VOL. XIII JULY, 1926 No. 7

THE BROWN BOVERI REVIEW

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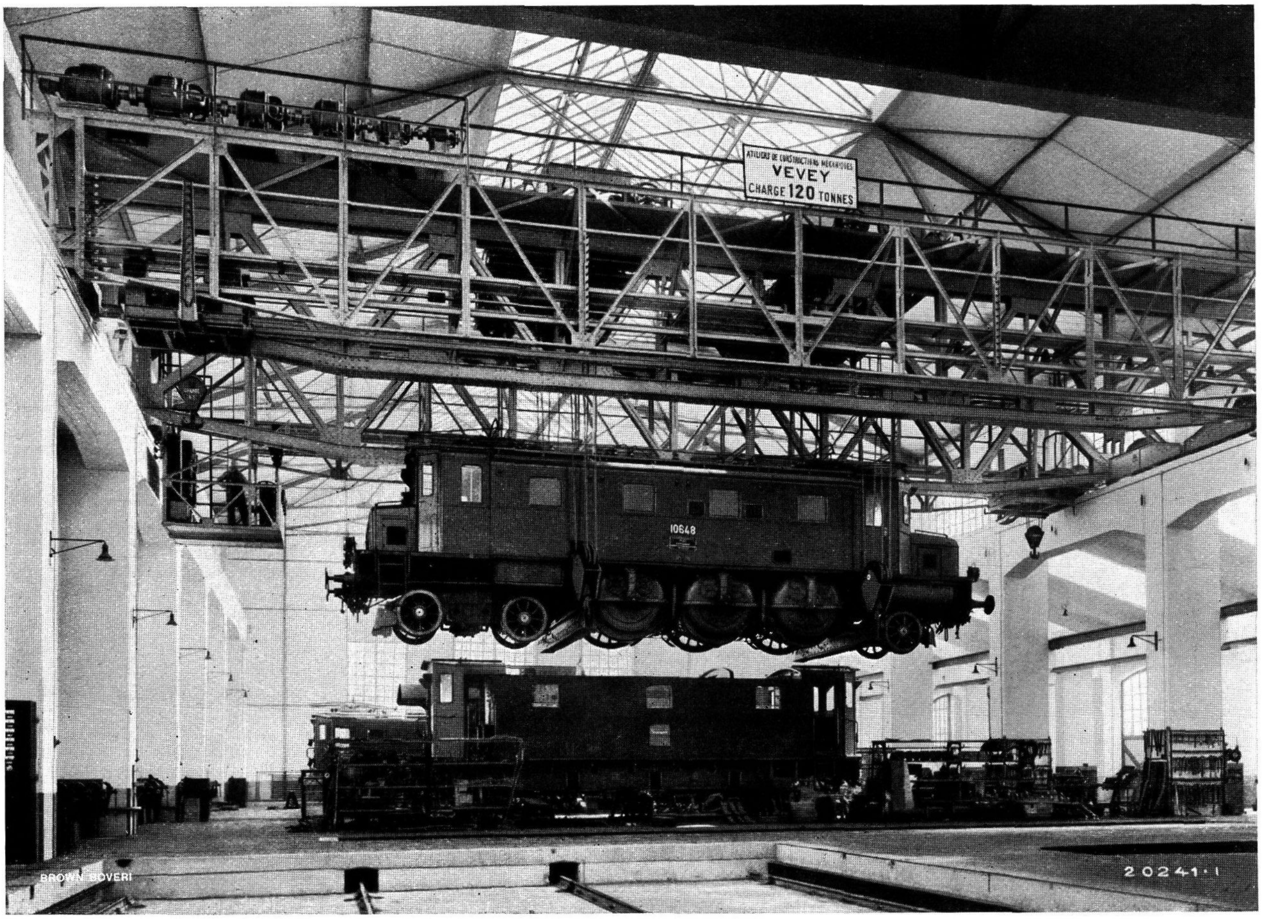

120 - TON LOCOMOTIVE CRANE AT THE YVERDON REPAIR SHOPS OF THE SWISS FEDERAL RAILWAYS.

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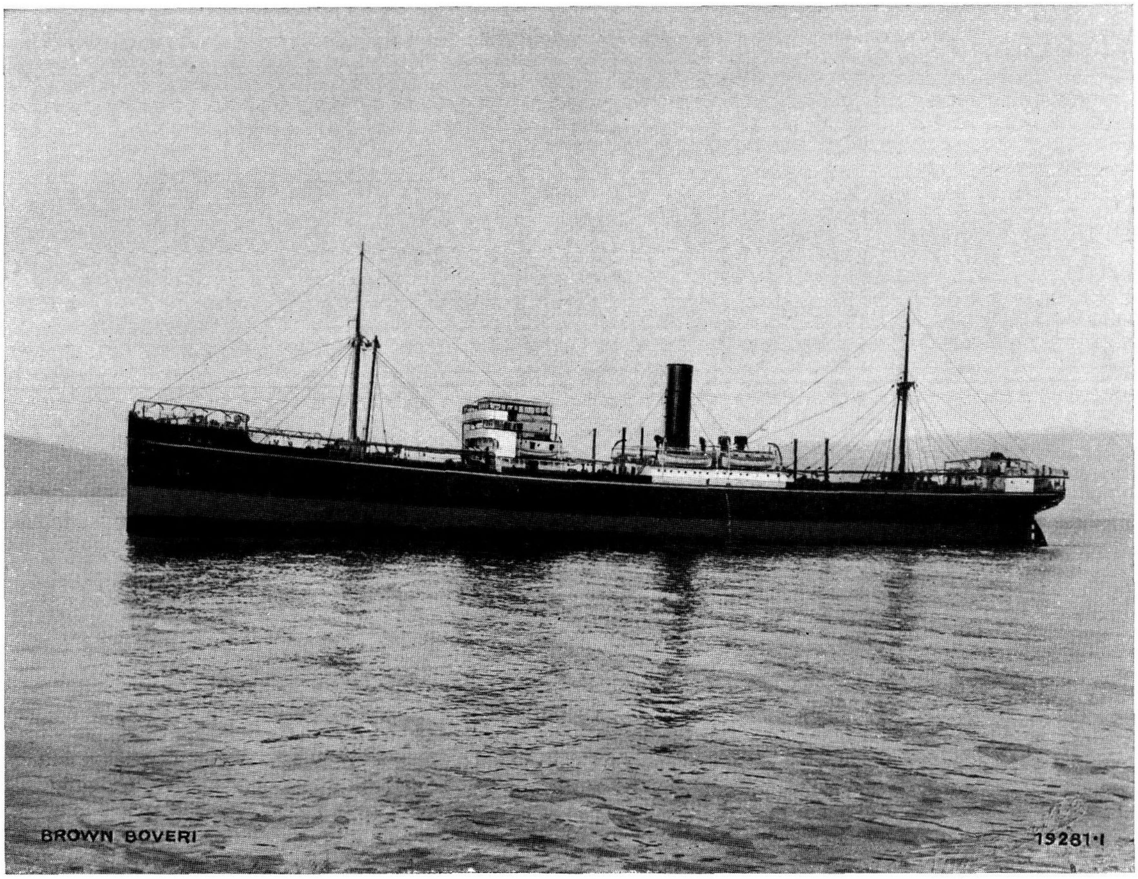
MARINE PROPULSION
AND
SHIPS' AUXILIARY MACHINERY



M. S. ATAGO MARU OF THE NIPPON YUSEN KAISHA,
equipped with two Brown Boveri scavenging turbo-blowers each for 540 m^3/min coupled to Sulzer, two-cycle Diesel engines.

TURBO-SCAVENGING AND SUPERCHARGING BLOWERS FOR MARINE DIESEL ENGINES
TURBO BLOWERS
FOR
FORCED DRAUGHT AND VENTILATION

THE BROWN BOVERI REVIEW

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

VOL. XIII JULY, 1926 No. 7

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NEW RAILWAY CONTROLLERS FOR DIRECT CURRENT.

Decimal index 621. 317. 4 : 621. 33.

If the development of apparatus for the control of direct-current motors is investigated, it will be found that the devices may be placed under three main headings:—

1. The box-type starter.
2. The tram-type controller (with main switch and reversing drum).
3. Contactors having elements operated either mechanically, electro-magnetically, or electro-pneumatically.

The box-type starter is still used for stationary motors; originally it was also employed for the control of lifting gear and vehicles. As spark-preventing devices are not usually fitted, and the current is led in through a single contact finger which slides over all the steps, excessive wear of the contacts occurs if the switch is operated more than about five times per hour. The suitability of these switches is therefore limited to simple connections with one motor.

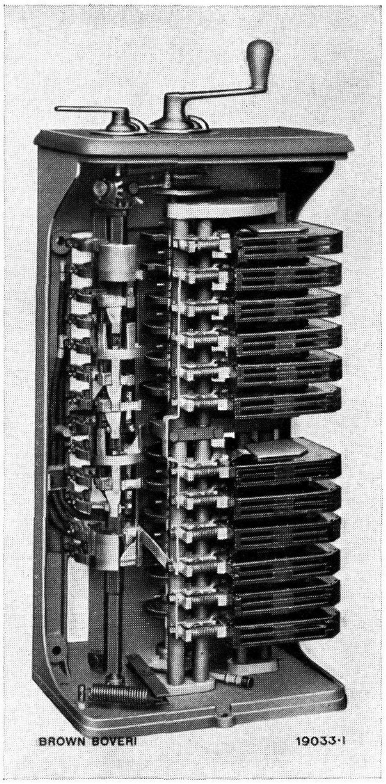


Fig. 1. — Type-P controller, opened, showing sparking chambers.

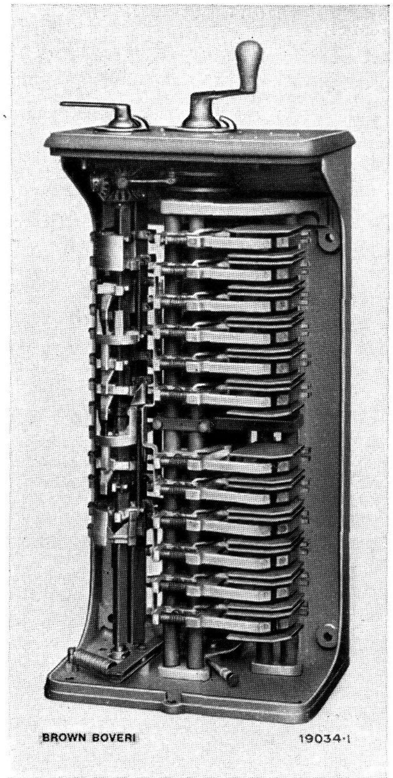


Fig. 2. — Type-P controller without sparking chamber.

For about the last thirty years, drum type controllers have been employed on electric vehicles. These controllers chiefly consist of a main cylinder and a reversing cylinder, the most varied connections being obtained by means of fingers and segments of different length. Special fingers and segments are provided for each step. The wear of the individual fingers is naturally much less than with a box-type starter, and an increased life of the contacts results from the fact that the sparking is considerably reduced by the magnetic blow-out. This type was generally employed by Brown, Boveri & Co. for pressures up to about 1000 V[1].

As the contact-wire pressure on direct-current interurban railways was increased, new controllers had to be developed because the distances between the current-carrying parts and earthed parts were too small for pressures above 1200 V, and the common blow out for all contacts, as shown in Fig. 3, was no longer sufficient. About 15 years ago, Brown, Boveri & Co.

[1] Die neuen Fahrschalter für Gleichstrom BBC Mitteilungen 1915 No. 4.

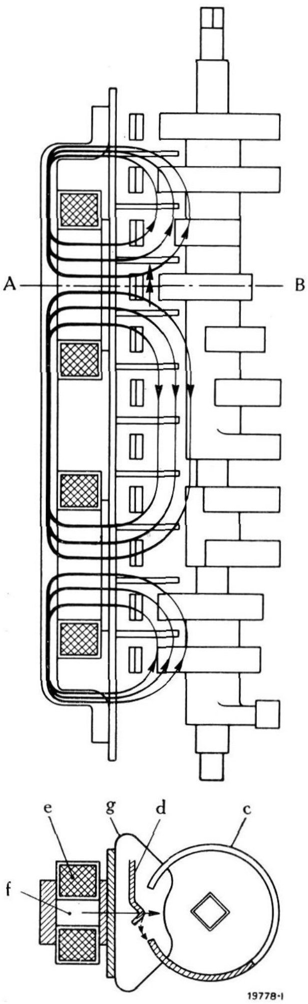


Fig. 3. — Diagrammatic representation of blow-out for a drum controller.

c. Switch drum.
d. Contact finger.
e. Blow-out coil
f. Iron core of blow-out magnet.
g. Partition for sparking.

built a new type of controller embodying entirely different principles. This controller was first used in the equipment of the Biasca-Acquarossa Railway[1]. The chief difference between this controller and the usual tram-type controller is found in the main drum. Instead of the drum, with copper segments which make variable connections between the fixed contact fingers, a number of cast-iron cams are mounted on the main spindle. Each cam operates a hammer switch which is provided with a separate blow-out, removable spark chamber and massive block contacts, and which is held closed by the pressure of a spring. Fig. 4 diagrammatically shows the direction of flow of the current in a switch element, and the direction of the lines of force in the blow-out magnet; the movement of the arc on breaking circuit does not change when the current is reversed, as occurs if collective blow-out coils are used. The cams cause the switches to open in the correct order. Fig. 3 shows a controller for direct current at 1200 V, as used on the Biasca-Acquarossa Railway. The switch elements on either side of the main spindle are similar to the contactors. The apparatus therefore is not different from a contactor control with mechanically operated elements. On account of the overall dimensions, these controllers are not suitable for erection in the drivers' cabs. It is usual to mount these controllers with the other high-tension apparatus in a cabin and to operate them by means of dummy controller in the cab.

Similar controllers were afterwards supplied for many local railways, for pressures up to 2400 V, both in Switzerland and other countries. The results obtained with the use of these controllers are most satisfactory.[1]

The controllers supplied for the five locomotives and two motor coaches of the Turin-Lanzo-Ceres Railway[2] are noteworthy as they are both drum controllers and cam-operated controllers. The direct-current potential of the contact line for this railway is 4000 V. Of the six independent switches, three are used for switching in or out and for the series-parallel connections of the four motors, while the remaining three are sparking switches for the starting and braking resistance drum which is operated completely without current.

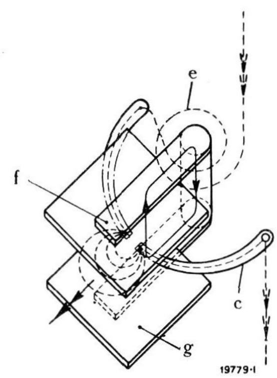


Fig. 4. — Diagrammatic representation of blow-out for a cam controller.

Current direction.
Direction of lines of force.
Motion of arc.

c. Switch element.
e. Blow-out coil.
g. Pole plate of blow-out magnet.
g. Sparking partition for blow-out coil.

The necessity for an improved controller became more and more apparent, even on interurban railways and tramways operating at low potentials. Indeed, many improvements had been made to drum controllers to enable the ever increasing motor output to be controlled. The contact fingers were fitted with individual blow-out coils, to enable a suitable blow-out effect to be obtained in both running directions, and also to permit speed

[1] Schweizerische Bauzeitung, 1911, Vol. 58 Nos. 17 and 18.

[1] See Revue BBC, 1915, No. 3 "Le chemin de fer Tavannes-Tramelan-Noirmont (Suisse)"; Revue BBC, 1915, No. 8 "Le chemin de fer Loëche-Loëche-les-Bains"; Revue BBC, 1916, No. 5 "Le chemin de fer Coire-Arosa"; Revue BBC 1918, Nos. 2—4 "L'équipement électrique du chemin de fer des Schoellenen"; Revue BBC 1921, No. 4 "Le chemin de fer local Peggau-Uebelbach"; Brochure No. 856 "The Nyon-St-Cergue-Morez Electric Railway.

[2] L'Elettrotecnica, 1921, Vol. VIII, No. 20, "Recenti impianti di trazione elettrica a corrente continua ad alta tensione". L'Elettrotecnica, 1925, Vol. XII, No. 13, "Le nuove automotrici a corrente continua 4000 V della ferrovia Torino-Cirie-Valli di Lanzo".

reduction step-by-step, without going to the off position each time. The contact arms are provided with hinges to facilitate inspection. Excessive wear of the fixed contacts as well as of the movable contacts could not be avoided.

Brown, Boveri & Co. have now produced a new controller which embodies the results of laboratory research and of investigations carried out under practical conditions on railways. These controllers are suitable for tramways and interurban railways and have the advantages of the high-tension controllers mentioned above; the dimensions are no greater than those of a drum-type controller for the same output.

Construction and operation. As a rule, a railway controller consists of a main drum for starting, braking and speed regulation, and a reversing drum to select the running direction, or to cut out single motors, or a group of motors, in the event of a defect. The new controllers (Fig. 4 and 5) are known as type P, and the reversing drum although of the usual form, is only rarely operated and is not under tension. A number of switch elements which are closed by the pressure of springs and opened by cams on the main shaft, are used to replace the main drum. When designing the switch elements which form the most important part, great care was necessary to ensure that the dimensions would not greatly exceed those of a similar drum-type controller. Eleven to seventeen elements, according to the required operations, are fitted in these controllers; the fixed and movable parts are secured to, and insulated from, the two iron transoms. The two contact blocks, made of copper are easily accessible and removable. A remarkably good extinguishing of the arc is obtained by means of the special shape of the contact arm, the blow-out coil and the spark chamber; also the wear of the contact blocks is reduced to a minimum. The number of contact positions with a cam-operated controller is considerably smaller than with a drum controller. The contacts of the latter kind of controller must be adjusted to have a two millimetre compression, and after 1·0—1·5 mm of wear has occurred they must be re-adjusted or renewed; re-adjustment is not necessary with hammer contacts. The contact blocks may be used to the last millimetre, as regulated by the lift of the cams; the slight roughness caused by arcing is not rubbed off, as with drum controllers, consequently the contacts have an exceptionally long life.

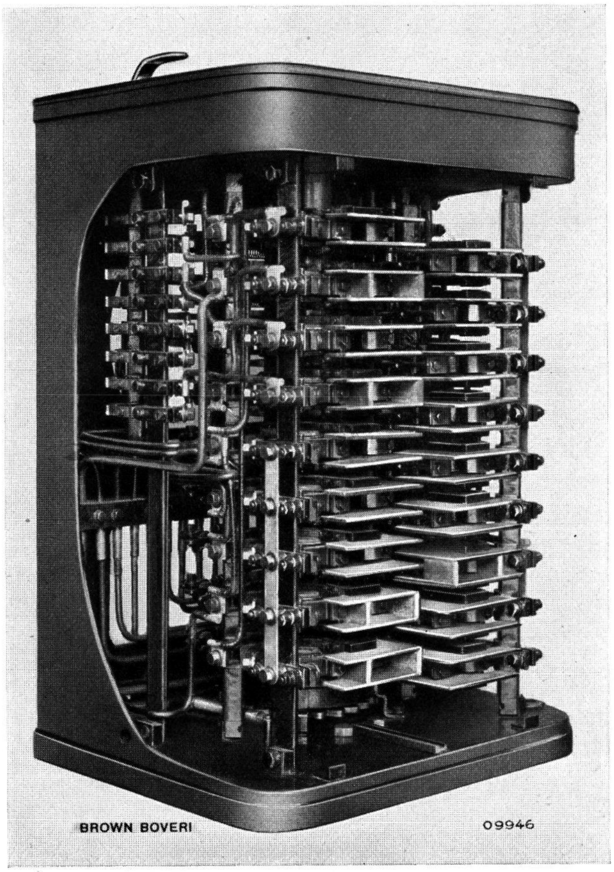


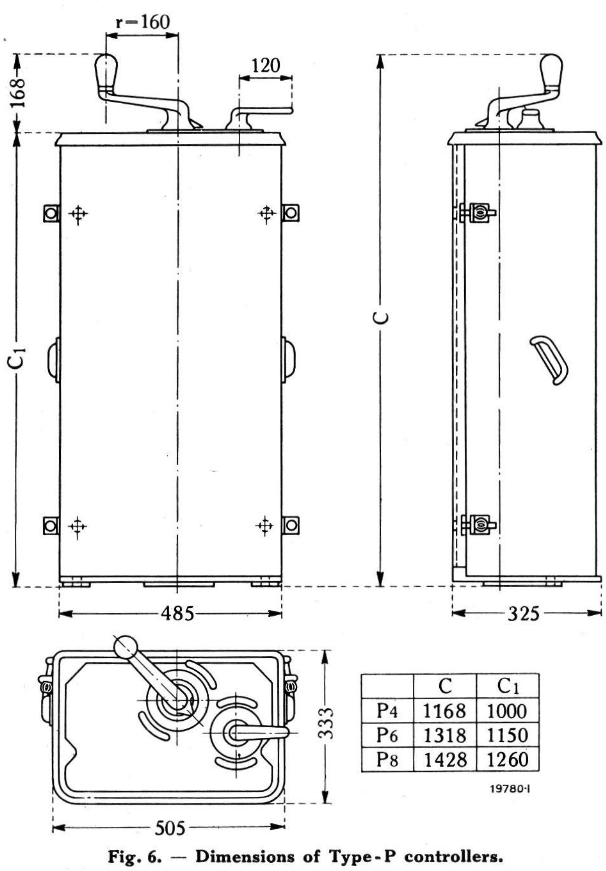
Fig. 5. — Controller (opened) as supplied to the Biasca-Acquarossa Interurban Railway.

The contacts are compelled to open by the cams, thus making it impossible for sticking to occur. A device consisting of a cam with roller lever is provided to equalise the torque of the main spindle, as much as possible, in all contact positions and to register the off position.

Wrong connections, particularly the operation of the reversing drum when under pressure, are avoided by interlocking the main spindle and the reversing drum. A crank with wooden hand grip is employed to operate the main spindle, the reversing drum being controlled by a simple lever. Neither of the handles can be removed except when the controller is in the off position. Electric or electro-pneumatic operation is used on large motor coaches.

These controllers are operated in a similar manner to those of the drum-type. After the reversing handle has been placed in the required running position, the crank of the main spindle can be turned from the off position, and thus start the motors. To brake the motors the crank handle is rotated from the running position to the braking position, by way of the off position. As the crank handle passes from the off position to the first braking position the reversing drum is rotated through a partial revolution by means of a cam and bevel gear, thus making the necessary braking connections.

Electrical data and connections. In tramways and interurban railways it is usual to employ two motors connected in parallel, or two groups, connected in parallel and each group consisting of two motors connected in series. These connections have the considerable advantage that it is possible to obtain two economical speeds which are in the approximate ratio of 1 : 2. Other economical speeds are obtained by field weakening, i. e., shunting or tapping the field. When braking electrically, the motors are disconnected from the overhead line, and connected in parallel with the armature connections reversed and the fields changed over. They then run as



	C	C1
P4	1168	1000
P6	1318	1150
P8	1428	1260

Fig. 6. — Dimensions of Type-P controllers.

generators loaded on to the starting resistances, by means of which the braking effect is regulated; should rail brakes be provided the braking current flows through them. If a motor becomes defective the journey can be continued with the active motor, or motor group. By suitable adjustment of the reversing drum, all poles of the damaged motor are disconnected. The journey is continued with only the series running positions effective; the parallel positions cannot be used. The controllers are made in three sizes, for 13, 15, and 17 switch elements. Their dimensions are shown in Fig. 6. The following table gives the number of the motors, their output and the service pressures for which the controllers are constructed.

Pressure in V	Hourly rating of motors H. P.	Hourly current rating A	Arrangement of motor groups	No. of switch elements		
				Normal connections	Rail brake connections	With field weakening [1]
500	2× 75	250		11	13	13
600	2× 90	250		11	13	13
750	2×110	240		11	13	13
1000	2×140	235		11	13	13
1200	4× 70	200	2 permanently connected in series	12	15	[2] 16
1500	4× 65	145		12	15	[2] 16
500	4× 60	400	2 permanently connected in parallel	13	16	17
600	4× 70	400		13	16	17
750	4× 80	360		13	16	17
1000	4× 80	270		13	16	17
1200	4× 80	220	2 permanently connected in series	14	17	—

[1] Field weakening by shunt connections in the parallel positions.
[2] Field weakening by means of tappings.

The size of the controller depends on the connections and the number of switch elements. Three of the different possible connections are shown in the diagrams (Fig. 7—9). Besides the development of the cam drum and reversing drum, typical, simplified connections for running and braking positions are shown. The development of the controller for two motors with combined brake connections, is shown in Fig. 8 in which five typical positions of the handles are depicted:— I = running position 1 (series), II = running position 7 (parallel), III = braking position 1, IV and V = running position 1 with motor I or II alone. The individual switches are denoted by I to XIII. Switches I, IX, and XIII are closed in the running position 1, all the remainder are open, the various

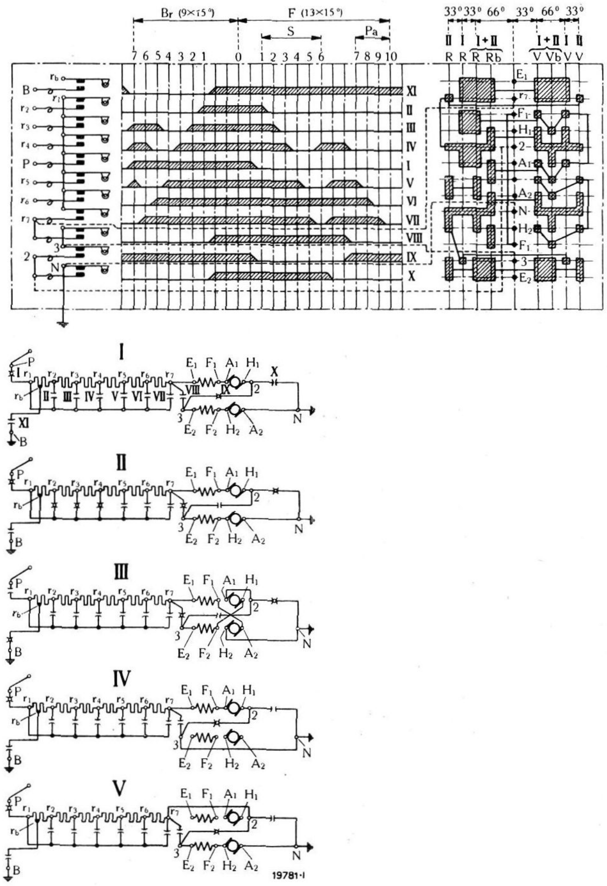


Fig. 7. — Connections for Type-P controllers, suitable for two motors at pressures up to 1000 V.

F.	Running.	Vb.	Forwards braking.
S.	Series connections.	Rb.	Reverse braking.
Pa.	Parallel connections.	I.	Running in series.
Br.	Braking.	II.	Running in parallel.
V.	Forwards.	III.	Braking.
R.	Reverse.	IV.	Running with motor I.
		V.	Running with motor II.

resistance steps are then bridged over in succession until, at position 6, both motors are connected directly to the contact wire in series and run at half-speed. On moving the crank handle to position 7 the following action occurs:— A part of the resistance is first switched in and motor I connected to the supply, motor II being short-circuited; the series connections between motors I and II are then opened, and finally both machines are connected in parallel. The series resistance common to both motors is gradually short-circuited, until, when position 10 is reached, both motors receive the full supply pressure and run at their normal speed. The controller is provided with 11 individual switches and a reversing drum with 13 contacts.

The connections shown in Fig. 9 differ from those described above, the two motors being replaced by two groups each consisting of two motors permanently connected in parallel. The groups are connected in a similar manner to the individual motors, as previously mentioned. In this case the number of economical running positions is increased by one, as, at the cost of a resistance stop, position 9 is used for short-circuiting, and position 10 produces field weakening. A resistance is connected in parallel with each of the four motor field windings. The

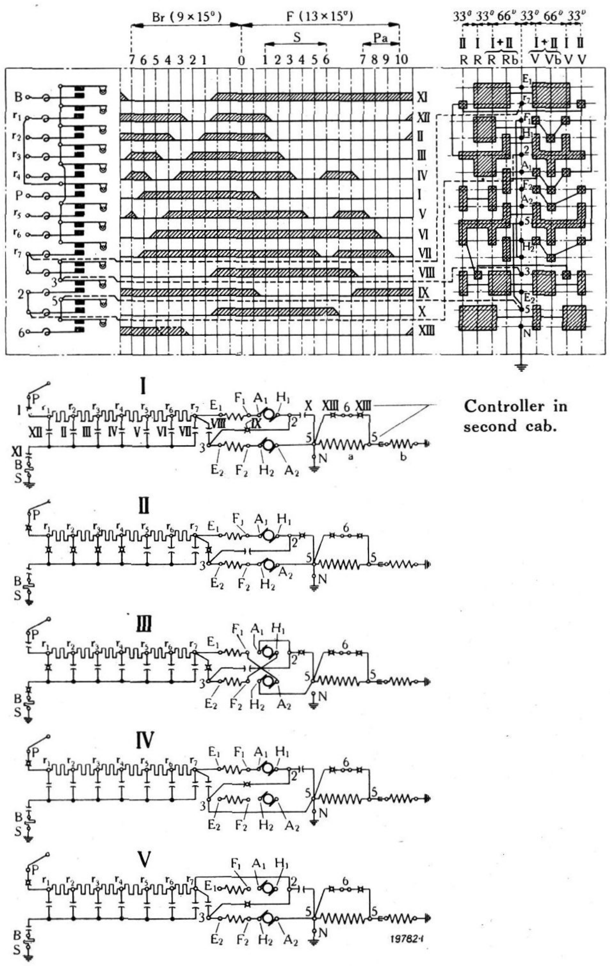


Fig. 8. — Diagram of connections for Type-P controllers, for two motors at pressures up to 1000 V, rail brakes with motor and overhead contact line.

F.	Running.	a.	Rail brake.
S.	Series connections.	b.	Solenoid brake in trailer.
Pa.	Parallel connections.	I.	Running in series.
Br.	Braking.	II.	Running in parallel.
V.	Forwards.	III.	Braking.
R.	Reverse.	IV.	Running with motor I.
Vb.	Forwards braking.	V.	Running with motor II.
Rb.	Reverse braking.		

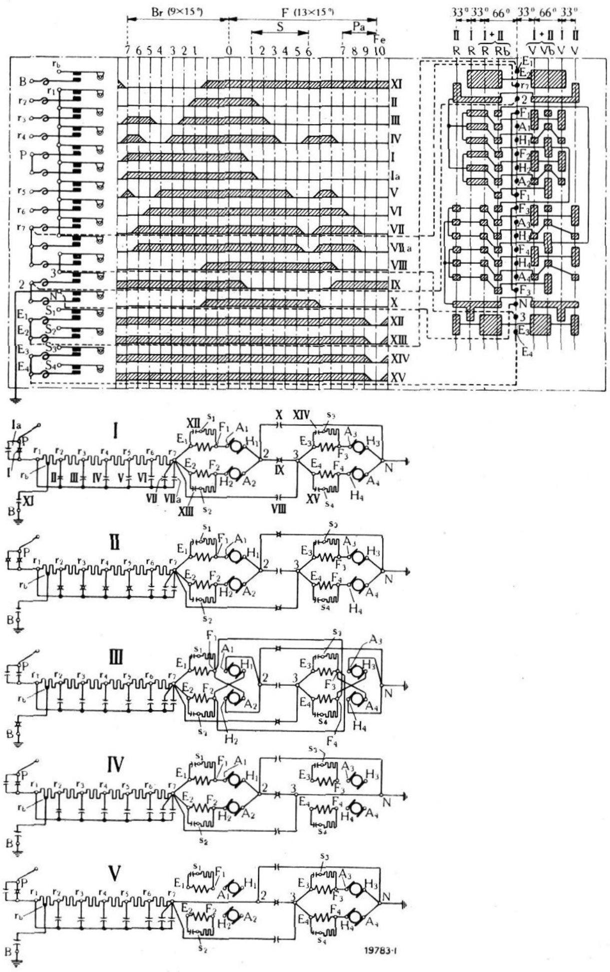


Fig. 9. — Connections of P-Type controller for four motors, divided into two groups permanently connected in parallel, pressure up to 1000 V.

F. Running.
S. Series connections.
Pa. Parallel connections.
Br. Braking.
V. Forwards.
R. Reverse.
Vb. Forwards braking.
Rb. Reverse braking.

I. Running in series.
II. Running in parallel.
III. Braking.
IV. Running by means of group I.
V. Running by means of group II.

weakening of the field results in an increased speed of the motors. The losses in the resistances are very small.

Two switch elements, connected in parallel, are provided for the two contacts I and VII which permanently carry the full service current. The controller consists of 17 switch elements and a reversing drum with 20 contacts.

Interurban railways, in which steep gradients occur, are generally fitted with electro-magnetic rail brakes. Fig. 8 shows connections suitable for the brakes of a vehicle with two motors. The short circuit brake is only applied in the first two braking positions, from the third, fourth or fifth stops onwards the rail brakes are supplied with current by opening switch XIII, according to the conditions of service. If fitted, the solenoid brakes of the trailer are connected from the first position. On the last stop the rail brakes are connected to the contact line by means of the series resistance.

Other connections, up to the total number of running and braking positions for the controller may be easily obtained by using cams of suitable profile, the maximum number of individual switches being 17.

The reversing drums of all controllers are provided with positions for one or both motors to run in either direction, as well as for the braking of both motors, in either direction. One motor alone cannot be electrically braked.

Results. The Brown Boveri new type of railway controller has already proved to be fully satisfactory on the various lines on which it is in service. Between 1921 and the commencement of 1926 more than 220 controllers have been delivered.

The covers of two controllers in use on the Mannheim Tramways were sealed for six months, during which time no inspection took place. After this time the controllers were still fit to remain in service for a further three months without overhauling. The Administration of the Basle Tramways have found from experiences that these controllers need only be examined and freed from dust once every three or four months. With drum controllers an examination is necessary every eight or ten days, occupying two working hours for two controllers per car. The annual cost for overhauling drum controllers, including material necessary for replacing contact fingers and segments, amounts to more than 100 francs. It is not yet possible to give any figures for the maintenance of the new controllers as most of those in service are still operating with the original contacts. The small maintenance costs and the great reliability of the new type, when compared with drum controllers, more than compensate for the somewhat greater first cost.

(MS 387) *G. Gut (J. R. L.)*

THE FATIGUE OF METALS WHEN STRESSED BEYOND THE YIELD POINT.

Decimal index 620. 112. 3.

GENERAL.

DURING the manufacture of a machine excessive strains cannot always be avoided. Every time a metal is worked at ordinary temperature a permanent change of shape takes place, i. e., stresses which exceed the elastic limit to a greater or less extent may be set up. This kind of stress is all the more important because its magnitude cannot be detected by the usual tests, and its effect upon the elastic properties of the material is only imperfectly known. Some exact knowledge of these facts is all the more desirable as excessive stresses are often purposely imposed on machine parts during the acceptance tests. One of the oldest, and still commonly used methods of testing depends on the application of a single overload. For example a finished steam boiler is subjected to a pressure considerably higher than any likely to be attained in service. If this test is withstood without appreciable change of shape — exact measurements of the deformation during the test are rarely made — the test is said to have been withstood and the boiler is passed as reliable. So long as machines were constructed with a very large factor of safety and with plenty of material even the test mentioned above can rarely produce an excessive strain; such a test would however only show very large mistakes. The modern tendency towards complete utilisation of the material is not always indicative of excessive economy, but it is often a prime factor in the design; in automobiles, aircraft, or gas cylinders, the weight is reduced to a minimum although additional costs may be incurred by this reduction. A further example is found in parts stressed dynamically — here a strengthening by an increase of the amount of material may entail a greater load. In designs as described above, where the material is fully utilised and consequently highly stressed, the dangers of such methods of testing cannot be overlooked. The overload may permanently change the form, as a result of which a variation of the stress distribution may be set up, and in many instances this change may not be advantageous. The excessive stresses set up during testing may have the effect of enlarging a small fault. During the test a small crack, starting from inclusion of slag or roughness on the surface, may form. Such an occurrence would have never resulted from ordinary stressing, but when once present is a source of danger even at normal working stresses. The suitability of the overload test must therefore be regarded as questionable until a thorough knowledge of the stresses produced by it has been obtained. At present overload tests can only be entirely recommended when similar overloads will probably arise occasionally during service. In such cases the possibility must be provided for by suitably dimensioning the various parts.

The effect of cold working on a material appears to be closely related to the question of fatigue discussed in this article. This also applies if the material at ordinary temperature is permanently deformed by external forces. Most cold working differs from single axis stresses, as the necessary change in the shape is usually produced by stresses in three directions, whereby the nature of the internal stresses and their influences upon the metal can be affected in an entirely different manner. More than a half of the work necessary when drawing a metal arises from pressure on the side of the die; only about 30—40 % of the total work performed is produced by the axial force. It is not possible to form conclusions as to the behaviour of a material stressed in a single direction, if results relating to cold drawn material only are considered, since, as well as the change in the internal stresses, the quality of the surface is vastly different in each case; the latter circumstance is of the greatest importance, as will be shown in the following paragraphs.

Bauschinger's investigations on stresses in one direction have shown that if the limit of proportionality is slightly exceeded the yield point is raised, but, on the contrary, if the material is overstrained considerably beyond the yield point the limit of proportionality will become quite small. If a specimen is subjected to a reversal of stress, e.g., a specimen previously stressed in tension is afterwards tested in compression, the test shows that the yield point is lowered. If the stresses are always applied in the same direction, the yield point appears to have an increased value after each test, while if the stresses are reversed each time, the yield point is found to have a lower value. If the specimen is allowed to rest unstrained for a long time after testing, the yield point gradually returns to its initial value. Gentle heating accelerates the recovery.

However, no deductions from reports on an iron specimen enable an accurate forecast to be made of the behaviour under alternating stress of a part of a structure which has been previously overstrained. The favourable increase of the elastic limit for stresses of one sign may easily be outweighed by the reduction of the limit for stress of the opposite sign if the stresses are to vary between equal positive and negative values. The utility of an increased value for the yield point is also problematic if it is accompanied by a reduction of the elastic limit to zero.

The questions raised can only be decided by fatigue tests on a specimen which has been previously strained. Fatigue tests have commanded more and more consideration during the last decade and their application increased considerably. The published reports of these tests, although touching upon the effects of overstrain, do not deal with the matter exhaustively. Some treatises on this subject however may be mentioned.

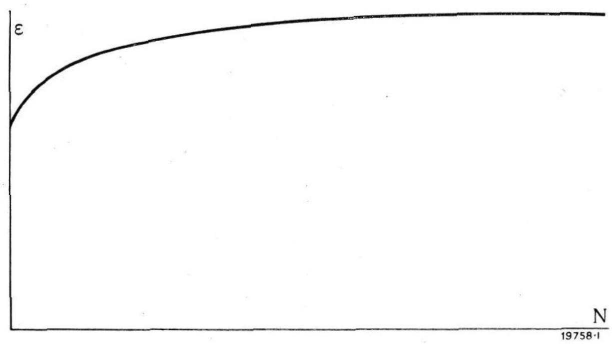


Fig. 1. — Increase in deformation with the number of repetitions.

N. number of repetitions.
E. extent of deformation.
(Mason).

For specimens subjected to repetition bending-tests, the stressing forces and the deformation being measured simultaneously, W. Mason[1] established that after a definite stress has been exceeded the extent of the deformation increases with the number of changes; this limit he calls the fatigue limit (Fig. 1). The increase falls off more and more until it finally stops altogether. The continued repetition of stress upon a specimen of mild steel having a carbon content of 0·12 % will eventually lead to a fracture. For example, the maximum change of shape occurs in a specimen after 1·75 million repetitions and the deformation then remains constant until fracture occurs after a further half million changes, in all making a total of 2·25 million repetitions. If the repetition test is interrupted and the specimen allowed to rest, the deformation after re-starting is smaller than before but soon increases again, following a curve similar to that in Fig. 1. It is worthy of note that the slower the changes of stress occur the greater the deformation.

[1] Engineering, 15th September 1916 and the 23rd February 1917.

P. Haigh[1] has established, for copper test pieces, that the permanent deformation occurring under either static or fluctuating loads is similar, but that caused by the latter kind of load attains far higher values before fracture occurs.

Ludwik and Scheu[2] have shown that the effect of fatigue up to a certain limit is to increase the strength of the material, at the same time repeated alternations of the load cause a loosening of the structure; this can lead to a permanent change of form and finally result in fracture. According to these authors, the curve for change of form for fatigued metals determined by statical considerations agrees with that for unstressed metal but discontinues earlier. The fatigue curve for mild steel which has been once overstrained is certainly higher than the curve for heat-treated metal, but reaches the same limiting stress asymtotically.

The investigations of F. C. Lea[3], also carried out on mild steel show the remarkable fact that the resistance offered by the specimen to stresses of an alternating character is greater at 400° C than at ordinary temperatures. Material shows an increased resistance to fatigue at 16° C, after having been previously subjected to alternating stresses at 400° C. In a smaller degree, after fatigue at the usual temperature, an improvement in the properties of the specimen was established.

The above problem has been carefully examined in the laboratories of the University of Illinois, U.S.A.

[1] Institute of metals, September 1917.

[2] The Zeitschrift des Vereins deutscher Ingenieure, February 10, 1923.

[3] The Engineer, February 16, 1923.

The results of the investigation are published by this academy in Bulletins Nos. 124, 136 and 142. H. F. Moore and D. M. Jasper observed an increase of both the static and ultimate strength under fatigue as a result of alternating stresses if these do not exceed a certain value; with certain untreated steels the increase of the fatigue stress was 25 %. After such facts as these have been established, the existance of the fatigue strength can scarcely be doubted any longer. The following table publishes the results of tests which show the action of repeated excessive stresses upon the fatigue limit.

Percentage by which the fatigue limit was exceeded	Number of repetitions	Reduction of the fatigue limit as a percentage
10	5000	practically 0
20	5000	„ 0
29	1000	„ 0
38	100	„ 0
35	1000	„ 4
29	5000	„ 11

The test material was sorbitic steel with a carbon content of 0·49 %.

There is therefore no danger in exceeding the fatigue limit, provided the excess is not too large, or that the number of repetitions is not too great. The overstraining as well as the subsequent fatigue were carried out on a machine for repeated bending produced by rotation. The results of the tests performed in the Brown Boveri laboratories and described below, agree fairly well with these statements. A series of specimens of rolled mild steel were permanently elongated by about 10 to 30 % and after heating to 260° C for a quarter of an hour, carefully polished and examined. The fatigue limit had been increased by 25 and 46 % from the value for untreated materials. At the same time the elastic limit was raised by 57 and 82 %, but the breaking stress was only raised by 10 and 19 %, thus the increase of the fatigue limit corresponds to a mean value. The authors explain that other tests show no increase in the fatigue limit as the specimens were tested immediately after elongation, so that the surface of the test piece was rough from the treatment. A considerable influence in the above tests is the recovery of the specimens at 260° C which results in raising the elastic limit.

Fig. 2 shows the reduction of the fatigue limit under repeated bending caused by rotation, for specimens of the same mild steel as was used in the previous tests, the specimens being previously subjected to overstrain

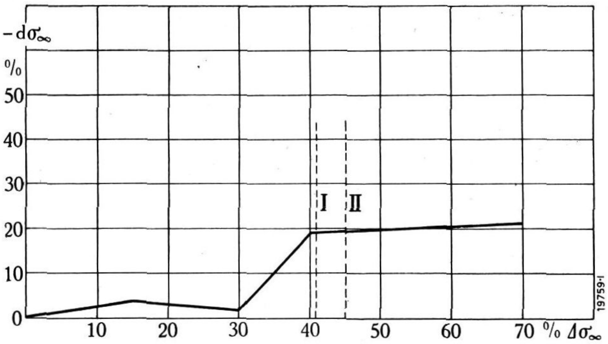


Fig. 2. — Percentage reduction in the fatigue limit (ordinate) after overstraining 20 times by axial tension, the overstrain exceeding the initial fatigue limit by the percentages on the abscissae.

$\Delta\sigma_\infty$. Percentage by which the fatigue limit was exceeded.
$-d\sigma_\infty$. Percentage reduction of the fatigue limit.
I. Limit of proportionality.
II. Yield point.

by axial tension. The curve corresponds to the mean value of three independent determinations which were in fairly good agreement. The first test was made directly after overstraining and the second after immersion in boiling water and putting aside for ten hours and the third on a test piece that had lain untouched for three months. From these results it is noteworthy that a considerable reduction of the limit of fatigue only occurs if the material is stressed 20 times above the original elastic limit whereas, in agreement with the former results, smaller tensions had no noticeable effect.

The most recent investigations are for the most part concerned with the heat treatment and the polish. From the previous remarks, specimens which have been heat-treated carry overloads better than if the structure is sorbitic. For example a sorbitic steel showed a reduction of the fatigue limit of 22·9 % after an overstrain of 70 % had been applied 20 times, whereas, after heat-treating, a reduction of the fatigue limit of less than 10 % was found for the same steel, after an overload of 80 % had been applied 20 times. Grinding the stressed test piece has a favourable, although not a very large, effect. A reduction of the fatigue limit by only 16·7 % occurred by stressing of the specimen after it had been ground, one of 22·9 % was obtained when the specimen was tested directly. Numerous tests prove that if the fatigue limit has been lowered by overstrain it can be raised by subsequent repeated loading by a small stress, but the fatigue limit may not completely regain its former value.

INVESTIGATIONS BY THE BROWN BOVERI MATERIALS TESTING DEPARTMENT.

These tests which were undertaken before the publication of the results of the latest American researches, were carried out upon commercial mild steel specimens, 27 mm in diameter and having the following properties:—

Yield point . . .	33—37 kg/mm^2
Ultimate strength .	46—50 kg/mm^2
Elongation . . .	28—30 %
Notched bar test .	11— 6 mkg/cm^2

Fig. 3 gives an average load-extension diagram for the material and Fig. 4 reproduces the structure as seen microphotographically.

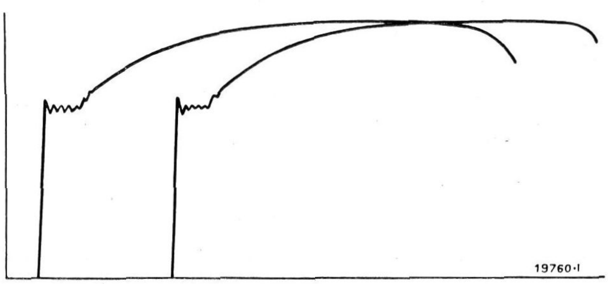
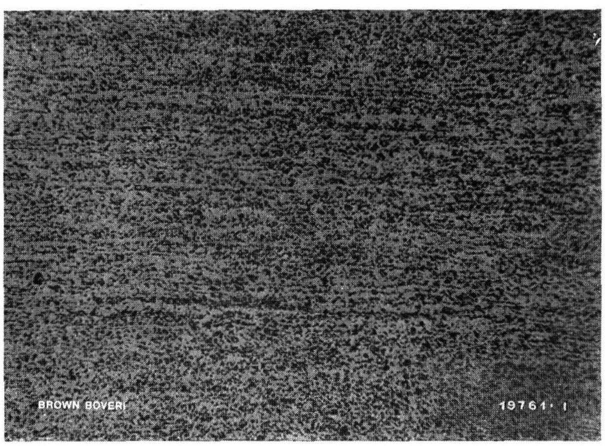


Fig. 3. — Load-extension diagram of the material tested to destruction.

The material was fatigued by repeated bending caused by rotating under load. The form of the test pieces used, which were ground to a circular section, is shown in Fig. 5. The apparatus was driven at 1000 r.p.m. The values for the fatigue stresses were calculated from the loads in the usual manner.

It was decided to test commercial mild steel in order to form an opinion of the behaviour of a good, largely used material. The inclusions, always present in such a material, can exert a considerable influence upon the strength of the specimen under repeated stress, according to their position. In fact occasional measurements deviate largely from the mean curve. Where the deviations were very large and could be directly traced to either obvious lack of homogeneity of the material or careless turning at the shoulder, the results were not used. If the curve for steel is not horizontal after ten million repetitions, then lack of homogeneity in the material may be assumed. The fatigue curve for the material after 15 million repetitions, and perhaps even beyond that limit still shows a tendency to fall (Fig. 6, curve 1) whereas in the tests on steel at the University of Illinois, previously mentioned, the horizontal branch of the curve was usually reached after a few million, but certainly after ten million repetitions.

In order to point out the influence of a previous overstrain, the fatigue curves were obtained for a number of specimens which had been previously subjected to an elongation of 5—10 %. In these cases the



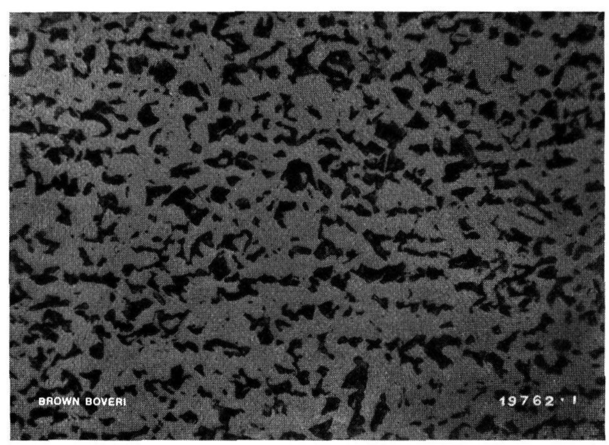


Fig. 4a and 4b. — These two photographs show the structure of the steel on a longitudinal section.
Magnification 50 and 150 respectively.

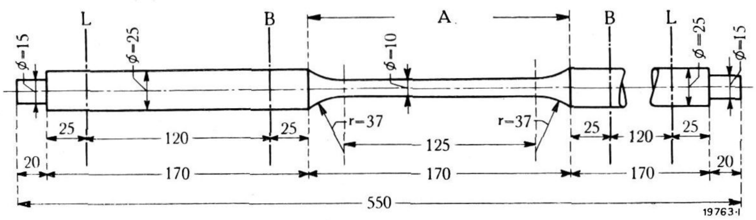


Fig. 5. — **One of the test pieces.**
A. Ground to size.

permanent elongation was about 0·2 % less than the total elongation and the diameter was reduced to 9·78 and 9·55 mm. A second series of test pieces were turned to a diameter of 16 mm, then elongated by 5—10 %, and subsequently turned and ground to 10 mm diameter. The fatigue strength of the material as supplied (Fig. 6, curve 1) was 23 kg/mm^2; the tensile stress produced exceeded this value by 75 % when test pieces were elongated by 5 %, and by about 98 % for specimens which had been elongated by 10 %. Fig. 7 reproduces some typical extension diagrams.

The lowering of the fatigue strength depends upon the magnitude of the initial overstress, that with 5 % elongation is greater than at 10 %, but in both cases it remains within the limits of about 10 % of the original value. The subsequent finishing operations partially compensate for the losses in the specimens which underwent a 5 % elongation, while with the test pieces elongated by 10 %, the fatigue strength even exceeds its original value.

These observations can only lead to the following conclusions:—

Overstressing a material leads to two different and opposing results. The overstress first strengthens the

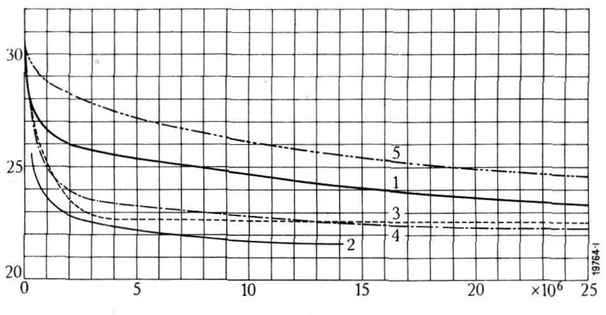


Fig. 6. — **Fatigue curves.**

1. Original material.
2. Material after 5 % elongation.
3. Same material as 2, but turned and polished before fatigue test.
4. Material after 10 % elongation.
5. Same material as 4, but turned and polished before fatigue test.

material, and then destroys it by loosening the structure. If machined specimens are overstressed then the latter influence predominates. A part of the effect is caused by the roughening of the surface, and this can therefore be removed by subsequent machining. The fact that the fatigue curves for specimens which have been more heavily stressed are higher than if the specimens had not been so treated must be ascribed to the strengthening produced by working when cold. From these investigations it was found that the curves for specimens which had been subjected to an elongation of 10 % and then machined were

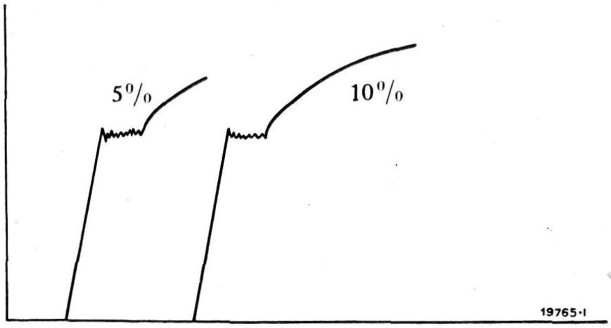


Fig. 7. — **Load-strain curves of the specimens previously elongated by 5 and 10 %.**

higher than those for pieces tested in their original state. The raising of the fatigue limit, however, was considerably less than was suggested in the reports of the University of Illinois. This may be attributable to the fact that the test pieces used in the Brown Boveri laboratories were not treated by heating after overstressing, and that the material employed was of ordinary purity.

Perhaps the disadvantageous results of overstraining become more perceptible in impure material than in particularly pure kinds of steel, because each inclusion may be the starting point of microscopic cracks. The condition of the surface of the bar becomes of unduly great importance in repeated bending, because the maximum values of the stress only occur in the outer fibres. With uniform distribution of stress over the whole section the relative increase of endurance produced by polishing might thus be expected to be smaller.

After several million reversals no alteration in the micro-structure could be observed.

Even if the above series of tests was too limited to permit of important general conclusions, one thing follows definitely from the results, i. e., an overstress which is only applied once but carried to a very high value has a comparatively small influence on the limiting fatigue stress of the material. Even overstresses which approach the tensile strength only reduce the limiting fatigue stress by about 10 %. This reduction becomes smaller or may even be turned into an increase if the specimen is subsequently machined and ground.

As has already been mentioned no definite conclusion with regard to the behaviour of cold drawn material can be obtained from these results. It may however be assumed that the drawing process, which has certainly a more favourable result than overstressing in one axis only, has no disadvantageous influence on the resistance of the material to fatigue. Further investigations, which were also carried out at the University of Illinois have actually shown that cold-drawn, medium-hard steel for screw cutting shows a resistance to fatigue of 47 % of the breaking strength (repeated bending by rotation), this being in perfect agreement with the conditions found for rolled specimens. After heat treatment at 700—850°C the metal showed a reduction of the fatigue limit, and of the tensile strength as well, the proportion of the two values remaining unaffected.

(MS 383) *Dr. E. Honegger (J. R. L.)*

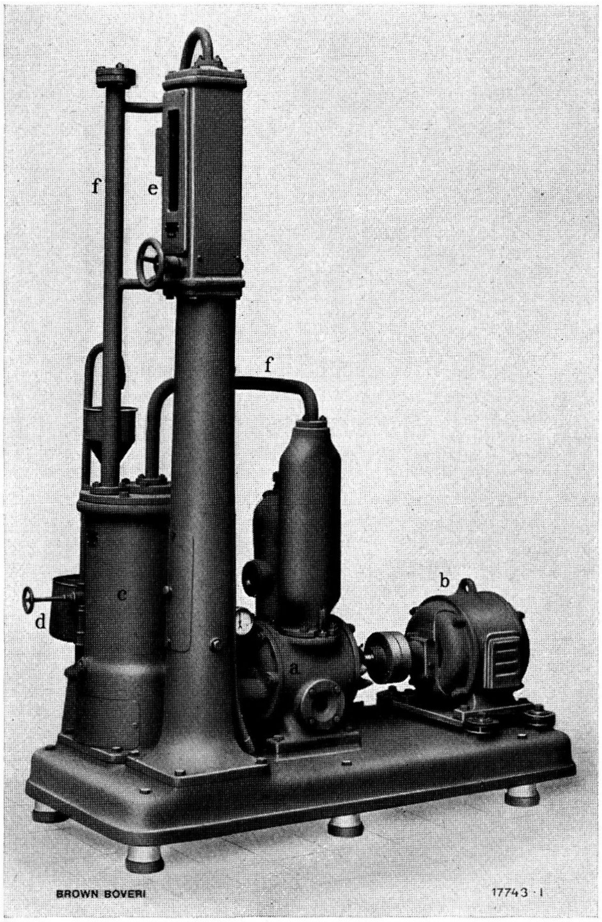
Centovalli Railway (Locarno-Domodossola), Viaduct over the Riale dei Mulini, with the village of Intragna in the background.

VACUUM PUMP SETS FOR MERCURY-ARC POWER RECTIFIERS.

Decimal index 533. 8: 621. 313. 73.

THE development of the mercury-arc rectifier, with metal cylinders, has naturally placed fresh stipulations upon the vacua required in order to satisfy the increased demands made upon rectifier installations in service. The pioneer work in this direction has been carried out by Brown, Boveri & Co., to whom the successful development of the vacuum pumps for mercury-arc power rectifier is due. They were also the first firm to appreciate the importance of the high-vacuum, mercury-vapour pumps for exhausting the rectifiers, and pumps of this type in conjunction with rotary oil pumps are employed with their rectifiers.

The Type GRL air pumps (Figs. 1 and 2) which have been supplied with rectifiers since 1923, are able to satisfy all demands for reliability in service. In spite of the number of components and their various actions, these air pumps require only the simplest attendance, and may be entrusted to untrained personnel, as it is impossible to make wrong connections. All operations requiring specialised knowledge or particular care are performed automatically. Experience has shown that the operation of the automatic devices is perfectly reliable. This type of air pump has been so simplified that it may be used without modification in unattended stations as well as those which are not automatic. A complete pump set comprises: —



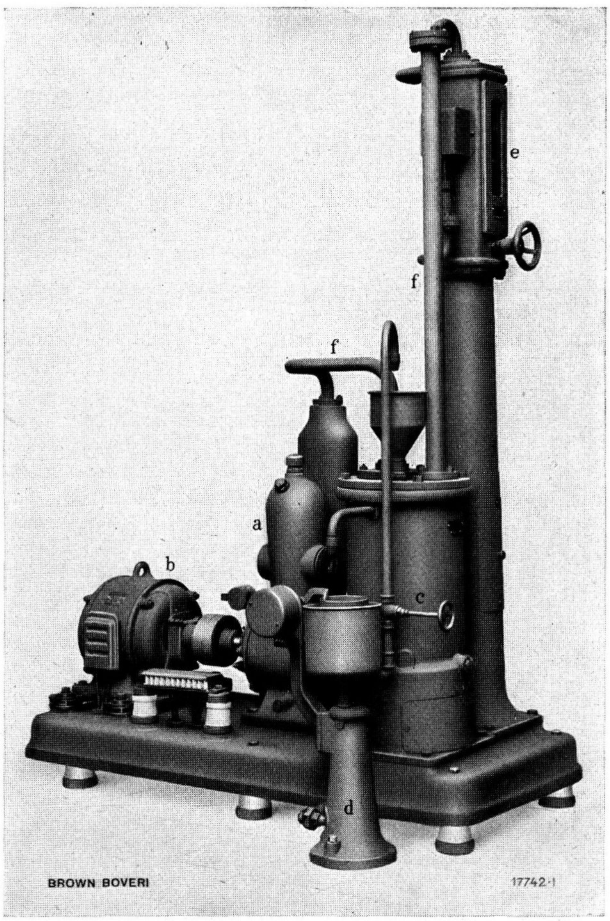


Fig. 1 and 2. — Air pump set type GRL (front and back views).

a. Preliminary vacuum pump with automatic oil pressure governing type GRP. b. Driving motor for preliminary vacuum pump. c. High vacuum mercury pump type GRH. d. Circulating-water fittings with alarm for the high-vacuum pump. e. Compression vacuum gauge type GRK, with hot wire gauge mounted on the side. f. Preliminary and high-vacuum piping.

1. A preliminary vacuum pump with combined automatic oil-pressure governor, Type GRP.
2. A driving motor for the vacuum pump.
3. A high vacuum mercury vapour pump, Type GRH.
4. The water supply fitting for the circulating water of the high-vacuum pump.
5. A vacuum gauge (one compression vacuum-gauge, Type GRK; if required by the conditions of the particular installation, a direct-reading vacuum gauge is also provided).
6. The preliminary and high-vacuum pipe lines.

These various components are mounted on a common baseplate. As the complete pump set is connected to the rectifier by the metallic vacuum pipes, it is at the same potential as the rectifier. Supporting insulators are therefore used to insulate the set from the earth.

1. *The preliminary vacuum pump* has to raise the pressure of the air-gas mixture contained in the receiving vessel (the rectifier) to that of the outside air (i.e., to atmospheric pressure); the mixture has previously been compressed by the high-vacuum pump. Apart from the considerations of capacity necessary, it is of considerable importance for the reliability of the installation that the pressure stages of the preliminary and high-vacuum pumps sufficiently overlap in their range of operation to prevent any interruption occurring in the high-vacuum pump (Fig. 3). A high-speed rotary oil pump, directly coupled to its driving motor is therefore used for the preliminary vacuum pump (Fig. 4). In order to be suitable for the oil-pressure governing, which is described later, a mineral oil, having the lowest and most gradual viscosity curve possible, is used as the medium in these pumps. The limit of the vacuum depends upon the vapour pressure and temperature of the sealing fluid and amounts to $2{\cdot}5 \times 10^{-2}$ to $1{\cdot}5 \times 10^{-2}$ mm of mercury absolute, at a normal temperature of 20° C. This limiting vacuum can be strongly influenced by the partial pressure of water vapour, according to the moisture contained in the oil, so that under certain circumstances the preliminary vacuum produced may not be sufficient to ensure the proper working of the high-vacuum pump which runs in series with the preliminary pump. In order to exclude this as far as practically possible, the Brown Boveri preliminary vacuum pump chiefly differs from the other existing designs in that the use of a vacuum sealing gland in the interior of the pump is avoided, so that the complete pump may be constructed as an *enclosed type.* The only point at which the oil is in direct connection with the atmosphere is at the chimney on top of the exhaust dome, so that the absorption of moisture is reduced to a minimum. Any moisture expelled from the apparatus collects on the bottom of the exhaust dome, and from there reaches the outer casing by means of a suitable opening. The water can do no damage in the outer casing, and, owing to its greater density, it collects at the bottom of the casing, whence it can be run off from time to time without interfering with the maintenance of the service. This type of pump, patented by Brown, Boveri & Co., also enables every inspection to be carried out in the simplest manner, all parts being readily accessible. The pump chiefly consists of a double casing in which the eccentric rotor, with the plate which acts as a rotating piston, is mounted. The pump is made with a double casing to ensure that a possible leak in the inner casing does not admit air but only oil, which is entirely harmless. The exhaust dome, and a valve which governs the escape of the air and the entrance of the oil, are fitted above the exhaust port. The valve is under oil and regulates the entrance of air and oil.

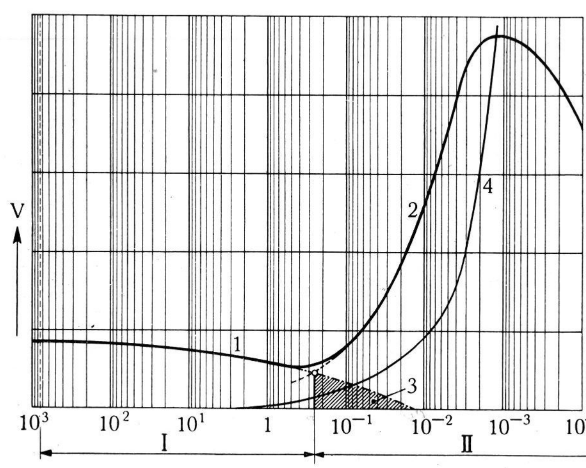


Fig. 3. — Characteristic curves for type GRL air-pump set.

1. Preliminary vacuum pump.
2. High vacuum pump.
3. Overlapping of capacities.
4. Theoretical pv curve for the optimum of the high vacuum pump.

I. First pressure stage (preliminary vacuum pump).
II. Second pressure stage (high vacuum pump).

The dotted line to the left represents the atmospheric line. The abscissae give the pressure in mm of Hg absolute.

An uninterrupted circulation of the oil is necessary in order to maintain the lubrication and sealing continuously, as well as to fill the clearance spaces of the moving parts with oil. If the clearance spaces were not oil-filled it would be impossible to maintain the necessary preliminary vacuum. The pump requires about eight kilogrammes of oil. A gauge glass on the exhaust dome enables the level of the oil to be observed. By reason of its *enclosed design,* the Brown Boveri pump enables

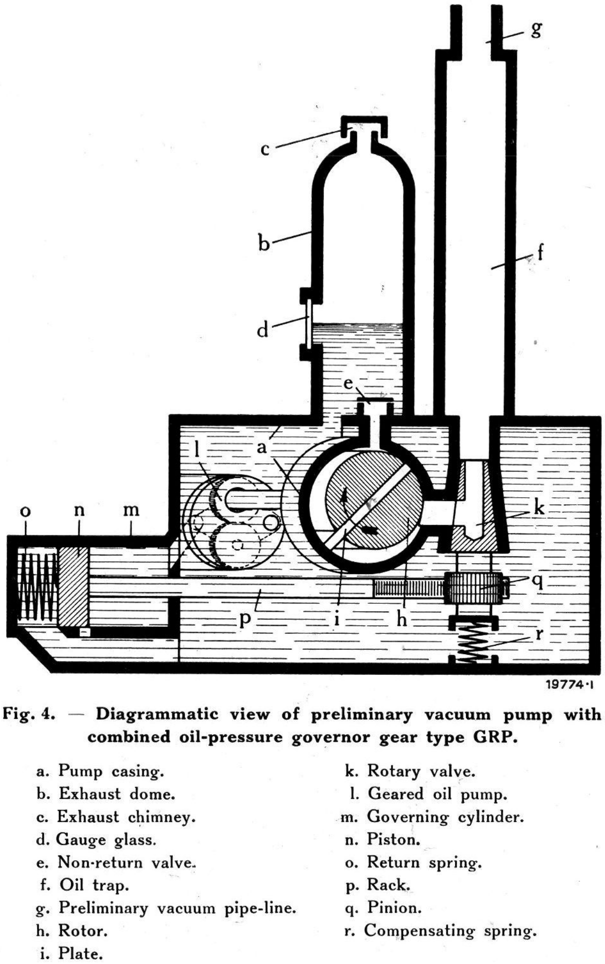


Fig. 4. — Diagrammatic view of preliminary vacuum pump with combined oil-pressure governor gear type GRP.

a. Pump casing.
b. Exhaust dome.
c. Exhaust chimney.
d. Gauge glass.
e. Non-return valve.
f. Oil trap.
g. Preliminary vacuum pipe-line.
h. Rotor.
i. Plate.
k. Rotary valve.
l. Geared oil pump.
m. Governing cylinder.
n. Piston.
o. Return spring.
p. Rack.
q. Pinion.
r. Compensating spring.

the oil to be used as the sealing fluid required to produce the vacuum, and also for sealing the complete casing, as well as for the automatic lubrication of all moving parts, and finally, as a medium for the oil-pressure governing.

The automatic oil-pressure control gear, patented by Brown, Boveri & Co., is mounted in the casing of the vacuum pump (Fig. 4), and is provided to open the vacuum lines after the preliminary vacuum pump has been started, and also to close the pipe lines, and thus maintain the vacuum, in the event of the driving motor stopping or running at too low a speed. This control gear essentially consists of a geared oil pump in connection with a control cylinder, the piston of which operates the rotary valve, on the suction side of the air pump, by means of a rack. The oil pump is directly coupled to the rotor of the preliminary vacuum pump. The rotary valve, on the suction side of the preliminary vacuum pump, is fitted to hold back the sealing fluid if the driving motor stops, or if its speed becomes insufficient, *while the column of oil, up to the height of the gauge glass in the exhaust dome, forms a seal for the vacuum.* By these means a perfectly reliable seal is guaranteed, thus further increasing the reliability of the rectifier. Further the holding back of the sealing fluid in the exhaust dome when the motor is stationary is an advantage of special importance, as moisture and other impurities are prevented from entering the parts under vacuum, so that on restarting, the vacuum pump is able to produce the required vacuum immediately. As soon as the pump is started and the necessary speed for the control pump attained, the rotary disc valve is opened by the pressure oil. The valve is closed by a return spring. While running, the piston in the control cylinder is held in equilibrium by the tension of the return spring and the pressure of the oil; a slight amount of hunting takes place so that the valve is always ready to close instantly, static friction being avoided. An oil receiver which also acts as a condenser is mounted on the suction side of the preliminary vacuum pump; in the event of the governor not acting, the oil is trapped in the receiver, thus preventing it from entering the high-vacuum pump. In other cases the receiver acts as a condenser, thus excluding the presence of oil vapour from the high-vacuum pump and the rectifier.

2. *The driving motor of the preliminary vacuum pump* is a three-phase motor with a squirrel-cage rotor. An insulated flexible coupling is used between the motor and the vacuum-pump set since the latter is at the same potential as the rectifier. The motor, which is also mounted on the insulated base-plate, requires a continuous input of about 0·3 kW. The housing of the motor is earthed to protect the supply system.

3. *The high-vacuum pump,* which is patented by Brown, Boveri & Co., is a static mercury vapour

pump. It operates only in connection with a preliminary vacuum pump as its pressure drop is comparatively small and amounts to only about 0·2 mm absolute of mercury. This pressure drop is sufficient to guarantee reliable working (Fig. 3). This pump is described more fully in the Revue B B C 1921, No. 6. The design is the simplest possible, as there are no internal fittings built on to the body. The working part consists of a cylindrical casting with a flat bottom which contains about two kilogrammes of mercury. The high-vacuum piping is connected, at the side of the pump, to the cooling zone, while the preliminary vacuum piping is connected to the top of the casing. The working chamber, made from steel plate, is mounted in a cast-iron cylinder, the upper portion of which is designed to form a cooling chamber. The heating element which is easily removable and consumes about 500 W, is fitted in the base of the pump. All components can be easily removed and are accessible for control. As there are no separate parts inside the body, the instructions provided enable the pump to be dismantled, inspected, and reassembled without special knowledge.

4. *The circulating water fittings of the high-vacuum pump* vary according to the particulars of the installation and the method of cooling used. In the simplest cases a pedestal with the cooling water union, supply valve, and outlet funnel is mounted on the base-plate near to the high-vacuum pump. In the event of it being impossible to guarantee an uninterrupted supply of circulating water, a water-flow indicator Type GRU, as shown in Fig. 5, is used. This device is provided to avoid disturbances caused by the cessation of the cooling water supply; a signal is actuated or a switch operated if the water supply is cut off. The heating element of the high-vacuum pump is immediately switched out in the event of a disturbance, thus preventing the mercury from entering the vacuum pipes. When the flow of cooling water recommences, the heating element is automatically switched in. The construction and method of operation of the water-flow indicator are as follows:— A receiving vessel with an adjustable opening in the bottom is carried by one arm of a double lever; the second arm of the lever supports a balance weight. The outlet is adjusted so that the receiving vessel is kept filled by the smallest allowable flow of water, and overflows into the large funnel. In the event of an interruption in the water supply the receiving vessel empties and the balance weight is lowered. By this means a switch is actuated and the protective apparatus comes into operation. A water stop-valve, Type GRA, is provided in unattended rectifier installations which use a continuous supply system for the cooling water, and also for plants in which water must be conserved (Fig. 6). The valve body contains a double beat valve which is operated by a no-volt coil; by this means the operating device is relieved from and made independent of the water pressure.

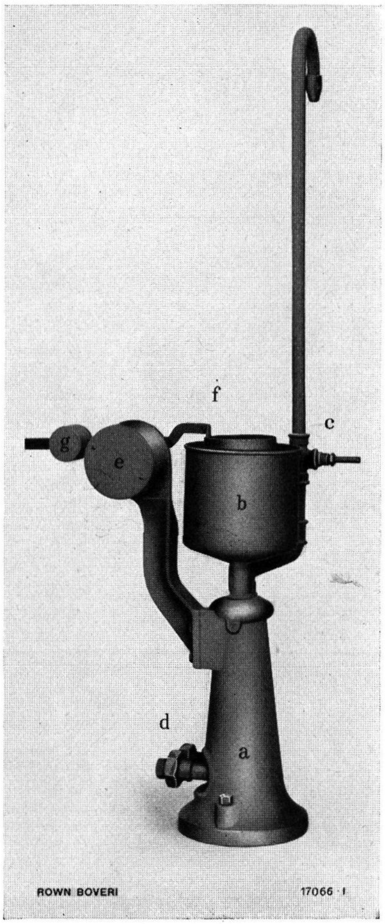


Fig. 5. — Type GRU water alarm.

a. Pedestal.
b. Outlet funnel.
c. Continuous supply valve.
d. Inlet and outlet for cooling water.
e. Switch.
f. Operating lever with water container.
g. Balance weight.

A link motion attaches the core of the solenoid to the valve spindle which passes through a gland before being secured to the valve disc. In order to overcome the friction in the gland effectively, the core is made very heavy and is connected to the link motion in such a way that it can fall freely through a certain distance both when opening or closing, thus giving a hammer blow which ensures positive operation. If the no-volt coil is energised the core is drawn up and the valve opened. When the excitation is removed the heavy armature which is connected by means of a link motion with a ratio of 1 : 12, falls and thus positively closes the valve.

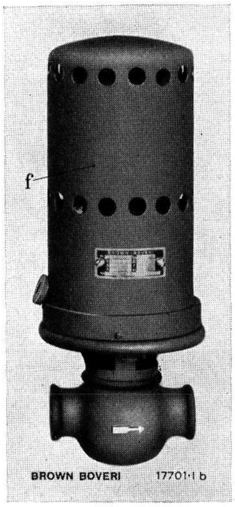


Fig. 6. — Automatic water stop valve, type GRA.

5. *The vacuum gauge, Type GRK.* The Brown Boveri vacuum gauge, which constitutes a practical application of Boyle's Law for determining the pressure, was first suggested by MacLeod. At present it is the only instrument for the *absolute* measurement of pressures of exceptionally low values. The method of operation is as follows. The gas, contained in the bulb connected with the rectifier by a capillary tube, is compressed into a capillary tube 1·5 — 2·0 mm in diameter (Fig. 7). For each reading, the mercury column is adjusted to a definite mark on the glass tube leading to the rectifier or to the barometric tube. The compression pressure can be found from the difference in level of the two mercury columns, and hence the initial pressure p^1 can be calculated from the compression pressure p and v, the volume occupied by the gases compressed in the capillary tube; by these means the vacuum is determined.

If V represents the volume of the bulb and capillary tube, which must be accurately calibrated, then by Boyle's Law:—

$$p^1 = p\frac{v}{V}$$

The scale is graduated in accordance with this formula and hence the pressure p^1 determined from the volume V, can be read off directly; the absolute value of the vacuum is obtained in mm of mercury.

The MacLeod compression vacuum gauge is directly influenced by the atmospheric pressure, hence the mercury meniscus in the glass tube which leads to the receiver (barometric tube) must be carefully adjusted before each reading. The mercury meniscus must be visible in the capillary tube also, hence this necessitates the manufacture of the barometric tube out of glass, which, owing to its fragility, can easily lead to breakdowns. Only inaccurate readings will be obtained unless attention is paid to the adjustment of the mercury meniscus in the barometric tube. A further disadvantage arises from the fact that at the level of the mercury meniscus a deposit of mercury oxide and metallic mercury (from the rectifier) appears, hence the exact level of the mercury is no longer visible. The glass portions must, therefore, be cleaned occasionally but, however, this does not affect the reliability of the rectifiers.

A Brown Boveri apparatus (Fig. 7) which is protected by patents, avoids all of these disadvantages. The chief feature of the improvement consists in the enlargement a, at the upper end of the barometric tube. The cross section f of the enlargement is made as large as possible, when compared with f_1, the annular section of the mercury container which is in contact with the air. By this arrangement, variations of the mercury column in the barometric tube due to atmospheric pressure or changes of temperature are compensated in a practical manner. The fluctuations are limited to the mercury container f_1 which is open to the atmosphere, and owing to the barometric height h, these have no effect on the measurements. In other words, for the correct setting of the mercury meniscus in the enlargement a, or in the barometric tube, the adjustment of the mercury container is independent of variations in atmospheric pressure and also of temperature changes of the surroundings, and hence the setting is always the same. From this it follows that the adjustment of the mercury meniscus in the barometric tube may be omitted i. e., it need not be visible.

The apparatus consists of an *iron tube* (barometric tube) on the upper portion of which an enlargement a, and a connecting branch s, are provided. The lower end of the mercury container b forms a telescopic connection. The only glass portion necessary is the bulb m with the capillary tube k which is connected to the branch of the barometric tube at q and sealed with mercury. In order to take a reading, the mercury container b is raised to the fixed stop d by means of the lifting device c. The position of this stop raises the mercury to the lowest altitude at which readings can be obtained. In this position (the measuring position), the mercury column in the capillary k automatically adjusts itself to the correct height, determined by the instantaneous value of pressure which can then be read directly on the scale in millimetres of mercury. After each reading the mercury container is lowered to its rest position, thus the apparatus is always ready for service. The scale and mercury column are illuminated to increase the accuracy of the reading.

The lifting device is fitted with an automatic friction brake, to prevent the container slipping as a result of careless attention. A special testing tube p, which is inserted instead of the bulb m and capillary tube k, is provided for checking the adjustment of the mercury and determining the quantity of mercury. The testing tube enables the level of

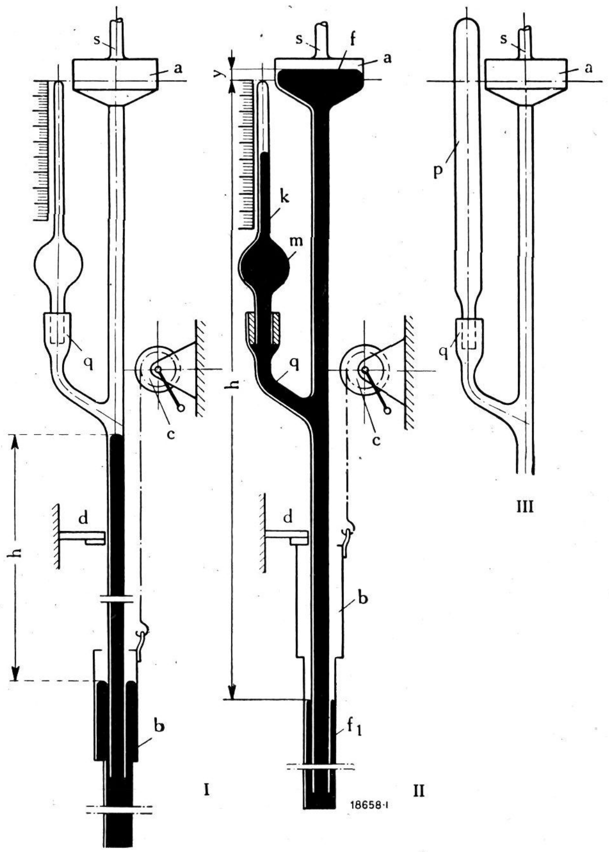


Fig. 7. — Compression vacuum gauge, type GRK.

I. Rest position.
II. Reading position.
III. Testing.
g. Additional head to compensate for the meniscus.
h. Barometric height.

the mercury in the enlargement a to be adjusted, sufficiently accurately for practical purposes, as soon as the instrument is placed under vacuum (about 0·1 mm of mercury column abs. being ample) a previously defined mark being used as datum. Compensation for the meniscus in the capillary tube is obtained by increasing the height of the mercury level f by an amount y. This adjustment is only necessary once and is carried out before the apparatus leaves the factory. The quantity of mercury may be subsequently checked by means of a float carrying suitable marks. The mercury necessary amounts to about 3·8 kg.

The improvements described thus enable the glass portions to be limited to the capillary tube and measuring bulb, the principal parts being made of metal. As the adjustment of the mercury in the barometer tube is no longer necessary before each measurement, a considerable technical advantage is attained. The attendance is extremely simple, special care and specialised knowledge are not required, since the mercury in the capillary tube automatically adjust itself as soon as the container is raised to the stop d.

The principal disadvantage of the compression vacuum gauge is due to the fact that for every measurement the gas content of the bulb and capillary tube must first be sealed by mercury and then compressed in order to determine the vacuum present. This integrating method only enables the instantaneous value of the vacuum to be obtained, any fluctuations, however, are not given. Brown, Boveri & Co. have, therefore, developed a direct-reading vacuum gauge which is an instrument of the hot-wire type and depends upon the heat conduction of the gas being a function of the pressure. This apparatus will be fully described later.

6. *The preliminary and high vacuum pipe lines.* Brown Boveri patented flange connections are used in all cases where flanges and connections for the air-pump set are under high or preliminary vacuum, e.g., for the compression vacuum gauge and the direct reading vacuum gauge connected to it (Fig. 8). This movable flange connection with round section rubber packing and loose flanges having neither welded nor rolled joints, permits rotation and even a slight oblique setting of the two flanges without endangering the retention of the vacuum; excellent results have been obtained from its use. This packing can also withstand light shocks since the round rubber packing presents greater elasticity than the flat-type packing.

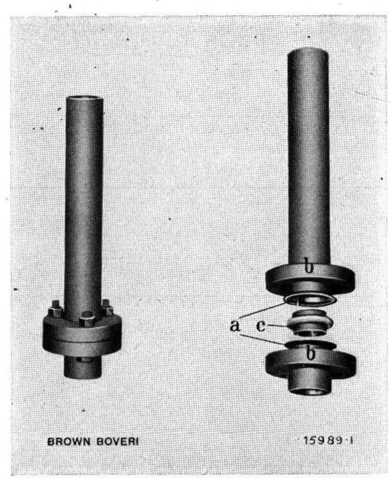


Fig. 8. — Movable flange connection, assembled and dismantled.

a. Flanged pipes.
b. Loose flanges.
c. Round section rubber packing with guiding bush.

(MS 379) *O. Seitz (J. R. L.)*

NOTES.

Increasing the speed of low-head water turbines.

Decimal index 621. 24 : 621. 313. 43.

DURING the last few years, very high specific speeds have been employed with propeller-type turbines with axial flow and with the diagonal type turbines with inward flow. An increase in the speed of diagonal type turbines with outward flow is still possible, by similar means to those used with high-speed Francis turbines, the diameter at the outlet of the runner being made greater than that at the inlet.

These very-high-speed turbines require a horizontal draught tube of spiral form owing to the importance of reducing the outlet-losses to a minimum.

It is not sufficient to govern the diagonal type of outward flow turbine by the use of Fink movable blades alone, but these must be supplemented by movable vanes on the runner in order to obtain the best possible efficiency at partial loads. The arrangement of the draught tube to form a horizontal spiral allows access to be obtained to the moving mechanism of the runner blades from below; their setting can be adjusted by means of a geared electric motor provided with remote control, and which rotates with the runner. If necessary an adjustable segmental step bearing of the Brown Boveri type can be used below the turbine.

The new type of turbine furnishes a means of increasing the speed of the electric generator to which it is directly coupled, and hence enables the overall dimensions of the generator to be reduced with the result that the initial outlay becomes considerably smaller. The vertical arrangement of the shaft is generally preferable as it leads to a cheaper building, but the horizontal type may also be used.

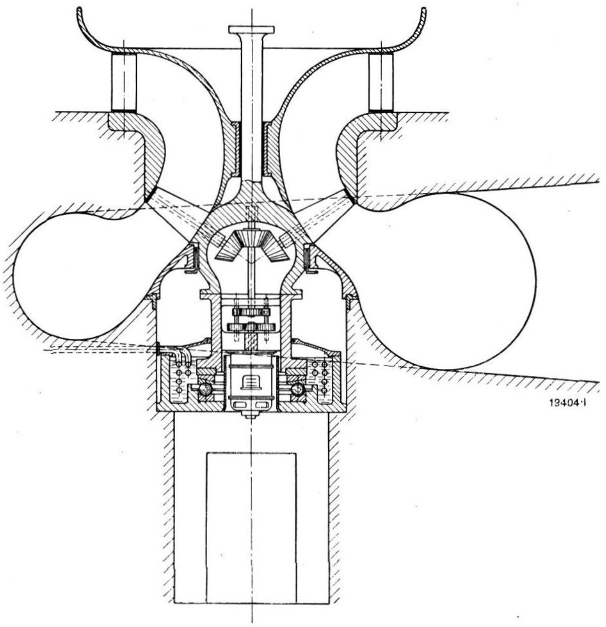


Fig. 1. — Diagrammatic section through an outward-flow diagonal-type turbine; with spiral draught tube at right angles to the shaft.

The outlet of the special draught tube can similarly be arranged to lead into the tail race without any trouble. The suitable design of the draught tube which determines the flow of water is of the greatest importance to the efficiency of the high-speed turbine.

(MS 367) *G. Leidig. (J. R. L.)*

Transport of a three-phase transformer for 16,500 kVA, 132/52·5 kV, weight 38·5 tons, for the Tœss Substation of the North-East Switzerland Power Supply Co.

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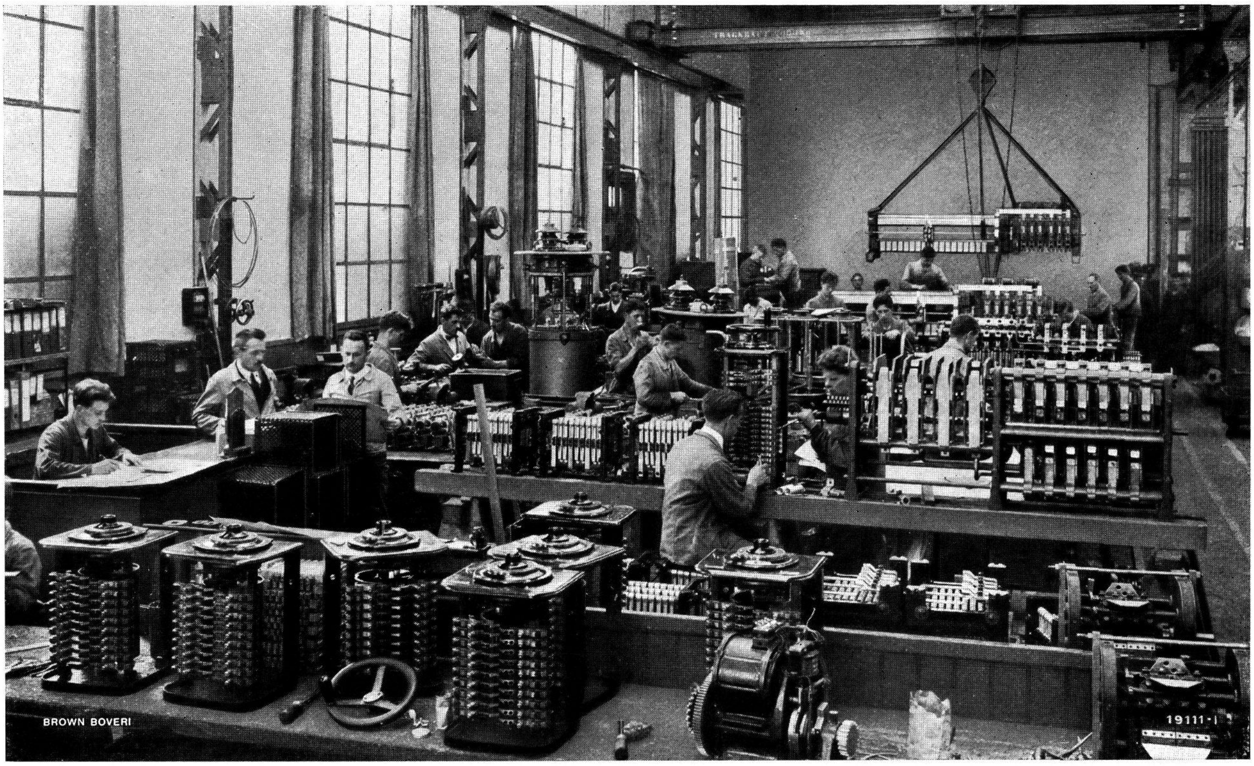

The apparatus workshop for electric locomotives, in the Baden Works of Brown, Boveri & Company.

Part of the transformer workshop in the Baden Works of Brown, Boveri & Company.

BROWN BOVERI
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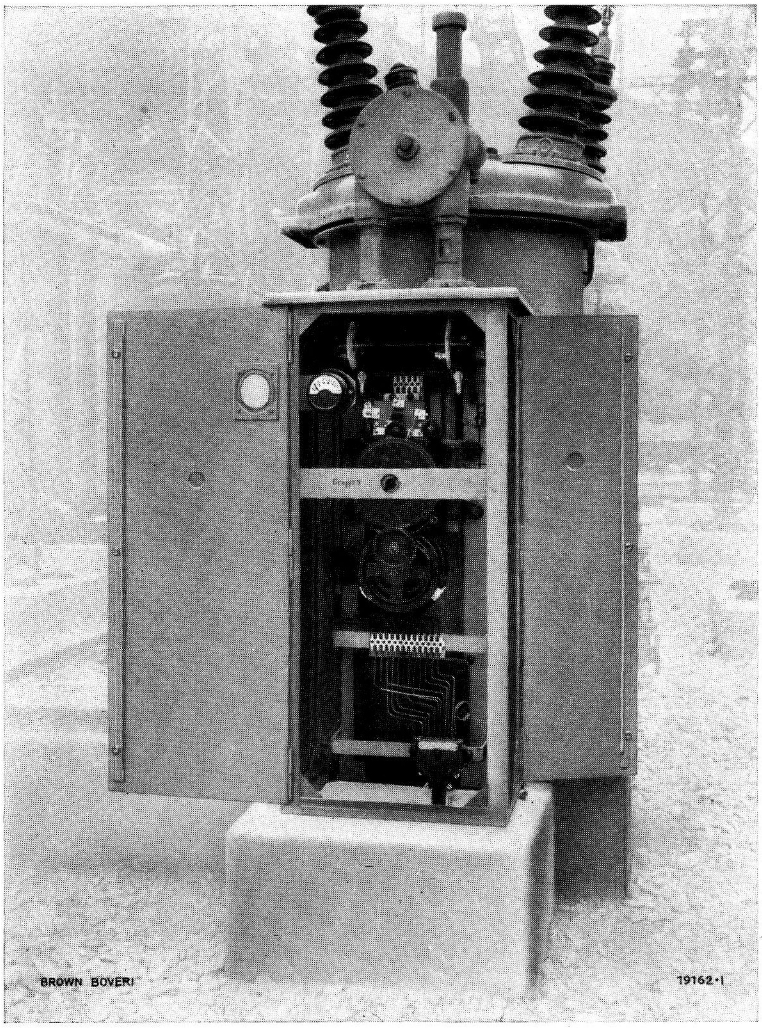

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