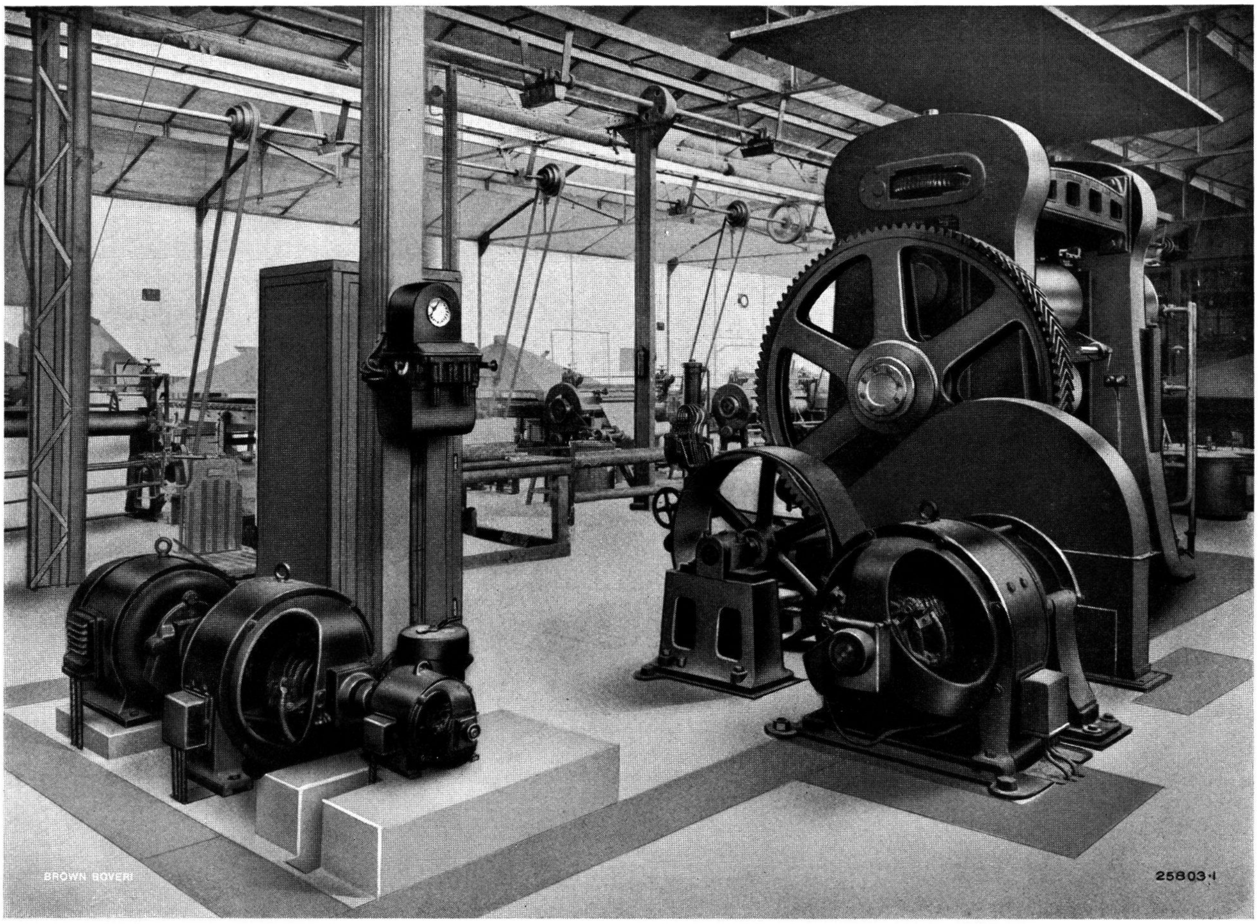
VOL. XVI FEBRUARY, 1929 No. 2

THE BROWN BOVERI REVIEW

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



STÉ INDUSTRIELLE DES TÉLÉPHONES, BÉZONS (FRANCE).
Electrical equipment of a rubber calender, comprising three-phase motor for 45 kW, 640/250 r. p. m., with Ward Leonard control set.

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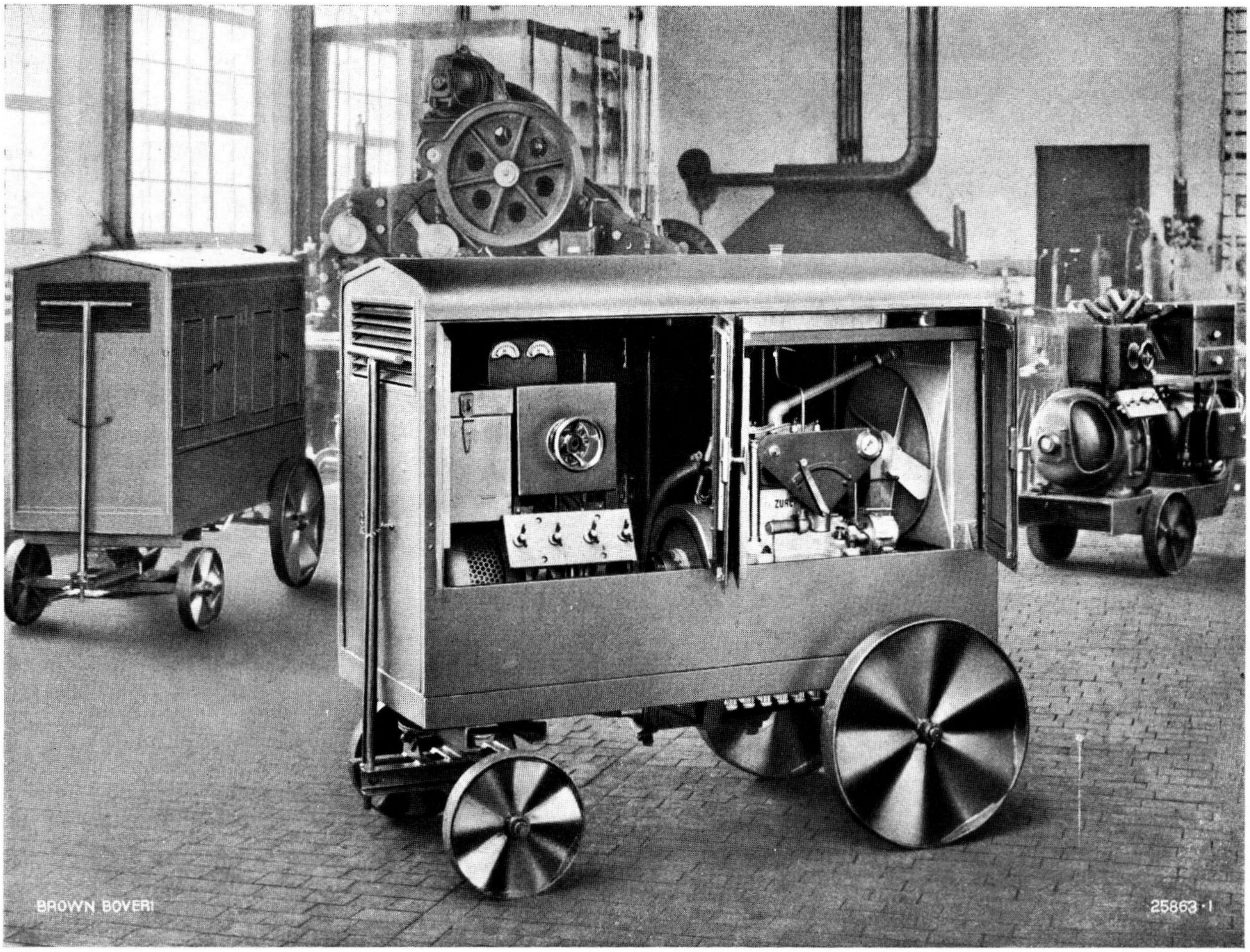

BROWN BOVERI ARC-WELDING SETS DRIVEN BY PETROL ENGINES.

GREATEST ECONOMY

WELDING OF STEEL, IRON, CAST STEEL AND CAST IRON

UNIFORM SUPPLY OF ENERGY TO THE ARC

PRODUCING HIGH-GRADE WELDS - FINE ADJUSTMENT OF THE CURRENT USED AT THE WELD

PROOF AGAINST SHORT CIRCUIT

ADAPTABLE TO ALL KINDS OF ELECTRODES

ALWAYS READY FOR SERVICE - SIMPLE AND SAFE IN ACTION

THE BROWN BOVERI REVIEW

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

VOL. XVI FEBRUARY, 1929 No. 2

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RECONSTRUCTION AND ELECTRIFICATION OF THE TEXTILE MILL OF MESSRS. FRIED. KUBINZKY, BERAUN.

Decimal index 621.39:677 (43.7).

ONE of the most important textile mills in Czechoslovakia at the present day is that owned by Messrs. Fried. Kubinzky, Beraun. From a small beginning at the commencement of the 19th century, as a water-driven plant, the mill has gradually been developed and extended until it has attained its present size.

In view of the large size of the mill and the necessity for introducing the latest technical improvements, the plant has been converted to electric drive, all the existing sources from which energy was obtained being combined into an accessible and very economical central power station.

Shortly before reconstruction, there were about 90,000 spindles, 1200 weaving looms, and 5000 doubling spindles in the mill, as well as a small cotton-waste spinning mill of about 900 spindles.

The power for the spinning mill was supplied by a compound steam engine of 800 I. H. P. and the power for the weaving mill by a similar machine of 150 I. H. P. Steam for both engines was raised in four Fairbairn boilers with a combined heating surface of 800 m^2 and a maximum working pressure of 9 kg/cm^2.

A Dörfel-valve compound superheated-steam engine of 1600 I. H.P. with rope-pulley flywheel and with an 800-H. P. generator direct coupled to the crankshaft supplied the power for the spinning shed and the first extension to the weaving shed. The engine was installed in the machine house adjoining the spinning shed.

A compound engine with rope-pulley flywheel capable of driving part of the machines in the spinning shed was kept in the machine house as reserve.

The current for lighting was supplied by a high-speed generator installed in a building adjoining the blow room.

The steam for the previously-mentioned engine was raised in three water-tube boilers with a total evaporative surface of 500 m^2 and a working pressure of 14 kg/cm^2. The boilers were provided with superheaters and economisers, and were installed in the boiler house II between the two machine houses (Fig. 1).

The small water-driven power plant, originally used for driving the mill, had been enlarged as much as possible and was being used as an electric power plant, of 40 H. P., for supplying part of the current for lighting and power.

As the original boiler house and the engines supplied from it had become out of date and were uneconomical to run, it was decided to acquire modern boilers and engines for the individual plants and to install a single large steam-driven electric power station for the whole mill, which was in keeping with the change-over to electric drive for the machines.

The problem which had to be solved was:—

(a) To provide *one* electric generating plant of a size sufficient to meet all the requirements of the mill and to enable the plant to be enlarged by 20 %.

(b) To provide a reserve power plant. Under normal conditions single shift is worked, the total working hours per week being 48. The reserve plant had therefore to be dimensioned such that, by running double or triple shifts, work could be continued if the main power plant should break down.

(c) Finally, to cause as little interruption to the work as possible when changing over from mechanical to electrical drive.

The mill company therefore approached the Association of the Mittelböhmischen Elektrizitätswerke with a view to obtaining electrical power from them. An agreement was made, and a transformer station containing two transformers, one for 500 kW and the other for 100 kW, was installed, at first in a temporary building.

The modern and still very efficient superheated-steam engine with generator direct coupled to the crankshaft serves as the second stand-by, the corresponding boiler plant in boiler house II also being retained.

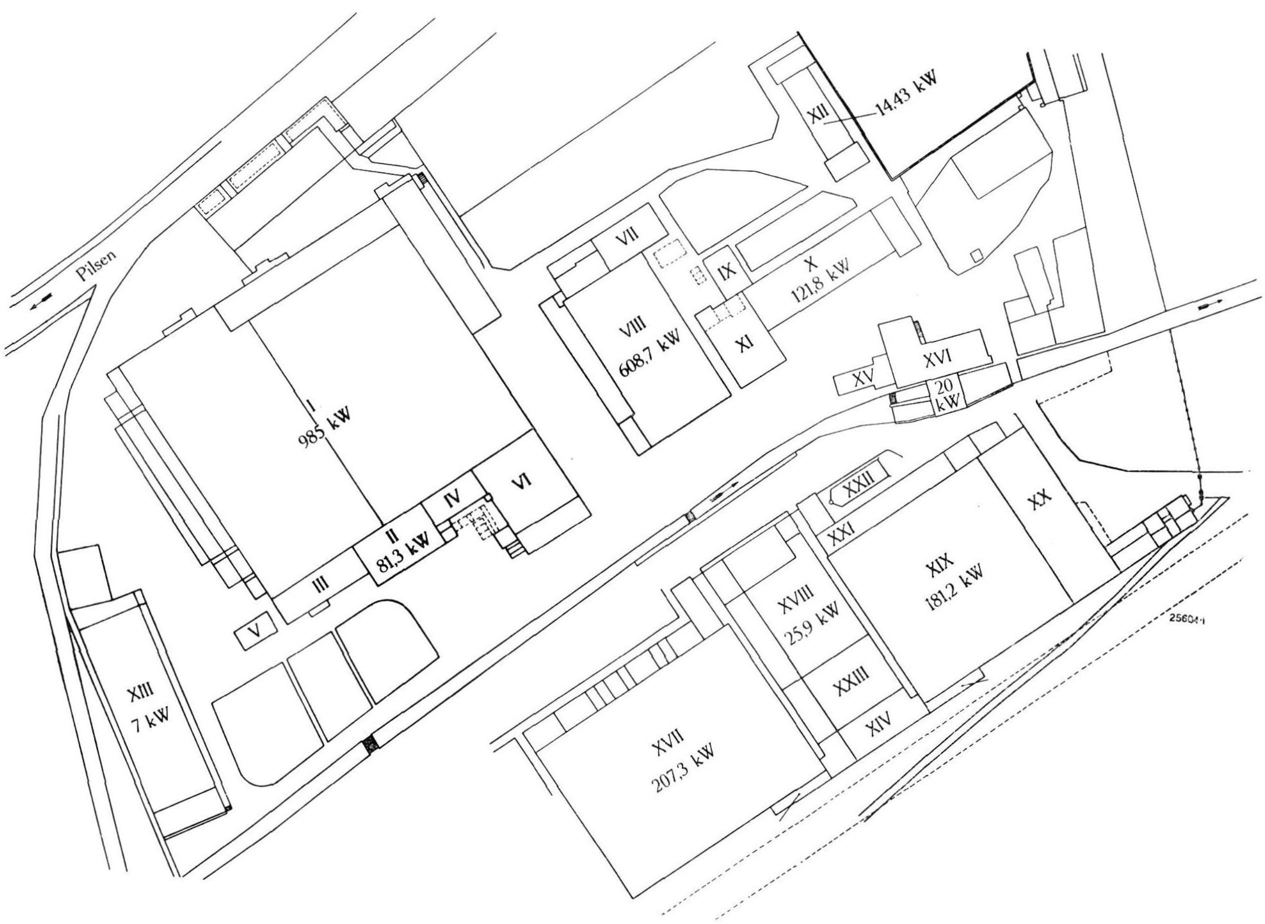


Fig. 1. — Plan of the textile mill of Messrs. Fried. Kubinzky, Beraun, after the reconstruction in 1928.

I. Spinning mill.
II. Boiler house.
III. Steam turbine.
IV. Steam engine.
V. Fire station.
VI. Cleaning room.
VII. Power station.
VIII. Spinning shed.
IX. Packing, loading.
X. Twisting, winding and reeling.
XI. Boiler house.
XII. Mechanics' shop.
XIII. Warehouse.
XIV. Twisting in.
XV. Oil store.
XVI. Warehouse.
XVII. Weaving mill II (new).
XVIII. Winding and warping.
XIX. Weaving mill I (old).
XX. Weaving mill (extension).
XXI. Dispatch.
XXII. Biological laboratory.
XXIII. Sizing room.

Since this steam-driven plant can develop an output of 750 kW, and the two transformers can together supply 600 kW, a reserve of about 1350 kW is available. This power is distributed from the common switchboard.

The output chosen for the steam turbine set was 2500 kW. This was decided on the maximum power requirement of the mill before reconstruction, which, including lighting, was 2600 H. P. or approximately 2000 kW, with an additional power demand of about 20 %.

A turbo-alternator set of the rating mentioned was installed. The set runs at 3000 r. p. m. and generates current at 525 V, 50 cycles. It is provided with a surface condenser, and all auxiliary pumps are electrically driven.

The boiler feed pump is of the centrifugal type, electrically driven, a Voith steam feed pump being provided as a stand-by.

Steam at a pressure of 20 kg/cm^2 and superheated to 375^0 C is supplied by two Oschatz inclined-tube boilers with a combined evaporative surface of 615 m^2, superheating surface of 155 m^2, and economiser surface of 205 m^2.

The design of the switchboard is such that the turbo-alternator set, the alternator driven by the reciprocating steam engine and the transformers can all be connected in parallel. It is also possible to feed current from the power station into the network of the power supply company. The small hydroelectric power plant is also connected up to the main

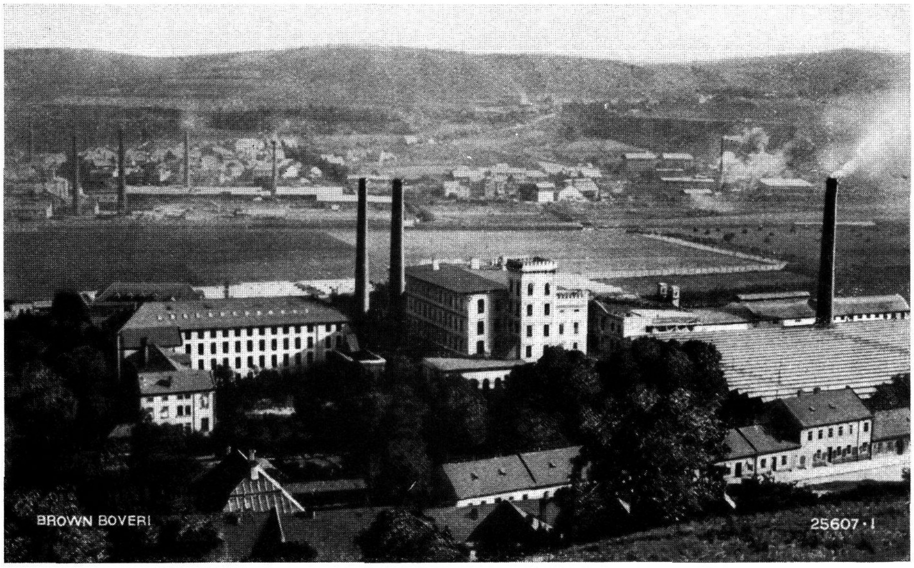


Fig. 2. — Textile mill of Messrs. Fried. Kubinzky, Beraun.

switchboard so that it can help to meet the demands on the main power plant.

The various parts of the mill are divided up according to their power requirements and each has its own supply cable connected through oil circuit breakers to the bus-bars of the main switchboard. Each individual circuit is protected by overload and no-volt relays. In addition to ammeters, recording meters are also provided so that the total daily power consumption can be measured in addition to the load at any particular time.

In view of the fact that the different points at which power is consumed are at considerable distances apart, a uniform pressure of 525 V was chosen for the turbo-alternator and all the motors. It was not desired to generate high-tension current and transform it down to 220 or 380 V.

Small transformers are provided in the buildings for stepping down the pressure from 525 to 120 V for the lighting circuits.

The alterations to the buildings were confined to raising the roof of the boiler house in the shed to make room for the inclined-tube boilers, and to building in new windows to light the boilers and pipes better.

The new turbo-alternator set together with the switchboard and transformer plant was installed in the machine house where the reserve steam engine used to be. To enable this to be done the foundations were lowered.

It was not necessary to make big alterations to the buildings on account of the electrification; only the mixing and blow rooms of the spinning shed were enlarged to suit the present turn-over.

When adopting electric drive it was stipulated that all machines having a heavy power consumption should be driven individually and that all unnecessary belt drives and reduction gears should be avoided. It was further required that the motors should be of

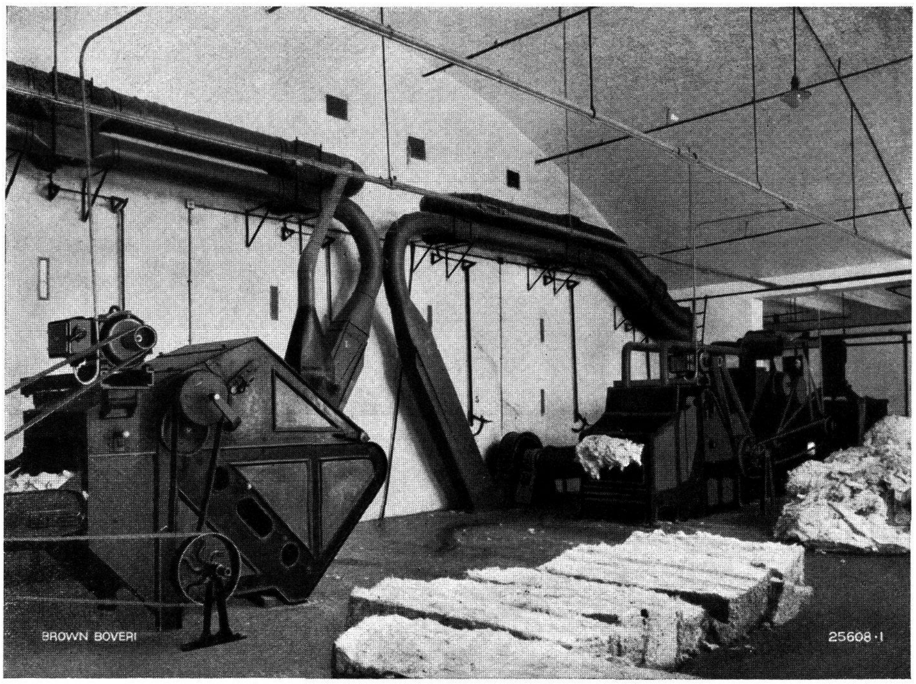


Fig. 3. — Mixing room in spinning shed.

Fig. 4. — Spinning shed. Cleaning room.

a type which is amply protected against the entry of dust and cotton fibres in order to prevent any danger of fire. For this reason no slip-ring motors were chosen, but, wherever possible, squirrel-cage motors. Some of the group motors were equipped with built-in centrifugal starters.

For these reasons not only was individual drive selected throughout for the opening machines and scutchers but also the drive of various machines such as the Buckley openers was still further divided up and the motor mounted as near as possible to the point where its power is utilized.

Carding machines require a big starting torque and therefore group drive was chosen for these. To a certain extent cotton fibres are always present in the air in carding rooms, and to avoid the harmful effect these would have on the motors, the motors were mounted either outside the room or in niches in the wall which were then sealed up and made dust-proof.

Since drawing frames and flyers require only low driving power, it would be comparatively expensive to drive them individually. Group drive was therefore chosen throughout for these machines. If the line shaft is run too fast, very small pulleys have to be used for driving the individual machines, and, as it was not practicable to fit large belt pulleys on the machines in the old buildings, chain drive was adopted.

It was thus possible to couple a faster running motor, and therefore one with a higher efficiency, to a line shaft rotating at only 200 r. p. m.

Individual drive was fitted to all ring spinning frames except where it was impossible to do so on

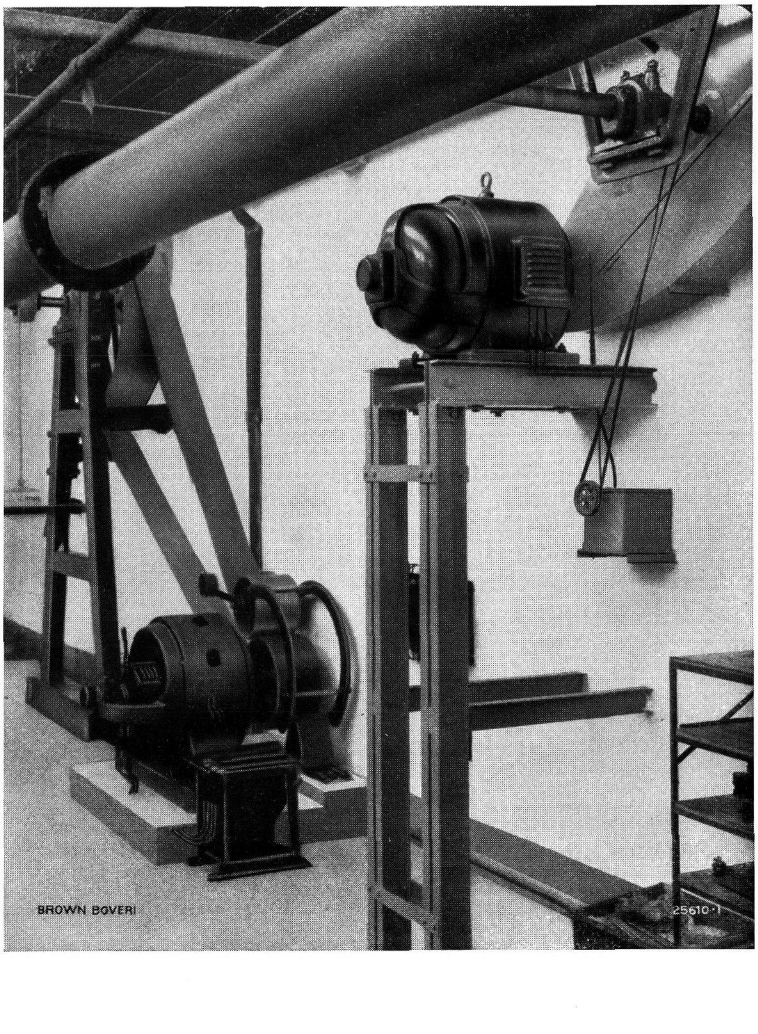


Fig. 5. — Spinning shed. Group drive for flyer frames and self-acting mules.

account of the age of the machines or because it was intended to rebuild them later on. The Brown Boveri individual drive with squirrel-cage motor mounted on the headstock and belt transmission over a jockey pulley between the motor and the shaft of the machine, and with star/delta switch built on the motor, was chosen.

The self-acting mules were assembled in the spinning mill and arranged in separate rooms in groups of 12, the number of spindles in such a group being about 10,000. Each group is driven by a synchronous motor with belt and jockey pulley. As high a belt speed as possible — 25 m/sec — was selected and the jockey pulley introduced to reduce the pressure on the bearings of the motor and thus enable the standard design with two bearings and overhung belt pulley to be used. This arrangement also has the advantage that the heavy fluctuations in the belt tension occurring with self-acting mules are reduced by the jockey pulley. As the variation in the speed of the line shaft is very low and the self-acting mules run fairly smoothly, it was only necessary to select motors about 50 % more powerful than the average load. These synchronous motors also serve to improve the power factor of the whole plant.

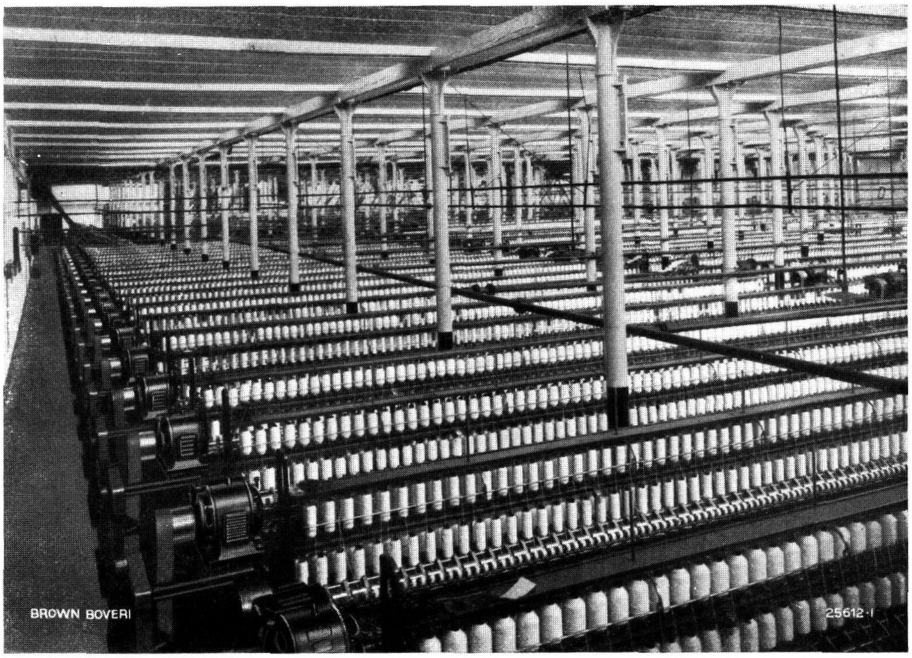


Fig. 6. — Spinning shed. Ring spinning frames.

Individual drive was chosen only for the cotton-waste self-acting mules, and has proved entirely satisfactory.

Group drive is used for the spooling, reeling and twisting machines, there being one motor on each floor of the building. A special motor was provided for the lift.

Group drive is used throughout in the weaving mill for the spooling, combing and sizing machines and also for the actual looms. So that the motors can be protected from dust, and particularly to enable a high belt speed to be obtained, the three driving motors for each room are installed in a

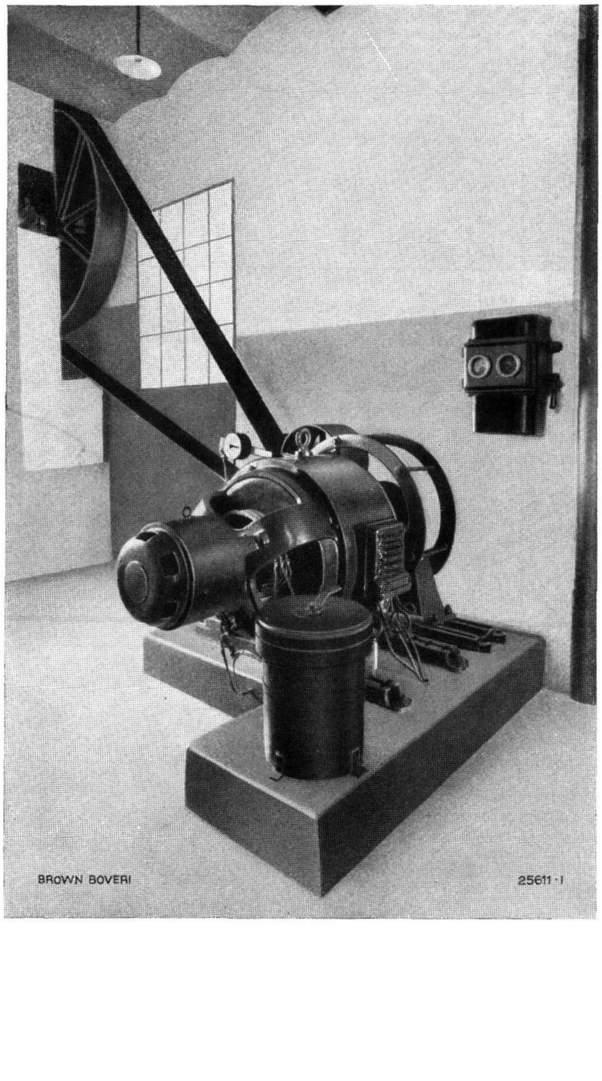


Fig. 7. — Spinning mill. Group drive for self-acting mules by means of a synchronous motor.

separate motor room. Each motor drives a centrally-placed line of machines directly, and, from this, two other lines are driven, one on either side of the middle row of machines. The three motors in a group are each capable of driving 216 looms. The motors are mounted on elevated platforms so that the gangway below them is left quite free. The transformers for the lighting current are also mounted on the same platforms. The distribution switchboards are arranged in convenient positions in these motor gangways.

The table on page 77 shows the number of spindles and looms in use in the mill before and after it was reconstructed, and also the average daily load of the whole plant. In textile plants it is particularly noteworthy that, especially in winter at the commencement of the week, the power demand exceeds the normal by about 20 %. Fig. 8 shows the power consumed in the various buildings by the individual machines or the groups. The motors were dimensioned to run with a high power factor. In normal service it varies from 0·85 to 0·88. The load of the plant itself is fairly steady, as shown by the daily load diagram. The small variations are caused by the self-acting mules; if these machines are stopped, a straight-line diagram is obtained.

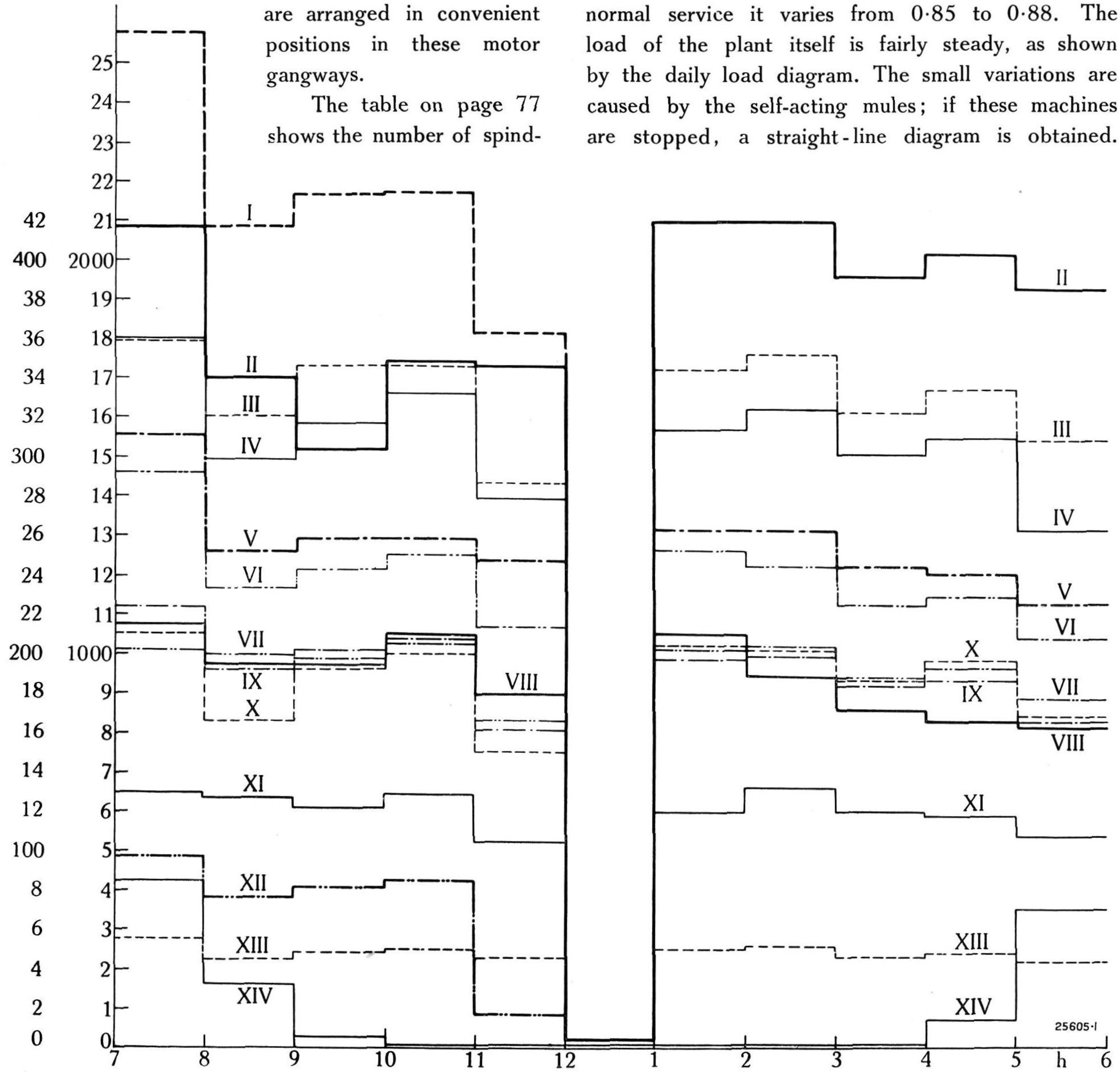


Fig. 8. — Power consumption in kilowatts of the individual groups of machines on 9th January 1928.

I. Total power consumption.
II. Turbo-alternator.
III. Mill II.
IV. Mill I.
V. Shed II.
VI. Shed I.
VII. Weaving mill I.
VIII. Shed IV.
IX. Shed III.
X. Weaving mill II.
XI. Twisting rooms, mechanics' shop.
XII. Power obtained from outside source.
XIII. Power station, warehouses.
XIV. Light.

	Before reconstruction 1919		After reconstruction 1928	
Spinning mill.				
S. A. mule spindles .		28,578		27,882
Ring spindles: warp .	13,080	13,080		13,040
		41,658		40,922
Spinning shed.				
S. A. mule spindles .		21,392		3,600
Ring spindles: warp .	26,160		40,664	
Ring spindles: weft .	2,184	28,344	18,944	59,608
		49,736		63,208
Total number of fine spindles:		91,394		104,130
Waste spindles:				
Self acting mules . .	880			
Ring spinning frames	360	1,240		1,240
Total number of spindles		92,634		105,370
Twistingroom: spindles	6,126		8,110	
Weaving mill. *No. of Looms.*				
Old mill (now warehouse)	154		—	
New mill (now twisting room)	480		—	
Weaving shed I . .	648		645	
Weaving shed II . .	—		668	
Total	1,282		1,313	
Indicated horse-power	2,600			
Kilowatts at generator			2,200	

The advantages accruing from the reconstruction and electrification of the plant are as follows:—

(1) Lower coal consumption obtained by installing one large and economical generating plant instead of producing the power required at four different points. Centralized supervision of the various driving motors by means of ammeters and recording meters.

(2) The machines in the various sheds and buildings can be started up and shut down easily, and they work independently of each other.

(3) In the various buildings, individual groups of machines can be stopped or can be run by themselves on current obtained from the mill power station or from an outside source.

(4) By suitably selecting the motors and arranging the line shafts correctly, the no-load losses of the motors can be reduced and the power required by the machines can be readily adjusted.

(5) Apart from the greater ease with which individual lines of machines can be started or stopped and the higher degree of safety thus obtained, there is a considerable saving in such commodities as oil, belts, ropes, etc.

Finally, it should be mentioned that the capacity of the large generating plant ensures that the various line shafts, motors and spinning machines

In the present case the exhaust steam could not be utilized, although an extraction point is provided on the turbine. During the summer months practically no other steam but that used for power is required in a cotton mill, with the exception of the small quantity of steam required for the sizing machines. In winter, steam is required for heating the buildings, but usually at such times when the turbine is not running.

Fig. 9. — Spinning shed. Ring spinning frames.

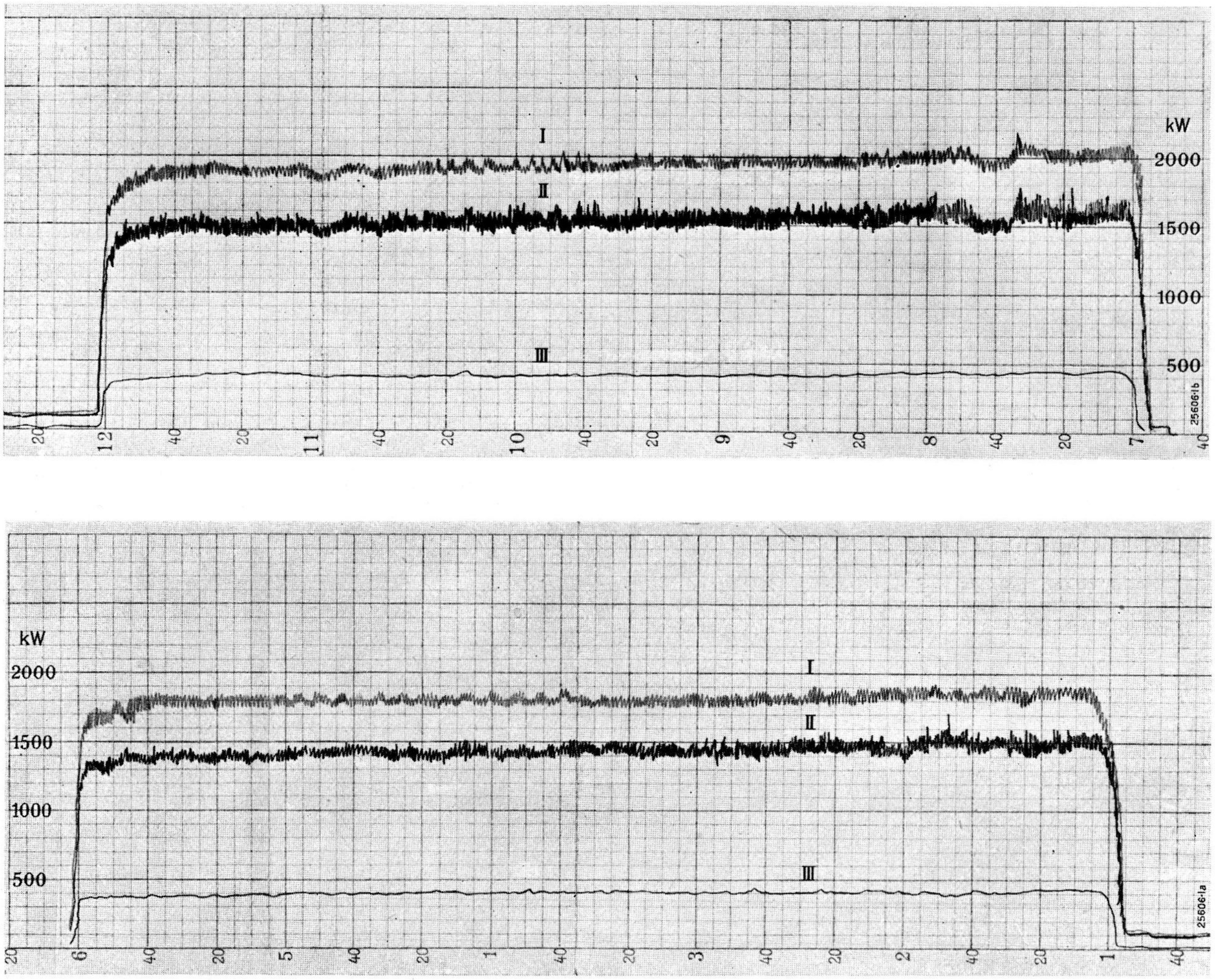


Fig. 10. — Power consumption on Tuesday the 14th June, 1927.

I. Total consumption (above, in the morning; below, in the afternoon).
II. Generator (current for spinning and twisting).
III. From outside source (for weaving).

run much more steadily. Thus one of the most frequent difficulties encountered in the drive of spinning machines and looms, namely, the speed variations which occur according to the load and the nature of the power transmission, is overcome.

The electrical drives were, for the greater part, supplied by the Czechoslovakian Works of Brown, Boveri & Co., Prague.

(MS 521) *O. Hellmann. (E. J. B.)*

Fig. 11. — Spinning shed.

THE AUTOMATIC RECTIFIER SUBSTATIONS OF THE BRNO TRAMWAY COMPANY (CZECHOSLOVAKIA).

Decimal index 621. 312. 64 : 621. 331. 34 (43.7).

I. GENERAL.

Introduction.—Statistics show that the owners of railway and tramway systems and lighting and power networks are gradually adopting the policy of making substations completely automatic. The movement began in America where the necessity of possessing high-efficiency plants is felt very acutely.

Existing economic conditions in Europe involving such factors as high labour costs, the eight-hour day and the high degree of safety demanded in the working of substations, result in the recognition of the automatic substation as the ideal solution. Substations controlled from some remote point by means of cables with three or four pilot wires have also made their appearance within recent years.

For substations supplying small tramway systems or for those at the end of a branch of an important network, automatic operation presents many valuable advantages. In both cases it enables a big reduction in working expenses to be realized. Labour is economized, and the substation is put into service only when the network requires its energy, thus effecting a big reduction in the no-load losses. A description of a substation for a small tramway system was published in The Brown Boveri Review 1927, No. 3, and shows the economic advantages which have resulted from modernizing the plant.

The main object of the automatic substation in light and power systems is not to enable the staff to be dispensed with — these stations are far too important to be left unattended — but to ensure simpler and more accurate working. The regulation of the network voltage and also the distribution of the load among the different sets is effected automatically; the circuit breakers on the outgoing lines are closed by means of push-buttons and are provided with reclosing devices which ensure that a tripped feeder will be connected up again as quickly as possible. It therefore only remains for the attendant to carry out the daily inspection of the various meters and registering devices, to maintain the substation plant in good order, and to discover the cause of the disturbance when a line is blocked or a set is permanently tripped. The Palais du Midi Substation, Brussels, described in The Brown Boveri Review, 1926, No. 9, is a typical example of the kind of substation under consideration. It supplies a current of 12,000 A by means of six rectifier sets, each for 2000 A, to a network supplied by thirty feeders, of which fifteen are automatically controlled.

In the various systems of automatic substation control, relays are employed, some of which make use of electro-magnets, others of servo-motors, for actuating the contacts of the control apparatus. In their apparatus for automatic substations, Brown, Boveri & Co. have altogether avoided systems which transmit energy by means of electro-magnets since these possess the disadvantage of utilizing at least half the electrical energy with which they are supplied for increasing the potential energy in their magnetic circuits. In other words, the efficiency of this type of apparatus is, at a maximum, 50 %. In actual practice it lies between 10 and 15 %; a tremendous expenditure of energy is thus necessary simply to move the armature of the electro-magnet.

The potential energy of the circuit not usefully employed is dissipated in the form of secondary currents at break and sparks at the points of the switches for distributing and breaking the feeding current. That is to say that the energy wasted by sparking is five times greater than the energy used in producing mechanical work.

The essential parts of the servo-motor system used in Brown Boveri automatic apparatus are a two-pole armature, a permanent magnet, and a strong helical spring. When the servo-motor is in operation, the armature is connected directly to the auxiliary bus-bars. Under the influence of the field of the permanent magnet and the helical spring, a continuous oscillatory movement is imparted to the armature, the frequency being the same as that of the alternating current supplied by the auxiliary bus-bars. These oscillations are transmitted by means of a suitable device to the spindle of the control apparatus, which is given a continuous rotary movement.

The characteristic feature of this system of control is that while the armature is oscillating there are no interruptions in the current, the change in the direction of motion being caused by the alternating field produced by the armature itself. It is thus seen that all parts such as friction contacts, contact pieces, or commutators, which are liable to cause disturbances in the working, have been carefully avoided. Due to these features, the control devices possess, in the highest degree, the reliability of operation which is demanded of the apparatus used in automatic substations.

The amount of energy consumed during an operation lasting from 10 to 60 seconds is only a few watt-seconds. Where a control apparatus should operate immediately the servo-motor has been energized, the necessary power for performing the succeeding operation is stored up in springs. The servo-motor of each apparatus is provided with a special switch. Immediately the servo-motor begins to run, this short-circuits the contacts of the instrument which started the motor for the whole of the time the operation is in progress. This special switch plays a very important part where the control apparatus is set in operation by means of delicate instruments with a slow closing speed, such as thermal relays, contact instruments, etc.

The apparatus developed by Brown, Boveri & Co. have been specially studied and designed for the various service conditions under which they will be used. By this means the complicated combinations of various standard relays, which were the cause of the disfavour with which automatic substations were regarded in Europe until recent times, are avoided.

Their robust construction and the great ease with which the pieces of apparatus can be adapted to meet the numerous exacting requirements arising during service guarantee exceedingly reliable operation for the installation.

As regards simplicity, rectifiers surpass all other kinds of converter sets. This characteristic, which was already in evidence in non-automatic substations, only came into full prominence in automatic substations.

When putting a rectifier set in operation neither complicated starting arrangements nor a verification of the polarity or synchronism are necessary, as with rotary machines. To connect the set to the network it is merely necessary to close the two switches, the one on the primary side and the other on the d. c. side, and to open the valve controlling the circulation of the cooling water. The striking of the arc and the excitation of the rectifier are effected automatically in all installations[1].

Due to this simplicity, and in spite of the great variety of service conditions which a rectifier set has to fulfil, the control apparatus can be reduced to three separate parts:—

(a) The apparatus for controlling the rectifier set.

(b) The apparatus for controlling the vacuum-pump set.

(c) The apparatus for controlling the outgoing feeders.

The apparatus mentioned above will be described in detail before its application in a plant is shown.

A. Apparatus for controlling the rectifier set.

This apparatus, which is known as control apparatus "type 9", is illustrated in Fig. 1. The arrangement of its connections, of which a diagram is given in Fig. 2, has been planned with a view to meeting all the requirements which can be placed on a rectifier set.

The conditions under which a rectifier set may be required to work are as follows:

(a) The set must be continually in service.

(b) The set must be connected up to the network according to the time, as the plant is shut down during periods of weak demand to reduce the no-load losses.

(c) The set is started up or shut down according to the temperature which other sets have attained. For this purpose thermal relays having the same heating characteristics as the transformer of the set under consideration are used. It is thus

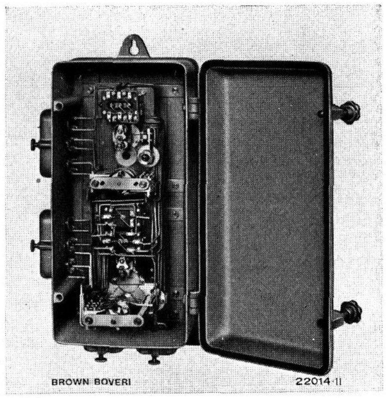


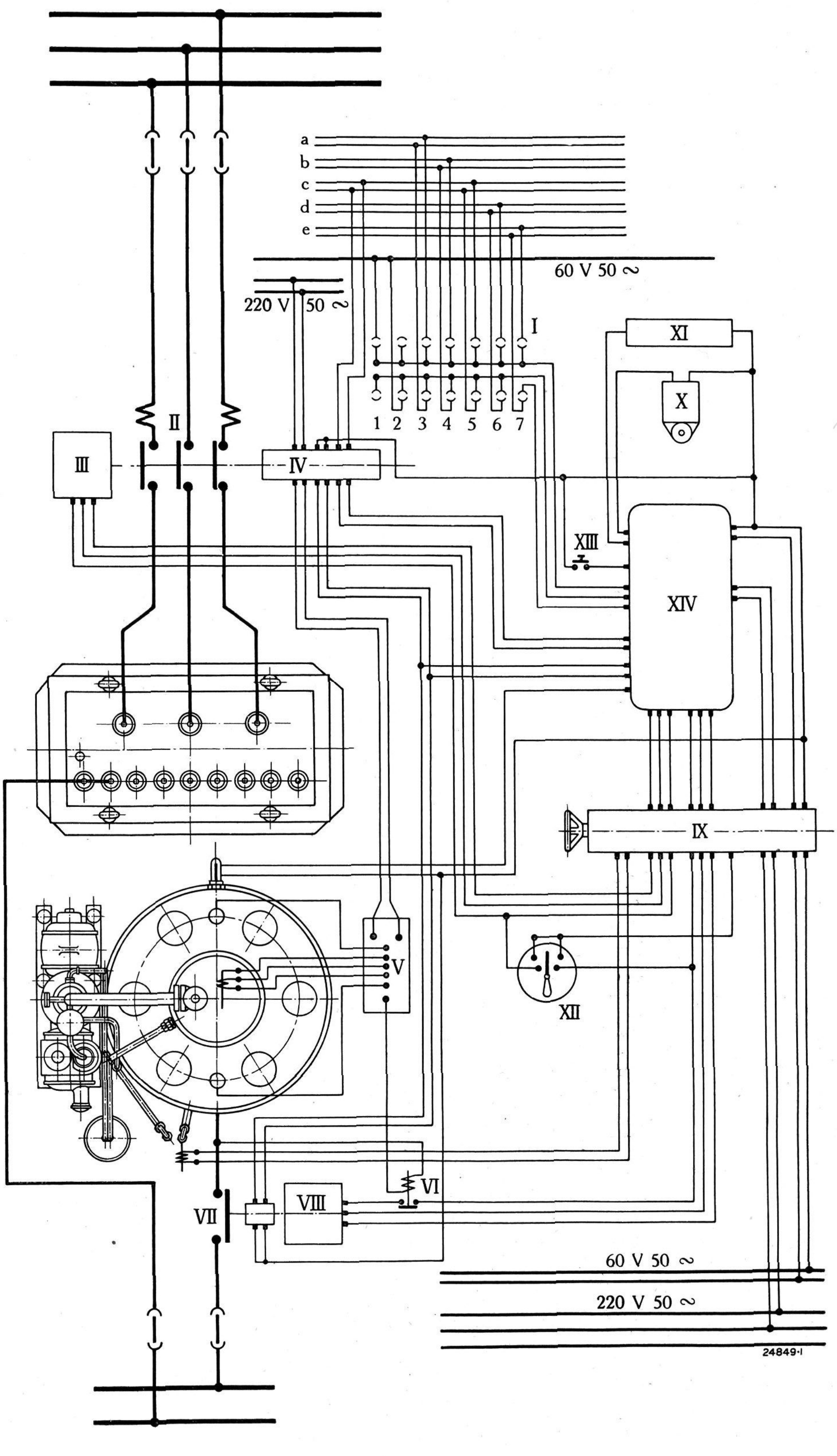
Fig. 1. — Control apparatus type 9 for automatic rectifier substations.

[1] The Brown Boveri Review, 1927, Nos. 5 to 8.

possible to keep just the right number of sets in service as will meet the power requirement.

(d) The set is put into or out of service by means of a remote-control switch situated in the control station.

(e) The set is connected up or disconnected according to the electrical conditions of the d.-c. network. When the pressure in the network falls to a predetermined minimum value the set starts up, and when the current supplied by the rectifier reaches a minimum value the set shuts down. This is effected by using a relay with differential action, its construction being such that the time lag for the closing operation can be adjusted between 0 and 60 seconds and that for the opening operation between 0 and 15 minutes.



I. Plug switch.
II. Oil circuit breaker.
III. Motor control for the oil circuit breaker.
IV. Auxiliary contacts on the oil circuit breaker.
V. Ignition and excitation device.
VI. Interlocking relay for the direct-current circuit breaker.
VII. Direct-current circuit breaker.
VIII. Motor control for the direct-current circuit breaker.
IX. Three-way switch.
X. Alarm.
XI. Indicator board.
XII. Change-over switch.
XIII. Push button for releasing the interlock.
XIV. Control apparatus type 9.

Fig. 2. — Diagram of connections of the automatic control apparatus type 9.

(f) The set should be in a condition to replace immediately and entirely a set which has become permanently shut down during service due to a serious disturbance.

The various pieces of control apparatus previously described are connected to the bus-bars a, b, c, d, e (Fig. 2). The change-over switches 1 to 7 enable the rectifier to be used for the kind of service required. The letters with which the bus-bars are marked denote the following pieces of apparatus:—

a. The time switch;

b. The thermal relay;

c. The permanently shut down position;

d. The relays for starting up the rectifier according to the electrical condition of the line;

e. The remote-controlled switch.

By means of the various plug switches the following working conditions can be realized:—

(1) Set continually in service;

(2) Set out of service;

(3) Control by time switch;

(4) Control by thermal relay;

(5) Set permanently shut down;

(6) Switches closed according to the current and the voltage of the network;

(7) Remote control.

The closing and opening commands are transmitted to the control apparatus by the two bus-bars to which the various plug switches are connected.

When a rectifier set is connected to several central control apparatuses by means of plug switches, there is the possibility that false switching operations could be made by the latter. The apparatus type 9 automatically ensures the predominance of closing impulses over opening impulses. As long as the busbar for transmitting the closing commands is under tension, the current circuit of the tripping solenoid is broken. The change-over switch with remote control, however, provides an exception to this rule; it fulfils its duties only if it can be closed at any instant by the attendant for the purpose of altering the connections of the plant in the substation. The switching in or out operations from the control room are always carried out immediately, whatever the working conditions of the set.

When a closing operation is made, the oil circuit breaker II is closed by means of its control motor III and the apparatus type 9. At the same time the rectifier cooling-water valve is opened.

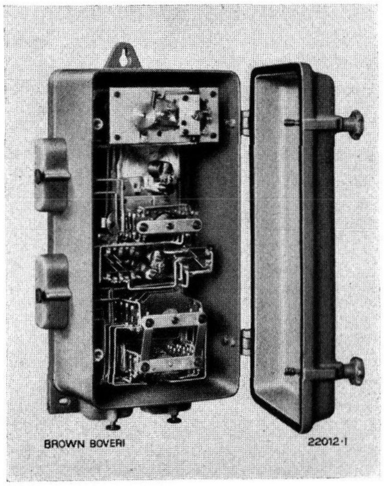


Fig. 3. — Apparatus type 12 for the automatic control of the vacuum-pump set.

The switch IV mounted on the spindle of the oil circuit breaker operates the ignition and excitation device V by means of two of its contacts. Immediately the arc has been ignited, the relay VI in the circuit of switch IV closes and the circuit breaker VII is closed by its control VIII. The operations for connecting the set to the network are then complete.

If the breakers are tripped due to an overload, the apparatus type 9 is switched in by means of the auxiliary contacts on the spindle of the circuit breaker. In the case of a permanent short circuit it then makes three successive re-closing operations. If the circuit breakers do not remain closed after three re-closing operations, the apparatus XIV assumes the interlocked position, closes the tripping circuits of the two breakers and the signalling circuits IX and X, and puts the auxiliary bus-bar c under tension. From this bus-bar the reserve set is started up to take over the duties of the set which is permanently shut down.

The set which is now shut down cannot be put into service again until the cause of the disturbance has been investigated and removed by the maintenance staff. To free the apparatus type 9 again, it is merely necessary to press the button XIII.

The following conditions can cause the set to be permanently shut down: —

Excessive overload of long duration;

Disturbances in the transformer (overheating, broken connections, short circuit between windings or in the laminations);

Disturbances in the rectifier (poor vacuum, failure of the cooling water, temperature of the anode plate too high).

The most frequent causes of the stoppages are overloads and shortage of water; disturbances in the transformer and rectifier are exceedingly rare as the design of these pieces of apparatus is now very simple and robust.

Although, in spite of the care given to its construction, it is still possible for automatic control apparatus to fail, and also due to the fact that it is often desired to regulate the automatic set by hand (but still using electrical control) a three-way switch IX has been provided. By its use the following working conditions can be realized:

(a) Automatic operation: this is the normal working position.

(b) Electrical control: in this case the apparatus type 9 is out of circuit and the rectifier set is put into or out of operation by means of the switch XII.

Thus it is possible to carry out inspections or clean and lubricate the control apparatus without interruption to the service.

(c) The set is tripped, all the control devices are out of circuit, and the installation can be subjected to a general inspection.

This control gear is thus a complete self-contained arrangement fully suited to meet all that can be required for an automatic substation.

B. Apparatus for controlling the vacuum pump set.

The pump set for maintaining the vacuum in a mercury-arc rectifier works quite independently of the rectifier set. It is started up or shut down according to the value of the pressure inside the rectifier. Fig. 3 shows the control apparatus, type 12, for the pump set; the diagram of connections is given in Fig. 4.

The various conditions under which this control apparatus works are as follows:—

(a) When the pump set is started up for the first time, the preliminary vacuum pump III does not begin to work until about 15 minutes after the high-vacuum pump II has been connected up, because since the latter is a static mercury-vapour pump, some time must elapse after it has been connected up before it comes into operation. By starting up the preliminary vacuum pump fifteen minutes later, the high-vacuum pump is enabled to attain its maximum efficiency, and an unfavourable variation of the pressure inside the rectifier is avoided while the pumps are beginning to work.

(b) When the pressure in the rectifier cylinder is sufficiently low, the preliminary vacuum pump III is stopped and the high-vacuum pump II alone remains in operation. By adopting this arrangement, the degree of reliability of the rectifier is increased as the pump set is always ready to work. The high-vacuum pump continually exhausts the gases liberated inside the rectifier and compresses them in the low-vacuum pipe.

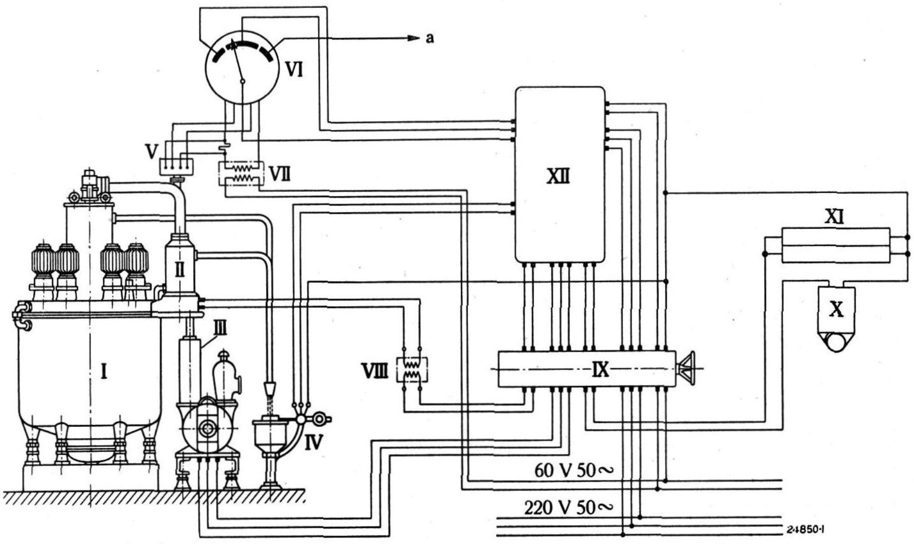


Fig. 4. — Diagram of connections of the control apparatus type 12.

I. Rectifier.
II. High-vacuum pump.
III. Preliminary vacuum pump.
IV. Water flow alarm.
V. Vacuum gauge.
VI. Galvanometer for measuring the vacuum.
VII. Transformer supplying current to the device for measuring the vacuum.
VIII. Insulating transformer for supplying the hot plate.
IX. Four-way switch.
X. Alarm.
XI. Indicator board.
XII. Control apparatus type 12.

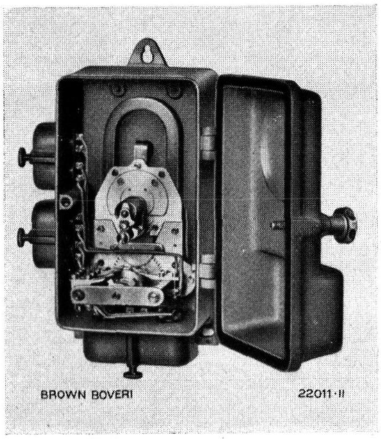


Fig. 5. — Control apparatus type 10 for feeder circuit breakers.

(c) When the pressure in the rectifier exceeds the maximum allowable limit, the preliminary vacuum pump III is started up by means of the vacuum indicator VI and the apparatus 12.

(d) If the circuit of the high-vacuum pump II is interrupted due to a disturbance, the pumps are stopped and the disturbance is signalled in the control room by the apparatus X and XI.

(e) If the supply of cooling water begins to fail, the pumps are put out of action by the water indicator IV and the disturbance is signalled to the control room.

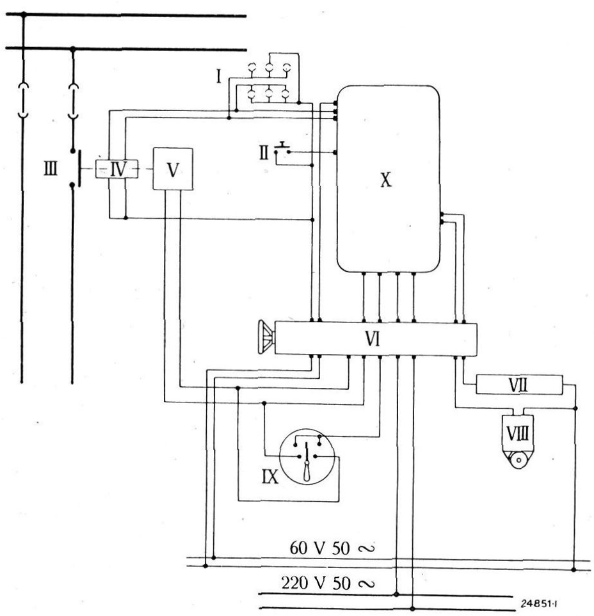


Fig. 6. — Diagram of connections of the apparatus type 10.

I. Plug switch.
II. Releasing push-button.
III. Feeder circuit breaker.
IV. Auxiliary contacts on the circuit breaker.
V. Motor control for the circuit breaker.
VI. Three-way switch.
VII. Indicator board.
VIII. Alarm.
IX. Change-over switch.
X. Control apparatus type 10.

When re-starting the pump set after the disturbances mentioned under (d) and (e) have been removed, the various operations are carried out as under (a).

(f) It may happen that the voltage of the auxiliary current with which the pump motors are supplied begins to drop. In this case the apparatus for permanently shutting down the set must be disconnected to avoid the rectifier remaining shut down when the voltage increases again. When the voltage is deficient, the pointer of the vacuum indicator assumes a position corresponding to an increased pressure in the rectifier, a position at which the interlocking would normally come into effect. At the instant the voltage returns, the needle moves slowly from this position to that corresponding to the actual pressure in the rectifier. For this reason the interlocking circuit should remain open during this period. When it is desired to control the pump set by hand, the four-way change-over switch IX is employed. This enables the following conditions to be obtained:—

(a) The pump set works automatically as already described.

(b) The pump set and the auxiliary apparatus are out of circuit and they can be inspected.

(c) The high-vacuum pump is connected up but the control gear is not in circuit.

(d) The two pumps are in service and the control apparatus is disconnected.

C. Control apparatus for the feeders.

The feeders are generally provided with over-current relays, while on the secondary side the rectifier set is equipped with reverse power relays and on the primary side with over-current time-lag relays.

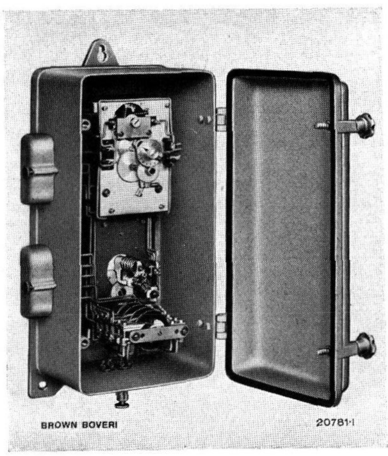


Fig. 7. — Control apparatus type 11 for feeder circuit breakers.

The circuit breakers of the feeders leaving

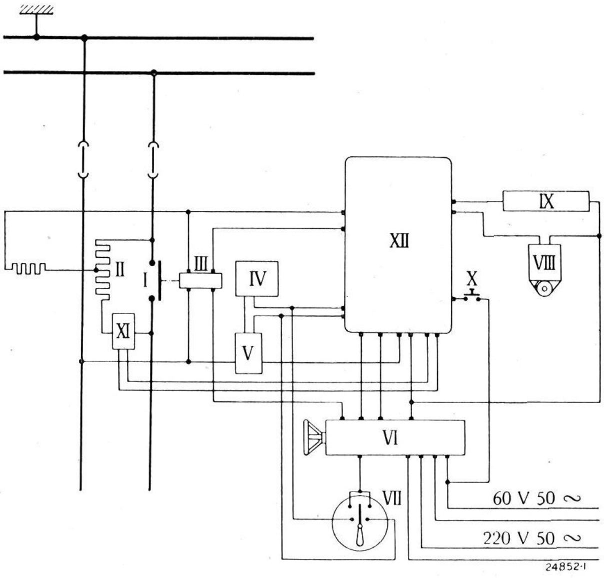


Fig. 8. — Diagram of connections of the control apparatus type 11.

I. Feeder circuit breaker.
II. Resistance in line-insulation testing circuit.
III. Auxiliary contacts on the circuit breaker spindle.
IV. Motor control for the circuit breaker.
V. Interlocking relay.
VI. Three-way switch.
VII. Change-over switch.
VIII. Alarm device.
IX. Indicator board.
X. Unlocking push button.
XI. Contactor.
XII. Control apparatus type 11.

the automatic substations are provided with re-closing devices. The apparatus type 10 (Fig. 6) enables this system of control to be realized; its principle of operation is as follows:—

The feeders are closed either according to or independently of the position of the cathode switch. The plug switch I enables the working conditions to be chosen. As soon as a closing operation is made, the apparatus type 10 immediately causes the breaker III to be closed by its motor control V.

Should a short circuit cause this breaker to trip, the auxiliary contacts IV give the apparatus 10 the impulse to re-close. This is in a position to make three re-closing operations before the breaker becomes locked and its condition signalled to the control room. After the third re-closing operation, the alarm devices VII and VIII are actuated. The interlocking of the feeder is released by means of the push button II.

The three-way switch VI enables automatic control to be used, electric control by means of the change-over switch IX, or all the apparatus to be put out of commission while an inspection of the substation is made.

It is often required that the feeders be provided with an arrangement which will enable the insulation of the line to be tested after the apparatus has been tripped due to a series of re-closing operations on a short circuit. This can be accomplished by means of the control apparatus type 11 (Figs. 7 and 8) which works as follows:—

If the circuit breaker is connected up for automatic service, by means of the switch VI, it remains permanently closed. When a short circuit occurs it puts in circuit the resistance II, which had previously been short-circuited and which now limits the current in the feeder. On an open short circuit, this resistance reduces all the pressure of the network to zero.

The relay V connected to the middle point of resistance II and to the negative bus-bar (earth) only functions when under full voltage; thus in the event of a short circuit it does not close and thus prevents the circuit breaker re-closing. When the breaker opens, the auxiliary contacts III start up a clockwork movement which interlocks the plant, within a time varying

Fig. 9. — Exterior view of Sebrowitz Substation of the Brno Tramways.

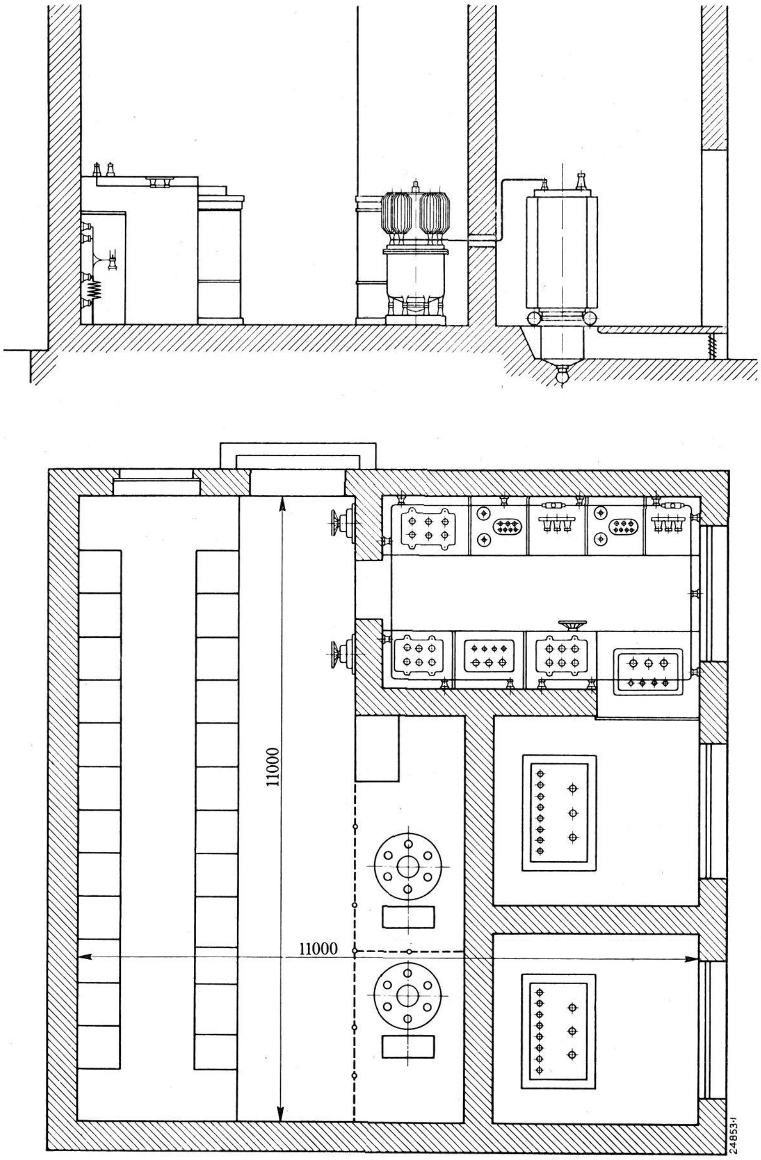


Fig. 10. — Plan and elevation of Sebrowitz Substation.

according to the service conditions, if the breaker has not re-closed. When the plant is interlocked, the contactor XI in the circuit of the resistance II is opened and the feeder disconnected. At the same time the alarm apparatus VIII and IX are put in circuit.

The interlocking of the feeder is removed by means of the push button X.

As in the previous case the three-way switch VI enables all the apparatus to be put out of circuit, electric control of the breaker by means of the switch VII and the servo-motor IV to be employed, or enables the breaker to operate automatically. When electric control is being used, the resistance II is not in circuit.

The problem of automatically controlling the feeders has thus been solved in a simple and convenient manner.

II. THE AUTOMATIC SUBSTATIONS OF THE BRNO TRAMWAY COMPANY.

The Brno Tramway Company, Czechoslovakia, owns a network system which is undergoing rapid development. For supplying this network, one standard type of substation has been adopted.

A view of the standard building used is shown in Fig. 9. It contains two 600-kW rectifier sets supplied with alternating current at 6000 V, 50 cycles, generated in the municipal power station of the town, and six outgoing feeders laid as underground cables, each being for 600 A.

A plan of the substation and the diagram of connections are given in Figs. 10 and 11 respectively. The building covers an area of 121 m^2 and has been designed to contain all the plant within a minimum of space. It is divided up into three separate parts. The first contains the high-tension gear (two incoming lines, the transformer and rectifier circuit breakers, the transformer for the auxiliary services, and finally a 300-kVA transformer for the lighting circuit). The second is reserved for the two main transformers and has a door communicating with the first room so that when the plant is being overhauled the 300-kVA transformer can be moved into the cells for the main transformers where hoisting gear is provided. The third part of the building contains the rectifiers and the gear for the direct-current feeders.

By means of this simple and clear arrangement a substation offering high reliability in service can be obtained. The plant is fully automatic and is equipped with the various kinds of apparatus described in the first part of this article.

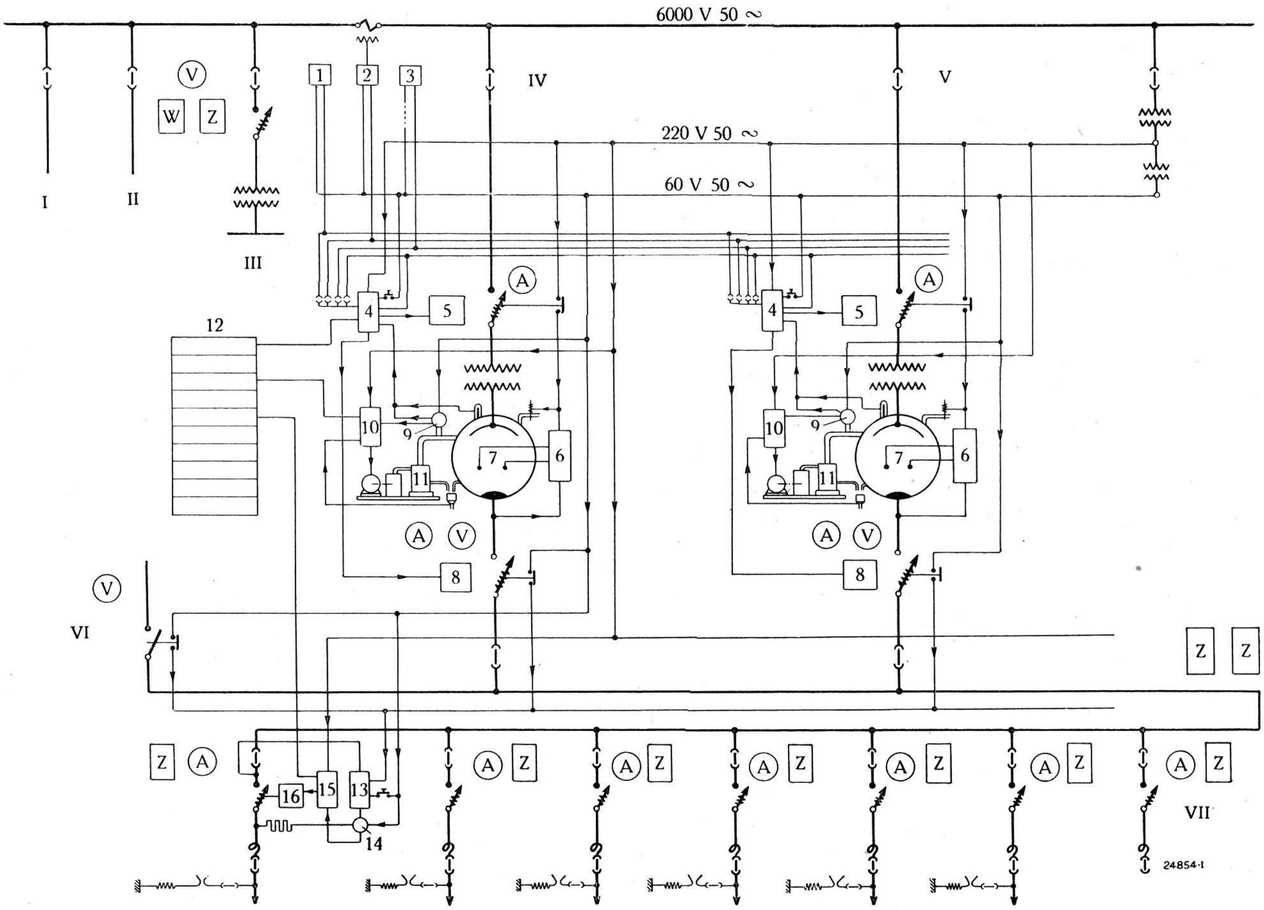


Fig. 11. — Simplified diagram of connections of Sebrowitz Substation.

1. Time switch.
2. Thermal relay.
3. Change-over switch for remote control.
4. Control apparatus type 9.
5. Control motor for the primary circuit breaker.
6. Ignition and excitation apparatus.
7. Rectifier.
8. Electric control of the direct-current switch.
9. Vacuum indicator.
10. Control apparatus type 12.
11. Vacuum-pump set.
12. Signal panel.
13. Relay for earth detector.
14. Ammeter for earth detector.
15. Control apparatus of the feeder switch.
16. Electric control of the feeder switch.

I and II. Supply cables.
III. Lighting-current transformer.
IV and V. Supply to rectifier sets.
VI. Connecting cable on the secondary side.
VII. Reserve panel for outgoing lines.

The different operations which have to be performed are as follows:

(a) Closing the circuit breakers of the set by a time switch.

(b) Starting up or shutting down the plant by a remote-controlled switch in the central power station from which the tramway network is controlled.

(c) Putting into service the reserve set by means of a thermal relay placed in the incoming line.

(d) Starting up the reserve set because the set which is in service has been shut down.

When a closing operation is made by one of the control devices 1, 2 or 3, the set is connected up to the network, provided that the corresponding plug switch is closed. The device 4 (control apparatus type 9) transmits the closing operation to the switch 5. The ignition and excitation apparatus is then started up by the auxiliary contacts on switch 5, and the set is ready for service. In the meantime the apparatus 4 has closed the direct-current switch by means of the electrical control 8.

The pump set is connected directly to the auxiliary network. The vacuum indicator 9 is provided with contacts which connect or disconnect the preliminary

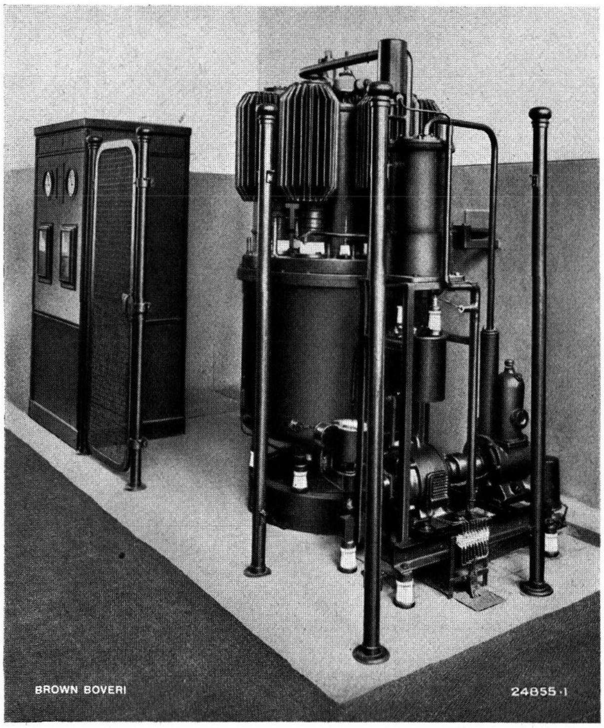


Fig. 12. — Sebrowitz Substation; 600-kW rectifier set.

vacuum pump by means of the apparatus 10 (control apparatus type 12) according to the conditions previously described.

A connecting cable is provided by means of which the set of bus-bars in each substation can be connected with those in the neighbouring one.

There are thus two quite independent sources of direct current in each substation and as a consequence the feeders should remain connected up as long as the rectifier circuit breaker or that of the connecting cable is closed. To obtain this interlocking, the control apparatus for the feeder circuit breakers are fed in parallel over the auxiliary contacts on the breakers under consideration.

Every circuit breaker is provided with a device for adjusting the number of re-closing operations, combined with an earth detector. The breaker on the outgoing feeder thus closes only if the earth detector shows that the circuit is satisfactorily insulated. If the breaker does not close after five re-closing operations, separated by definite time intervals, the outgoing feeder is interlocked and the state of affairs signalled to the control room.

The feeders are provided with over-voltage protective devices, and the six lines leaving each substation are all furnished with the same equipment. A reserve feeder panel is also provided. This enables a complete set of control apparatus for a feeder to be connected to any one of these six outgoing lines by means of a free cable, should a fault occur in the apparatus of a line. The reliability of the plant is thus increased to a very high degree and the staff have plenty of time to carry out repairs after a disturbance.

In the following subdivisions, several kinds of disturbances and the way in which they are signalled will be considered.

(a) *Incorrect polarity.* — A fault of this nature is impossible in a rectifier substation.

(b) *Reverse current.* — When the rectifier is working normally a reverse current cannot flow through the rectifier set. Under certain circumstances, however, it happens that the valve action of the rectifier fails and the reverse current causes an internal short circuit. The selective protective device then shuts down the set immediately. (This device was briefly described in The Brown Boveri Review 1927, No. 10.) This shut-down is sufficient to eliminate the cause of the disturbance. The set can then be started up again by means of the re-closing device.

(c) *Overloads.* — Each set is protected on the primary side by over-current relays; the circuit breaker is provided with a re-closing device. In the substation there is also a thermal relay for putting the reserve set in service.

(d) *Short circuits in the direct-current network.* These are tripped by the circuit breakers on the outgoing feeders. Since a leakage detector is connected with the re-closing device, the latter merely connects up the insulation-testing circuit and after several attemps interlocks the circuit breaker if the short circuit is permanent.

(e) *Inadmissible rise in the temperature of the rectifier.*—If the temperature attains an inadmissibly high value due to insufficient cooling, the contact thermometer closes the circuit of the servo-motor of the apparatus type 9 which then interlocks the set. The signalling circuits are closed, and at the same time the duties of the locked set are transferred to the reserve set.

(f) *Failure of the cooling water.*—This event is signalled by the water flow alarm and the apparatus type 12. Only the alarm indicator is then put under tension. The set is not shut down until the pressure in the rectifier becomes too great or the temperature rises to an inadmissible value. Shutting down is effected by means of the apparatus type 9.

(g) *Failure of the voltage on the primary side.*—The substation is now no longer able to feed the network, although it remains connected up because the various circuit breakers are not provided with under-voltage coils. As soon as the voltage is re-established, the substation again supplies the network.

With regard to the maintenance of the vacuum, the failure of the primary voltage has no effect whatever, as the valve in the vacuum pipe-line from the preliminary pump is operated by oil under pressure. As soon as the speed of the rotary pump reaches a certain minimum value, this valve closes.

(h) *Overheating of the transformer.*—If this is due to an overload the remarks made under "overloads" also apply to this case. If it is caused by the effect of a short circuit between windings, the over-current relays trip the breakers and shut down the set.

Since the transformers have natural cooling, other protective measures are unnecessary.

(i) *Short circuit in the plant in the substation.*—The plant is immediately disconnected, as the over-current relays operate directly on the tripping gear of the breaker. Signalling and interlocking are performed by the apparatus type 9.

(j) *Failure of the pumps.*—This may be due to shortage of water (this case has already been considered under f), a mechanical breakdown of the rotary pump, or damage to the hot plate. If either of the two last circumstances occurs, it is first signalled by means of the apparatus type 12. Then if the pressure in the rectifier exceeds the allowable value, the rectifier set is shut down by means of the apparatus type 9. The reserve set is then again put into service, as already described.

Fig. 12 shows a rectifier set, by the side of which the meter panel for the primary power supply can be seen.

Figs. 13 and 14 illustrate the switchboard of the substation. Figs. 15 to 17 show details of the principal panels, such as the cubicles containing the measuring instruments and the central control apparatus,

Fig. 13. — Sebrowitz Substation; front view of the direct-current switchboard.

the cubicles containing the various automatic control devices for the rectifier set and the lighting and excitation apparatus, feeder panel with circuit breaker, and the various pieces of automatic control gear.

These photographs show very decidedly how very much simpler and clearer the switchboards of the automatic plant become by employing the recently developed automatic apparatus.

Due to the fact that all the control gear is mounted in closed cases which are kept sealed and are completely dust-tight, the engineer in charge of the substations can rest assured that the apparatus cannot become damaged or disarranged.

Fig. 18 shows the load curve taken at the Sebrowitz Substation on December 15, 1926. By means of this curve and the values of the efficiency of the rectifier sets, it is possible to compare the working costs of a rectifier plant with those of a rotary converter substation for the same output. The guaranteed efficiencies of the 600-kW rectifier set were as follows:

Load . .	$^1/_4$	$^2/_4$	$^3/_4$	$^4/_4$	$^5/_4$
Efficiency	91·5	93·1	93·2	93·1	93 %

The average daily efficiency for a substation of this type is 92·3 %, whereas that for a rotary-converter substation working under the same conditions is 87·6 %. An economy of 4·7 % can thus be

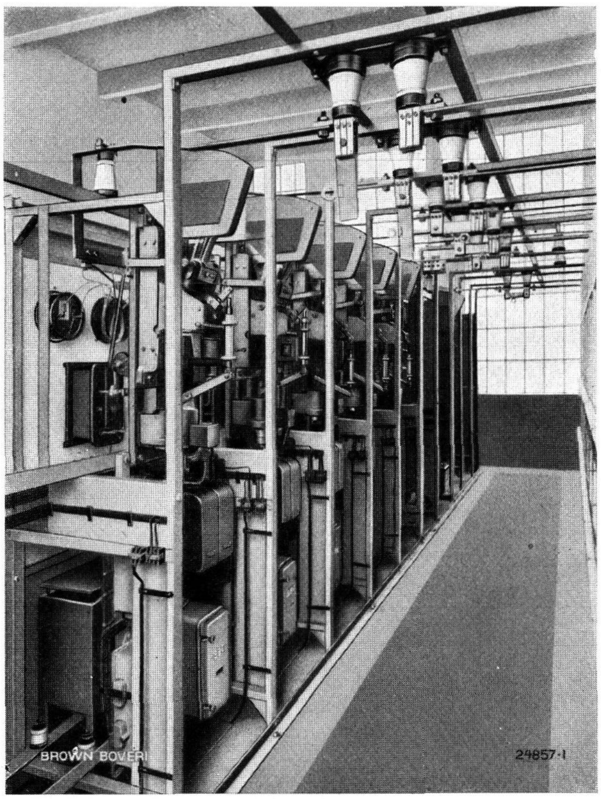


Fig. 14. — Sebrowitz Substation; rear view of the direct-current switchboard.

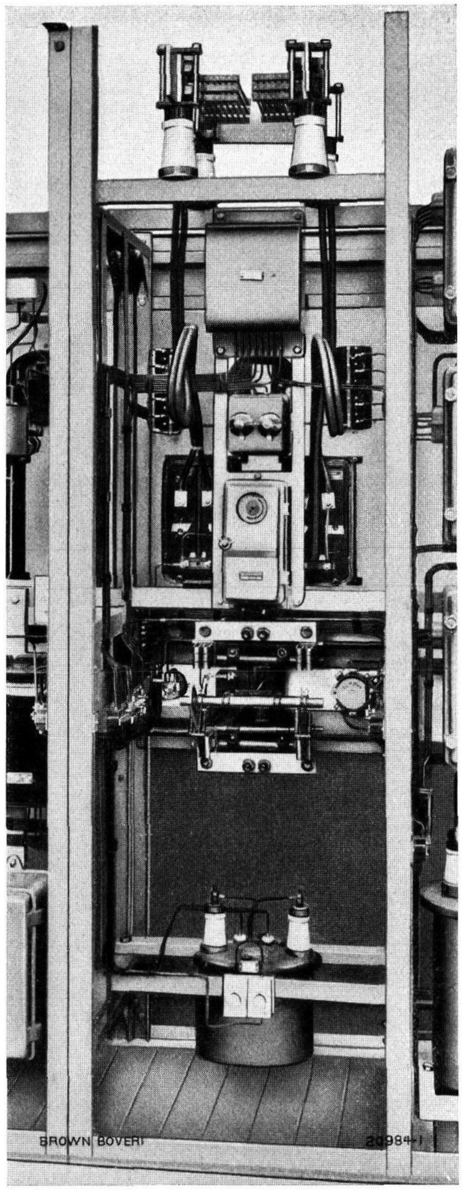


Fig. 15. — Cubicle containing meters and control apparatus.

effected, that is to say, about 690 kWh per day, or a total of approx. 250,000 kWh per year can be saved. Taking the price of a kWh as 0·05 francs it is seen that 12,500 francs can be saved per year on the purchase of electrical energy.

These considerations show perfectly clearly the undeniable advantages of an automatic rectifier substation. Moreover, besides the question of running expenses and the cost of current, labour costs occupy a very important place in the general expenses of these plants. For this substation the salaries of three shifts of two men had previously to be paid, amounting to about 24,000 francs a year. Thus as the result of using an automatic substation the yearly saving which can be effected amounts to approximately 29,000 francs, due consideration having been taken of the maintenance costs and the wages of the staff required to attend to the plant from time to time. A brief inspection of these plants is made once a week and their working is controlled in detail every month.

These facts show that due to the economies realized it is possible to pay off in four or five years

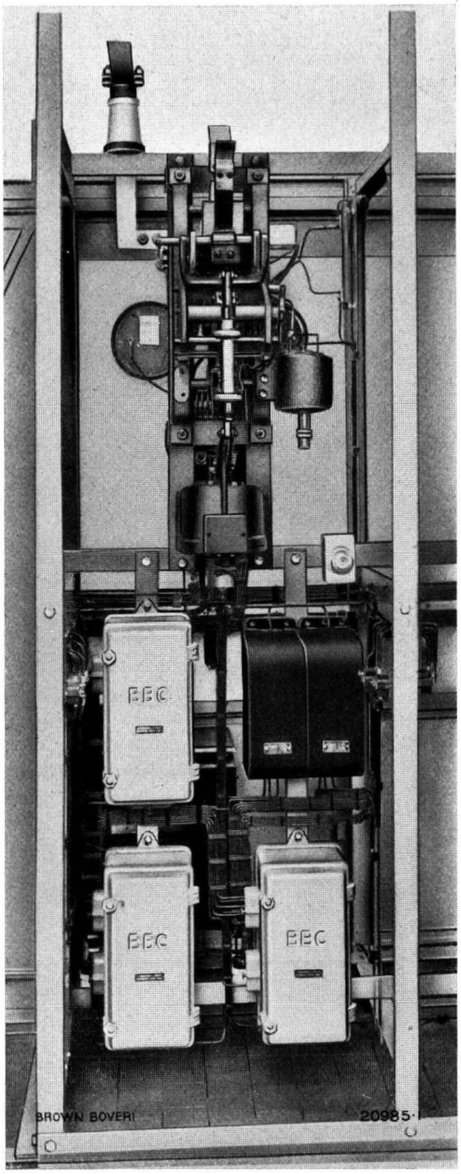


Fig. 16. — Cubicle for the rectifier control gear.

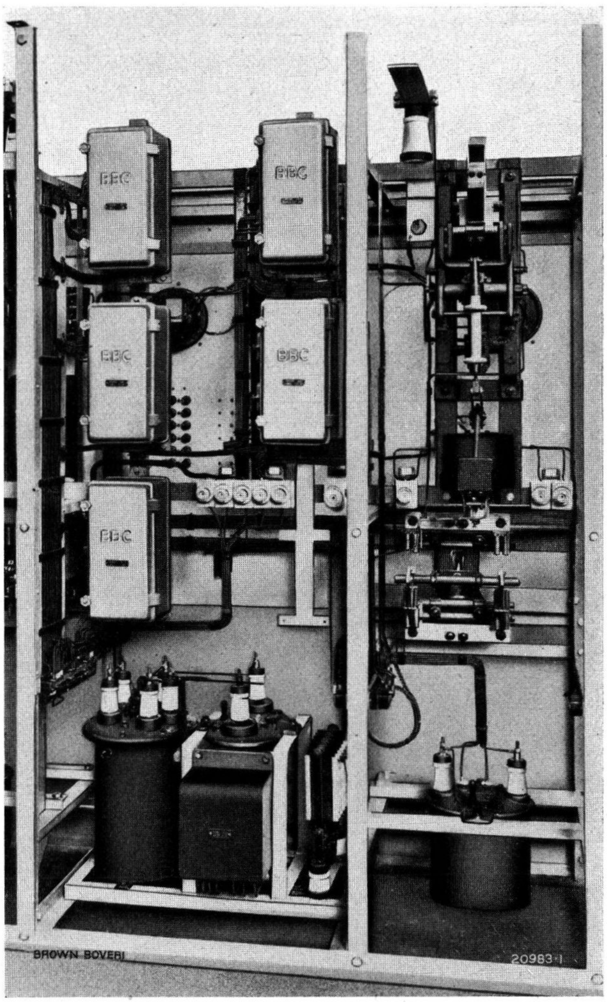


Fig. 17. — Cubicle containing control gear for the outgoing lines.

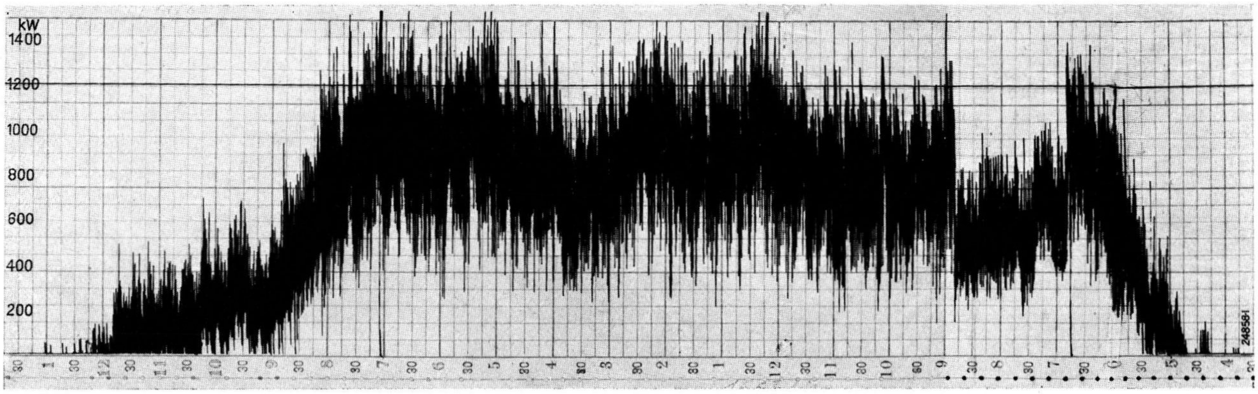


Fig. 18. — Load diagram taken at Sebrowitz Substation on December 15, 1926.

the cost of replacing a hand-controlled converter plant by an automatic rectifier plant.

The Brno Tramway Company possesses two plants of this type, namely, the Sebrowitz and Stare Brno Substations. One of these substations has been in service since the autumn of 1926 and the other since the spring of 1928. Both are working perfectly, to the complete satisfaction of the owners.

(MS 490) *J. Blandin. (E. J. B.)*

CONDITIONS FOR LUBRICATING OILS FOR STEAM TURBINES.

Decimal index 620. 196 : 621. 165.

I. GENERAL.

THE continually increasing outputs for which high-speed steam turbines are being built impose much greater stresses on the bearings, both as regards the specific pressure and the journal speed. The requirements placed on the lubricating oils are therefore increased to a corresponding degree. While the oil is circulating in the oil system of the turbine, decomposition phenomena occur which tend to change the properties of the oil. It has been found that the speed at which this "ageing" process (which can only be attributed to oxidation) takes place varies with different kinds of oils according to the sources from which they are obtained and the degree to which they have been refined. Thus the extent to which the oil can change during service varies considerably. Until a few years ago the ageing was not taken into consideration when testing oils, and the acceptance tests were usually made on the oil as it was delivered. It was then tried to produce the ageing by means of artificial oxidation as used in determining the tar figure, and the tar figure itself was taken as the criterion of the quality of the oil. In a previous article[1] it was pointed out that these methods of testing are not sufficient to reproduce phenomena capable of being compared with the ageing process, and that these cannot, therefore, be completely comprehended. As a result of large-scale service tests, extending over several years, carried out on various turbines by the Verein Deutscher Eisenhüttenleute in co-operation with the Vereinigung Deutscher Elektrizitätswerke (long duration tests on the ageing of steam turbine oils during service, Berlin, 1927), it was concluded that:— It is inadequate to test steam turbine lubricating oils only in the condition in which they are supplied, as the properties can change considerably during service due to the ageing of the oil. Further, that the artificial oxidation employed in determining the tar figure is not sufficient to reproduce the ageing process. Brown, Boveri & Co. have conducted tests regarding the ageing of oils (Archiv für Wärmewirtschaft, 1927) and have thoroughly investigated the products of the reaction and the accompanying changes in composition. It was found that when mineral oils decompose during service,

[1] The Brown Boveri Review, 1925, pp. 131 and 150.

oxidation products are formed; some are soluble in the oil but others form a more or less solid sludge which is liable, for example, to choke the oil coolers. The reaction products contain polar or active groups, which, due to the alteration in the molecular forces, can change certain properties of the oil. Thus, for example, the cohesive force, and therefore the stability of the oil film, is increased by the molecular groups of these reaction products. The viscosity also increases. The cohesive force itself, however, is not directly connected with the viscosity, although, on the other hand, these molecular groups alter the saponification value and its consistency. The tendency to emulsify is also increased. It was shown that the acid reaction products are not alone sufficient for the formation of emulsions, and that neither the acid value nor the tar figure is an accurate indication of the way the oil will behave in service. The emulsification cannot be determined by such arbitrary methods, which are very frequently used in the testing of oils. The surface tension with respect to certain liquids is also not a reliable criterion for the emulsification, as will readily be understood when it is remembered that various emulsions only in apparent equilibrium can form. The acknowledgement of this fact disperses the old theory that emulsions are caused by saponification. This theory can also be shown to be false by the fact that very stable equilibrium between emulsions has been achieved using pure distilled water. Even though, in certain special cases, saponification is an important adjunct to the formation of emulsions, in the majority of cases the building of the separation film and the formation and arrangement of the polar groups within that film are of greater importance. According to the research carried out in the Brown Boveri laboratories, the method of testing turbine oils by means of salt solutions, as employed by certain marine companies, is fundamentally incorrect, because the formation of emulsions is not aided by the salt solution. Emulsions are, rather, broken down or destroyed by its action.

Brown, Boveri & Co. have therefore provisionally laid down the following regulations for testing turbine oils, based on the results of their experiments. The greatest value is laid on the artificial ageing test. The method of determining the resistance to oxidation has been developed as the result of experience and by making comparisons between laboratory tests and practice, but has not yet been perfected.

(1) Specific gravity at 20° C .	not over 0·93
(2) Flash point in open crucible .	not below 170° C (338° F)
(3) Fire point " " "	not below 210° C (410° F)
(4) Acid value	not over 0·1
(5) Viscosity at 20° C . . .	not over 250 cp_χ (30° Engler 1020 sec Redwood 1200 sec Saybolt)
" " 50° C	25—40 cp_χ (3·46—5·34° Engler 105·2—164·5 sec Redwood 121·8—193·8 sec Saybolt)
" " 80° C	not under 7 cp_χ (1·57° Engler 43·8 sec Redwood 48·1 sec Saybolt)
(6) Ash content	0·01 %
(7) Asphalt content	0
(8) Fatty oils content	0

(9) *Ageing tests*	On delivery	After ageing
Acid value	0·1	0·3
Saponification value .	—	not over 1·5
Sludge content . . .	—	0
Steam-jet test . . .		see page 97
Emulsification in distilled water	0	0
Emulsification in a 1 % soda solution . .	0	0

II. INSTRUCTIONS CONCERNING METHODS OF TESTING LUBRICATING OILS FOR TURBINES.

(1) Specific gravity. According to the usual methods with picnometer, araeometer, etc.

(2) Flash point. In open Marcusson crucible.

(3) Fire point. " " " "

(4) Acid value. As milligram KOH per gram of oil. Indicator: blue alkali 6 B.

(5) Viscosity. Nowadays viscosity is generally measured by some empirical system, e. g., according to Engler, Redwood or Saybolt, where the time of flow is used as a measure of the viscosity.

The values thus obtained cannot be converted directly into the absolute system of measurement. The great difficulties encountered in determining these values, simply due to the different methods of testing employed, and which have led to the standardization of the test method in America, were described in a very interesting report presented by Chechot at the International Congress on the Testing of Materials in Amsterdam, 1927. The empirical values have already been the cause of numerous mistakes, and are responsible for the still prevalent misconceptions of the meaning of viscosity. It is particularly in the measurement of the viscosity of thin oils that the previously-mentioned apparatus give inaccurate results because the dimensions of the outlet capillaries of the Engler, Redwood and Saybolt viscometers are such that in these cases the flow of the oil is no longer steady but decidedly turbulent. The conditions under which Poiseuille's Law can be applied are thus no longer fulfilled and the measurements are inaccurate. In these cases values are obtained which depend on both the viscosity and the turbulence, though under certain circumstances the viscosity hardly enters into the question.

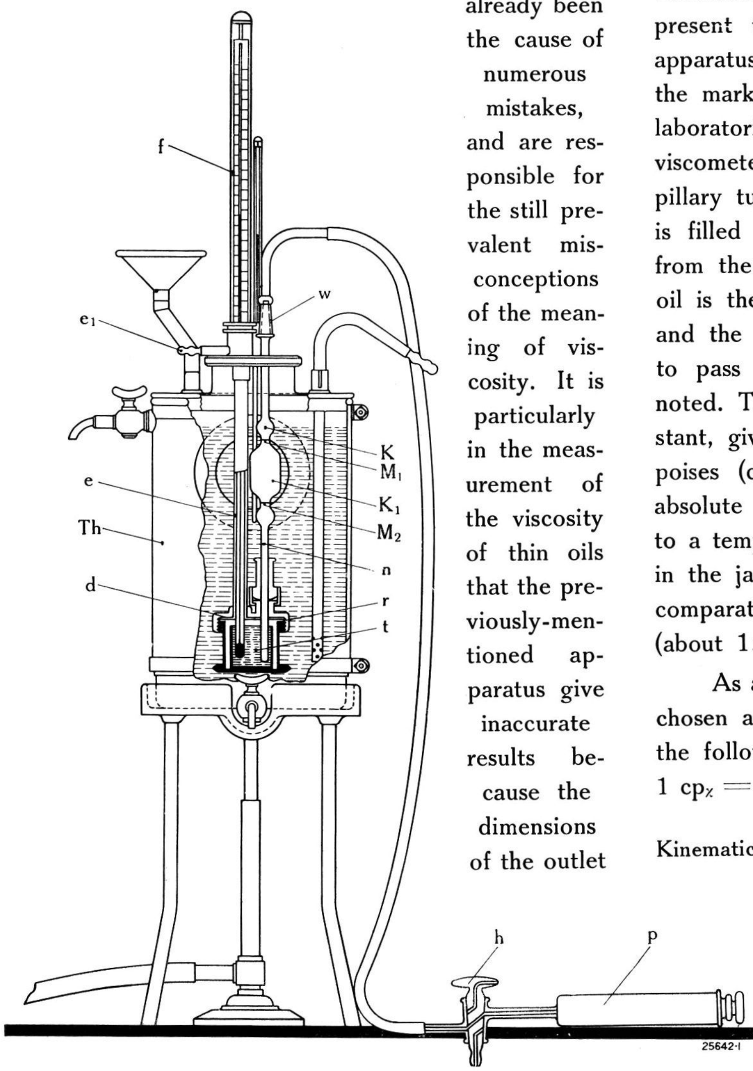


Fig. 1. — Vogel-Ossag viscometer.

To avoid these inaccuracies, Brown, Boveri & Co. have expressed (since April, 1928) the viscosities of the oils which they use as absolute kinematic viscosities in the CGS system.

The absolute viscosity can be determined with comparative ease by means of the Ostwald capillary viscometer according to Poiseuille's Law. At the present time, however, very convenient laboratory apparatus based on this principle is to be found on the market. Measurements of viscosity in the firm's laboratories are made exclusively with Vogel-Ossag viscometers (Fig. 1) as follows:— The graduated capillary tube (the constant for the tube is etched on) is filled with oil by drawing up a certain amount from the container t by means of the pump p. The oil is then allowed to flow out under its own head, and the time taken for the top surface of the oil to pass from mark M_1 to mark M_2 is accurately noted. This time is multiplied by the capillary constant, giving the absolute kinematic viscosity in centipoises ($c\,p_\chi$). By means of this simple apparatus, absolute viscosities can be determined accurately up to a temperature of 150^0 C by using a suitable liquid in the jacket Th. A further advantage is that only comparatively small quantities of oil are required (about 15 cc).

As already mentioned, the "centipoise" has been chosen as the unit of absolute kinematic viscosity, the following fundamental relationships obtaining:

$1\ cp_\chi = 0{\cdot}01\ p_\chi$, where p_χ denotes "kinematic poise".

$$\text{Kinematic viscosity} = \frac{\text{absolute viscosity}}{\text{specific weight (at temperature of test)}}$$

The absolute viscosity of water can be taken as a basis of comparison. At $20{\cdot}5^0$ C this is 0·01 p or 1 cp.

The kinematic viscosity can be readily changed to the absolute viscosity, expressed in cp, by multiplying the former value by the specific gravity of the oil at the temperature at which the test was carried out. Table I, page 96, gives the corrections to be made to the specific gravities at various temperatures.

For converting the absolute viscosity into other mass systems the following equations should be used:—

Viscosity in CGS units:—

$$n\ cp_{\chi} = \frac{n\,\delta}{100}\,p = \frac{n\,\delta}{100}\left[l^{-1}\cdot m\cdot t^{-1}\right]$$

Viscosity in practical units:

$$n\ cp_{\chi} = \frac{n\,\delta}{100\times 981}\ \text{gm sec/cm}^2$$

Kinematic viscosity in practical units:

$$n\ cp_{\chi} = \frac{n\,\delta}{100\times 981}$$

practical kinematic units.

From the values of the absolute viscosity obtained by means of these equations, it is immediately possible to obtain, with perfect accuracy, the viscosity in degrees Engler or seconds Redwood or Saybolt. To do the reverse is impossible on account of the difficulties already mentioned. Corresponding values are tabulated in Fig. 2.

For the present the viscosities determined by the empirical method are given, in addition to the absolute kinematic values, and, alongside these, the specific gravity at the corresponding temperature (for corrections see table I).

(6) Ash content. Determined according to usual methods.

(7) Asphalt content. Mix with petroleum ether. The mixture must be quite clear.

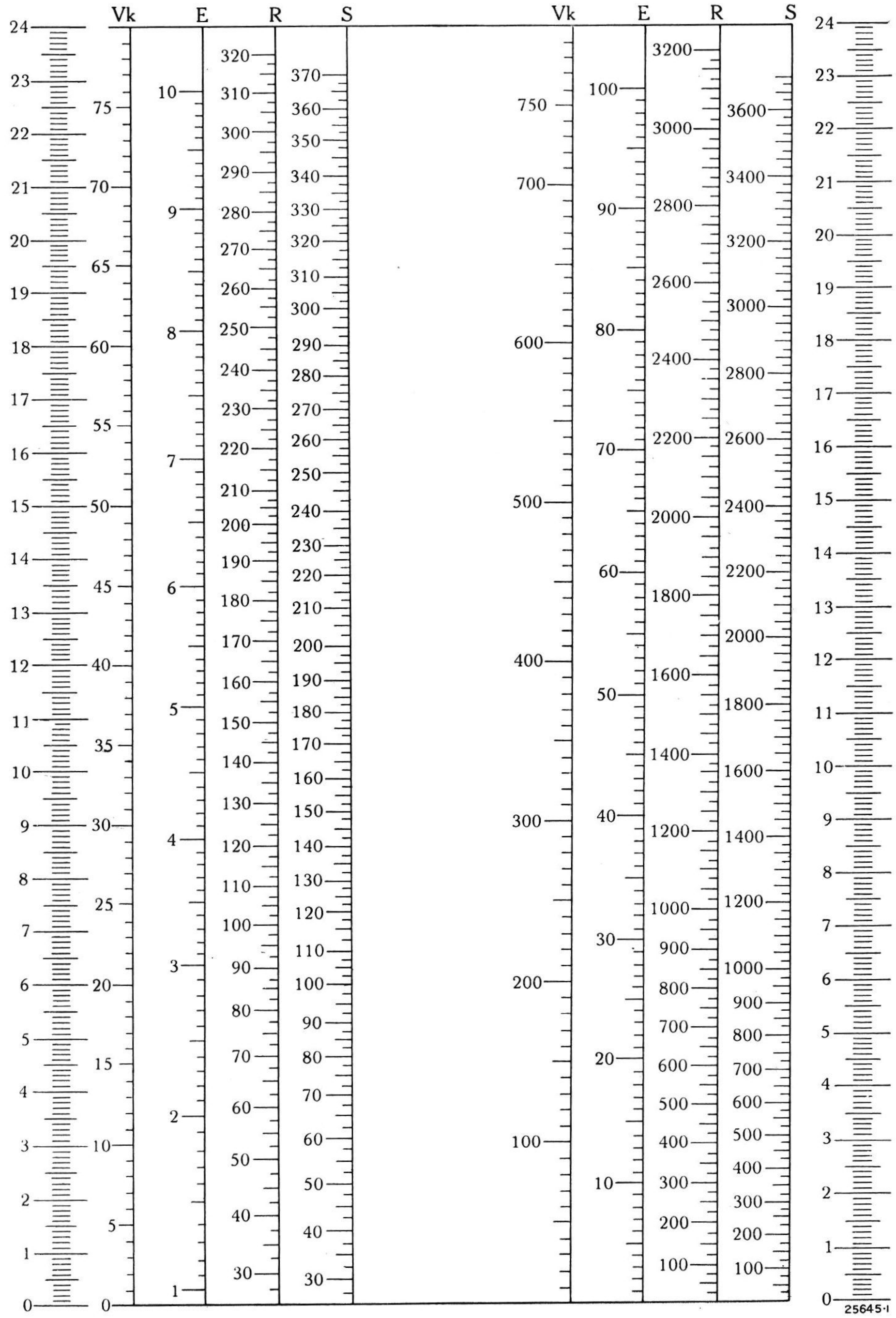


Fig. 2. — Comparison of viscosities according to the various standards.
Vk = absolute kinematic viscosity. E = Engler. R = Redwood. S = Saybolt.

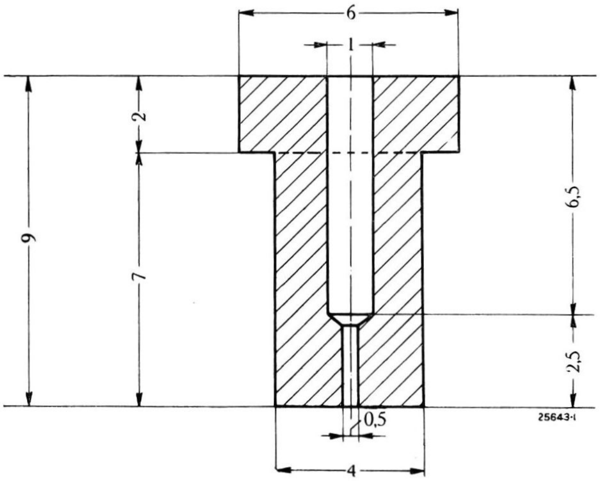


Fig. 3. — Outlet nozzle on boiler.

TABLE I.

Specific gravities of mineral oils and fatty oils at various temperatures.

At t° C	Correction for s_{15}	Correction for s_{18}	Correction for s_{20}	At t° C	Correction for s_{15}	Correction for s_{18}	Correction for s_{20}
	Add				Subtract		
0	0·011	0·013	0·014	80	0·046	0·043	0·042
5	0·007	0·009	0·011	85	0·049	0·047	0·046
10	0·004	0·006	0·007	90	0·053	0·050	0·049
15	0·000	0·002	0·004	95	0·056	0·054	0·053
	Subtract			100	0·060	0·057	0·056
20	0·004	0·001	0·000	105	0·063	0·061	0·060
25	0·007	0·005	0·004	110	0·067	0·064	0·063
30	0·011	0·008	0·007	115	0·070	0·068	0·067
35	0·014	0·012	0·011	120	0·074	0·071	0·070
40	0·018	0·015	0·014	125	0·077	0·075	0·074
45	0·021	0·019	0·018	130	0·081	0·078	0·077
50	0·025	0·022	0·021	135	0·084	0·082	0·081
55	0·028	0·025	0·025	140	0·088	0·085	0·084
60	0·032	0·029	0·028	145	0·091	0·089	0·088
65	0·035	0·033	0·032	150	0·095	0·092	0·091
70	0·039	0·036	0·035	155	0·098	0·096	0·095
75	0·042	0·040	0·039	—	—	—	—

If the specific weight of an oil is known at 15°, 18° or 20° C, to obtain the specific weight at any other temperature a correction must be introduced. This correction per degree centigrade is approximately the same for all oils and has a mean value of 0·0007. The table above gives the value of this correction for temperatures from 0° C to 155° C to be added to (or subtracted from) the specific gravities at 15, 18 and 20° C.

(8) Fatty oils content. By determination of the saponification number. If this is greater than 0·5, separate by the Spitz and Hoenig method and determine the fatty acids.

(9) Ageing test. As indicated, the effects of age on turbine oils during use can be traced to oxidation caused by the oxygen in the air at high temperatures. Under certain circumstances the products of this reaction can alter the properties of the oil very considerably. To resist oxidation, a good oil should still satisfy the delivery conditions after being subjected to the following ageing test.

Ageing test. — 200 cc of oil are poured into a 400-cc beaker (tall form) of Pyrex glass and kept

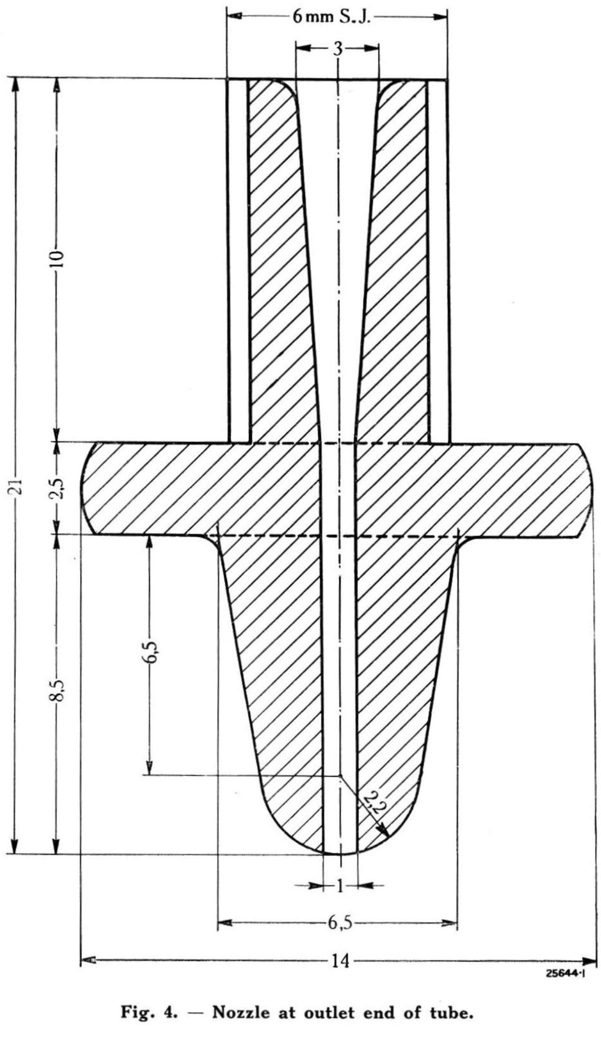


Fig. 4. — Nozzle at outlet end of tube.

at 110° C for three days in an open oil bath. A copper plate 40×70×1 mm thick is placed in the beaker to accelerate the reaction by acting as a catalytic agent. The plate must be carefully cleaned and polished with precipitated chalk which should comply with the following test:— 1 gram of the chalk mixed in water in a 25-cc Eggertz tube should be completely sedimented in 2 hours. Acid or other chemical reagents must not be used for cleaning the copper plate. After being heated for three days, the oil is allowed to cool down, and, after standing for 24 hours, is filtered. The sludge left behind in the filter is carefully freed from oil by means of petroleum ether and dissolved in chloroform. Then after the chloroform has been evaporated off, the amount of sludge is determined gravimetrically. The filtered oil is used for the determination of the acid and saponification values and also for the steam-jet test.

Steam-jet test. — Steam at a gauge pressure of one atmosphere is produced from distilled water in a boiler and passed through a nozzle 0·5 mm in diameter (Fig. 3) into a brass tube about 80 cm overall length, 8 mm external diameter and 1 mm thick. A second nozzle (Fig. 4) is fitted at the outlet end of the tube. The pressure in the boiler and the diameter of the first nozzle determine the quantity of steam, and the second nozzle the intensity of the steam jet. The mixture of oil and distilled water (50 cc of each), or of oil and soda-solution, is put into a calibrated test tube, 36 mm internal diameter and 320 mm long. The steam jet is directed for half an hour into the bottom of the mixture, which is standing in boiling water. The exit nozzle should not be more than 2 mm from the bottom of the test tube. At the end of this time the tube containing the mixture is removed from the hot bath so that the speed of separation of the mixture can be determined. This is given by observing the change in the position of the surface of separation of the two phases according to the time. The curves in Fig. 5, drawn on logarithmic paper, illustrate a separation process of this kind. The zero line represents the surface of separation of the original oil—water mixture, or oil—soda solution mixture, as the case may be.

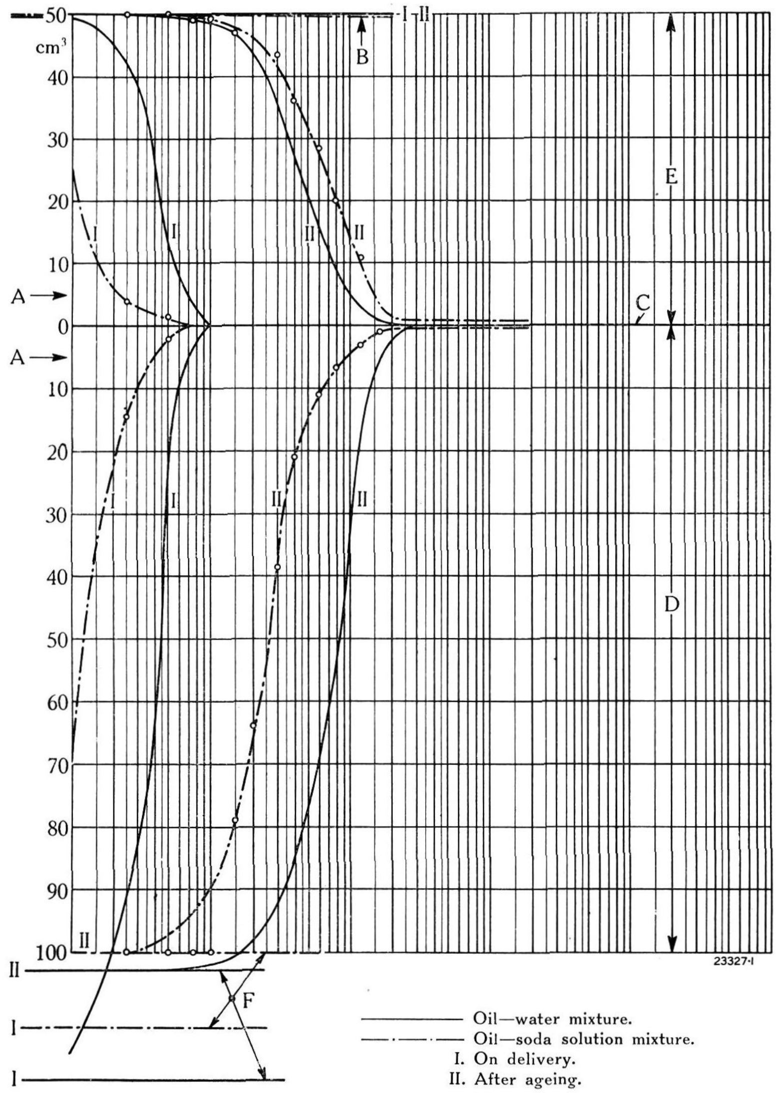


Fig. 5. — Graphical representation of the separation process of emulsions.

A. Phases of the emulsion.
B. Upper limit of oil.
C. Theoretical separation line.
D. Phase of liquid with which oil is mixed.
E. Oil phase.
F. Lower limit of liquid.

The scale of abscissae is 0·1—1—10—100—1000—10,000 minutes, where 0·1 is at the origin.

(MS 522) *Dr. Stäger. (E. J. B.)*

NOTES.

Brown Boveri rectifier plants for 1500 V and over in Italy.

Decimal index 621.313.73 (45).

WITHIN the last few years the mercury-arc rectifier has attained to very great importance as a means of converting alternating into direct current on account of the rapid developments which have been made in its design and method of construction. It has proved very satisfactory under all manner of service conditions, and, due to its numerous advantages over converters of the rotary type, is finding a continually increasing field of application. It is most extensively used, however, for railway and tramway electrification, as it is particularly suited to the conditions prevailing in traction service. During recent years many hundreds of mercury-arc rectifier plants have been installed, some in new substations, others for replacing rotary machines. The conversion of a plant with rotary machines to one with mercury-arc rectifiers is particularly advantageous when the substation is situated in a town and where, as a consequence, space is limited. Due to the small space required by rectifiers, plant for considerably increased output can be installed when such a conversion is made.

From both a technical and an economic point of view mercury-arc rectifiers are practically the only type of converter which can be considered for the electrification of main line and interurban railways with high-tension direct current. The well-known advantages of rectifiers over rotary converters and motor generators are so great at pressures of 1500 V and over, that it may safely be said that, in this field, the rectifier is the only suitable type of converter. The important orders for rectifier plants which have recently been executed by Brown, Boveri & Co. provide ample testimony to the accuracy of this statement. In addition to the rectifier plants installed in Italy, and which are described in detail in this article, some others may also be mentioned. For example, seven substations with a total continuous rating of 21,000 kW have been installed for the electrification of the Dutch Railways,[1] which are operated at a contact-wire pressure of 1500 V. All the substations on this railway are now in service and giving complete satisfaction. Plants for 1500-V direct current are also in operation in the South of France and other European countries, America, Japan, and, in particular, in Australia. The New South Wales Government Railways & Tramways, Sydney[2], recently ordered ten rectifier sets for a full-load pressure of 1500 V. This order was placed as a result of the satisfactory experience obtained with the plant supplied by Brown, Boveri & Co. for Gordon Substation in 1925, and again shows that Brown Boveri mercury-arc rectifiers are gradually superseding other types of converters for main-line railway electrification. The aggregate rating of all Brown Boveri rectifier plants for 1500 V and over is now about 120,000 kW.

[1] The Brown Boveri Review 1928, No. 12.
[2] The Brown Boveri Review 1928, No. 10.

In Italy, the first 3000-V plants for supplying current for traction purposes have been installed. By way of experiment the Italian Government Railways electrified the Benevento-Foggia Line in South Italy at a contact-wire pressure of 3000 V. The contact wire is fed through three substations, two equipped with rectifiers and the other with a motor generator. Electric traction on the line has proved very satisfactory and the administration are particularly pleased with the service given by the rectifiers. In view of the good results obtained, it is proposed to electrify this section as far as Naples and it is very probable that rectifiers will be used as the converters in the new substations. A list of the most important 1500-V plants which have been put into operation in Italy or will shortly be installed is given on the next page.

Apice Substation supplying the Benevento-Foggia Line contains one rectifier set comprising two cylinders and one transformer with absorption choke coil. Closed circuit cooling with forced air draught is used for cooling the plant.

Biella Substation, which has now been in service for several months, contains one 1100-kW rectifier set for a full-load pressure of 2500 V. The set comprises a single cylinder with the usual auxiliaries and a rectifier transformer with fork connections. The high-speed cathode switch is provided with reverse-current release, so that if the rectifier set should become damaged it can be selectively disconnected from the motor generators with which it is working in parallel in the same station. The rectifier and high-vacuum pump are cooled by a closed-circuit cooling set.

The North Milan Railway Company, who own a number of important steam lines in the north of Italy, recently decided to electrify their railways with 3000-V direct current. As is common knowledge, two essential factors have to be considered when projecting the electrification of a line, namely:— the gradients encountered and the volume of traffic. It was the latter factor which led to the railway under consideration being electrified; all the lines terminate in Milan and the traffic in all directions is very heavy. The rectifier plant for feeding the Milan-Meda and Milan-Saronna sections is now being erected. It comprises three rectifier sets. For the present this substation alone will supply the network, but when the electrification is extended it will work in parallel with other substations. Each set comprises one rectifier for 2000 kW at 3000 V together with a rectifier transformer with fork connections; the transformers are supplied at 23,000 V, 42 cycles. The well-known selective protection, now in general use in rectifier plants, is used for tripping out a faulty set, while those working in parallel remain in operation. Sufficient room has been provided in the substation for the installation at a later date of a fourth set. Each set is provided on the direct-current side with two switches: the one, a high-speed circuit breaker, has reverse-current release and is included in the negative lead. A resistance in parallel with this switch limits the current in the event of a short circuit. The other switch, in the positive lead, is tripped by a solenoid which is energized

Railway	Substation	Output		Rectifiers		Primary network	
		kW	Volts	No.	Type	Cycles	Volts
1. Ferrovie dello Stato, Apice	Apice	1700	3000	2	GRZ/156	45	62,000
2. S. A. Biellese Distrib. Energia Elettrica	Biella	1100	2500	1	GRZ/156	50	14,000
3. Soc. Ferrovie Nord, Milan	Novate	6000	3000	3	GRZ/1612	42	23,000
4. Fermo-Amandola S. A. Adriatico Appenino, Milan	Servigliano (autom.)	1400	2600	2	GRZ/136	50	30,000
5. Ferrovie Vicinali, Rome	Centocelle	850	1650	1	GRZ/156	45	30,000
6. Soc. Tramvie Vicentine, Vicenza	Vicenza	2200	3000	2	GRZ/156	42	10,000
7. Ditto	Valdagno (autom.)	1500	3000	2	A 26	42	10,000
8. Ferrovie delle Dolomiti	Cortina d'Ampezzo	2200	3000	2	GRZ/156	42	18,000
9. Ferrovia Castellamare-Penne	Moscufo	1400	2600	2	A 26	50	24,000
10. Ferrovia Arezzo-Sinalunga	S. Savino	1200	3000	2	A 26	50	30,000
11. Ferrovie Vicinali, Rome	San Cesareo	850	1650	1	GRZ/156	45	22,000
12. Ferrovia Ora Predazzo	San Lugano	1820	2600	2	A 26	50	19,200

by means of a contact device on the high-speed circuit breaker. A closed-circuit system is again used for cooling the sets. At such a high pressure as that used in this plant, direct or indirect cooling cannot be employed.

Servigliano Substation on the Fermo-Amandola Railway has been built for automatic operation. It contains two rectifier sets, each for 700 kW at a full-load pressure of 2600 V. One is normally kept as a stand-by, though the plant has been so arranged that the two sets can work in parallel. The following working conditions can be realized by means of the automatic control gear:—

(a) Starting up and shutting down the plant according to the time.

(b) Starting up and shutting down either set, or tripping either feeder, according to the position of a switch at the control point.

(c) If the set in service is permanently shut down due to a disturbance, the reserve set takes over the load and all starting-up or closing-down commands are transmitted to this second set.

(d) By means of a special time switch the sets are used alternately, one on one day, the other on the next. It is thus ensured that both sets are always in working order and that the reserve set can be started up immediately should the one in service be permanently shut down.

The point from which the plant is controlled is at Servigliano Railway Station in the immediate neighbourhood of the substation, near the station-master's office. All disturbances occurring in the plant are signalled to this control point by an alarm. There is, further, a system of optical signals in the substation from which the nature of the disturbance can be determined. Re-closing devices are provided on the primary oil circuit breaker and cathode switch of each set. These re-close their respective switches three times if they have been tripped (either singly or simultaneously) due to a disturbance. If the third re-closing is unsuccessful the switches are interlocked, as it is then assumed that the fault is a permanent one. There is an interval of several seconds between each re-closing. The two feeder switches are also provided with similar re-closing devices. The air-pump set of each rectifier set operates automatically according to the state of the vacuum inside the cylinder. The set in service is interlocked if the vacuum falls inadmissibly low in spite of the preliminary vacuum pump working at the time; if the temperature rise in the cylinder or transformer is too great; or if the cooling fails. The plant has already been in service for some time and the automatic gear is working with complete satisfaction.

The Società Tramvie Vicentine are electrifying their suburban railways with direct current at 3000 V. Two substations are being provisionally erected for supplying the contact-wire pressure, viz., one at Vicenza and one at Valdagno, and a third will be built when the electrification programme is extended. Valdagno Substation is intended for three 1100-kW rectifier sets, but at present only two have been installed. There are two 750-kW sets in Valdagno Substation which is also equipped for automatic control. The operating conditions are similar to those described for Servigliano Substation. The rectifiers in both Vicenza and Valdagno Substations are supplied with three-phase current at 10,000 V, 42 cycles.

The chief reason for replacing steam traction by electric traction on the Ferrovie delle Dolomiti was the large number of stiff gradients on this railway. 3000-V direct current was chosen as the most suitable contact-wire pressure, as for other main and secondary lines. The three-phase supply will be converted into direct current by means of mercury-arc rectifiers in Cortina d'Ampezzo Substation.

The Castellamare-Penne and Arezzo-Sinalunga Railways are being electrified with direct current at 2600 and 3000 V respectively. One substation with two rectifier sets (one set for 700 kW and the other for 600 kW), is being provided provisionally for each railway.

The programme for the electrification of main-line and secondary railways with direct current at pressures in excess of 2000 V will be enlarged still further in the near future, as this system has very decided advantages for many sections of the Italian State Railways. How far this electrification will be carried is not yet known, but in view of the exceedingly satisfactory results so far obtained it is practically certain that further lines will be electrified with direct current.

(MS 524) *A. Greco. (E. J. B.)*

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