil circuit is also dependent to a certain extent on the temperature and tends to reduce the movement as the ambient temperature rises. With the vacuum gauge connected up as in Fig. 1, the error introduced by the sensitivity to temperature variations is about $\frac{1}{1000}$ mm Hg per 10° C and is of no importance for rectifier operation. The vacuum gauge itself requires no maintenance. On the other hand, it is important if accurate readings are to be obtained that the current for measuring should always be available, even if the rectifier is out of operation. As long as the heating current is switched in, the platinum coils of the vacuum gauge remain at a temperature above that of the surroundings, provided the pressure does not fall below 0·2 mm Hg. This prevents mercury vapour, and possibly any vapour from grease and oil, from condensing on the platinum wires and thus altering their radiation coefficient.

(MS 558) *E. Kobel. (E. J. B.)*

BIENNE SUBSTATION OF THE SWISS FEDERAL RAILWAYS.

Decimal index 621. 312. 62 : 621. 331. 31 (49.4).

BIENNE Substation of the Swiss Federal Railways, which was put into partial operation in December, 1927, and into full operation in May, 1928, and since then has always worked in an entirely satisfactory manner, is situated south of the locomotive sheds at Bienne between the tracks to Solothurn and Berne. It receives single-phase current at 66—60 kV, $16^2/_3$ cycles, from the Swiss Federal Railways substation at Kerzers, and steps the voltage down to 15 kV, the standard contact-wire pressure of the Swiss Federal Railways. The energy stepped down is carried away by nine feeders. The tracks to Solothurn, Berne and Neuchâtel are each served by two of these feeders, and three are used for supplying current to the passenger depot, the shunting yard and the locomotive shed. Possibilities of enlarging the substation are provided by means of two further 60-kV transmission lines to Delémont, to be connected to the 60-kV lines coming from Kerzers over the bus-bars of the substation, and two additional 15-kV feeders, the latter for the track to Sonceboz which it is proposed to electrify later on.

Fig. 1 shows the main diagram of connections of the substation. The potential and current transformers, the equipment for the location of short circuits, surge protection and auxiliary current supply for the substation have been omitted from the diagram, as well as the projected extensions. With its aid it can be studied how the transformers, bus-bars, feeders and contact wires are protected by the various systems of oil circuit breakers, and which combinations can be made when a breakdown in a part of the system occurs. As a matter of fact, the high-tension side can be considered as split into two portions corresponding to the two 60-kV transmission lines, which is facilitated by the existence of two systems of 60-kV bus-bars. The two portions of the system are only connected at the 15-kV side. However, it is possible, as can be seen on the diagram, to establish connections also on

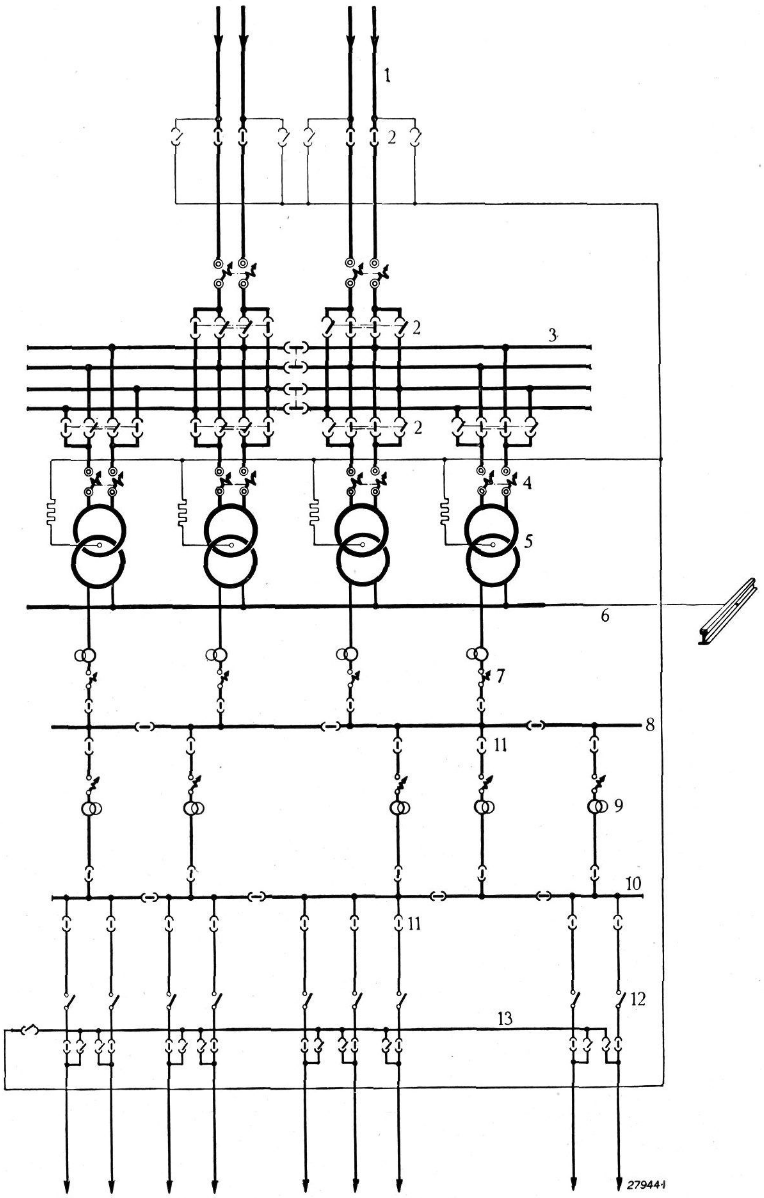


Fig. 1. — Diagram of connections of Bienne Substation.

1. Incoming 60-kV lines.
2. 60-kV isolating switches.
3. 60-kV bus-bars.
4. 60-kV oil circuit breakers.
5. 3000-kVA, 60/15-kV transformers.
6. Earthing bar.
7. 15-kV transformer circuit breakers.
8. 15-kV bus-bars.
9. Feeder oil circuit breakers.
10. Contact-wire bus-bar.
11. 15-kV isolating switches.
12. Line breakers.
13. Earthing bar.

the high-tension side in case of breakdowns or if it is desired to carry out inspections.

It will further be noticed that the neutrals of the high-tension side of the transformers are earthed through oil-immersed resistances of 60,000 ohms each. On the secondary side one of the terminals must, of course, be directly earthed as is always done in railway service.

In the usual buildings belonging to the substation, which also contain the oil-cleaning equipment, a workshop and an erection bay for the transformers, the two panels for the 60 and 15-kV side are mounted.

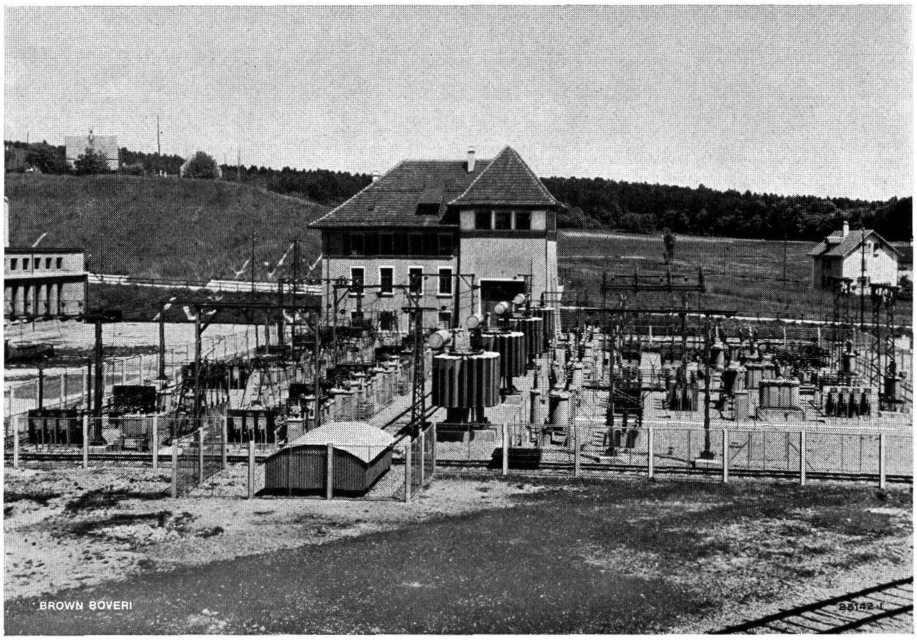


Fig. 2. — Bienne Substation.

Similarly to Fribourg Substation, described in The Brown Boveri Review 1928, No. 5, Bienne Substation is also equipped with automatic control apparatus which enables the substation to operate with only one attendant. During normal working hours the attendant is on duty in the control room, but at other times he has merely to be available in case of emergency, and is summoned from his near-by dwelling by an acoustic signal if it should be necessary to make some switching operation at the control desk.

The main task of the switchboard attendant, in the fulfilment of which he is considerably aided by the automatic devices, is the sectionalizing and cutting out of parts of the system affected by a short circuit. The automatic devices in Bienne Substation are of the type invented by Schild. Consider first the 15-kV side, which is particularly subjected to short circuits owing to its containing the contact-wire systems. When a short circuit occurs there, the corresponding feeder oil circuit breaker trips first, because its rupturing capacity is sufficient for all contingencies. Parallel to it is connected a testing

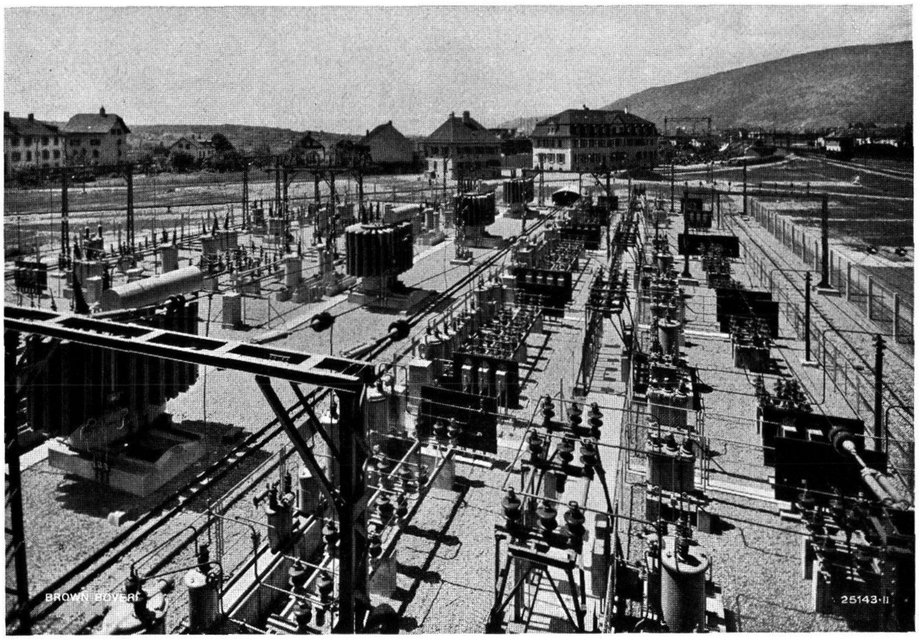


Fig. 3. — View from the control room.

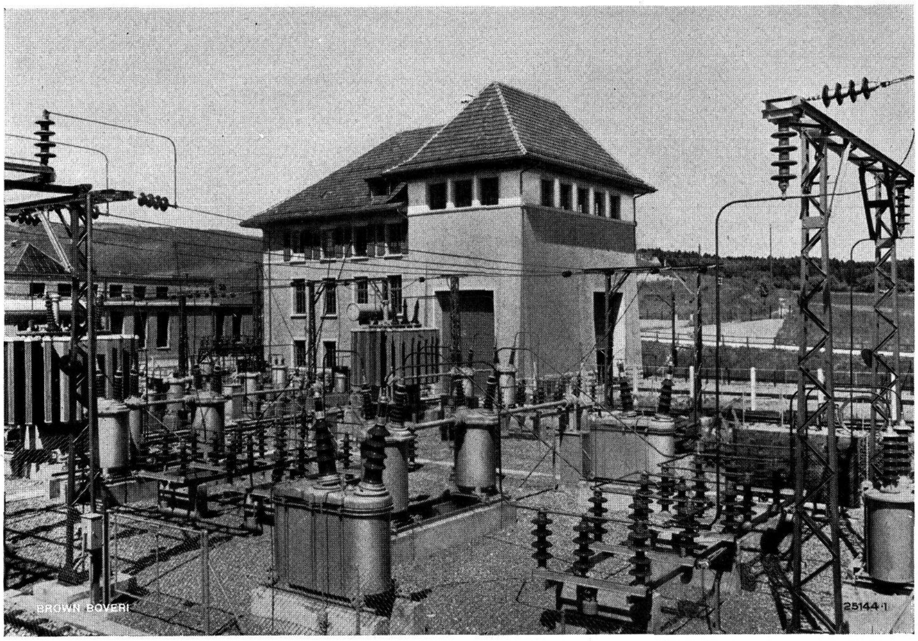


Fig. 4. — Section for an incoming 60-kV supply line.

resistance of about 2000 ohms, which carries a current of about 7·5 A as long as the short circuit persists. A coil prevents the reclosing of the main breaker, which would otherwise occur every three seconds. If the short circuit persists for 40 seconds it is considered permanent, and the testing resistance is cut out by a special oil circuit breaker. The feeder breaker remains open and the switchboard attendant is called by the acoustic signal. He trips the different line breakers through remote control from the panel. Should the short circuit and therefore the current in the test resistance disappear before the 40 seconds have elapsed, the feeder breaker is reclosed automatically after three seconds, and normal operating conditions restored without the intervention of the attendant.

In case of a permanent short circuit, the feeder breaker can be reclosed after all the line breakers have been tripped, and the testing of the different lines departing from the section in question can then be undertaken. This is done by hand from the panel with the aid of a further testing resistance, which can alternately be connected in parallel with the different line breakers. In this way it is possible to locate the line affected by the short circuit. All other lines can be immediately put into service again by reclosing the respective line breakers.

A further automatic device is provided for the high-tension side breakers and the secondary transformer breakers. If such breakers trip on account of a short circuit, they are successively reclosed automatically with the aid of a motor-driven controller, provided there is voltage at their terminals. Those showing no potential difference on account of short circuit remain open. These breakers can be identified by means of the pilot lamps on the panel.

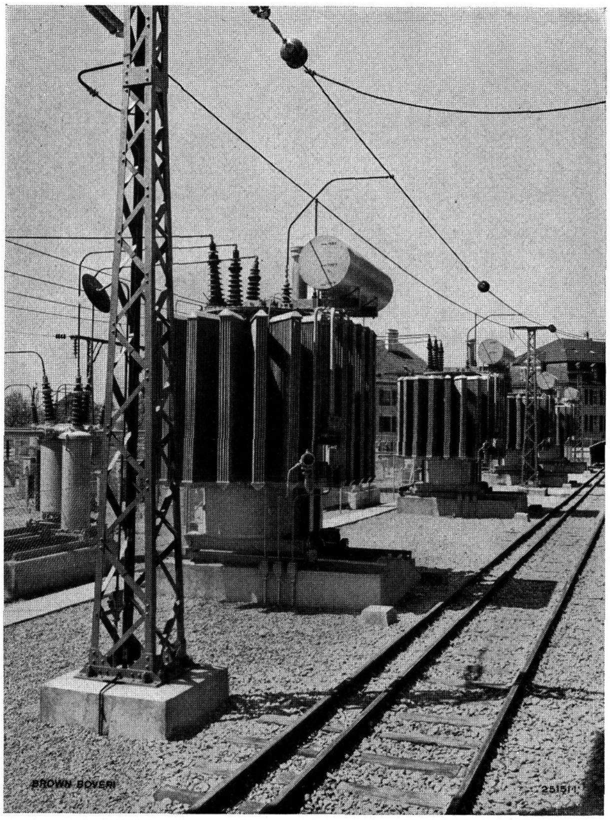


Fig. 5. — Central gangway with transformers.

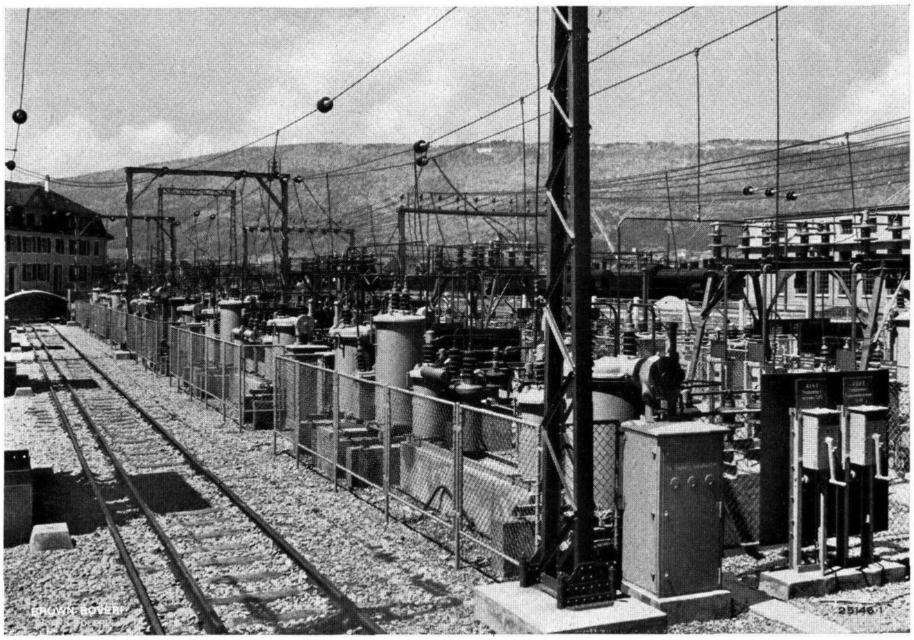


Fig. 6. — General view of the 15-kV switchgear.

The transformers and the major part of the switchgear at Bienne Substation are of the outdoor type, as in nearly all other substations of the Swiss Federal Railways; a new kind of arrangement, the so-called "flat type" has, however, been adopted for this substation. The essential feature of this arrangement is that the isolating switches are mounted on low concrete foundations, thus enabling the high structural steelwork, necessary in the previous type of outdoor substation, to be eliminated. This makes the whole plant very easy to supervise, especially if the apparatus is placed exactly according to the diagram of connections as in Bienne. Furthermore, the flat-type substation can be erected at much lower cost, the saving being approximately 30 to 40 %. It is also typical of the new arrangement that the bus-bars consist of copper cable, with very widely spaced supports, instead of copper tubes. The increased space required by the new type of substation will not, in most cases, influence the first cost very much.

The remarks made about the flat-type substation are illustrated generally by Figs. 2 and 3. The other figures show details of the plant, Fig. 4 illustrating one of the 60-kV sections, from the incoming line up to the part of the bus-bars and the two transformers belonging to it, and Fig. 5 the central gangway with the transformers. Fig. 6 is a photograph of the feeder sections seen from the central gangway, Fig. 7 of a central feeder section, and Fig. 8 of the outgoing lines in the direction of Zollikofen.

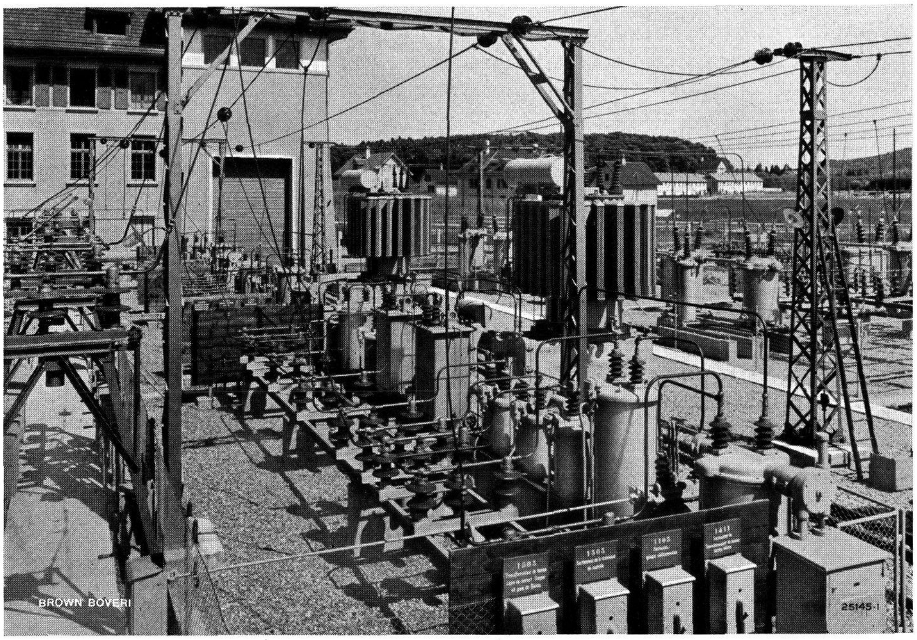


Fig. 7. — Central feeder section.

The four main transformers as well as the majority of the apparatus at Bienne Substation have been supplied by Brown, Boveri & Co. Other contractors for some parts of the electrical equipment were the Sécheron Works at Geneva, the Elektrizitäts A.-G. in Wädenswil and Messrs. Karl Maier, Schaffhausen.

(MS 569) *Th. Boveri.*

Fig. 8. — Outgoing lines in the direction of Zollikofen.

NOTES.

Testing-transformers type TPKH.

Decimal index 621.314.3.

THE design of a testing-transformer with auxiliary windings was described in The Brown Boveri Review 1927, No. 4, p. 105 under the title: "The new Brown Boveri testing transformer." This design has proved very satisfactory, and several such transformers have been built for pressures of 500 and 750 kV. Many advantages, especially as regards space requirements, accrue from producing such high pressures in a single transformer. Electrically the arrangement is also better than when several units are connected up in series. This is particularly true as regards the capacity, which, up to the present, has often received too little consideration in high-tension testing laboratories.

The insulation of the transformers is capable of withstanding the most exacting requirements. Up to the present, no failures of the insulation have occurred. The glands on the bushing insulators have also proved very satisfactory. In fact, all the packing glands on the transformers, which have now been in use for a considerable time, have remained perfectly oil-tight.

Fig. 1 shows a 500/750-kV testing transformer of recent design with a one-hour rating of 500 kVA. Of the five terminals mounted half-way up each limb, one is for the end of the high-tension winding, and the other four for the ends of the exciter winding, which was made in two parts to enable the connections to be changed over from 500 to 1000 V.

When the two parts are connected in series, the full voltage of the generator or induction regulator supplying the transformer can be utilized, producing a secondary pressure of 375,000 V. Both limbs are exactly similar, so that, according to the space available or the nature of the test being conducted, one or the other end of the high-tension winding can be earthed. Low-tension terminals are provided on the lower yoke so that the transformer can operate with the mid-point of the high-tension winding earthed. The transformer can thus meet all requirements.

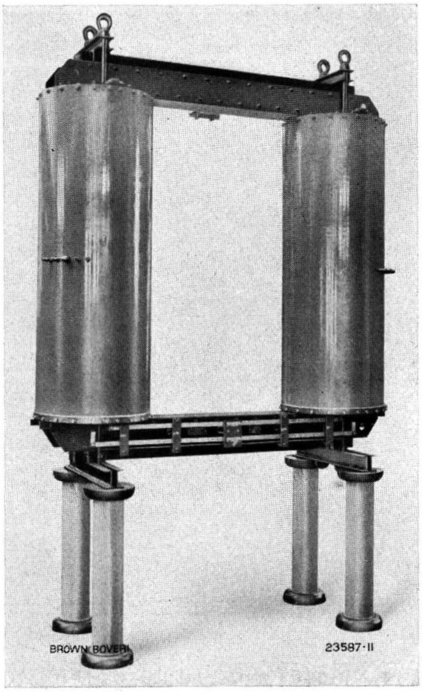


Fig. 1. — Testing-transformer type TPKH for 500/750 kV. Rating 500 kVA.

(MS 562) *A. Meyerhans. (E. J. B.)*

Express locomotive for the Circumvesuviana Railway.

Decimal index 621.334.2 (45).

A detailed description was published in The Brown Boveri Review, 1926, No. 9, of the railway (owned by the

Soc. An. per le Strade Ferrate Secondarie Meridionali, Naples) which encircles Mount Vesuvius, starting from Naples. At the time the article was written the passenger and goods traffic was considerable, and since then has developed to such an extent that it was found necessary to supplement the normal motor coach service by trains hauled by locomotives. The railway company had already experienced very satisfactory results with Brown Boveri material, and therefore, at the beginning of the present year, ordered a trial locomotive, type 1 D_o 1, with Brown Boveri individual axle drive, from the Tecnomasio Italiano Brown Boveri, Milan. This is the first locomotive with this type of drive to be built in Italy, and, incidentally, the 200th locomotive to be fitted with Brown Boveri individual axle drive. If the trials are satisfactory, four more similar locomotives will be built.

The chief particulars concerning the railway and locomotive are as follows:—

Gauge	950 mm
Minimum radius of curvature on open sections	120 metres
Minimum radius of curvature at points	70 metres
Maximum gradient	3 %
Maximum permissible axle load	11 tons
Kind of current	direct
Contact-wire pressure	1200 and 2400 V
One-hour rating of locomotive at motor shafts	1000 H. P. at 42 km/h
One hour tractive effort at tread of wheels	approx. 6200 kg
Tractive effort at starting	approx. 9500 kg
Maximum speed	70 km/h
Weight of mechanical part	approx. 41 tons
Weight of electrical equipment	approx. 16·3 tons
Total weight of locomotive	approx. 57·3 tons
Adhesive weight	approx. 41 tons
Total weight of train	200 tons

A contact-wire pressure of 850 V is used for the present motor coach service. Later on, however, this pressure will be increased to 1200 V for the whole railway system. When the system is extended (by the addition of connecting lines) it is proposed to adopt, for the extensions, a pressure of 2400 V, which is very widely used in Italy at present.

The general layout of the locomotive will be seen from Fig. 1. From the mechanical point of view the chief interest centres in the arrangement of the running gear. The narrow gauge, and, in particular, the sharp curves on open sections which have to be negotiated at normal speeds, introduced some quite new problems regarding the general running characteristics of the locomotive, particularly on curves. There are four sets of 1400-mm diameter driving wheels, and the two middle axles, which are mounted directly in the frame, have a lateral movement of 2 × 15 mm. Each of the two outside driving axles is combined with the adjacent pony axle in such a manner that by means of an arrangement recently developed by Brown, Boveri & Co. it is forced by the pony axle to adjust itself in an approximately radial position on the curves. The locomotive has outside frames, and the gear for transmitting the power to the driving axles therefore lies inside the frames and driving wheels. The torque is transmitted from the shafts of the double motors by two pinions on to a large spring gear wheel (reduction 7·43:1) the boss of which is rigidly fixed to a hollow shaft. The driving axle is connected with this gear wheel through the well-known Brown Boveri universal coupling.

The following points concerning the electrical equipment should be mentioned. To avoid expensive alterations later on, the electrical equipment must be made suitable for operating on either of two contact-wire pressures. Using four double groups of motors provides the best solution. The two motors in each group are connected permanently in series. With a contact-wire pressure of 1200 V, all four groups of motors are connected in parallel. At 2400 V, two groups of four motors each, all connected in series, are formed, and these two groups connected in parallel. The connections can be changed over at any time from 1200 to 2400 V by means of a voltage change-over switch. Two field-control positions are provided on the last notch for increasing the speed of the motors if this should be necessary due to a drop in the contact-wire pressure. The motors are cooled with forced draught. Bridge connections are used when starting, and the 12 groups of resistors, which, according to the contact-wire pressure, are connected up in series or parallel, are cut out in steps by a mechanically operated cam controller. The resistors are of cast iron. The other apparatus in the main circuit, and also the auxiliary equipment, must be suitable for the two contact-wire pressures. A Brown Boveri reciprocating compressor supplies the air for the pneumatic control apparatus and for the Westinghouse brakes.

The Tecnomasio Italiano Brown Boveri, Milan, will supply both the electrical and mechanical parts, the latter being built in their workshops at Vado Ligure.

(MS 557) E. Hugentobler. (E. J. B.)

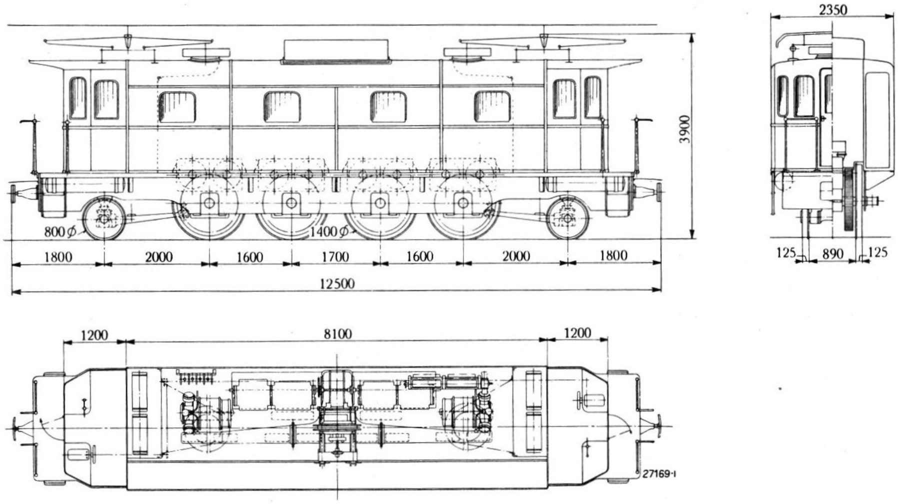


Fig. 1. — Express locomotive for the Circumvesuviana Railway (Italy).

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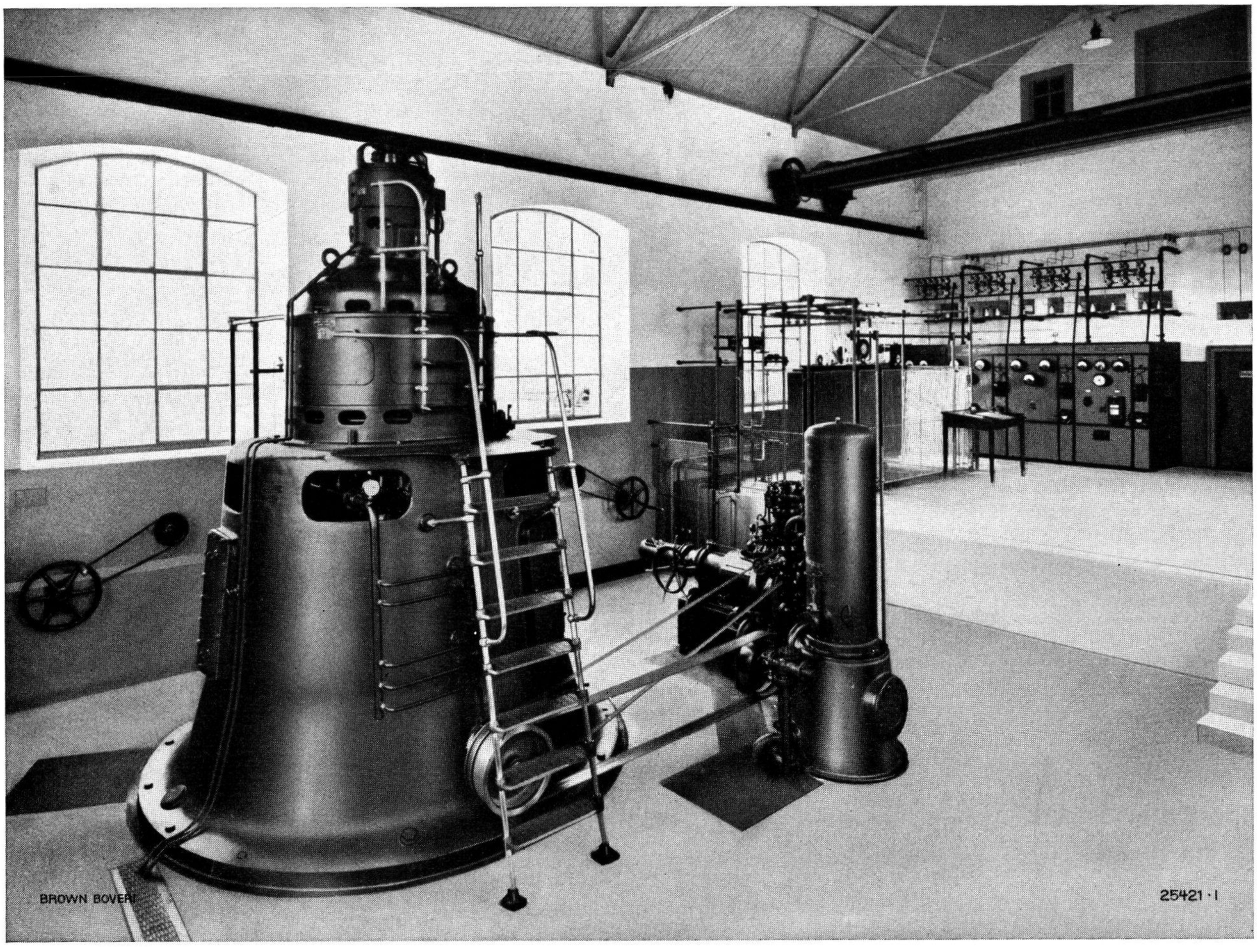
AUTOMATIC HYDRO-ELECTRIC STATIONS



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