VOL. XII JULY, 1925 No. 7

THE BROWN BOVERI REVIEW

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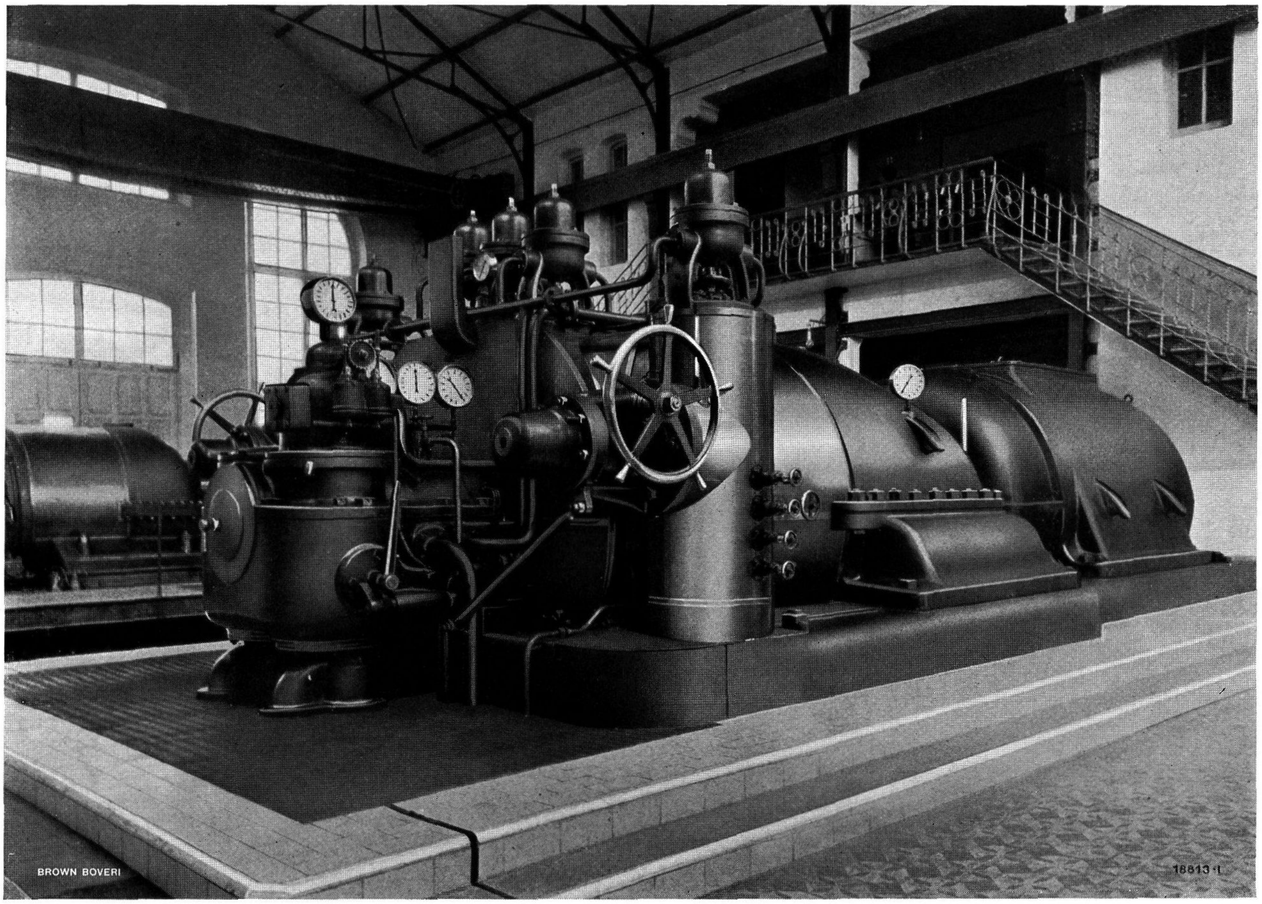

STEAM POWER STATION OF THE SOCIEDAD HIDROELECTRICA ESPAÑOLA, MADRID.
Three-phase turbo-alternator set: 10,000 kW (12,500 kVA), 6000 V, 50 cycles, 3000 r. p. m.

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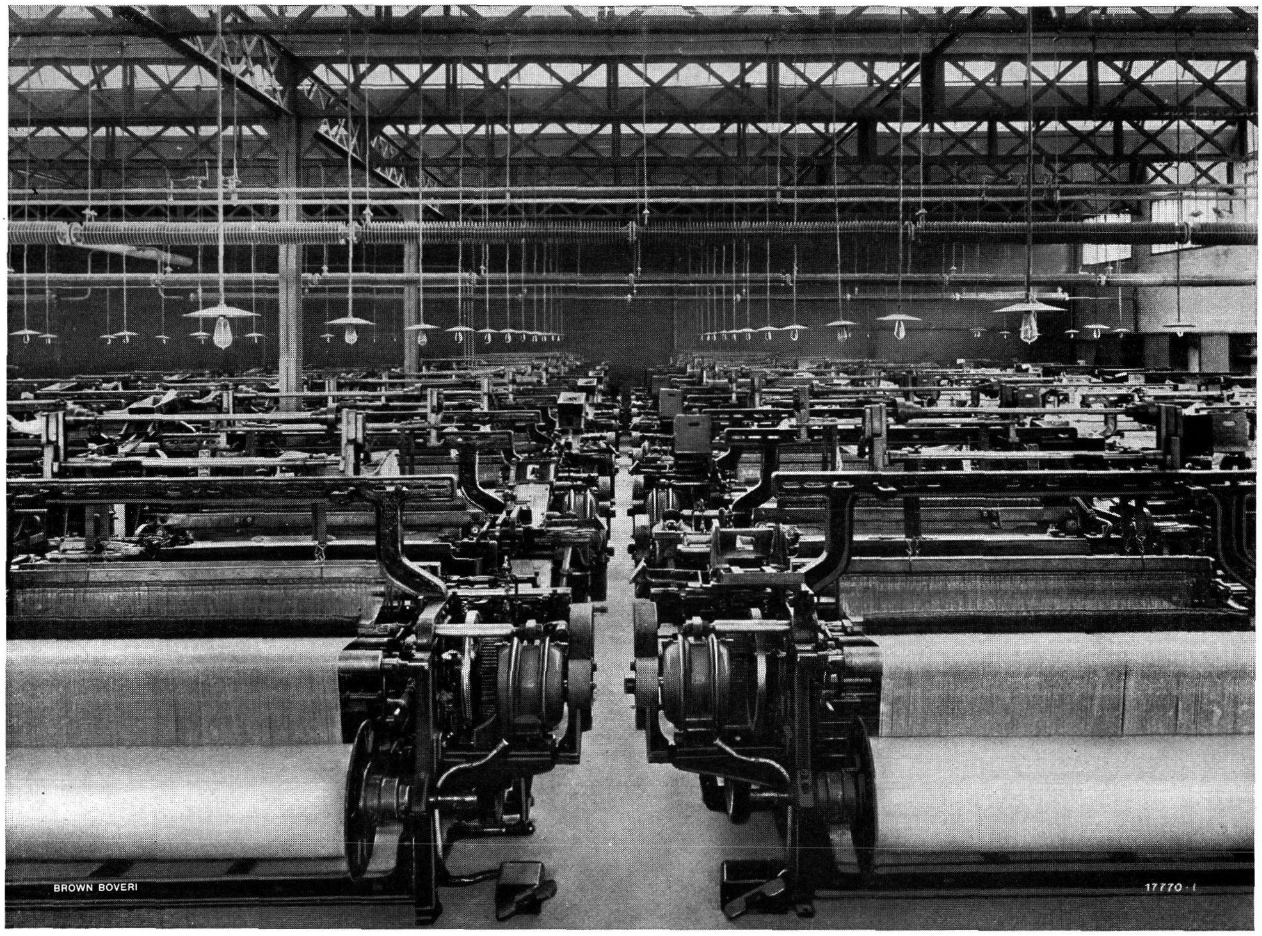

LOOSE-REED AUTOMATIC LOOMS, DRIVEN BY HIGH-EFFICIENCY LOOM-MOTORS
through reduction gearing.

TEXTILE, PAPER-MAKING AND PRINTING WORKS
CHEMICAL, CHOCOLATE AND SUGAR FACTORIES
CEMENT AND FLOUR MILLS - BREWERIES
MACHINE TOOLS - AGRICULTURE - SMALL INDUSTRIES

THE BROWN BOVERI REVIEW

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

VOL. XII JULY, 1925 No. 7

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THE FERROCARRIL ELECTRICO DEL GUADARRAMA.

Decimal index 621.331.34 (46).

I. GENERAL.

ABOUT 60 km to the north-west of Madrid are situated the mountain ranges of the Sierra de Guadarrama. The country here forms a holiday resort in summer and contains many winter-sport centres. Tourists proceed to Puerto de Navacerrada from Cercedilla, at the foot of this mountain range having travelled on the Madrid-Segovia-Irun Railway. Puerto de Navacerrada is a sport centre from which many excursions start; it is situated in the Sierra at a height of 1700 m and is about 15 km from Cercedilla. The Guadarrama Railway connects Cercedilla and Puerto de Navacerrada. The chief traffic on this line is the conveying of tourists and visitors. Later the railway will be extended to the north as far as Puerto del Paular, another sport centre and holiday resort in the Sierra, and also southward, thus providing direct connection to Madrid for a number of large villages between which there is no rail communication at present.

As with every other railway which supplies large tourist centres, the traffic varies greatly. On an average about 400 people travel by the first train every morning to Cercedilla and wish to continue their excursions into the mountains without delay. In order to relieve these sudden congestions large motor-coach trains must be run. During the remainder of the day, however, the traffic decreases to such an extent that the use of large motor coaches is no longer necessary. On this account, the railway company must sooner or later provide smaller motor coaches also. At present the rolling stock consists of two large motor coaches and four trailers.

II. RAILWAY CONDITIONS.

The railway is a single-track metre-gauge line of the adhesion system, adapted to the formation of the mountains. The difference of height on the whole length of 13·5 km amounts to 605 m, and, with the exception of the comparatively short sections in the eight stations, the railway has an almost continuous gradient of 6 %. A radius of curvature of 60 m is used almost throughout for curves on the open track, but this radius is reduced to 38 m at points in the stations. The trolley wire has a cross section of 100 mm^2, and is doubly insulated from the posts and cross members, from which it is suspended. The supports are formed by a horizontal rolled-steel arm fixed to a pine mast; at the stations double arms are used. The trolley-wire pressure is 1200 V and can be varied by $\pm$ 15 % from this mean value.

III. THE SUPPLY OF ENERGY.

The railway obtains the necessary energy from a special power station, situated two kilometers to the west of Navacerrada. The original plan was to obtain three-phase current from an outside source and to convert it to direct current by means of a mercury arc rectifier. When the whole of the electrical plant was finished, however, the railway company found that it would be unable to obtain the power as planned and finally solved the difficulty by installing a Diesel-alternator set of its own. The three-phase current generated in this manner is converted to direct current at 1350 V by a Brown Boveri mercury arc rectifier Type HG $^4/_6$ supplied through a transformer situated in the same building. The open three-phase winding of the generator is connected to the six-phase side of the rectifier transformer. The transformer thus ensures the particular load distribution, to the individual phases, necessary for the rectifier service and at the same time forms the neutral point of the system. The continuous rating of the rectifier is 350 kW, with an overload capacity of 25 % for forty minutes, of 100 % for four minutes, and of 200 % for one minute. A second rectifier of the same type has been provided which at present acts as a reserve. After the completion of the distribution system, and the installation of a second transformer, which may be supplied if necessary from an outside source, the power available will be doubled. A very favourable efficiency is obtained over the whole day with this plant, resulting from the use of rectifiers instead of converters.

The supply of the whole of the electrical equipment of the railway including the motor coaches was entrusted to the Sociedad Española de Electricidad Brown Boveri, Madrid, in the middle of 1921. The machines and apparatus were designed and constructed at the Baden Works of Brown, Boveri & Co., the coachwork and the bogies being manufactured by the Swiss Car Works, Schlieren.

IV. THE MOTOR COACHES.

The most important particulars of the motor coaches are given below:—

Length of body	16550 mm
Width of body	2680 mm
Height of coach	3500 mm
Length over buffers	17550 mm
Bogie wheelbase	2400 mm
Distance between bogie centres	11000 mm
Total wheelbase	13400 mm
Seating accommodation	
2nd Class	24
3rd Class	46
Standing room	
2nd Class	8
3rd Class	40
Total number of passengers	118
Weight of mechanical portion	22·6 tons
Weight of electrical portion	10·4 tons
Total weight of coach empty	33·0 tons
Load carried	9·0 tons
Total weight of loaded coach	42·0 tons
Maximum axle load	10·5 tons
Train weight	70·0 tons
Weight of loaded trailer approximately	14·0 tons

As far as the mechanical portion of the motor coach was concerned the problem was to construct a vehical having the greatest passenger

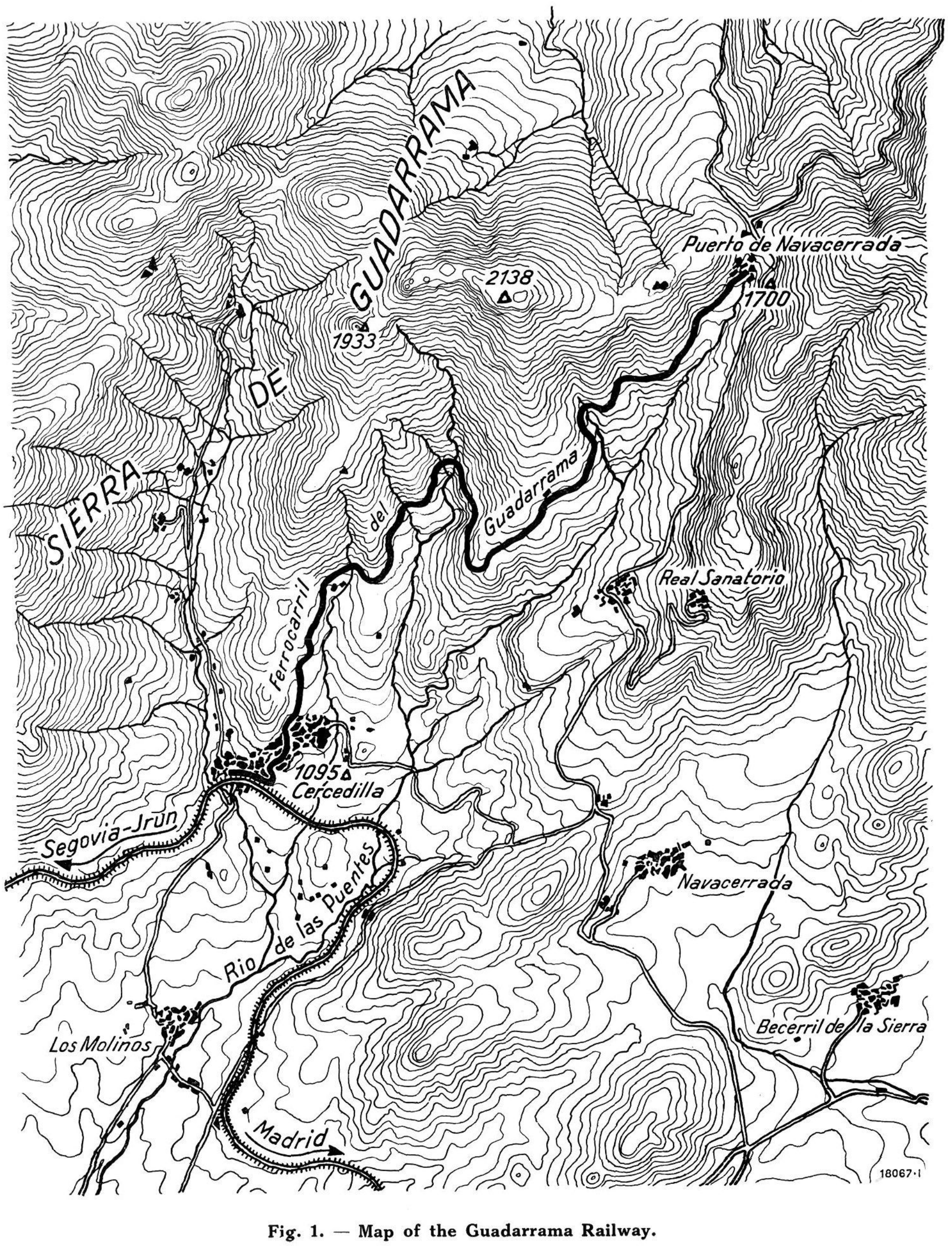


Fig. 1. — Map of the Guadarrama Railway.

accommodation. The coach may be considered as consisting of two main parts rigidly connected to each other viz. the body of the coach and the underframe with the two two-axle bogies. As shown in Fig. 2, the coach is divided into compartments for the two classes, with a large vestibule in the middle for standing room; two driver's cabs entirely separate from the remainder of the coach are also provided. In order to deal adequately with the "rush-traffic", particularly at the two termini, three entrances are provided on each side of the coach; free access is given to the vestibule from either compartment. Direct communication between the coach and trailers is obtained by means of doors in the end walls of each. The coachwork is built up on an oak frame, the roof and floor frames being of pitch-pine. The seats in the vehicle are also of oak, and curtains are provided to shade the balanced, frameless windows. The underframe of the body is made from rolled-steel sections riveted together and carries part of the electrical and pneumatic apparatus, the two bogie pivots, and the two bearing surfaces on which the body rests. The bogies are of the two-axle type, and doubly sprung. The bogie framework is composed of plate and rolled-steel sections riveted together, and, as shown in Fig. 5, it carries the link-work operating the wheel brakes, the spring-suspended driving motors, the bogie bearings and bearing rollers for the support of the body, the compressed-air cylinder and also brakes to act on the rails. Plain axle-bearings are provided, and the motor coach is fitted with central draw and buffing gear. The employment of steel sleepers for the track contributes to the safety of running.

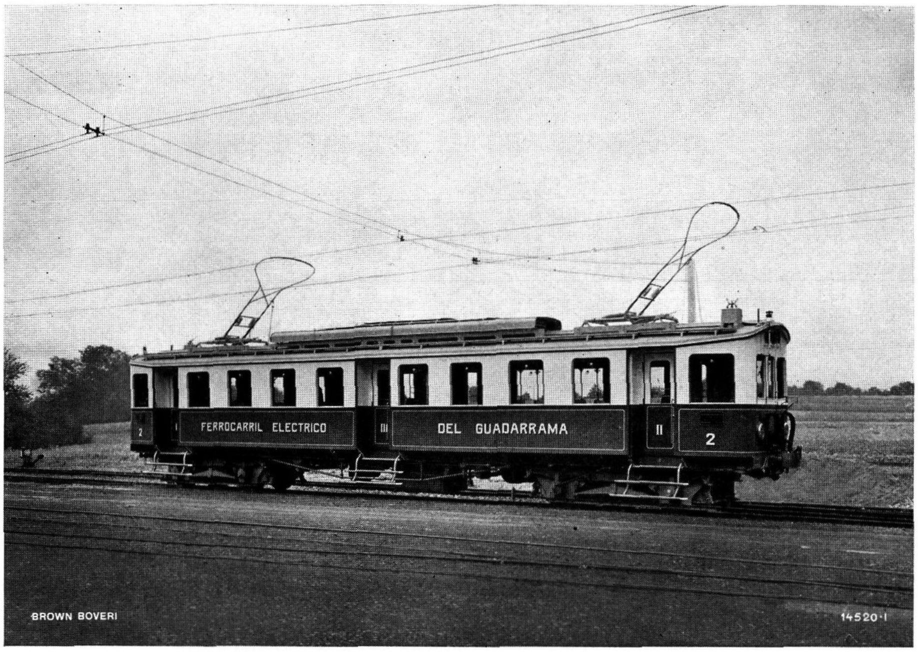
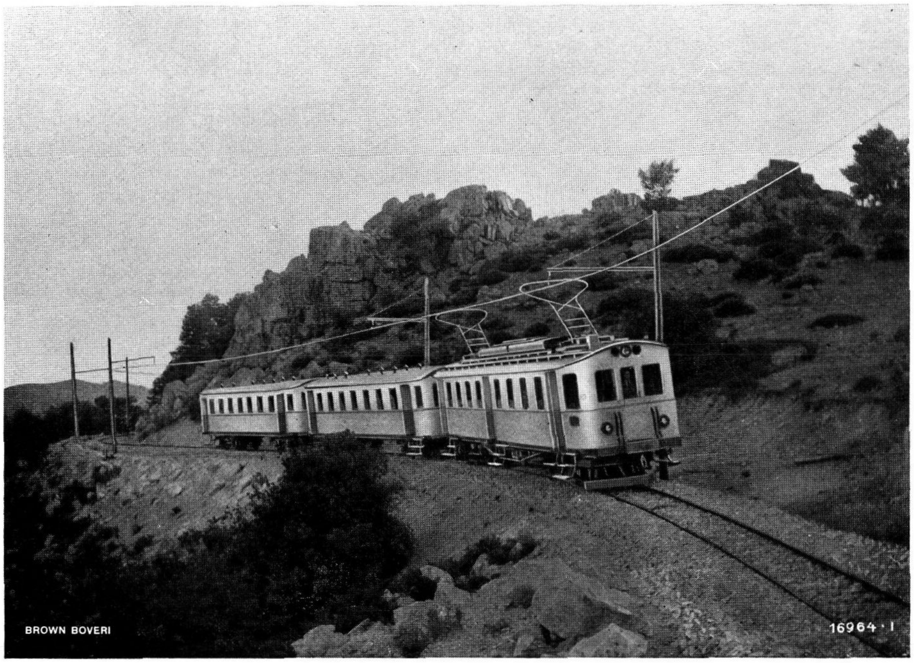


Fig. 2. — Motor coach of the Guadarrama Railway.



Typical train on the Guadarrama Railway.

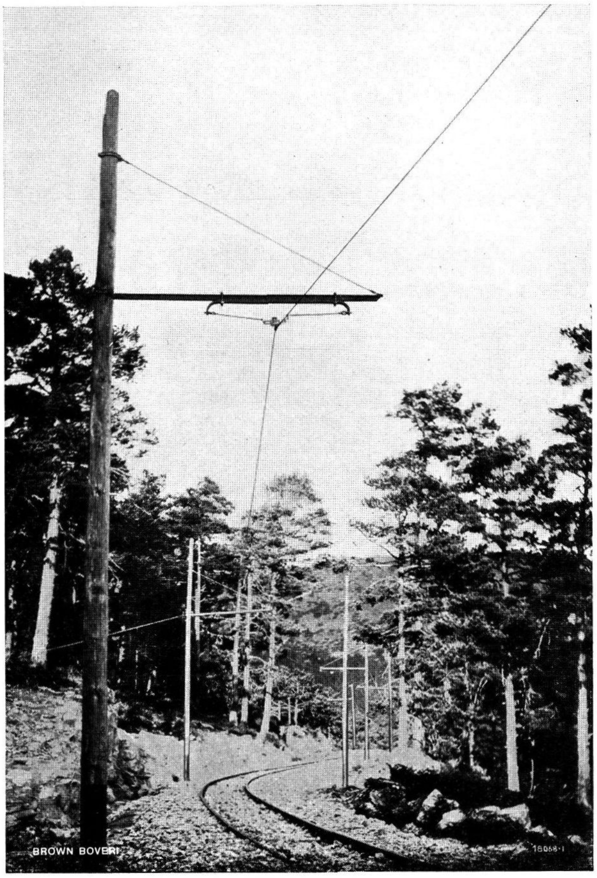


Fig. 4. — A curve on the line showing trolley wire.

V. THE ELECTRICAL EQUIPMENT.

The electrical equipment is arranged as shown in Fig. 6. The two driving motors of each bogie are permanently connected in series. To indicate the necessary dimensions, it was specified that the one-hour rating of the motors should be such that the motor coach must draw a total train weight of 70 tons up on a 6 % gradient at a speed of 18 km/h. The highest speed to be attained is 40 km/h. Each of the four axles is driven by a totally-enclosed, unventilated, direct-current, series-motor of the GTM 8 Type, connected to the 920-mm driving wheels by a simple reduction gear of 5·2 to 1. The one-hour rating, of each motor, taken at the shaft, amounts to 102 H. P. at 550 r. p. m. and a pressure of 1200/2 V, which produces a total power of about 390 H. P. at the tread of the wheels. Each motor has an undivided casing, series winding, four main poles, and four interpoles. The armature bearings and also the axle bearings are of the plain, pad-lubricated type. The large gearwheel is made in two parts and is protected, together with the pinion, by an oil-tight welded steel-plate cover; its clearance from the top of the rail is 95 mm. Also, with these motors, in order to facilitate the replacement of the shaft should this be necessary, the armature laminations are not mounted directly on the shaft itself but are pressed onto a special spider. For the same reason, the commutator is also fixed to this spider, thereby giving the advantage that the connections between the commutator and armature winding need not be broken when the motor is overhauled.

Cam-operated contactors are used for the control of the coach, as shown in Fig. 7, these are mounted below the centre of the floor in a casing completely dust and water-proof, and covered with Eternite plates. On both sides, suitable inspection covers are fitted which render examination possible even when the controller is fixed in position. The main drum, which has six series, four parallel, and six braking positions, is mechanically operated through shafts, chains and sprockets from the controllers fitted in both the driver's cabs. The reversing drum, which reverses the driving motors is also mechanically operated from either of the controllers. The handwheel of the main drum is mounted vertically; it is rotated through 90° in a clockwise direction for each new running position. The brake is controlled in a similar manner, and is applied by rotating the brake handwheel counter-clockwise, each 90° representing one position; a pointer which moves over a scale fitted on the

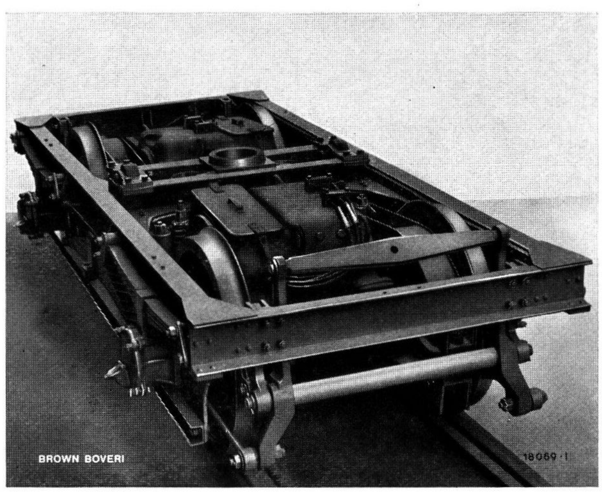


Fig. 5. — Double-sprung motor-coach bogie, complete with driving motors, brake gear, swivel bearing, and roller-bearing axle boxes.

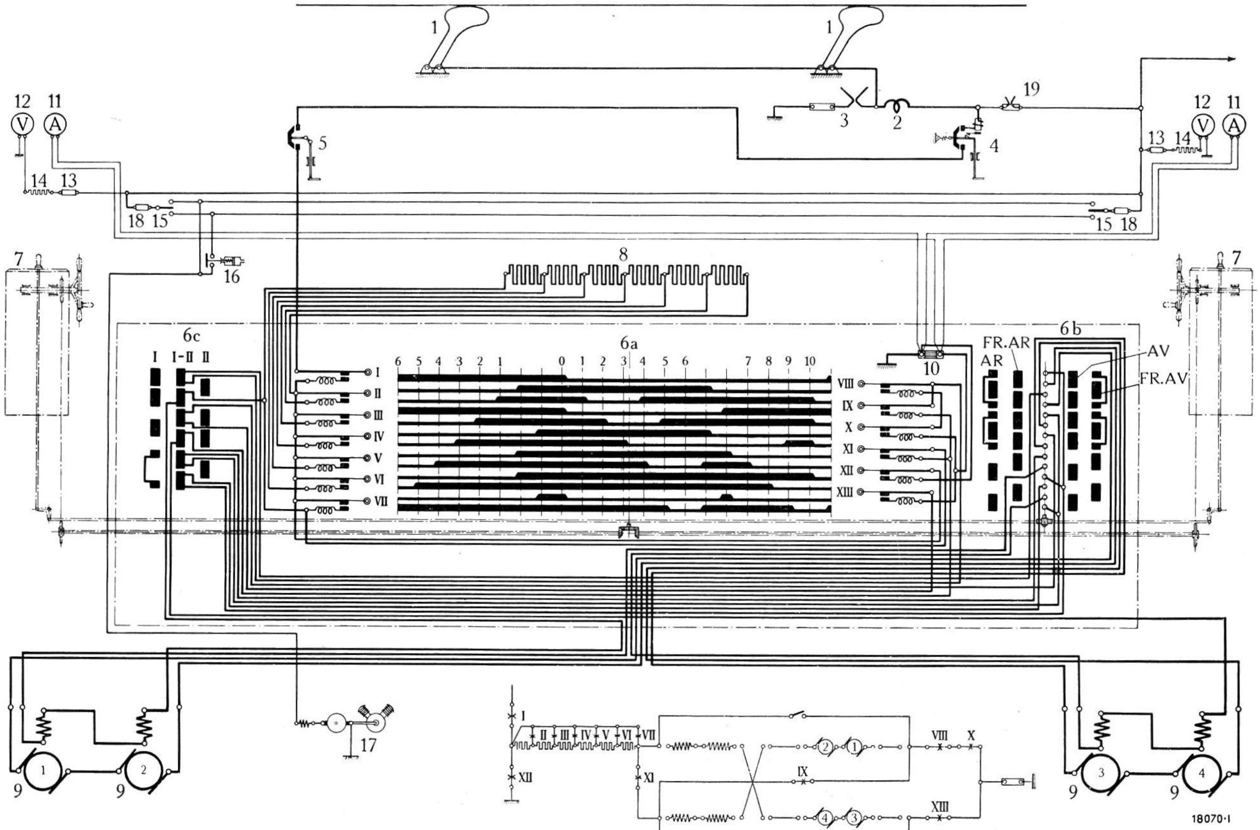


Fig. 6. — Diagram of connections of motor coach.

1. Bow collector.
2. Choke coil.
3. Lightning arrester.
4. Main switch.
5. Hand-controlled switch.
6a. Cam-operated main controller.
6b. Reversing drum.
6c. Motor selector.
7. Controller.
8. Starting and braking resistances.
9. Main motor.
10. Shunt.
11. Ammeter.
12. Voltmeter.
13. Voltmeter fuse.
14. Series resistance for voltmeter.
15. Compressor change-over switch.
16. Automatic pressure regulator.
17. Motor-compressor.
18. Compressor-motor fuse.
19. Fuse for auxiliary apparatus.

control desk, indicates the position of the brake. The reversing lever, on the contrary, is mounted parallel to the surface of the control desk, and gives the required connections by being rotated through the necessary angle. A third drum, which can only be operated after opening an inspection cover in the main controller, serves to cut out one or other of the two motor groups.

The starting and braking resistances are insulated for a working pressure of 1200 V. They are designed for natural cooling, and for continuous braking with a train of 40 tons on a decline of 6 %, at a speed of 20 km/h. These resistances are mounted on the roof of the coach. They are designed for ten startings per hour, each operation continuing for 25 seconds and with a mean starting current of 300 A. A sheet-steel casing protects the resistance from rain or snow.

Two bow collectors, kept against the trolley wire by tension springs, and fitted with aluminium

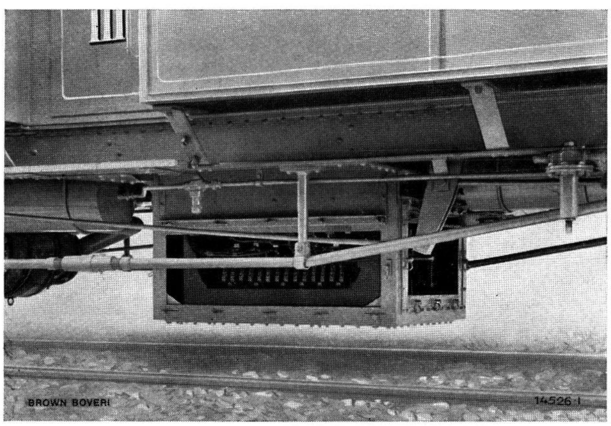


Fig. 7. — Cam-operated main controller mounted under coach body, cover removed. To the left, the air compressor with reservoir and safety valve.

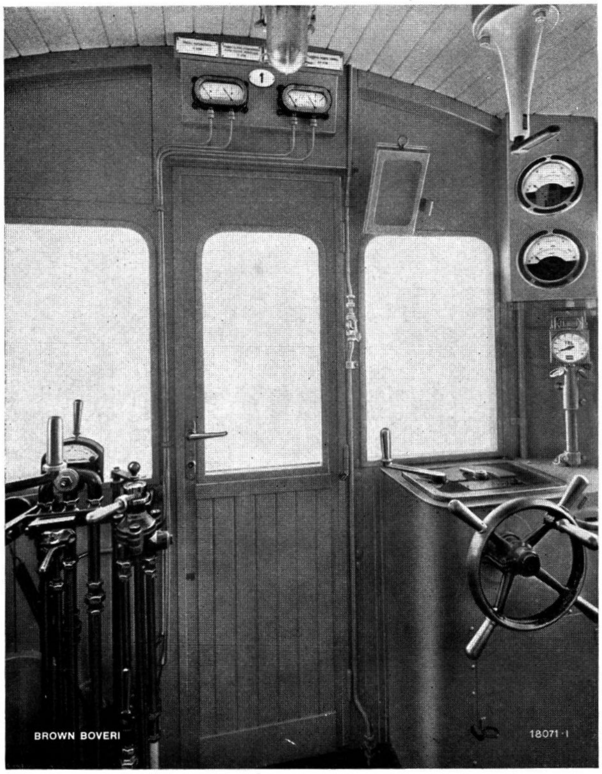


Fig. 8. — Inside view of driver's cab.

bows 1500 mm wide, collect the currents. To facilitate reversing, the bows are fitted with spring-controlled telescopic tubes, the withdrawal of the collector from the trolley wire being effected by means of a hand rope. The coach roof is 3500 mm above the rails; the height of the trolley wire varies from 5 m to 5·6 m on the open track and is increased to 6·5 m in the stations. A choke coil with horn gap and also a Silith resistance are fitted on the roof of the coach as lightning protection.

Over one of the two driver's cabs a single-pole automatic circuit breaker with horn spark extinguishers is mounted. The switch is dimensioned for a working pressure of 1200—1300 V, a maximum permissible pressure of 2000 V, and a current of 250 A, the tripping current being adjustable between 400 and 500 A. This circuit-breaker, which is protected against the weather, also serves as a hand switch, and is provided with a handle in order that it may be operated from the inside of the driver's cab. A switch is mounted above the second cab, this is similar in construction to the circuit-braker mentioned above but not automatically released; this switch is only actuated by means of the hand control.

On account of the almost constant decline of 6 ‰ on this railway, special attention had to be paid to the brake gear fitted. In addition to the hand brake acting on eight brake shoes, and the usual rheostatic braking, the effectiveness of which was ensured by the particular attention paid to the winding of the driving motors, the coaches are also equipped with a pneumatic rail-brake, and a compressed-air brake. The four shoes of the rail-brake prevent all slipping of the coach in any emergency; they are effective even in the case of the rails being covered with ice. This brake is controlled by a special handle which brings it into operation at the same time as the resistance brake and the compressed air brake. The shoes of the rail brake are pressed against the rail by the piston of the compressed-air brake cylinder. Upon the air being exhausted from the cylinders the shoe is lifted from the rail by a return spring. The compressed-air brake uses the same shoes as the hand brake.

The sanding gear and the signal whistle are pneumatically operated as well as the brakes. The necessary compressed air is supplied by a Brown Boveri motor-compressor set, Type GC2, suspended under the middle of the floor of the coach, near the main controller. It is driven by a motor of 5·5 H. P. at 700 r. p. m. and a terminal pressure of 1200 V, and delivers about 560 litres of free air per minute at a pressure of 6 kg/cm^2. The compressor is of the reciprocating type with two cylinders inclined at 90°. The valve heads with the delivery valves are mounted on the cylinders, while the suction valve is in the piston; all the valves are of the circular-plate type. The compressor is overhung on the shaft of its driving motor, which is a four-pole, series-wound machine with interpoles, and so arranged that it can be switched in without the use of a series resistance. The covering of the motor is rain-proof. All the bearings are ring-lubricated. The set is operated automatically by a pressure regulator, the effective range of which can be adjusted to suitable limits. A single-pole change-over switch with zero position enables the compressor to be operated by hand, i. e., independent of the pressure regulator.

The current for the illumination of the coach is obtained from the trolley wire; the coach is wired in three circuits of 150 V, with eight lamps on each. Eight two-bulb ceiling lamps fitted with frosted globes illuminate the inside of the coach, while the platform and instrument lamps in the driver's cabs each contain a single bulb. The track is illuminated by three single-bulb headlamps, the two lower ones on either end of the coach being fitted with clear glasses; the connections are such that either end of the coach may be lit independently. The upper reflector lamps are placed in the centre of the coach, and each is provided with a red and a green signal disc. The current required to illuminate the trailer is supplied by rod couplings from the coach, the sliding couplings and necessary rods are fitted to the front and rear edges of the roof of the vehicles.

In addition to the controller already referred to, with its change-over switch for the compressor and the hand lever for the circuit breaker, each driver's cab is provided with the usual levers and hand controls, cocks and valves for the brakes, signal whistles, and sanding gear, besides four pressure gauges for the pneumatic brakes of the motor coach and trailers, voltmeters and ammeters for the motor circuit, and a speedometer. The switches, change-over switches, and fuses for the lighting circuit are mounted on the rear wall of each driver's cab. The flexible couplings which connect the compressed-air brake reservoir of the motor coach with those of the trailers, are fitted outside the driver's cab, and half way up the front of the vehicle.

The connections between the bow collectors, the incoming leads with the automatic circuit breaker, and hand-operated switch, all leads for the lighting circuit, and those for the starting and breaking resistance are laid in a wooden casing 200×60 mm. This casing occupies the middle of the roof and extends for the whole length of the motor coach. The motor cables and the cables for the auxiliaries are laid under the floor in a sheet-steel channel 35×80 mm which connects the driver's cabs. Inspection panels in the floor of the coach enable the cables, motors and main controller to be inspected.

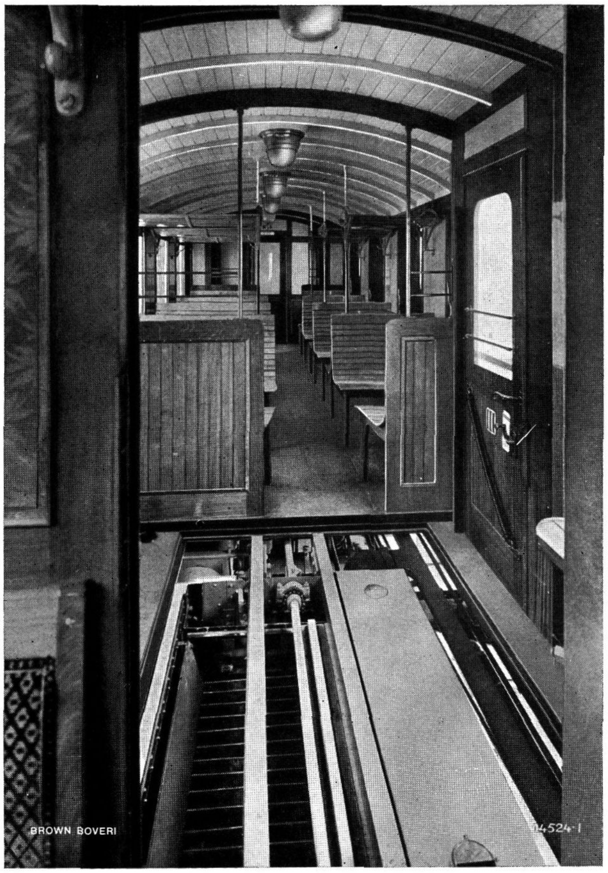


Fig. 9. — Inside view, with inspection panel in floor of central vestibule raised, showing cam-operated controller, transmission shaft with chain and steel cable channel.

VI. THE OPENING OF THE LINE.

Both motor coaches were finished at the end of July, 1922 and trial runs were made in Switzerland on the line between Bremgarten and Dietikon in order to test the electrical equipment and particularly the efficiency of the braking devices. The results of the tests were very satisfactory in every respect, so that the coaches could be delivered immediately to the Guadarrama Railway Company. Owing to the fact that the permanent way was not completed at that time, the opening of the railway had to be postponed until 12th July, 1923. The opening was attended by the King and Queen of Spain and proceeded without the slightest hitch. Both the power station and the motor coaches were running at full load. Since the opening, a regular service has been maintained on the first section of the railway.

(MS 331) *F. Eckinger. (J. R. L.).*

BROWN BOVERI STARTING AND REGULATING RESISTANCES FOR CRANES.

Decimal index 621. 317. 4 : 621. 39 : 621. 87.

I. GENERAL.

AT the close of the article on Brown Boveri drum controllers in The Brown Boveri Review, 1924, No. 5, page 87 it was stated that a description of the resistances for starting, braking, and speed regulation, to be used in conjunction with the controllers would be published later. The requirements of crane service are very exacting in all respects. Owing to the shocks inseparable from crane service all parts of the resistances have to be very strongly constructed; further, the heating of the resistances which are loaded intermittently is not so definitely determined as with machines and apparatus for continuous operation. It is necessary, therefore, to take the temporary high overloads into consideration when deciding on the choice of material to be used. To meet the demands of crane operation and other intermittent work, Brown, Boveri & Co. have developed two special types of resistances known as resistances Type N and Type B respectively.

II. MECHANICAL DETAILS OF THE RESISTANCE.

Type-N Resistances. These are made in six different sizes and are suitable for use with direct-current motors with outputs of less than 22 kW and for three-phase motors having outputs up to 20 kW. Fig. 1 shows the general design of these resistances with guard. The framework is made of angle iron and has four feet by which it may be secured to the floor. The resistance itself is of Constantan wire spirals secured in a strong frame which is attached to the framework of the guard by four screws. The connecting terminals are mounted on a Bituba-covered transverse member below the resistances. When more than ten connecting terminals are used another cross member is necessary. The transverse members are not heated by the ascending warm air as they are situated below the resistance. The position of these members, therefore, prevents the shrinkage of the insulation, and also the terminals from becoming loosened through heating; thus continuous good contact is assured. The leads are connected by means of screwed terminal pieces, and are carefully tinned to improve the contact. For reasons of mechanical strength, only wire of a larger diameter than 0·5 mm is used. All current-carrying portions are protected by unperforated sheet steel casings. Sufficient space has been left between the sides and the upper cover to ensure unobstructed air circulation for cooling purposes.

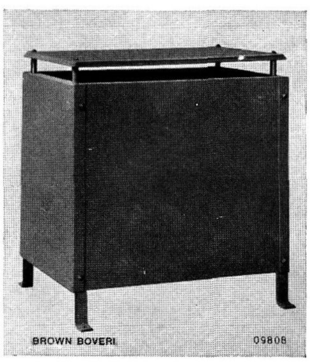


Fig. 1. — Type-N crane resistance with guard.

Type-B Resistances. These are manufactured in five different sizes, and are suitable for direct-current motors having outputs between 4—50 kW, and also for alternating-current motors of outputs from 6—50 kW. The lowest output for which these resistances are suitable is determined by the ohmic value of the elements which can be mounted in the space. The resistance elements consist of nickel-alloyed cast iron; the maximum resistance per element is 0·6 ohms at a temperature of 15° C. For motors having larger outputs than those mentioned it is necessary to connect two or more resistance frames together. The mechanical parts are made so that two or more resistance frames may be connected, without difficulty, either side by side, or one above the other. Owing to the necessity of maintaining an unimpeded air circulation for cooling purposes, Type - B resistances may only

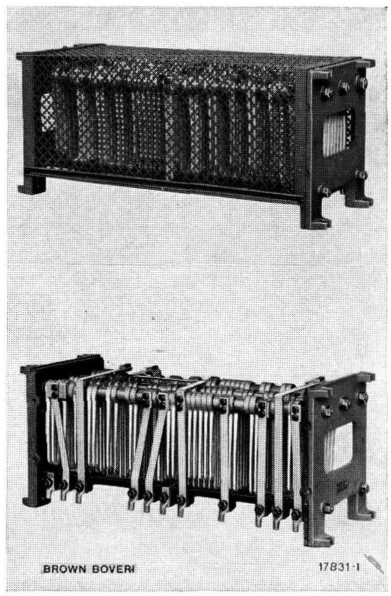


Fig. 2. — Type-B/1d crane resistance with cast-iron elements, with and without guard.

be mounted on the floor. The mechanical parts of the resistances are very strongly made. The frame consists of two cast end pieces provided with attachment lugs and connected by five strong steel bolts. The cast-iron resistance elements have three eyes; these are passed over the three upper bolts which are protected by insulating mica sheathes. Copper connections are provided to join the resistance steps to the controller. Where the resistance elements are to be electrically connected to each other, tinned copper washers are inserted between each, and where they have to be insulated from each other mica discs are used between each element. By the use of insulating material consisting of pure mica an extraordinarily high resistance to heat is obtained, so that the superior insulating qualities are retained even if the resistances should become red-hot through overload, or as a result of carelessness on the part of the attendant. The elements are securely clamped together by means of nuts on the ends of the bolts. As a slight shrinkage of the insulation material on heating can never be completely prevented, the resistances are repeatedly heated during manufacture and the nuts tightened, so that decrease of the contact pressure in service need not be feared. The connection terminals are mounted below the resistance on a Bituba-covered cross-member in a similar manner to those of the N-Type resistances. The cast portions are made from a special alloy having a comparatively high specific resistance as well as a good elasticity; in this way fracture of the elements is avoided even although they are subjected to violent vibrations. It is impossible for the resistance elements to touch, as they are separated by sufficiently wide gaps. To prevent the elements rusting, when used in humid atmospheres, they are coated with heat-resisting paint composed of aluminium-bronze; this method has proved to be very satisfactory. The resistances are protected against accidental contact by a perforated sheet-metal guard, thus all parts under tension are protected and good cooling guaranteed. A single guard can be supplied to cover all the resistances in the event of the resistances being used alongside each other or one over the other.

III. ELECTRICAL DETAILS OF THE RESISTANCES.

Resistances of Types N and B. The upper limit of current for N-Type resistances necessarily depends upon the cooling available. Since the increase

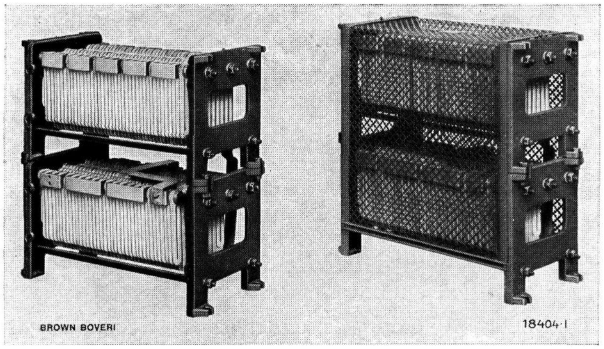


Fig. 3. — Type-B/2 c m crane resistance with and without guard.

in cooling surface is not proportional to the volume, it follows that thick wires are more unfavourable than thin wires. Consequently N-Type resistances are constructed for a maximum current of 35 A per spiral. For higher currents more resistance spirals should be connected in parallel.

With the B-Type resistances the highest permissible current per element amounts to about 85—110 A according to the distance between the elements. The smaller value requires a spacing of 13 mm, and the higher value, 26 mm. As with the N-Type resistance, parallel connection of the elements is necessary for currents exceeding the values given. Tests and calculations have shown that there is a certain interval at which the resistance elements can be spaced for greatest economy in construction. For the usual cast elements this interval is found to be 26 mm. With small powers it frequently occurs that the total resistance required cannot be attained with this spacing; in such cases, therefore, the intervals are reduced to 13 mm. The individual resistances are arranged in such a manner that the change may be easily accomplished without the necessity for any additional parts. Both types of resistances are designed for 60—120 switching operations per hour, at approximately regular intervals, and with starting lasting from 3·5—5 seconds. With a large number of switching operations the time required for each start must be the shorter of the times stated, while with a reduced number of starts per hour this time can be increased. Owing to the special conditions which have to be satisfied in cranes, a starting torque of 2·5 times the normal torque is often required; it was necessary, therefore, to design the resistances to withstand a mean starting current of 1·8—2·0 times the normal current of the motor. The starting torque and stator current are approximately directly proportional when three-phase induction motors are used; i.e., doubling the normal current produces a mean starting torque of twice its previous value. The conditions are more favourable when direct-current, series motors are used since an increase of 1·8 times the normal current doubles the starting torque. The resistances designed for intermittent operation must not be used for continuous speed regulation, as, under certain circumstances, they could be overloaded; for such cases a special design of the resistances is necessary.

As mentioned in the article on Brown Boveri drum controllers[1], under certain circumstances, the resistances are often loaded to a higher degree when used for rheostatic braking than when starting, hence special calculations are often required to enable such conditions to be fulfilled. With rheostatic braking for direct-current series motors, the machine works as a generator connected to the resistance while lowering; so that this fact must also be considered when the resistance is designed. Since braking does not continue until a state of rest obtains, and, in consideration of the efficiency of the motor and gearing, the maximum value of the brake output amounts to 50% of the motor output on normal load and is independent of the speed with which lowering is performed.

With the safety or potentiometer brake, patented by Brown, Boveri & Co., the energy produced by lowering the load is almost entirely absorbed in the resistance, which must be suitable dimensioned.

The starting resistance is also used to absorb the brake energy when travelling cranes are stopped. In these instances the braking period is of comparatively short duration. The braking period coincides with the working period of the motors during lowering, and the breaking period during travelling, is about the same as the starting time. Braking after moving can be considered, therefore, as an increase in the frequency of the switching operations. The starting power is necessarily greater than the braking power, since the crane is not braked to a standstill and also the mechanical efficiency of the motor and driving gear has to be considered, as this is not perfect the power required to bring the crane to rest is only about 50% of that required for starting. When designing the resistances, allowance can be made for the power required to brake the crane, and a corresponding increase in the frequency of switching operations permitted. As the resistances are usually designed for a maximum of 120 switching operations per hour, they can be used for braking 80 times per hour without alteration.

[1] See Brown Boveri Review 1924, No. 5, page 87.

The most important question with three-phase induction motors is super-synchronous lowering. In such a case, the motor runs as a generator, at a speed above synchronism, supplying current to the distribution system. When lowering by this system the resistance must be cut out quickly, otherwise the motor may attain an inadmissibly high speed. When exceptionally light loads are lowered very quickly, the resistance being inserted, the braking current required is considerably smaller than the mean starting current. As lowering is always preceeded by raising the load, compensation takes place when lowering with the resistance connected in series with the motor, because the power is correspondingly smaller than that required for raising. When super-synchronous lowering is employed, therefore, it is not necessary to design the resistance specially, since listed resistances may be used, provided they are suitable for the starting conditions.

With counter-current lowering, which is applicable to single and three-phase commutator-motors, it is necessary, under certain circumstances, to connect resistances in the circuit to prevent the self excitation of the motors as generators. The mechanical portion, as well as the electrical conditions, must be considered when the resistances are designed; it is therefore impossible to decide upon the dimensions of the resistances until complete particulars are known. In order that the supply system may be loaded gradually, so that smooth lifting on light loads may be assured and the contacts of the controller protected from damage, auxiliary steps are provided on the resistance. These are dimensioned for the following currents when the rotors are stationary.

Controller Type	No. of auxiliary steps	Current strength as a percentage of the normal, in position 1	2	3	4	5
A 4/3	0	250	—	—	—	—
A 6/3	1	125	250	—	—	—
A 8/3	2	100	175	250	—	—
A 10/3	4	70	115	160	205	250

These values are applicable to normal resistances and are the mean values for three-phase current with a tolerance of ± 15 %. For direct current the values are about 10 % lower. The listed resistances of drum controllers for three-phase motors are arranged for part of the resistance to remain permanently connected in the rotor circuit, even when the controller is placed in the last position. This arrangement has the advantage that the current taken from the mains is limited, even if the attendant turns the controller to the last position too quickly. The motor even in this case is able to start because it develops a higher starting torque than if the resistances where short circuited. When the motor always operates intermittently, the fact that this resistance involves a slightly lower efficiency of the set and about 4% greater slip is not of very great importance, particularly as the starting peaks occurring with excessively rapid switching are reduced. When lowering loads with super-synchronous connections of the motors, it is necessary to bridge over the permanent resistance so that an excessive increase in the motor speed may be avoided.

The N and B-Type resistances are constructed for pressures up to 660 V. The insulation tests of the resistances and also of the terminals to the frame are carried out with a pressure of 2300 V, applied for one minute.

IV. INSTALLATION.

The resistances must be mounted in an upright position on account of the resistance material and to ensure correct cooling. If they are erected where water falls, or in the open, a protective roofing must be provided. The air circulation necessary for cooling the resistance must always be taken into consideration when the resistance is installed. It is also necessary to remember that, if more resistances are mounted on top of the existing units, cooling may be impaired. The maximum watt loading of the cast elements when two units are placed above each other is 85 % of that of a single element, while if mounted three-high the capacity is only 75 % of the single value. When the units are installed side by side the interference with the cooling is negligible; therefore, a reduction of the load per unit is not necessary. Resistances may not, as a rule, be mounted in places containing acids or explosive gases; in the first case corrosion of the resistance elements and destruction of the insulating material may arise, and in the second the gases may be ignited by the comparatively high temperature attained by the resistance in service.

V. SERVICE CONDITIONS.

The heating conditions with intermittent work are usually more complicated than when the resistance is in continuous service, because the heating curves are substantially influenced by the cooling which occurs when the resistance is idle. The treatment of the heating problem by calculation or by graphical methods will not be gone into more closely in this article, but it is sufficient to summarise the most important facts briefly.[1] The characteristic cooling curves, for a resistance similar to those described, are shown in Fig. 4. The heating curve for intermittent operations

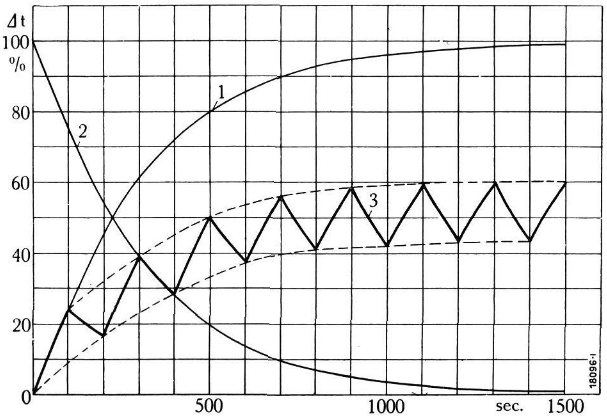


Fig. 4. — Heating curve of resistance on intermittent work.
1. Heating curve of Type-N3 resistance on continuous load.
2. Cooling curve of the resistance.
3. Heating curve with intermittent loading.

consists of a series of sections from the continuous heating and cooling curves. The curve is of a zigzag form and the bounding curves approach the highest value asymptotically; the maximum value is very easily determined graphically when once the heating curve is known. The maximum value is calculated when the heat given up during an idle period is equal to that produced during the preceeding working period. The longer the pauses compared with the loaded time, the quicker will these conditions of balance be realised. In practice this dependence is characterised as the

[1] G. Gut: "Ein neues graphisches Verfahren zur Vorausbestimmung der Erwärmung elektrischer Maschinen und Apparate für intermittierende Betriebe einschliesslich Bahnen", Bulletin de l'Association Suisse des Electriciens, 1918, No. 2.

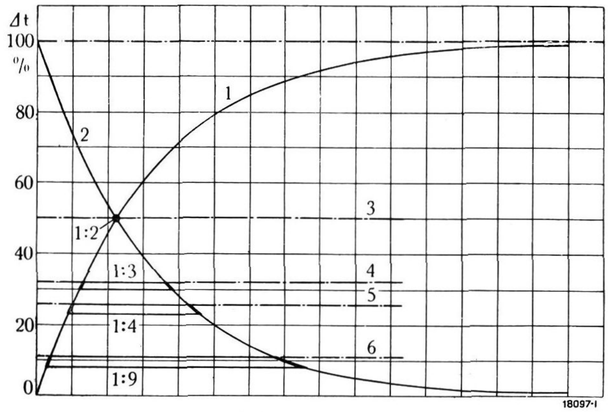


Fig. 5. — The influence of the intermittence on the heating of the resistance.

1. Heating curve of Type-N 3 resistance.
2. Cooling curve of resistance.

intermittence, by which the relationship between the working period and the total time is understood (total time = load time + idle time). Curves are reproduced in Fig. 5 to show the influence of the intermittence, which it is necessary to consider when designing the resistances for intermittent work. These curves show the highest temperature attained by a resistance on the same load and frequency of switching operations but with various intermittences. On the contrary, the influence of the frequency of operations is only very slight, and within wide limits, it has no great effect on the maximum temperature attained, providing that the other conditions remain unchanged. Taking account of these conditions, resistances for intermittent work are usually specified for an intermittence of 1 : 9 with a frequency of switch operation of 60—120 per hour. Under such conditions, the highest temperature attained with Type-N resistances is 300° C and with Type-B resistances about 280° C. As the safety of operation of the complete set depends very largely upon the faultless working of the resistances, they are dimensioned, not only for the normal conditions, but also to withstand extraordinary stresses, such as could occur as a result of unskilled control of the motors.

(MS 321) *W. Schaffner. (J. R. L.)*

THE TAR FIGURE AND THE TESTING OF OILS FOR TRANSFORMERS AND STEAM TURBINES.[1]

Decimal index 620. 196.

As stated in the previous part, the oxidation can be accompanied by auto-oxidation, and the formation of peroxides. It is not possible to consider this process analytically, thus, in order to be able to follow it to a certain extent, attempts were made to study the effects on other substances. In transformers, very much fibrous substance, chiefly cotton, is present as insulating material, hence, cotton yarn was chosen for the above purpose, tapes frequently giving unreliable results on account of faulty manufacture. During the peroxidation the oxygen is in an active and free state; it violently attacks the cotton and transforms the cellulose into oxycellulose. Attempts have been made to determine the quantity of oxycellulose directly, by means of the copper-figure method, and at the same time to measure the decrease in tensile strength. For the experiments the yarn was wound onto a copper mandrel, so as to reproduce the conditions prevailing in a transformer. The following table gives the results obtained from experiments on two oils, A and B, which had been treated in various ways.

[1] Concluded from June, 1924.

		Copper number after deduction of cellulose number	Tar figure
Oil A 1.	After heating in glass flask for 1000 hours in the presence of a stream of oxygen	9·2	0·12%
Oil A 2.	Heated in air only, other conditions as for A 1 . .	5·9	0·12%
Oil B.	Similar conditions to A 2 .	0·7	0·11%

The tensile strength of the yarn was as follows: —

After 100 hours in Oil	A 1	0 g
„ 100 „ „ „	A 2	56 g
„ 100 „ „ „	B	225 g

The strength of the cotton yarn as delivered was 240 g (the above are mean values for 15 sets of results).

The table shows that the tar figure indicates but little of the behaviour of an oil, since it determines only the acids, all else, particularly the very dangerous intermediate reaction products being excluded. With reference to Fig. 3, in the part of curve II where there is no great difference in the tar figure, there is an enormous difference in the action of the oil, upon cotton. It is, however, impossible to deal completely with the matter here.

It should be pointed out that the various reaction products resulting from the decomposition of transformer oils are not taken into account with the tar figure, which, therefore, does not form a perfect criterion for the suitability of an oil.

Steam-turbine oils, are also specified by the tar figure. The oxidation products with these oils are the same in principle as the sludge-forming products of transformer oils. For this reason, the relation between the tar figure and the decomposition products actually formed in service is not given, the latter are not so important for turbines as for transformers. While, with transformers, the changes in the oil alter the heat-conduction coefficient or produce substances which destroy the insulation, with steam turbines, the changes result in the formation of emulsion, and consequently a reduction of the lubricating qualities. While friction depends chiefly upon the surface tension of the oil with regard to air and metal; the surface tension with regard to water is of the greatest importance with steam turbines, and, after a definite working period, this tension may vary considerably as a result of the reaction products of the oil[1].

The ease with which the oil becomes emulsified with water changes greatly after a definite time. The force of adhesion between the oil and the metal varies; this, being a very important factor in lubricants, must be determined separately by the method suggested by Dallwitz-Wegener[2]. It is impossible to deal with all details of this subject in this article, but it must be pointed out that the problems involved are very complicated, and that it is dangerous to rely entirely upon laboratory tests. For satisfactory lubrication of bearings, the molecular forces must be sufficient to prevent the rupture of the oil film. Certain colloidal substances collect on the surface and help to make the film constant, as stated by Dukam and Bowrey[1]. According to these authors, the majority of the oxidation products are colloidal substances. From this point of view, the oxidation products may be considered very favourable, on the other hand, they tend to make the emulsion permanent, so that it is extremely difficult to separate the water and the oil, particularly when the water is alkaline.

It is evident that it is of little use to examine new oils for the emulsive properties using distilled water, as the results would be completely different from those obtained with the oil after it had been used, or tested with an alkaline water or brine solution. At present, it is impossible to say which group of compounds exert the greatest influence upon the emulsive properties, as the experimental material available does not permit generalisation; it is even more dangerous to give an opinion based upon only one group of reaction products. The following table has been compiled from results obtained from a long series of experiments carried out in the Brown Boveri laboratories. These results enable a comparison with the "Herschel Test" to be made.

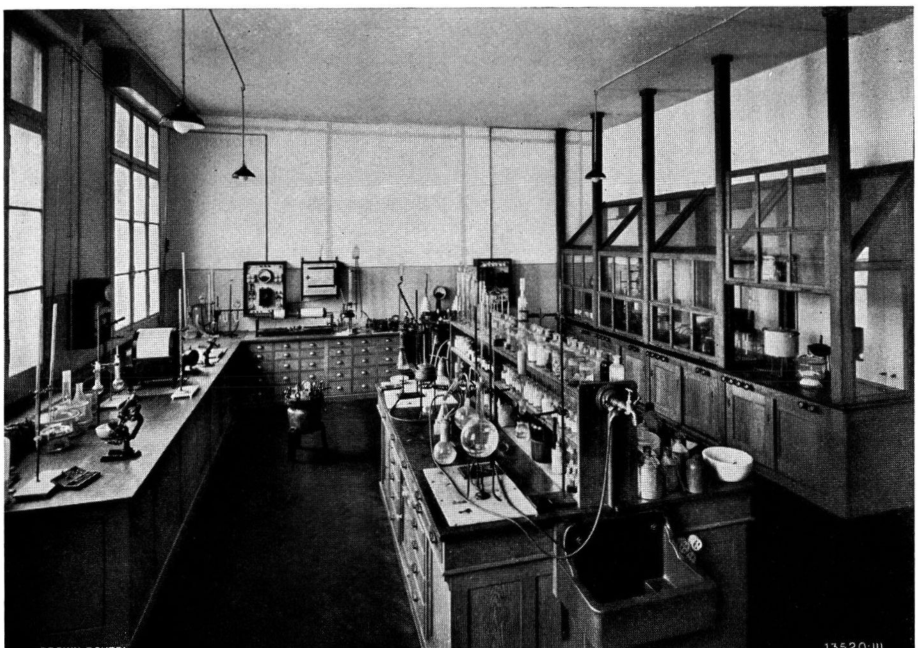


Fig. 4. — The Brown Boveri Chemical Laboratory.

[1] Gurwitsch: "Die wissenschaftlichen Grundlagen der Erdölverarbeitung", Berlin 1924.

[2] Petroleum, 1923, Vol. 19, page 1247.

[1] Engineering, 1923, page 353.

Oil	Acid figure	Tar figure	Emulsion with		
			Water	1% Na Cl.	1% Na OH
A	1·2	0·6	5% after 30 mins.	50% after 30 mins.	98% after 1 hour
			4% after 1 hour	30% after 1 hour	65% after 2 hours
B	0·4	0·35	3% after 30 mins.	6% after 30 mins.	100% after 1 hour
			separated after 1 hour	2% after 1 hour	100% after 2 hours

Both these oils were derived from the same crude oil but were distilled in different ways. The oil B had a smaller acid figure and tar figure and its emulsion properties with water were better than those of the oil A. In the presence of a 1% caustic soda solution, however, the emulsive properties of the oil A were more favourable. The behaviour of the oil does not depend solely upon the manner in which it was distilled, but particularly upon the filtration which in turn depends not only upon the filtering medium, such as Fuller's Earth, Filtrol, or Silicagel, but also upon the number of times the oil is passed through the medium as shown in the following table.

No. of filtrations	Acid figure	Tar figure	Emulsions		
			% distilled water	1% Na Cl.	1% Na OH
2	0·29	0·25	separated in 15 mins.	separated in 15 mins.	100% after 1 hour
4	0·04	0·08	separated in 5 mins.	separated in 10 mins.	separated in 35 mins.
5	0·07	0·08	separated in 1 min.	separated in 2 mins.	separated in 3 mins.

In some cases it has been shown that acids having a chain formular do not exert such a stablising effect as others. When dealing with transformer oils the dependency of the tar figure upon the degree of refining was mentioned; this relation is also of great importance in connection with turbine oils.

Practical experience, and the latest researches of the author, have shown that emulsion tests carried out, even with brine solution and caustic soda, do not indicate the probable behaviour of the oil when in use.

Cases often occur in which oils giving the same tar figure and acid figure in the laboratory, as well as producing very good emulsion test results with all reagents, suddenly develop totally different emulsion qualities after having been in operation for an equal length of time. These observations agree with the detailed report [1] of the important research work which has been carried out in America by specialists and the users of oil in various industrial enterprises. These researches have shown that oils having the same chemical and physical properties do not necessarily give similar results in use. For these reasons, the author of the report suggests a "Sludge Accelerator" by means of which the oil to be tested is maintained, for a considerable time, under working conditions and the sludge products formed determined from time to time. These experiments have shown that the presence of water assists the decomposition of certain oils. With this apparatus, it is possible to obtain results comparable with those which will be given when the oil is in operation, and further, the observations given above can be comfirmed, viz., that the formation of acid is not a continuous process and, therefore, entirely different conditions are required for the emulsion tests.

The tar figure represents the acidity of the oil determined gravimetrically after heating to 120° C, the relationship between the degree of refining and the tar figure, and the other properties depending upon it being neglected; thus its use is bound to lead to incorrect conclusions. Owing to this fact the method is not suitable for the comparison of turbine oils.

Conclusion.

This article has shown that the tar figure is not a suitable basis for the comparison of transformer or turbine oils since it takes into consideration only the acidity of the oil under given conditions.

As the processes are of an extraordinarily complicated nature, only continuous tests reproducing the working conditions as nearly as possible can lead to any satisfactory conclusion as long as it is impossible to determine the compounds which are the definite case of oxidation. For the present, this is certainly impossible owing to the interdependency of refining and filtration.

(MS 336) *Dr. H. Stäger. (J. R. L.)*

[1] Funk, on Lubrication, National Electric Light Association New York, 1924.

NOTES.

The choice of low-tension or high-tension motors.

Decimal index 621. 313. 1.

THE transmission of energy by means of alternating current presents the great advantage that it is possible to transform the voltage in a simple manner and with only slight losses to the value most suitable for each part of the system. This transformation enables high tension to be used for long-distance transmission, copper being saved, and the percentage pressure drop and loss of energy minimised.

Generally speaking, low-tension current is preferred at the points of consumption, as the plant and attendance are simpler, and the motors and apparatus are less costly. The higher cost of high-tension motors is not only the result of more expensive manufacture, but very largely depends upon the fact, that the greater space necessary for the insulation of the stator windings makes the whole machine larger. The difference in size is greater as the output becomes smaller, which explains the fact that the construction of motors for pressures of 1000 V and more is only worth while for outputs exceeding a certain figure dependent upon the voltage and number of poles—on the average from about 20 kW upwards. For smaller outputs, low-tension motors with special transformers are not only cheaper, but usually superior as regards efficiency and power factor. If a number of low-power motors are installed in the same plant, as is usually the case, the comparison is still more in favour of the low-tension machine, because the proportion of the cost of the transformer per motor is smaller.

The conditions are entirely different when high powers are concerned, as in this case the losses occurring and the cost of the cables are of considerable importance. On account of the large amount of copper required, low-tension cables to carry a given load are very much more costly than the corresponding high-tension cables, so that when they are of considerable length, the saving in first cost of low-tension motors is neutralised by the more expensive cable; the energy lost in the cable influences the question in a similar manner.

Figs. 1 and 2 show the cost and overall efficiency of motors with all auxiliaries including the cable leads, as functions of the single cable length, losses in the leads being taken into account. The curves are drawn for motors of about 300 kW, such as would be employed, for example, for driving tube mills in cement factories, and for working voltages of 500, 1000, 3000 and 5000 V at a frequency of 50 cycles. Two types of machine are considered:

1. High-speed motors with precision reduction gearing, 1000/166 r. p. m. (full lines).
2. Slow-speed motors for direct coupling, 166 r. p. m. (dotted lines).

The values for the curves in Fig. 1 are expressed as percentages of the price of the 500-V high-speed motor with reduction gear and auxiliaries.

The curves demonstrate above all else the superiority from the point of view of economy, of the high-speed motor with reduction gear compared with a slow-speed machine working under the same conditions. As regards first cost and efficiency, it is shown that, even when the length of cable is relatively short, more favourable results are obtained with high-tension current. From the price curves it can be seen that the length of cable making the employment of current at 3000 or 5000 V desirable is very much greater for slow-speed than for high-speed motors. This is explained by the fact that slow running motors are necessarily very large, and the difference in price between high and low tension machines is relatively great, so that the higher cost of the high-tension motor is only saved on the cost of the cable when the latter is of considerable length.

To present the question of economy in a clearer manner, the first cost and operating expenses must be

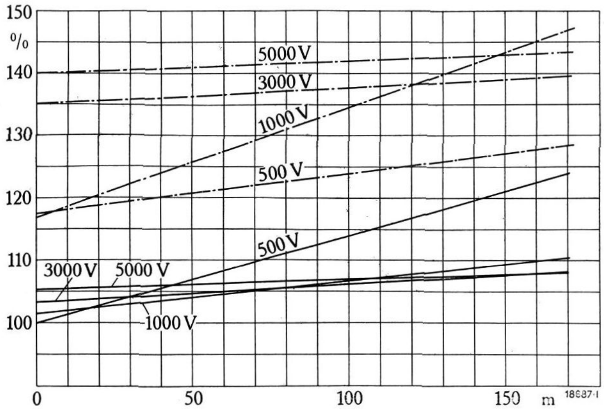


Fig. 1. — **Price of motors with all accessories including cables, as a function of the single cable length.**

———— High-speed motor with precision reduction gear.

—·—·— Slow-speed motor.

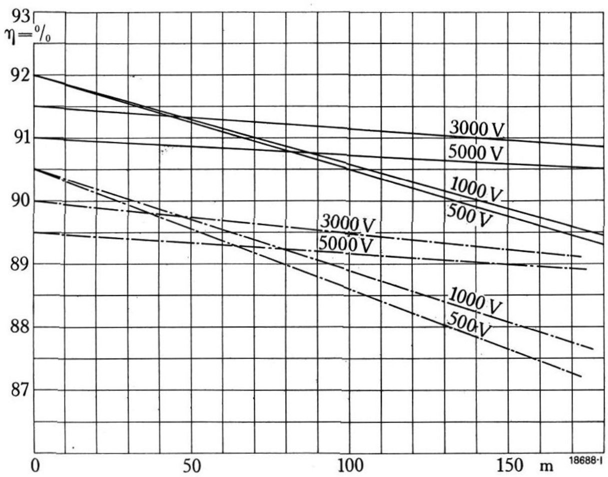


Fig. 2. — **Efficiency of motors including cable, as a function of the single cable length.**

———— High-speed motor with precision reduction gear.

—·—·— Slow-speed motor.

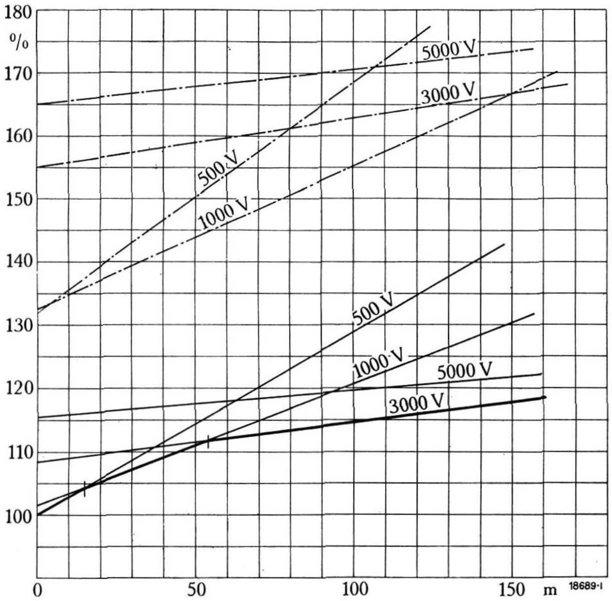


Fig. 3. — **Total equivalent capital outlay (first cost + capitalised operating expenses) for motors with all accessories including cables, as a function of the single cable length.**

——— High-speed motor with precision reduction gear.
—·—·— Slow-speed motor.

brought to a common basis, either, by adding the annual charges for depreciation and interest on capital to the annual operating expenses to give the total annual outlay, or by capitalising the operating expenses and adding this amount to the first cost. It is not possible to make this conversion in a generally applicable form, as some of the factors to be taken into account may vary very considerably from one case to another: the rate of interest, the cost of energy, the total annual running time, etc. In the present instance, however, calculation shows that the points at which it becomes more economical to employ a different voltage correspond to very nearly the same length of cable whether the increase in operating expenses resulting from a 1% drop in efficiency is taken as equivalent to a 5%, 10%, or 20% increase in capital outlay. Thus the curves in Fig. 3, in which economy is represented by its equivalent capital value under the assumption that a decrease in efficiency of 1% corresponds to about 10% increase in the equivalent capital, are applicable over a considerable range as regards the length of cable. They indicate that the most favourable pressure from the point of view of economy is 3000 V when the length of connecting cable is between 50 and 400 m (i. e., for the lengths of cable occurring in all large installations), the employment of high-speed motors with precision reduction gearing being assumed. For motors of powers other than 300 kW, the conditions will be somewhat different; the length of cable for which low-tension machines are more economical than high-tension is greater for powers lower than 300 kW, and less for higher powers.

The choice of voltage to give maximum economy does not depend solely upon the outputs of the various motors and the length of their cables; the size and arrangement of the whole installation are of fundamental importance in this connection. Of equal importance is the question as to whether a uniform voltage can be employed for all motors, or whether the choice of a different voltage for some of the motors is desirable, necessitating a transformer and other apparatus, the cost and efficiency of which greatly affect the economy of the plant. These considerations, however, could not be taken into account within the scope of the present article.

(MS 341) *S. Hopferwieser. (G. T. S.)*

Single-phase, three-voltage transformers.

Decimal index 621.314.3.

BROWN, BOVERI & CO. have received orders from the Swiss Federal Railways for four, three-voltage transformers which are noteworthy on account of their size.

Each transformer is constructed to fulfil the following conditions:—

1. A continuous output of 9000 kVA with a ratio of 15—66 kV.
2. A continuous output of 9000 kVA with a ratio of 15—132 kV.
3. A continuous output of 9000 kVA with a ratio of 66—132 kV.

The outputs 1 and 2 are developed simultaneously, but, that referred to in case 3 is not delivered at the same time as 1 and 2. The transformation is carried out in the same apparatus to meet the requirements of the Electrification Department of the Swiss Federal Railways and it was possible to omit the low-tension busbars and all apparatus connected to them, in the plant for which the transformers were designed.

In addition to the stated outputs a provision has to be made for overload, so that each transformer has been designed for a continuous loading of $2 \times 11{,}000$ kVA.

The windings of one limb of these transformers can, therefore, deal with the same output as one limb of a three-phase transformer having a total output of

$$\frac{22{,}000}{2} \cdot 3 \cdot \frac{50}{16 \cdot 66} \cong 100{,}000 \text{ kVA at 50 cycles.}$$

As far as is known, no transformer having such an output has yet been built.

The weight of the transformer, without oil, amounts to about 94 tons, the oil alone weighs 23 tons. The overall dimensions of the transformer are 2900 mm $\times$ 4650 mm $\times$ 7500 mm.

Each tank was made in two parts, in order to facilitate transport, and finally assembled on site, the two parts being bolted together and the joint made oil tight.

(MS 344) *C. Giudici (J. R. L.)*

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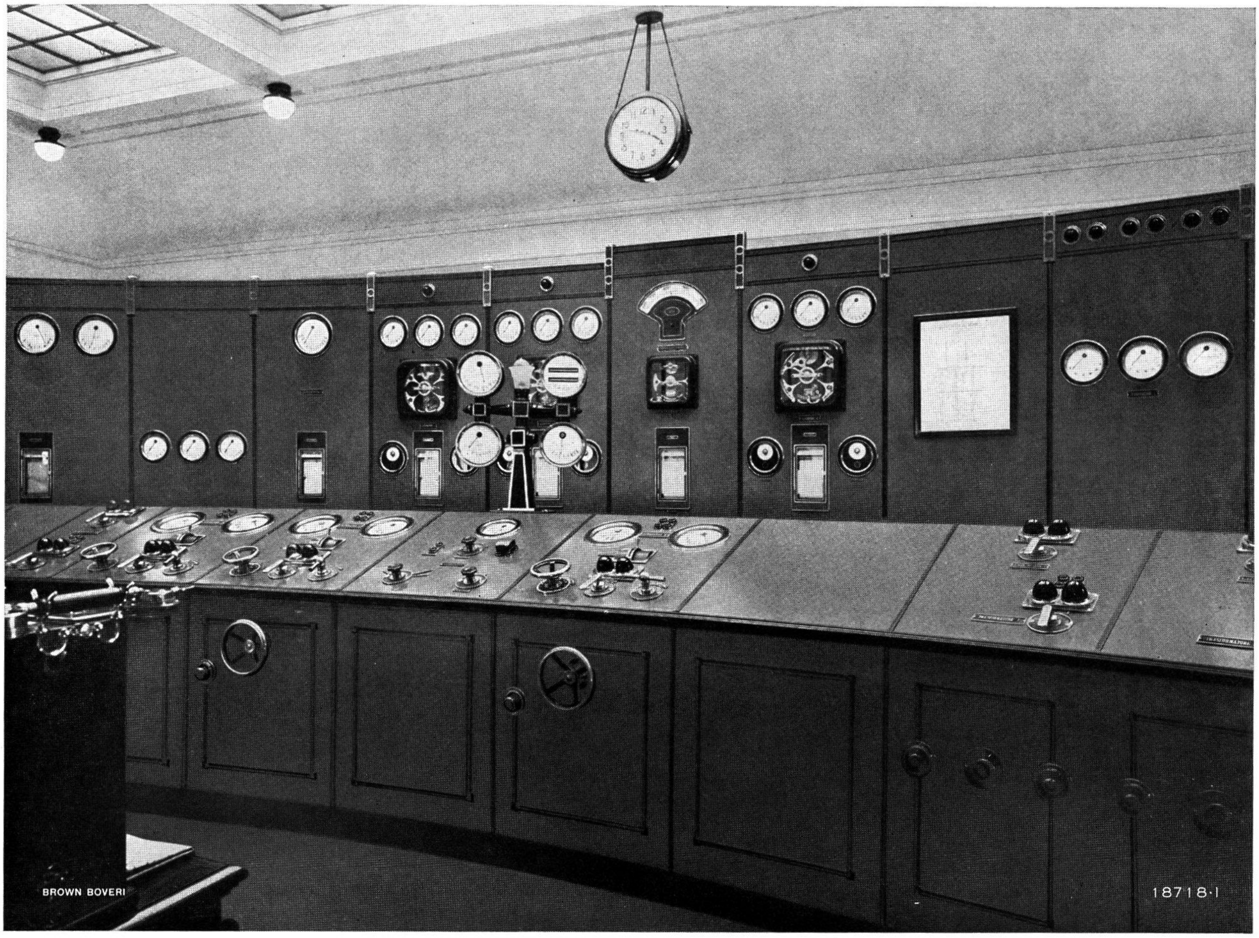

VENAUS POWER STATION OF THE SOCIETÀ DELLE FORZE IDRAULICHE DEL MONCENISIO, TURIN.
Arrangement of the switchboard in the control room.

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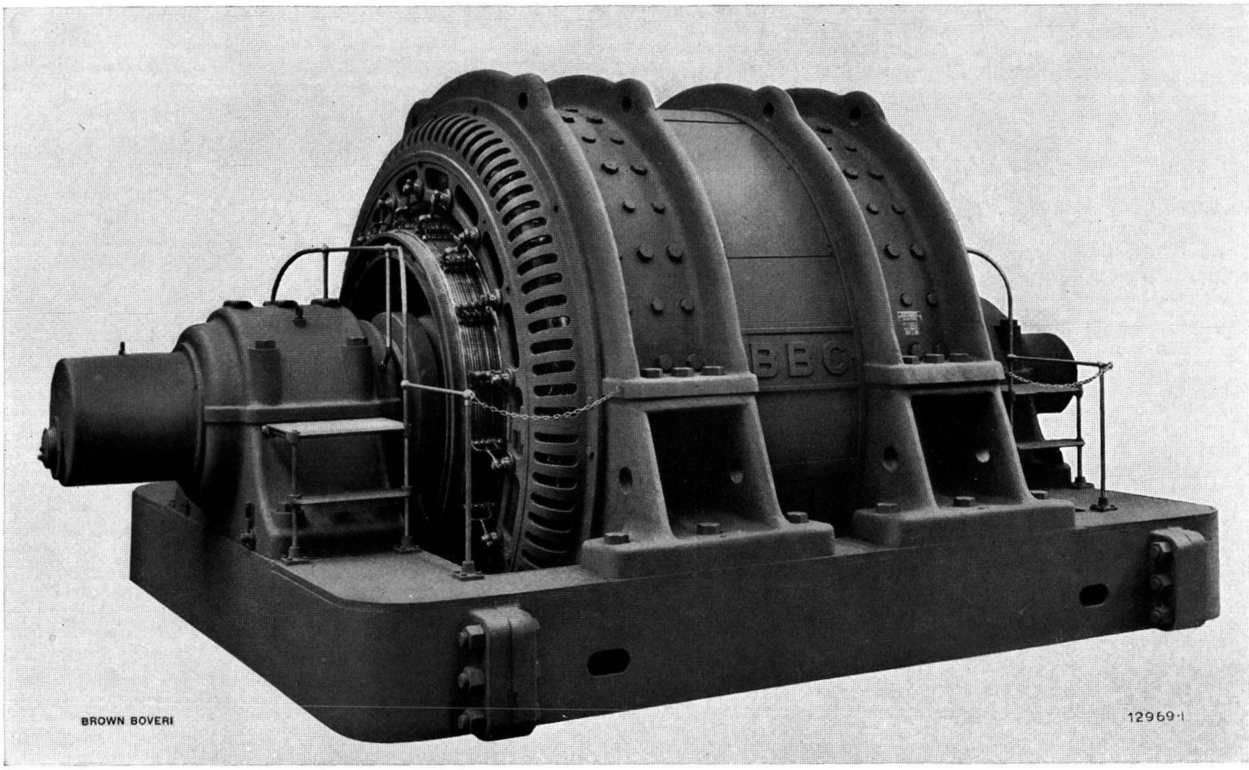

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