THE BROWN BOVERI REVIEW

The first gas-turbine locomotive in the world.

In the autumn of 1941, just before the celebrations which marked the fiftieth anniversary of the foundation of Brown Boveri, the Swiss Federal Railways carried out successful first trial runs with the gas-turbine locomotive. This new type of locomotive, which requires no water, is particularly suitable for countries where water is scarce, but the necessary fuel oil is available at less than half the cost of Diesel oil.

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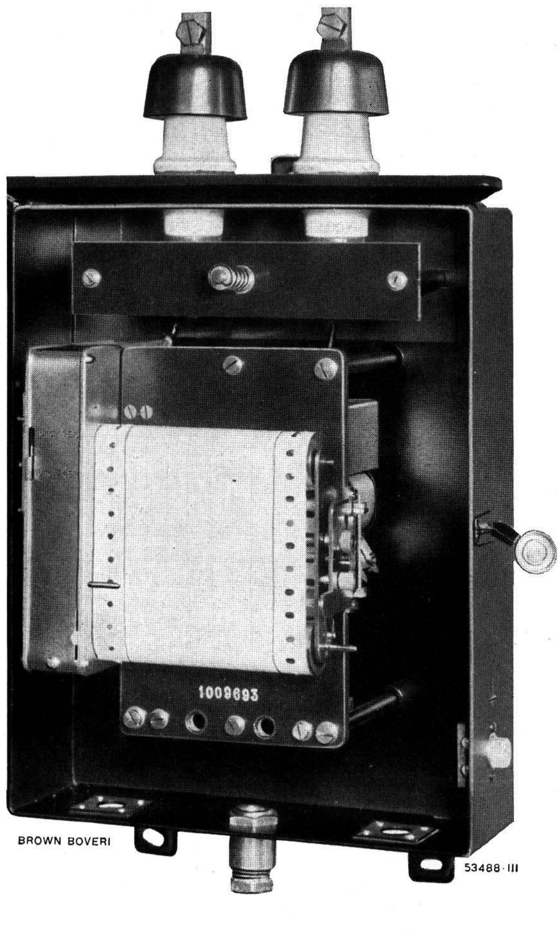

INCREASED SERVICE RELIABILITY THANKS TO ARRESTORS AND DISCHARGE COUNTERS. — CONSTANT SUPERVISION OF SERVICE CONDITIONS MADE POSSIBLE

THE BROWN BOVERI REVIEW

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THE FIRST GAS-TURBINE LOCOMOTIVE.

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The development of the gas turbine from the steam locomotive, through the Diesel locomotive, is described here and the operating process of the combustion turbine briefly touched on. A description is then given of the first gas-turbine electric locomotive built by Brown Boveri for the Swiss Federal Railways with reference to its general layout, capacities and governing equipment. Finally, the future of the gas turbine locomotive from the economic point of view, as compared to that of the steam and Diesel locomotive, is gone into. Although the gas turbine locomotive is still at the beginning of its development it is possible to foresee that its chief field of utility is going to lie in countries where water is scarce and in those having oil wells and that it will be chiefly used for long-distance runs with express as well as goods trains.

WHENEVER a new form of engine has been invented, a desire has soon arisen to apply it to the propulsion of vehicles intended for the transport of passengers and goods. Thus the first steam car appeared almost at the same time as the first stationary steam engine and its failures were to be attributed not so much to the driving engine as to the — for modern ideas — incredibly bad state of the roads at the time.

It was not till some 30 years after the first steam car in the world, which was equipped with a tiny steam boiler, coughed its way through the streets of Paris with its inventor Cugnot, that Trevithik, in 1804, hit on the idea of putting his car on the iron rail track known already since the middle ages, thereby creating the first locomotive. Through his work and through the tenacious labours of the Stephensons father and son, a development was started which led to an absolute triumph of the steam engine in traction service, and completely changed the life of the world.

This, until then unparaleled development in the transport domain, has been surpassed only by that brought about by the invention of the internal combustion engine by Otto and Diesel.

Here again the trackless self-contained car was the first object of the inventors who harnessed the internal combustion engine to vehicles, but unlike the steam cars, by far the greater part of the combustion engine cars or motor cars as they are now called have remained faithful to the roads. The latter were already incomparably better at the period the automobile appeared than they had been at the time of Cugnot and Trevithik, a fact which was largely responsible for its rapid progress, just as in its turn the automobile was responsible for even greater and quite unforeseen extension of the road system.

Whereas steam locomotives exceed to-day in both number and power not only the steam road cars but also stationary steam engines, in the case of the internal combustion engine, not the locomotive, but the motor car has in an incredibly short time overtaken and almost completely displaced every other form of road vehicle so that now it exceeds in number and in total power all the wind, water, steam and stationary internal combustion engine power plants of the world.

The combustion engine locomotive is still relatively young and is represented mainly by the Diesel engine locomotive which, contrary to the steam locomotive, is almost always provided with an indirect drive in the form of an electrical transmission.

That the electric transmission, which, from the engineering standpoint, is not only entirely reliable but also possesses many advantages, has been used on steam locomotives only in exceptional cases, is due not so much to its economical drawbacks (high weight and high price due to triple conversion of energy) as to the fact that by the time the electrical engineering profession still in its infancy, was able to offer a satisfactory solution of the problem, the steam locomotive with mechanical drive could look back on nearly 100 years of development which had already led to the successful creation of distinct types for nearly all the different classes of service.

Notwithstanding this, the first electrical transmission of power to the wheels of a vehicle was applied to a steam locomotive. This was the "Heilmann Locomotive" so named after its French inventor and promoter, and for which the electric drive was supplied in the year 1896 by the young Swiss firm of Brown Boveri under the leadership of its very young technical leader, Charles Brown. Since various novel features were incorporated in this ancestor of all locomotives with electrical transmission, it may be of interest to mention them briefly here and to show a view of this locomotive (Fig. 1) [1].

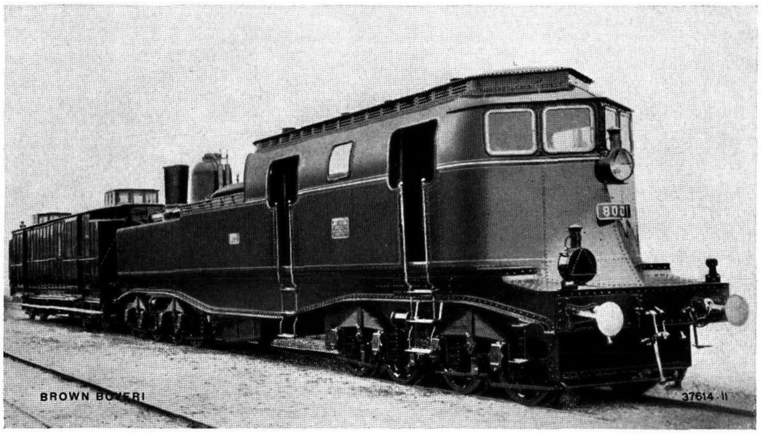


Fig. 1. — The Heilmann locomotive built in 1896.
The young Swiss firm, Brown Boveri, equipped the first thermal locomotive to have electric power transmission. All the axles were driven by 125 H. P. motors which gave the locomotive a maximum speed of 60 m. p. h.

The power was developed by a 6-cylinder Willans & Robinson steam engine of 1350 H. P. Here is seen for the first time the increase in the number of cylinders which has since become so characteristic of piston-type vehicle engines in order to achieve high speeds and hence low weights and prices. The speed thus obtained was 400 r. p. m. and enabled two direct current generators of 450 kW, 450 V to be driven one from each end of the shaft.

A separate two-cylinder steam engine drove a 15-kW compound-wound generator for supplying the excitation of the main machines. This complete power plant was mounted on a common frame supported in turn by two four-axle bogies, each axle of which was provided with a hollow shaft 125 H.P. series motor capable of propelling the machine at the quite modern speed of 60 m. p. h.

[1] Before the locomotive shown in this engraving there had been built a very much smaller one which, because of its small size, could however hardly be regarded as a practical machine. In this case Brown, Boveri & Co. supplied not only the electrical but also the steam part, the latter being designed as an opposed piston engine by Eric Brown under the guidance of Charles Brown senior.

I. GENERAL REMARKS.

After experience in the design and operation of one or two stationary plants appeared to show the suitability of the gas turbine for traction work, one of the first questions which Brown Boveri and the author had to consider, was whether or not electrical transmission, which is used on the majority of big Diesel locomotives, should be utilized here as well. The decision arrived at was governed by both practical and technical considerations.

Among the former was the desire not to employ for the gas-turbine locomotive any new feature which was not made unavoidable by the use of the gas-turbine drive in order not to compromise the success of the latter by possible faults in parts in no way connected with it. On the other hand the adoption of electrical transmission seemed natural in view of the fact that the system developed by Brown Boveri for Diesel-electric cars which had been successfully tried out in more than a hundred cases could readily be applied to a gas-turbine unit.

To be able to appreciate properly the technical considerations it is necessary to recall first briefly the operating principle of the gas turbine, in particular that of the combustion turbine, formerly incorrectly called the constant-pressure turbine. This is best done by referring to Fig. 2 which shows diagrammatically the power unit of the gas-turbine locomotive, without the transmission system conveying the power to the driving wheels. The air, which is supplied by the compressor C in considerable excess over that required for combustion, is heated in the chamber A by the combustion of oil issuing from the burner 3. The compressed air serves to reduce the temperature of the gases to a value admissible for the blades of the gas turbine. The gases then pass at a temperature of 850—1100 °F from the combustion chamber to the gas turbine where they expand giving up heat for the production of mechanical work and suffering a corresponding drop in temperature. Thereupon they flow through the air preheater where

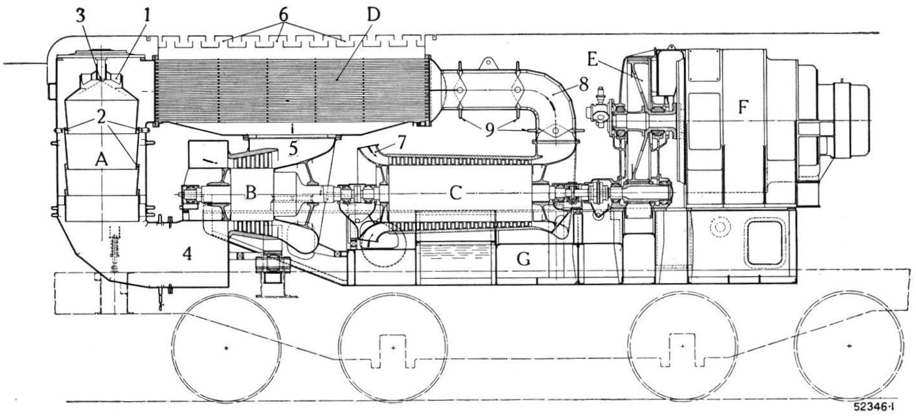


Fig. 2. — Section of the gas-turbine set of the locomotive.

A. Combustion chamber. C. Compressor. E. Gear. G. Bedplate of unit.
B. Gas turbine. D. Air heater. F. Generator.

The compressed and pre-heated air is introduced to the combustion chamber partly as combustion air through the swirl vanes 1, partly as cooling air through the slits 2. The fuel is injected through the injection nozzle 3. The combustion gas and the cooling air mix in chamber 4 and form the driving gas. The exhaust gas, which is still hot, passes into the air heater at 5 and is exhausted to atmosphere through slits 6 in locomotive roof. The air inlet is at 7. The air outlet pipe 8 has several expansion joints 9 in order to deal with the different expansions of the gas turbine set and the air heater.

they give up heat to the compressed combustion air and finally escape through the roof to the atmosphere.

In order to deliver a useful output of 2000 H. P. the gas turbine must develop an output of 8000 H. P. because the compressor absorbs 6000 H. P. The excess or useful power must now be transmitted to the driving wheels either mechanically, hydraulically, pneumatically or electrically or by some combination of these four methods.

Direct mechanical transmission is excluded for a number of reasons. Firstly, this would cause the speed of the gas-turbine and compressor unit to vary directly with that of the locomotive which would not be admissible even if a gear shift arrangement were provided. Secondly the reduction gear with ratio of the order of 10:1 would have to allow the set to be coupled and uncoupled while running, for, just as in the case of the automobile, the power unit has to be run up light and engaged afterwards. Gear-changing and clutch devices for such high powers have, however, not yet been tried out in practice.

The same applies to the hydraulic and pneumatic transmission systems which might overcome the first mentioned difficulties. It is true that numerous hydraulic transmissions have been successfully applied to locomotives of up to 400 H. P. but satisfactory operating experience with considerably higher powers does not appear to be available. Notwithstanding this, the Allis-Chalmers Mfg. Co. of Milwaukee, a licensee of Brown Boveri, is proposing to build a 5000-H. P. gas-turbine locomotive with a mechanical-hydraulic transmission, and the operating results of this locomotive will be awaited with interest.

When, therefore, the Swiss Federal Railways in a praiseworthy contribution to this development placed the order with the author's firm for a 2000-H. P. gas-turbine locomotive it was decided, because of the reasons given above, to build the locomotive with electrical transmission. The locomotive Type $1A_o$-B_o-A_o1, was ordered at the beginning of 1939 for service on branch lines when the traffic density did not justify electrification.

The main particulars of this gas turbine-electric locomotive of the Swiss Federal Railways are:

Guaranteed continuous output of the thermal unit measured at the generator coupling . 2200 H.P. at 5200/812 r.p.m.

Tractive effort at the wheel rim:

at starting: . . .	29,000 lb.	at 0—16 m.p.h.
during 1 hour: . .	17,000	„ 30
continuous: . . .	11,000	„ 45

The fuel consumption at full load is about 1·0 lb/H.P. hour at the wheel rim equivalent to a consumption of about 2000 lb. fuel oil per hour at 2000 H.P. at the wheel rim.

Maximum speed . . . . 70 m. p. h.

Effective weight with fuel tanks full

on branch line service . . . . . 92 tons

on main line service . . . . . . 93·5 „

Permissible driving axle load

on branch lines . . . . 16 tons

on main lines . . . . 18 „

The entire thermal unit was erected on a common auxiliary frame which serves at the same time as a reservoir for the fuel oil (4·2 m^3) and the lubricating oil (0·85 m^3), see Figs. 3 and 4.

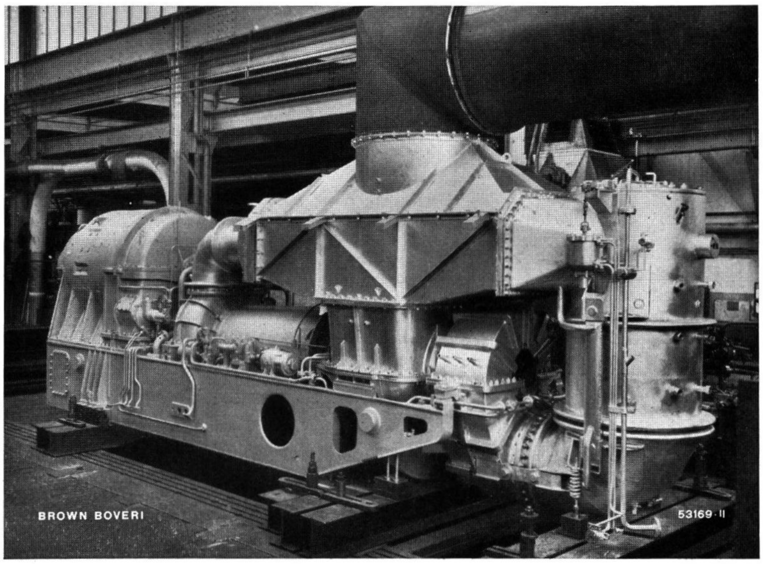


Fig. 3. — Gas-turbine generator set on the test bed.
The whole set is mounted on a common frame which contains reservoirs for fuel oil and lubricating oil.

Acceptance.

Extensive tests were carried out on the set at the Baden works by the Swiss Association of Steam Boiler Proprietors, the Swiss Association of Electrical Engineers and the purchaser. The points measured are recorded in the curve Fig. 5; they show a very good agreement with the calculated values. After the tests the unit was transported to Basle where it was fitted as a whole on the locomotive (Figs. 6 and 7). The external appearance of the completed locomotive is shown by Fig. 8.

Running.

Having reviewed the general operating principles of the gas turbine locomotive we can best follow the interesting details

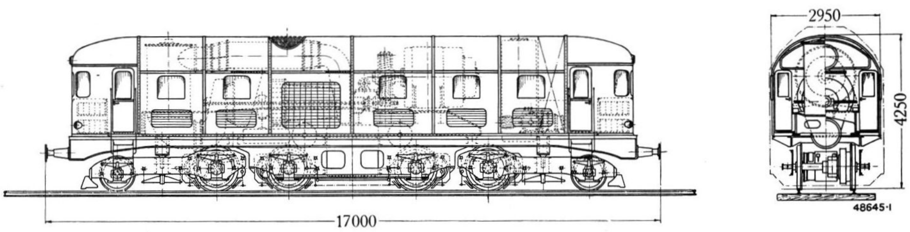


Fig. 4. — Gas-turbine locomotive with electrical transmission for the Swiss Federal Railways. Rating at generator coupling 2200 H. P.

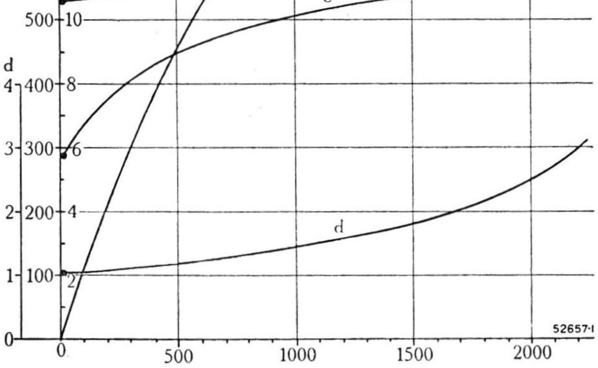


Fig. 5. — Operating characteristics of a gas-turbine plant for traction purposes.

Abscissae: Output in H. P.
Ordinates: a. Thermal efficiency in %.
b. R. p. m. of generator.
c. Temperature of gas at inlet in °C.
d. Compressor delivery pressure in kg/cm² abs.

by imagining ourselves as accompanying the driver on one of his runs. We use the singular because there is one-man control.

His first duty on climbing into his locomotive in the morning is to start the auxiliary Diesel driven generator of 75 kW which serves to bring the main power unit to such a speed that enough air is delivered by the compressor to permit lighting the burner. The time lapse between the starting of the auxiliary Diesel set and the lighting of the burner is about 4 minutes which the driver can use to put on his overalls. He then ignites the fuel by means of an electrically heated ignition element whereupon the set now assisted by the combustion begins to accelerate more rapidly. Returning to the driving cab (Fig. 9) he now switches over the Diesel driven generator from the generator of the gas turbine to the driving motors, and can in this manner shunt the locomotive at a speed of about 6 to 12 m. p. h. to the train without having to use the gas turbine set which in the meantime continues to accelerate automatically until after a period of 4 minutes the normal light load speed is attained. Whilst the locomotive is being

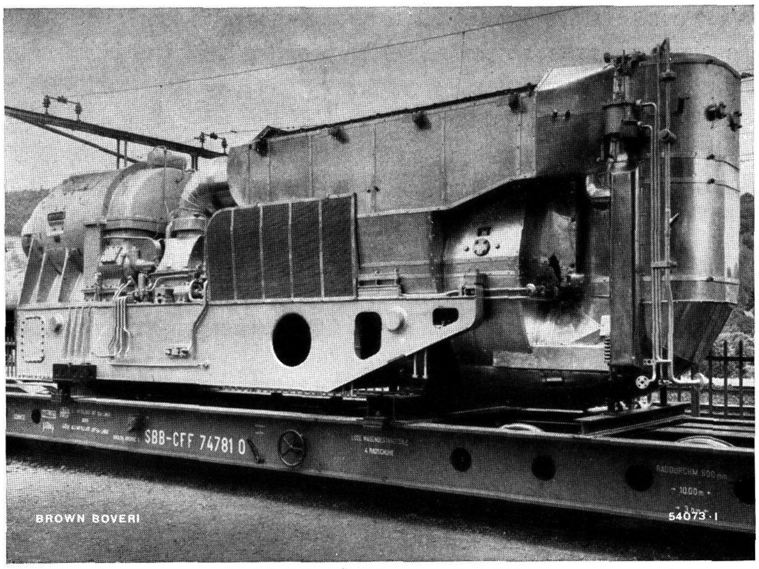


Fig. 6. — Gas-turbine set on crocodile truck prior to transport for fitting into locomotive.

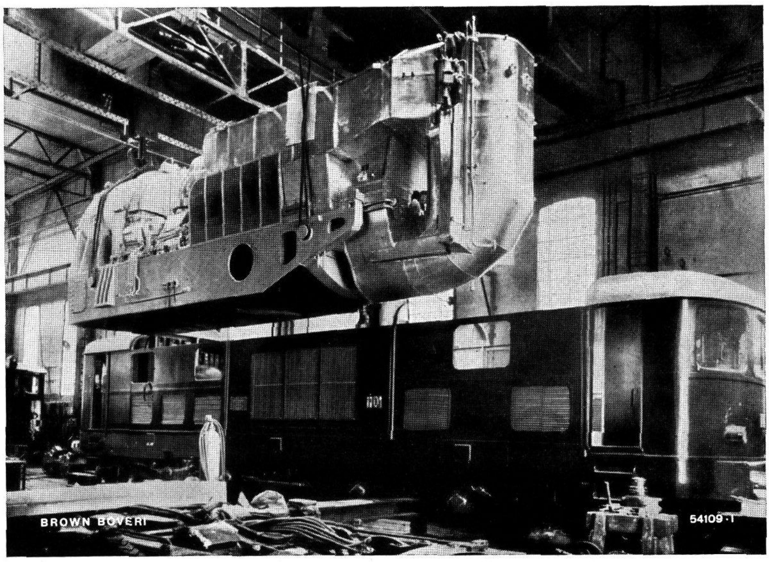


Fig. 7. — Fitting of gas-turbine set in the locomotive.

The set complete can be fitted in the locomotive, the roof of which is removable.

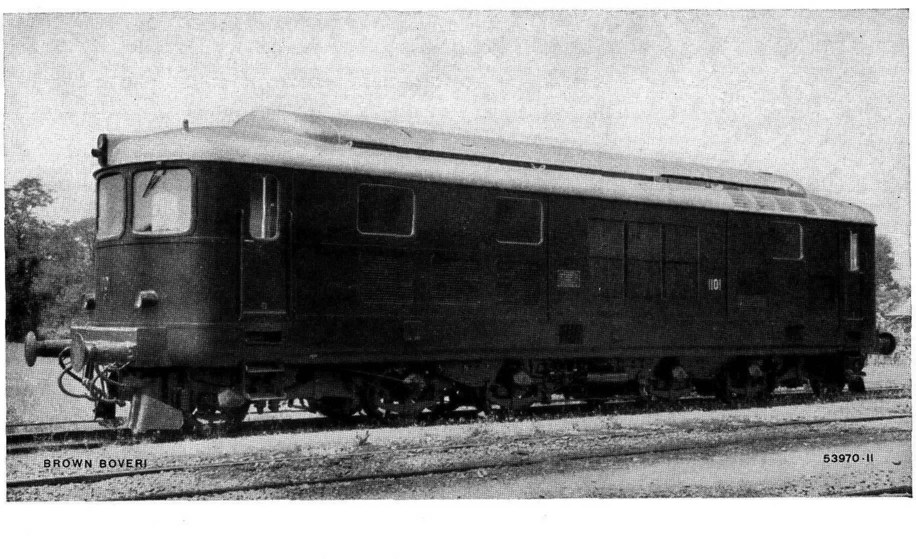


Fig. 8. — 2200 H. P. gas-turbine locomotive type 1 A_o-B_o-A_o 1 for the *Swiss Federal Railways. Maximum* speed 70 m. p. h.

The compressor draws in air through an aperture, fitted with a noise-reducing wire screen, in the centre of the locomotive.

coupled to the train, the driver shuts down the auxiliary Diesel engine unit and switches the driving motors over to the main generator. A small storage battery, which is used to start the Diesel engine, supplied the requirements of the auxiliary services up till this moment.

Fig. 9. — Driver's cab for one-man control of the locomotive.
Apart from the apparatus for railway service proper, the driver can supervise without difficulty the instruments which record the operation of the gas turbine.

It was at first intended to make this battery large enough to be able to serve for starting the gas turbine. Closer consideration led, however, to the abandonment of this idea as for frequent starting the Diesel engine appeared more reliable.

The run may now begin. The driver treads on the dead man's spring floor board, which when released interrupts the fuel supply and applies the compressed air brakes thereby bringing the train to a standstill, a safety measure also in use on other forms of electric locomotives. The driver then starts the train by gradually moving the control handwheel through the starting notches, at the same time drawing our attention to the smooth and regular, though fast, acceleration which is to be attributed to the high inertia of the fast rotating masses of the power unit; the train gradually acquires full speed, the steady riding of the locomotive being particularly noticeable even on the relatively poor track of the branch line on which we are running.

This is due partly to the good springing of the mechanical portion supplied by the *Swiss Locomotive and Machine Works, Winterthur,* and partly to the method of supporting the power unit the base plate of which, carrying all components, namely, combustion chamber, gas turbine, compressor and generator is supported on a three point elastic suspension just as is a modern automobile engine. The gyroscopic effect of the power unit is hardly noticeable.

We now approach a rising grade for which more power is required. The driver has then only to rotate his control wheel a few notches further, the governing gear does the rest. It is, therefore, time for us to consider the governing system (Fig. 10).

II. THE GOVERNING SYSTEM.

The regulation of the power developed by a locomotive with electrical transmission, whether driven by a Diesel engine or by a gas turbine, requires a coordination of the power developed by the engine and that delivered by the motors or rather by the generator. This is effected by regulating the field of the generator by means of a servo-field regulator 24 operated by the oil pressure governing system shown in Fig. 10.

The pump 9 delivers oil under pressure to the pressure line common to all control devices from which, during starting, lubricating oil is also furnished to the bearings through the throttling orifice 31. During running the bearing lubrication is assured by the direct driven pump 8. The main control wheel 14 operated by the driver regulates simultaneously via the lines 18 and 19 the amount of fuel delivered by the pump 7 to the burner 12 in the combustion chamber 2 by means of the servo-motor 20 and also the position of the speed governor sleeve 21 by means of the servo operated cam 22 thereby causing the speed to vary with the oil pressure according to a definite law, the speed regulator in turn controlling the servo-field regulator 24 and also the electrical output, this through line 23.

If for instance more power is required for a rising gradient, the driver opens up the oil supply to lines 18 and 19 by rotating the control handwheel, thus increasing the oil pressure in these lines. The servomotor 20 allows more fuel to pass to the nozzle 12 of the combustion chamber 2; the cam sector 22 is rotated by the rack and alters the position of the governor sleeve 21 so that the latter causes the

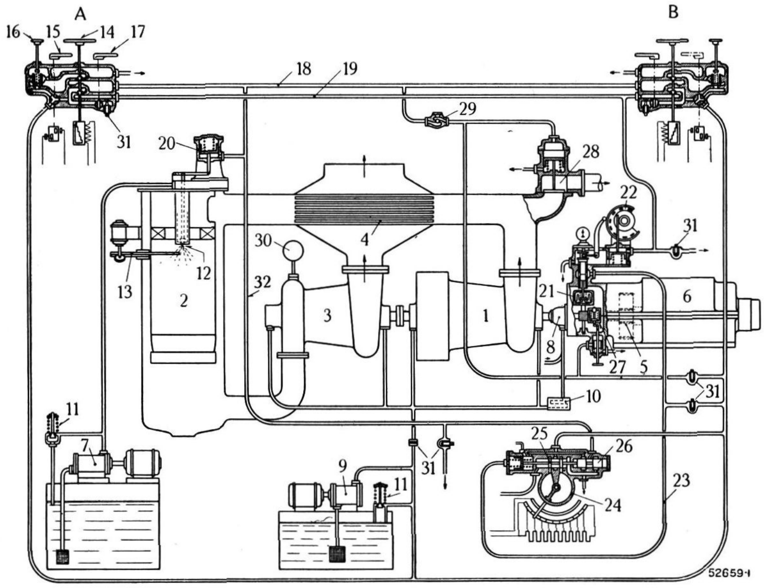


Fig. 10. — The oil-pressure control of a gas-turbine plant for traction purposes.

A.B. Driver's cabs.

1. Compressor.
2. Combustion chamber.
3. Gas-turbine.
4. Air preheater.
5. Gearing.
6. Generator.
7. Fuel pump.
8. Control and lubricating oil pump.
9. Auxiliary pump.
10. Oil cooler.
11. Pressure limiter.
12. Fuel nozzle.
13. Remote-operated ignition rod.
14. Main control wheel with double valve and excitation resistor.
15. Reversing switch with oil stop cock and removable key.
16. Temperature adjustor.
17. Lever for adjusting lower or higher no-load speed (in readiness for service).
18. Pipe to fuel control oil system.
19. Speed control oil system.
20. Piston for fuel nozzle.
21. Speed regulator.
22. Cam for varying speed from driver's cab (displaces sleeve of regulator 21).
23. Hydraulic transmission of control impulse from 21 to field rheostat.
24. Field rheostat with rotary valve.
25. Control valve for 24.
26. Control valve for varying amount of fuel during regulating process.
27. Emergency governor for preventing overspeeds.
28. Blow-off valve.
29. Non-return valve.
30. Safety temperature regulator.
31. Oil baffle.
32. Oil pipe for fuel control system.

speed of the set to increase. Because, however, of the large inertia of the rotating masses, of the turbine 3, the compressor 1 and the generator 6, the speed lags temporarily behind the value corresponding to the new governor setting. This condition is equivalent to that occurring upon overload and the servo-field regulator is, therefore, influenced first by the speed governor in such a way as to remove load, notwithstanding that an increase in output is being initiated.

This apparently wrong operation of the field regulator is, however, as we shall see presently, quite correct and of direct assistance to the achievement of the desired result by making the entire excess of power resulting both from the reduction of the electrical load and the increase in fuel quantity, available for accelerating the set, thereby reducing considerably the temporary period of increased gas temperature, and causing the final speed at which the compressor delivers an air quantity corresponding to the increased fuel quantity to be attained in the shortest possible time.

This action is further assisted by a piston valve 26 coupled with the field regulator which in the overload position causes an additional increase in the supply of fuel oil by increasing the pressure in the line 32.

As a result of the processes described above, the speed of the set soon begins to exceed the new setting of the governor. At this instant the pressure begins to rise in the line 23 from the speed governor causing the field regulator to be moved back again until equilibrium is attained between the load on the generator and the useful output of the gas turbine.

If the load is reduced the same processes take place in the reverse sequence.

The lever 15 when in the off position shuts off the governing oil supply from the driving stand A when for instance stand B is in use. In the forward and reverse positions it also serves as a reversing switch for the motors. The screw knob 16 enables the relation between the fuel oil quantity, i. e. the output and the speed which is otherwise fixed by the form of the cam sector 22 to be adjusted, when a considerable change of the external temperature renders such an adjustment desirable.

Finally the lever 17 enables a similar adjustment to be made temporarily when, for example, during a short stop, it is desired to keep the light running speed high in order to reduce the time required to accelerate the set upon restarting and to be able to obtain a maximum starting torque in the shortest possible time.

It is seen that the automatic control attends to everything in a way which could not be improved upon by the driver himself, whilst leaving him at all times the possibility of intervening in the regulating process should he consider it necessary to do so.

The control system also comprises a number of *safety devices*. If our driver instead of starting to give extra fuel on approaching the gradient does not begin to do so until the train has begun to climb and is losing speed, he may be tempted to make up for his oversight by cutting out several notches at once. As however the high inertia of the fast rotating masses may possibly not enable the speed of the set and hence the air quantity to adjust itself sufficiently rapidly to the increased fuel quantity an excessively high temperature might result which could in time prove harmful to the blading. A red warning lamp suddenly lights in front of the driver: "Temperature too high". If he improperly refuses to heed this warning and neglects to move the control wheel back one or two notches, after the temperature has continued to rise by a further 30° C, the same thermostat which lights the red lamp causes the fuel pump to be shut down, thus protecting the blading from harm and causing a short but annoying interruption of service, as some 1—2 minutes are required for reignition although the set is still running. Such a mishap is hardly likely to happen twice to the same driver.

A further safety arrangement guards against overspeeding of the set if, because of a broken connection or any other reason, the load should be removed suddenly. The intervention of the normal governing gear in reducing the fuel might in such a case come too late to prevent an excessive rise in speed. The overspeed governor 27 then comes into action, releasing the oil pressure through non-return valve 29 when the speed exceeds the normal by 10%, thereby causing the atmospheric blow-off valve 28 to open, overloading the compressor and reducing the air quantity in the combustion chamber to such an extent that the rising gas temperature causes the above mentioned thermostat to operate, shutting down the fuel pump 7 and hence also the set.

The converse case may occur, that is, the flame may suddenly go out (due to the presence of water in the fuel oil or to some such cause) without the driver noticing it. Oil would then continue to flow into the combustion chamber without being burnt. This is prevented by a thermostat which receives heat only by radiation from the flame and which upon extinction of the latter causes the fuel pump to be shut down after an interval of 5 seconds.

A further safety measure is provided by an oil pressure relay which also shuts off the fuel should the governing oil pressure fall below a certain minimum.

Power braking.

Having reached the crest of the rise we are now running down the other side towards the valley. It would be convenient to be able to use here some form of power braking instead of the compressed air brakes with their objectionable wear of brake blocks and of wheel tires. Although our gas turbine locomotive is not yet fixed up for power braking this can now be arranged for. It will be recalled that the output of the gas turbine at full load is 8000 H. P. and the power taken by the compressor 6000 H.P. leaving 2000 H.P. as useful power. If now whilst coasting downhill the fuel oil supply is shut off or reduced to such an extent that the flame just continues to burn and the motors are converted to generators by suitably exciting the fields, they will deliver their power to the main generator which operating as a motor drives the turbine and compressor. By opening the blow-off valve which normally is actuated only by the over-speed governor, the greater part of the air delivered by the compressor escapes to atmosphere, only a small fraction flowing through the combustion chamber, turbine and air heater, just sufficient to keep the burner alight with a small flame, unless it is preferred to shut off the oil fuel completely. In this manner it is possible to make use of the full motor power for braking without having to employ any additional apparatus.

Heating.

If we are returning over the Gotthard from a run in the south we may need heating. The gas turbine is here ideal as it enables us to supply electrical energy for heating to the extent of 25% of the useful power at the wheel rim, without increasing the fuel consumption (Fig. 11). For this purpose a single phase generator of suitable voltage and frequency for delivering the heating requirements of the cars is built into the frame of the main generator. It is seen from Fig. 11 that with decreasing temperature of the inlet air the power taken by the compressor remains the same whereas that developed by the gas turbine increases and hence the excess of power grows to such an extent as to cover fully all heating requirements whatever the outside temperature, for the lower the outside temperature, the greater the excess power.

Shutting down.

When the driver returns the control wheel to the off position either on stopping or during a downhill run, he does not shut off the fuel entirely but only reduces it to an amount just sufficient to keep the set running light, the governing gear at the same time automatically reducing the speed from the full load value of 5200 r.p.m. to about 2800 r.p.m.

Only when the run is completed and the locomotive has been brought to the depot does the driver shut off the fuel completely by stopping the fuel pump.

Having studied the design of the locomotive and the details which characterize its running qualities, we will now try to estimate what future it has.

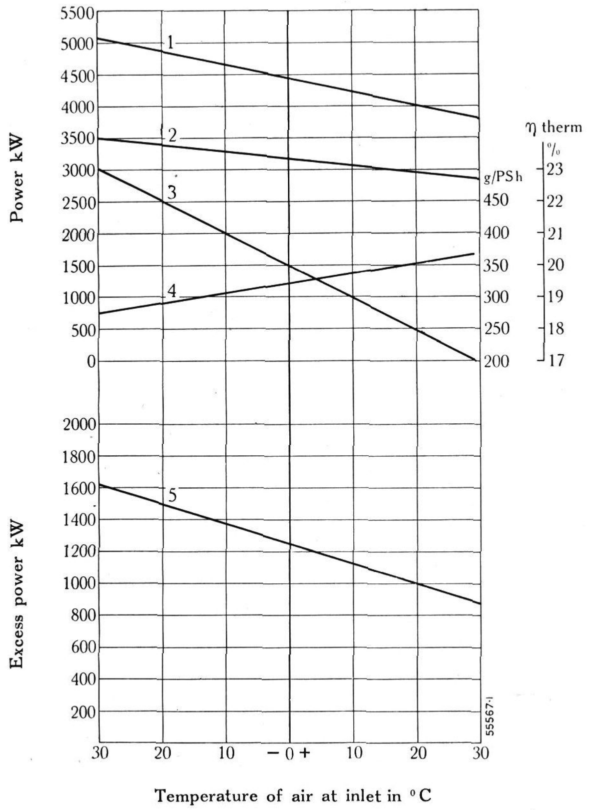


Fig. 11. — Gas-turbine output and fuel consumption in function of temperature of air at inlet.

As the temperature of the air drops, the power delivered by the gas turbine rises more than the power required to drive the compressor.

By means of an auxiliary generator, the power necessary for heating the train can, in emergencies, be obtained without extra cost.

1. Gas-turbine output.
2. Compressor power.
3. Thermal efficiency.
4. Fuel consumption.
5. Excess power available.

III. ECONOMIC PROSPECTS OF THE GAS-TURBINE LOCOMOTIVE.

In weighing up the economic value of the gas-turbine locomotive it is best to consider the subject first from the point of view of the traffic density which is the determining factor of any traction system. If a dense traffic has to be dealt with, full electrification will always receive the first consideration. Wherever this latter is justified, any other form of locomotive is immediately excluded, which means that the principal competitors of our machine will be the steam locomotive and the Diesel locomotive.

Comparison with the steam locomotive.

When compared with the steam locomotive, the oldest form of mechanical substitute for draft animals, it should be noted that coal cannot yet be employed as a fuel for the gas-turbine locomotive. This fact restricts its use to countries in which oil occurs or in which oil can be obtained relatively easily and cheaply. To such lands might be added those where considerable developments are expected in the near future in the conversion of coal to oil, motor spirit and other valuable products instead of burning it directly. There may, however, be also other reasons in favour of the use of oil instead of coal, such as the desire to avoid polluting the atmosphere with smoke and ashes, which has in fact, in certain large cities, resulted in legislation forbidding the use of coal for locomotives.

In countries rich in oil resources or where oil is readily available and is even used for firing steam locomotives, the reduction of the oil consumption to a little more than half is likely to be a deciding factor in favour of the gas turbine locomotive.

Lubrication.

Considerable saving is also realized in lubricating oil costs as experience shows that the consumption of lubricants of the purely rotating machinery is extremely small whereas according to American authorities[1] the lubrication costs of steam locomotives amount to 10 % of the fuel costs. The corresponding figure in the case of the gas turbine may be taken as being less than 1 %.

Water requirements.

A further advantage of the gas-turbine locomotive, doubly reflected in the operating costs, is the absence of any water. This does away not only with the necessity of having to carry a supply of water (up to 100 tons in modern American locomotives) but also with all the arrangements for procuring delivering, purifying and softening the same. The absence of water is also very noticeable in the maintenance and accordingly results in increased availability since there are no interruptions for cleaning or repairing boilers.

Wear.

Experience also shows that the wear of turbine machinery is smaller than that of reciprocating machinery. Moreover, according to Swiss experience with electric locomotives, far less maintenance should be required for the electrical part and hence fewer interruptions of service than with a steam locomotive.

Initial cost.

The price is, of course, an important factor because of the investment and amortization charges. According to American data the cost of a steam locomotive in the U.S.A is about \$ 35 per H.P. and that of a Diesel-

[1] Steam vs. Diesel-Electric Power by E. E. Chapman, Railway Age, July 25, 1941.

electric locomotive about $ 88 per horse power. The price of a gas turbine should lie between these two, somewhere in the neighbourhood of $ 65 per horse power, assuming the manufacture to be organized on the same lines as those used to-day for the production of standardized types of steam and Diesel-electric locomotives. All these prices refer to pre-war conditions.

Comparison with the Diesel locomotive.

During the last few years, the Diesel-electric locomotive has become a serious competitor of the steam locomotive. The motor car and the aeroplane have, by causing a demand for higher train speeds and more frequent service, led to a steady increase in the number of Diesel-electric locomotives. This applies particularly to the U.S.A. which country we may, therefore, consider as typically representative of modern tendencies in the traction field. Fig. 12, which shows the number of locomotives ordered between 1929 and 1940 for different classes of traction, gives a very good picture of these developments. The comparison includes steam, electric and Diesel-electric locomotives. The curve shows, apart from the great fluctuations due to years of varying industrial prosperity, how constant and almost insignificant the orders for electrical locomotives have been in the U.S.A. It also shows especially how Diesel-electric orders have taken the upper hand, increasing uniformly up till about 1939 in which year a still more rapid rise took place. The figures for the year 1940 are as follows: steam 219, Diesel-electric 462, electric 13; total 694 locomotives. In 1941

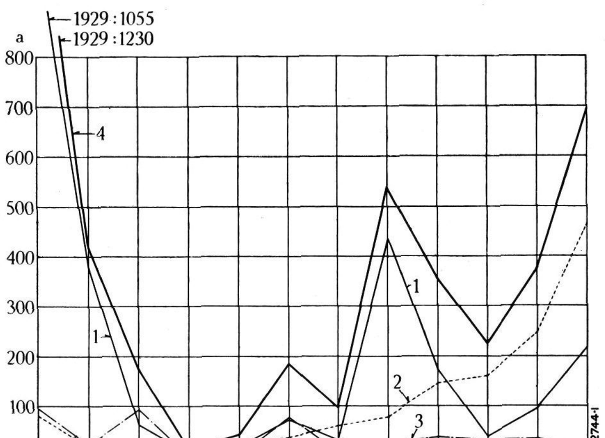


Fig. 12. — Number of steam, Diesel electric and Diesel locomotives constructed in the U.S.A. between 1929 and 1940.

The number of Diesel-electric locomotives is increasing markedly. There is a big field of utilization for the gas-turbine locomotive which is superior in many respects.

a. Number of units.
1. Steam locomotives.
2. Diesel-electric locomotives.
3. Electric locomotives.
4. Total number.

development was in the same direction, the number of Diesel locomotives ordered being more than double the 1940 figure and the proportion they represent of all locomotives ordered passing from $^2/_3$ in 1940 to $^3/_4$ in 1941. These figures show that the U.S.A. already possess appreciable experience of Diesel-electric locomotives extending over both number and length of service.

In a paper by E. E. Chapman on Steam vs. Diesel-Electric Power[1] these two forms of operation are compared in the light of modern American experience, and in the subsequent discussion many interesting facts were brought to light.

The principle data characteristic of steam and Diesel engine service, according to E. E. Chapman's judgement are reproduced below together with the corresponding data for the gas-turbine locomotive. As no operating experience is yet available for the latter, the data for a number of the points has had to be estimated on the basis of other experience such as that obtained with stationary steam turbine plants.

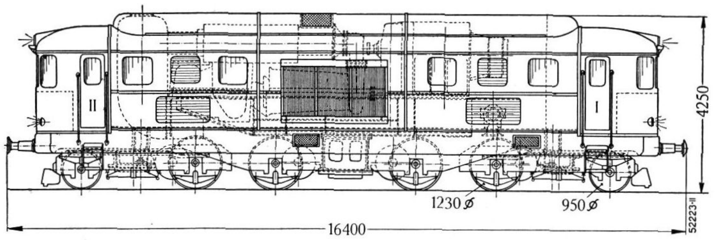
Comparison between steam, Diesel-electric and gas turbine-electric locomotives.

	Steam	Diesel	Gas turbine
(a) Approx. cost per H. P. in $ . . .	35	87	65
(b) Efficiency at draw-bar %	6—8	26—28	15—16
(c) Milage per year .	180,000	250,000	> 250,000
(d) Time for tanking and refuelling . .	greatest	least	small
(e) High schedule speed	lowest	higher	higher
(f) Track wear . . .	large	less	least
(g) Power braking . .	none	full power	full power
(h) Approx. life in years	30	15—20	30
(i) Maintenance . . .	lower	high	least
(k) Fuel costs . . .	100 %	50—75 %	50—75 %
(l) Lubrication costs % of fuel costs . .	10 %	20—30 %	< 1 %
(m) Water costs % of fuel costs	10 %	small	nil
(n) Starting effort . .	minimum	larger	larger

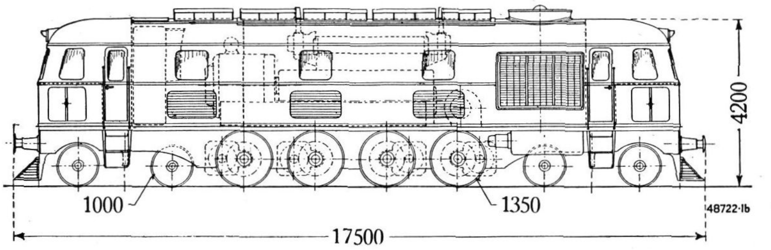
The following facts should be noted in connection with the above table:

(a) Cost of gas-turbine locomotives are assumed for production in similar series to those in which steam

[1] The Railway Age Vol. III (1941), No. 4, p. 149. Extract of a paper presented to the American Society of Mechanical Engineers.



2200 H. P. gas-turbine locomotive Type 1-A_0-B_0-A_0-1.



2200 H. P. Diesel-electric locomotive Type 2-D_0-2.

Fig. 13. — Comparison of a gas-turbine locomotive and a Diesel-electric locomotive.

Weight	Locomotive 1-A_0-B_0-A_0-1 Gas-turbine locomotive	Type 2-D_0-2 Diesel-electric locomotive
Mechanical part	37·5 t	50 t
Thermal part	23·7 t	
Diesel plant and accessories		26 t
Electrical equipment	25·6 t	30·2 t
Stores and equipment	5·2 t	5·8 t
Total weight in running order	92 t	112 t
Maximum driving axle pressure	16 t	16 t
Runner axle pressure	14 t	12 t
Maximum speed	70 m. p. h.	60 m. p. h.
The gas-turbine locomotive is lighter by	20 t	

The gas-turbine locomotive is lighter than a Diesel-electric locomotive of equal power. It needs no water and little lubricating oil. Further it burns a poorer and cheaper quality of oil.

locomotives and Diesel-electric locomotives are built in the U.S.A.

(b) The steam turbo-locomotive which, despite the many attempts to introduce this type of vehicle, has not been adopted to any extent, is not taken into account.

(c) Since the gas turbine locomotive possesses no reciprocating parts it is to be expected that it will require the least maintenance. In discussing the expectancy of life the question most frequently asked concerns the durability of the turbine blading. The operating temperature range in the case of the locomotive has been conservatively fixed at 850—1100 ° F. For this range of temperature experience extending over many years is available on supercharging sets for Diesel engines, and Velox boilers, as well as with gas turbines for Houdry oil refining plants. According to this experience there is, with oil firing, no danger for the blading, provided the maximum admissible temperature is not exceeded for any appreciable length of time, an event which has happened only three times although there are over 1000 exhaust and gas turbines in service.

Another question is the behaviour of the combustion chamber. Since the latter is air-cooled, and the cooling air is supplied by the same compressor which furnishes the combustion air, the cooling air can never fail whilst combustion is going on. This ensures the greatest degree of security for the cooling of the combustion chamber.

(d) The Diesel locomotive requires little, the gas-turbine locomotive no water. The fuel tank of the gas turbine locomotive must be about twice as large as that of the Diesel locomotive for the same radius of action.

(e) As the gas-turbine locomotive has no reciprocating parts and no critical speed (the speed range of turbine and compressor is below the critical speed), it should, in principle, be more suitable for still higher speeds than those attainable with the Diesel-electric locomotive.

(f) The steam locomotive has balancing weights in the wheels, Diesel and gas locomotives have none. The total weight of the gas turbine locomotive is less than that of the Diesel-locomotive.

(h) Since the gas-turbine locomotive has no reciprocating parts its expectancy of life should be greater than that of the steam locomotive.

(i) The same reasons hold good here as for h.

(k) Equality of costs for fuel for the Diesel locomotive and for the gas turbine locomotive applies naturally only to the U.S.A. and other lands in which fuel oil costs about half as much as Diesel oil.

(l) The lubricating costs of the power unit of the gas turbine are negligible, the lubrication requirements of the wheel axles are of course the same as those of other locomotives.

(m) The water for the auxiliary Diesel set has not been included as the set only runs for about 5 minutes per day and because it is intended to replace water cooling by air cooling on account of this.

(n) The even distribution of the tractive effort on all wheels assures much better starting conditions, especially in wet weather. This is also true of the Diesel-electric locomotive.

Another interesting comparison is afforded by Fig. 13 which compares the gas-turbine locomotive with another locomotive built in Switzerland.

Possibilities of improvement.

In all these comparisons it must be remembered that the gas-turbine locomotive is the youngest member of the great locomotive family and that it has its whole development period before it, of which much may still be expected. These expectations concern particularly the efficiency of the turbine and the maximum admissible operating temperature.

There appears to be no reason why it should not be possible to achieve an efficiency of 90 % for the gas turbine if 85 % can be attained in the compressor since the heat losses which are wholly disadvantageous to the latter are partly recuperable in the former. A 4 % improvement of the turbine would result in a 16 % improvement in the efficiency of the locomotive.

Fig. 14 shows the creep strength of heat resisting steels has increased during the last few years. Let us hope that our metallurgists will see to it that this improvement is maintained; for an increase in temperature of 150 ° F, with the same creep strength as has been achieved in the past 5 years, would result in a further improvement of the gas turbine process of the order of 25 %.

If we succeed in solving the problems inherent to the pulverized-coal gas turbine, the future of the gas-turbine locomotive would be very bright indeed. We

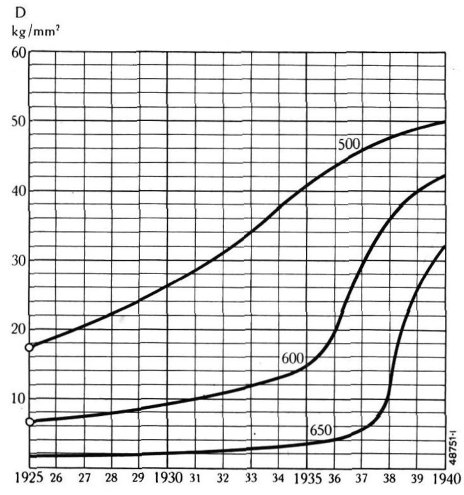


Fig. 14. — **Development of steels of high-creep strength for gas turbines, 1925 to 1940.**

The illustration shows the interesting development of the steel properties. A still greater improvement in quality would mean considerably higher gas-turbine efficiency.

—. Highly alloyed austenitic steels.

D. Highest value of creep strength recorded by measurement.

have a turbine developing 2000 H. P. of this type on our test bed and the results obtained justify our hopes of being able to put similar units on the market in the near future.

By developing and perfecting such an eminently peace-time piece of engineering, in spite of all raw-material difficulties and other restrictions of like nature, at a time when other countries are obliged to devote every effort to the production of war material, Switzerland can be said to be fulfilling a duty, which can be considered as incumbent on it, as good fortune has so far spared it the tribulations of the World War.

(MS 840) *Dr. ing. h. c. Ad. Meyer.*

A NEW HIGH-PRECISION METHOD FOR SHORT-CIRCUIT MEASUREMENTS ON TRANSFORMERS.

Decimal index 621.314.21.001.4

Based on the fact that the electro-magnetic phenomena, in short-circuited transformers, follow strictly linear laws, a bridge connection employing the zero method has been evolved for making measurements. It is characterized by great precision.

IN all the progressive stages of development through which electrical machinery and apparatus have passed, in the course of the last fifty years, the transformer has been distinguished by one important property, namely the great precision with which its characteristics could be calculated in advance. To-day, this property is still as evident as it was in the earlier period of development.

One of the results of this has been, that the testing engineer was constantly obliged to improve his methods of measurement, because there is no other field in electrical engineering in which the margin allowed by the tolerance between calculated and measured magnitudes is as narrow as it is in transformer construction.

This applies especially to short-circuit tests, the object of which is, on the one hand, to determine the impedance voltage and, on the other, to determine the copper losses under load (i. e. the pure resistance losses and the stray eddy-current losses).

I. PHYSICAL CONSIDERATIONS ON WHICH THE NEW METHOD IS BASED.

In all standard-transformer designs (magnetic circuit of the shell type or of the core type, windings of the disc type or of the concentric coil type), the magnetic field which forms under short-circuit conditions, exists chiefly in the spaces between the high-tension and low-tension windings, because the windings are composed of ampere turns in opposition. Obviously these magnetic lines of force close outside the windings, either through the air, or through the laminations but the flux density in these regions is very low. For this reason, the reluctance of the field is really confined to the air, in other words, the reluctance and, therefore, the inductive component of the short-circuit impedance are constant values which remain absolutely independent of the strength of the current flowing in the windings during the short-circuit test.

As is well known, the resistance component of the impedance voltage depends on the pure resistances and the additional resistances of the eddy-current circuits. The pure resistances are constant values quite independent of the strength of the current. This is also true of the additional resistances in the eddy-current circuits, which owe their existence to a magnetic field uninfluenced by the degree of saturation.

These considerations show that there is a strictly linear relation between voltage and current during a short-circuit test in any standard transformer.[1] The considerations in question are not only confirmed by measurements but by calculation as well, in which the magnetic properties of the iron are never introduced. Every standard transformer when short-circuited can be considered as a constant impedance independent of the strength of the current. Under these conditions, it is logical to choose a measurement current which is most suitable from the point of view of measurement requirements alone instead of the normal full-load current.

II. DESCRIPTION OF THE NEW METHOD.

Obviously a bridge connection seems the best solution for carrying out measurements, the primary terminals of the transformer to be measured being connected in place of the unknown impedance while the secondary terminals remain short-circuited. The measurement bridge is then supplied with a voltage the magnitude of which is determined solely by the zero indicating instrument. There is, however, one point to be strictly observed, namely identity of measurement frequency and rated frequency of the transformer. An absolutely perfect supply voltage curve is not indispensable if the zero indicating instrument has a sufficiently sharp resonance at the given frequency. For example, a vibration galvanometer is quite suitable for this purpose.

It is easy to conceive how different bridge connections can be used here. As a rule, the modified Wheatstone bridge connection for alternating-current measurements shown in Fig. 1 is used. For example, resistance r is regulated and capacity c (that is the capacitive reactance $x_c = \frac{1}{\omega c}$) until the galvanometer G indicates the exact zero. Then the follwing equation is satisfied when $R + j X$ (complex notation) represents the measured value of the impedance of the short-circuited transformer,

$$\frac{R + j \cdot X}{q} = \frac{p}{r - j x_c}$$

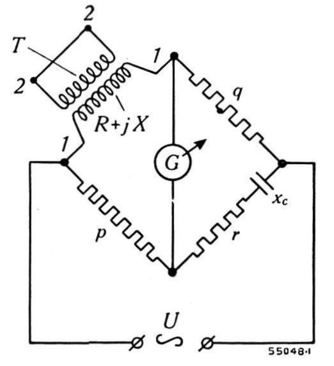


Fig. 1. — Modified connection diagram of a Wheatstone bridge for measuring the impedance of a short-circuited transformer.

T. Short-circuited transformer to be measured.
1—1. Primary terminals of T.
2—2. Secondary terminals of T.
$R+jX$. Short-circuit impedance of T, referred to primary side.
p, q, r. Resistances.
$x_c = \frac{1}{\omega \cdot c}$. Capacitive reactance.
G. Zero instrument.
U. A.-c. supply voltage.

The impedance of a short-circuited transformer is strictly constant independently of the currents flowing through the windings and can be measured in a Wheatstone bridge connection modified for a.-c. currents.

which, when the real and imaginary parts are separated, leads to

$$R = \frac{p \cdot q}{r^2 + x_c^2} \cdot r \qquad X = \frac{p \cdot q}{r^2 + x_c^2} \cdot x_c$$

As soon as R and X are known, it is an easy matter to find the active and reactive load corresponding to the operation of the transformer in short circuit.

[1]) This reservation with regard to standard transformers is made in order to exclude certain transformer designs in which primary and secondary windings are insufficiently interleaved (for example, primary winding on one leg and secondary winding on the other).

The Wheatstone bridge cannot be recommended when the impedance $R + j\,X$ is very small, i. e. when the transformer winding inserted in the bridge has a small number of turns. In this case the unavoidable contact resistances can no longer be ignored and would falsify the measurements. In such cases, the Thomson double bridge, in the modified connection for alternating current, can be used to advantage, as shown in Fig. 2. As is known the influence of the contact points is eliminated with this bridge connection.

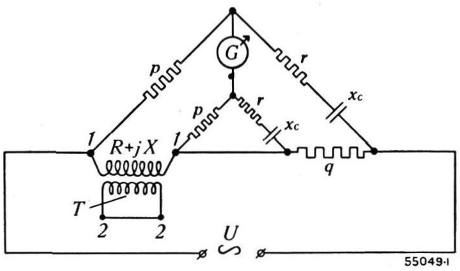


Fig. 2. — Thomson double bridge in modified form for measuring the impedance of a transformer in short-circuit connection, when the impedance is low.

T. Short-circuited transformer.
1—1. Primary terminals.
2—2. Secondary terminals.
$R+jX$. Short-circuit impedance of T referred to primary side.
p, q, r. Resistances.
$x_c = \frac{1}{\omega \cdot c}$. Capacitive reactance.
G. Zero instrument.
U. A.-c. voltage of supply.

When the short-circuit impedance to be measured is very low, it is necessary to avoid mistakes due to contact resistances. The Thomson double bridge in modified connection for a.-c. currents is then the suitable solution.

We have used as zero indicating instrument both a vibration-type of galvanometer and a cathode-ray valve, similar to those used in radio receiving sets as resonance indicators. The voltage sensitivity of these is attained by a valve amplifier and the selectivity by different filter circuits. We give below the characteristic data of an apparatus of this type built by Trüb, Täuber & Co. of Zurich (see Fig. 3). A measurement voltage of two micro-volts produces a quite distinct movement of the unlighted part of the screen of the cathode-ray valve. The sensitivity drops by 50 % for a frequency variation of 7 % both in positive and negative sense. The input impedance of the instrument amounts to 800 Ohms for the total frequency range made use of.

There is a remark to make on the bridge measurement applied to *three-phase* transformers, because the bridge can only be used in single-phase connection. This difficulty can be overcome easily by carrying out three successive measurements on terminals *UV*, *VW*, and *WU*. This process is fully justified by the principle of superposition. If there was any possible

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Fig. 3. — Zero instruments by Messrs. Trüb, Täuber & Co. A. G., Zürich, for a.-c. currents and frequencies of 100 to 500 cycles.

This zero instrument is composed of a cathode-ray valve supplied by a valve amplifier through suitable filters.

doubt regarding the correctness of this argument, the equivalence of losses measured in single-phase or three-phase could be established for all standard transformer connections by calculation both for the pure resistance losses as well as for the stray losses.

III. APPLICATION OF THE NEW METHOD AND ITS ADVANTAGES.

Our transformer testing department is equipped with an impedance bridge for carrying out short-circuit measurements according to the method explained in the preceding paragraphs. It is very striking to note that this bridge is supplied through a transformer of 40 MVA rating only and, under these conditions, allows of carrying out with the greatest facility measurements of a precision unattained up till now on transformers up to 40 MVA.

On the basis of statistics drawn up from the results of about thirty measurements, it was proved that there was no fundamental difference between the results obtained by the usual method with voltmeter, ammeter and wattmeter and those with the new method, both as regards impedance voltage and short-circuit losses. Indeed, the characteristic feature of the new method is that, as compared with measurements carried out under the full rated current, those resulting from the new method repeated on the same transformer or on several identical transformers show considerably more constant results. This advantage of the bridge method is explained, on the one hand, by the higher sensitivity[1] and, on the other, by the

[1] In reality, there is nothing to prevent an unlimited increase in the sensitivity in so far as we have zero-instruments to-day for extremely low a.-c. currents.

elimination of the influence exercised by temperature, because the measurement current used is far too low to produce any temperature rise of the windings under test.

The bridge method is exceptionally suitable for carrying out short-circuit measurements on transformers of big outputs and very high voltages, because these units have a very low power factor in short circuit (for example, 0·05 and less). Under such conditions, there are big difficulties encountered in using a wattmeter. For some time, the measurement of the voltage ratio has been carried out in potentiometer connection with voltage supply from the low-voltage side (220 V). The measurement bridge, described here, completes this apparatus in a most desirable manner, because in future it will be possible to measure with great accuracy the voltage ratio, impedance voltage and the copper losses of the biggest transformers. This also applies to all the magnitudes influencing the possibility of parallel operation. Further, all these measurements can be carried out with the aid of a low-voltage source of current with an output of only a few volt-amperes. Finally, only the no-load test to ascertain the losses in the iron and the voltage tests (with induced voltage or with external source of voltage) demands an appreciable source of power.

IV. NEW METHOD AND ACCEPTANCE TESTS.

We have used the new method in numerous special problems for which it was necessary to make very precise short-circuit measurements. It is certain that no other method of measurement would have met the requirements in the majority of cases (see the Bulletin of the SEV, number 4 of 21st Feb., 1941, "Zusatzverluste im Kupfer von Dreiwicklungstransformatoren"; further we would refer to an article which will appear later in the same journal, dealing with eddy-current losses due to rectifier currents).

But outside the sphere of these investigations, there is the question of whether the validity of the new method can be recognized in acceptance tests. The onus of clearing this question up should certainly not be put on us, builders of transformers, alone. We, therefore, take this opportunity of placing the matter before competent technical circles in the hope that it may arouse their interest. Our own conviction is that the method is rigorously exact for transformers which can be designated as of standard design, that is such in which the different windings are properly interleaved, in the usual way. This reservation does not seem to us to be an objection of any practical importance.

Firstly:— because all experienced transformer designers see to the proper interleaving of the windings of power transformers.

Secondly:— because if the stray-field lines of force penetrated into the iron on account of a poor magnetic balance of the windings, the stray losses measured at reduced currents would be bigger than under rated current. As is known, the depth of penetration of eddy currents is the smaller the lower the saturation in the iron.

(MS 827) *Dr. P. Waldvogel. (Mo.)*

MODERN ELECTRICAL EQUIPMENTS FOR AUTOMATIC CONVEYING PLANTS.

Decimal index 621.34 : 621.86-52

Automatic conveying plants for handling goods in piece or in bulk are becoming increasingly important in every branch of industry. The fundamental conditions which such plants must satisfy are:— reliability in service, simplicity in operation and in supervision, low upkeep charges. This article describes the principles applied in developing the electric equipment, the conveying equipment of a gas works being given as a practical example to show how a new type of programme switch fulfils the above-mentioned fundamental conditions.

IN the November number of The Brown Boveri Review, 1940, we published an article on "A new kind of electrical drive in a coal-conveying plant" in which a detailed description was given of how coal was handled in the Basel gas works and what had been done to render its conveyance automatic. The interest aroused by this article in various branches of industry has led us to give a more general description of modern electrical equipments fulfilling similar purposes in different branches of industry, with details on the fundamental principles applied and the apparatus appropriate to this end.

I. GENERAL NOTES.

In the course of the last twenty years, conveying plants have played an important part in the improvement of industrial undertakings and have invaded a variety of new fields. Among these we have mining, where conveying plants are of primary importance either below ground as an auxiliary to the extraction process proper or above ground in sorting, washing, processing and moving both coal and ore; steel works, foundries and blast furnaces which must be fed constantly with coke and ore, etc.; gas works and steam power stations, chemical plants, cement mills, in fact every plant where considerable quantities of material in bulk or in piece have to be conveyed. Another interesting field of application is found in storage plants, silos, loading and

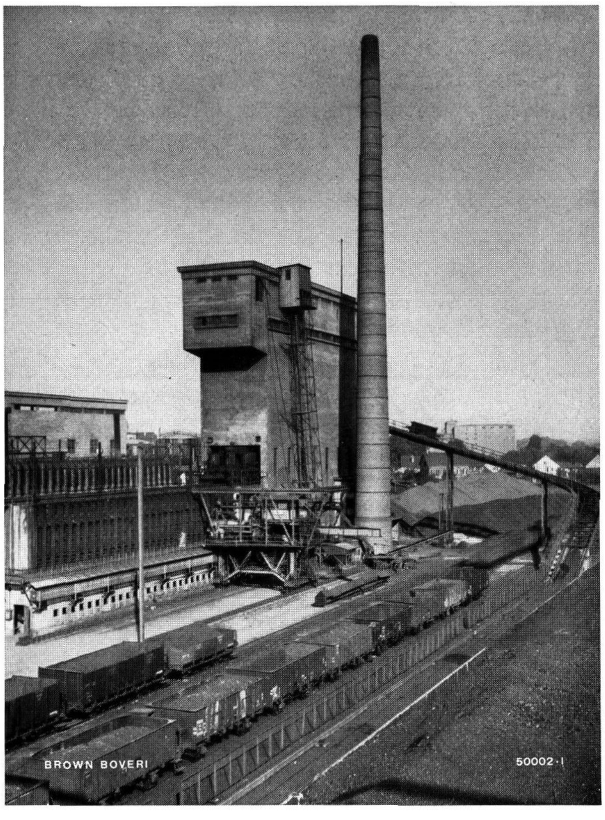

Fig. 1. — Coal bunkers and coke ovens of a modern gas work.
Coal and coke are conveyed automatically. The different conveying devices are very simple to operate and work with entire reliability.

unloading yards, etc., where we face the same conveying problems. Fig. 1 gives an example of an installation in which different kinds of conveying devices are used simultaneously.

As the quantities of material to be conveyed went on increasing, the distances over which conveyance took place getting longer and subjected to more complications, while at the same time operating or production costs had to be kept down, the managements of conveying plants were obliged to replace, as far as was possible, manual control by *automatic control*. Automatic control has *great advantages* of a technical order and does much to render the operation of the plant more profitable. Among its undoubted advantages we would mention the elimination of the "human element", liable to error and an increase in the handling capacity of the plant due to there being fewer idle periods and, speaking generally, a considerable reduction of upkeep charges. We will have the opportunity of examining these different advantages in more detail in the course of this article.

II. WORKING CONDITIONS.

Let us first see what conditions automatic conveying plants have to fulfil. Obviously, these conditions depend on the object aimed at which, in its turn, can be summarized by the two fundamental conditions:— safety and speed. *Safety* is an imperious necessity in all conveying plants. These generally comprise different devices, placed one after the other, in the general process of conveyance. The first one feeds the second and the second the third and so on, in other words these are plants working on the chain principle. The result is that any sudden failure of one link may stop the whole plant or, at least, a section thereof. As, generally, conveying plants supply services in which no stops can be allowed, the slightest breakdown may have very onerous results. To allow the reader to grasp this fact, we would recall the charging equipments of blast furnaces, for example, in which a stoppage in the supply of coke or ore due to some piece of apparatus breaking down has disastrous consequencies. The question of *speed* is not important to conveying plants alone but it is an indispensable condition of rational and cheap production in most branches of industry. The conveying branch plays only an auxiliary part in an industrial process but it should nevertheless satisfy this condition of speed just like all other sections of the plant. Speed means frequent and usually consecutive starting operations and braking operations with the current surges resulting therefrom. Thus, there are certain cases in which several hundreds of switchings have to be carried out per hour. Such plants impose severe stresses of an electrical and mechanical nature on the electrical control equipment.

Further, the atmospheric conditions under which the electrical gear is called on to operate may have an injurious effect on its performance if proper constructive measures are not taken to protect it. These equipments are frequently called on to work in damp surroundings or in rooms filled with smoke, with corrosive vapours or conductive dust, in rooms in which the temperature is high or even in the open air where they are exposed to the weather. Further the equipments are exposed to mechanical shocks and to vibrations originating in the structural parts of the plant.

The above conditions call for *simple* and *strong* equipment. The strength thereof must not, however, be acquired at the cost of too heavy weight, which is incompatible with the necessity of having as instantaneous starting and braking operations as possible. Here the essential factors which should guide the management of a plant in choosing their equipment are:— rational layout, proper choice of materials, irreproachable design based on experience and on the results of many tests. The need of rapid and reliable performance calls for the following qualities:— easy control and supervision, little and simple upkeep, rapidity in replacing parts worn out, an easily grasped layout of the apparatus. On the other hand, the surroundings in which the equipment will be called on to work determines the protection it should be provided with, this from the mechanical and insulation point of view.

III. FUNDAMENTAL PARTS OF THE EQUIPMENTS.

Although the object of the present article is, chiefly, to determine the characteristics of the apparatus serving to control the conveying plant, we would like at the same time to stress here the importance of choosing the most suitable types of *driving motors* for the plant. The outputs of the said motors vary from about ten to several hundreds of kilowatts. Usually, these outputs are continuous ratings, in other words, the motors run continuously or, at least, for long periods without a stop. In certain particular cases, especially for reversible drives, the motor is not continuously in circuit but is connected up according to a cycle which comprises switched-in periods and stop periods and which recur at regular intervals. In such cases the motor is subjected to intermittent loading and the so termed switching ratio is determined by the ratio:—

$$\frac{\text{switched-in duration during a working cycle}}{\text{duration of complete working cycle.}}$$

Intermittent services as encountered in conveying plants correspond in practice to the switched-in ratios of 15, 25 and 40 %, the latter figure only being exceeded in exceptional cases.

According to the working conditions of the plant and, particularly, according to the frequency of switchings or the starting torque required, motors with squirrel-cage rotors, with centrifugal starters or with slip rings will be chosen when the plant operates with three-phase current. In certain cases, speed variation is called for, to be carried out in accordance with a determined programme, in which case three-phase motors with commutators or d.-c. motors in Ward-Leonard connection are put in. As regards protection from the mechanical point of view, it is often possible to use standard motor designs of the drip-water proof type. In other cases, the motors having to be placed in the open air or in an injurious atmosphere, the design chosen is the pipe-ventilated or totally-enclosed one.

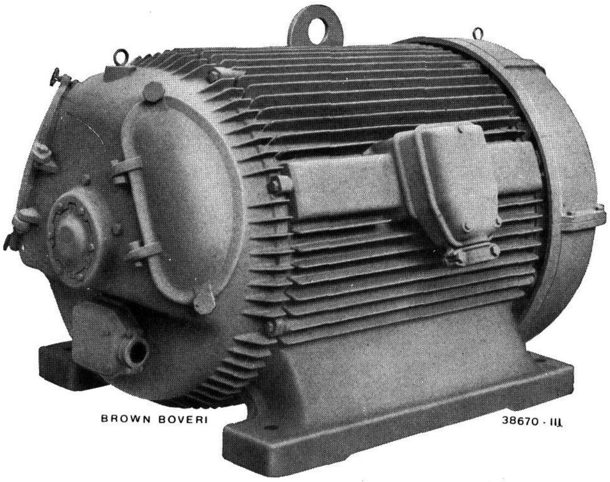

Fig. 2. — Totally-enclosed three-phase slip-ring motor with cooling ribs on the housing and external cooling by fan.

This design is very suitable for severe working conditions in injurious atmospheres.

Fig. 2 shows one of the latter type of motor which is commonly used in conveying plants. These machines are very strong indeed, both mechanically and electrically, have a totally-enclosed housing with numerous ribs to increase the cooling surface. There is a powerful fan mounted outside the housing and protected by the shield bearing; it is effectively protected against accidental contacts and mechanical damage and, along with the fan inside the housing, it produces a thorough cooling action of all parts. This excellent cooling system allows of reducing the dimensions of the motor. The windings have special insulation while the external parts are given an anti-corrosion coating. The ample bearings are of the roller type, with big grease boxes so that the machine can run for a long period without attendance. These motors are very suitable for trying operating conditions.

The *choice of the apparatus* depends, obviously, on what principle is applied for the automatic control. Here there are two different fundamental principles entailed. The first meets the conditions necessary for automaticity by a suitable combination of various control devices which act directly on the apparatus controlling the motor. This solution implies a choice of apparatus with a large number of contacts, in order to meet the needs of the numerous interlocks and connections between the different parts of apparatus and a complicated diagram of connections; this often gives rise to difficulties when the plant is put to work and also when it is overhauled or repaired.

The second principle has been developed and perfected by Brown Boveri for all combined installations, which are those in which there are several motors which have to run alternatively or the speeds of which have to be varied in function of a programme laid down in advance. This is the *programme-switch* principle. A central control apparatus which gets the requisite impulses from the manœuvring switches, in its turn, imparts to the contactors and relays the successive impulses corresponding to the desired programme. The programme switch ensures the proper succession of the various operations while excluding all faulty switchings and, thus, is the "brain" of the automatic control. Not only does it allow of equipping the whole plant with simple manœuvring switches, which are mostly of one-pole type, and with very few auxiliary circuits, but it also permits of trying out and tuning the complete plant in the shops by reproducing identical conditions to those of practical running. This allows of reducing tests on site to a minimum and shortening the time required to put the plant into service.

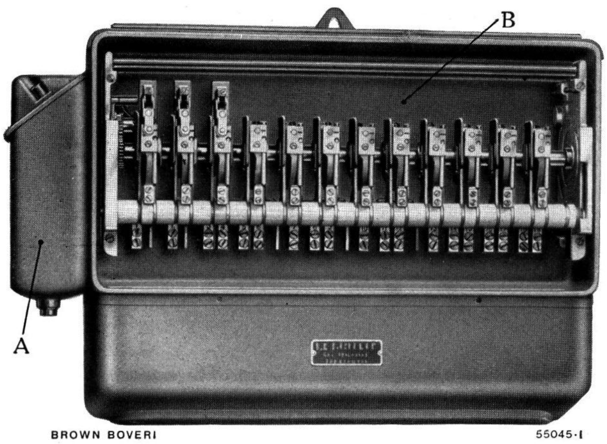

Fig. 3. — Programme switch.

The brain of the automatic control. It ensures the right sequence of switching operations according to the programme decided on. This strong device simplifies the control very considerably and increases reliability.

A. Oil tank of auxiliary motor, made of light metal.
B. Hammer-type contacts actuated by cams.

Cover removed to show contacts.

In accordance with its important functions, the programme switch Fig. 3 is made very strong. There is a servo-motor which drives a shaft on which cams are mounted each of which governs a hammer-type contact of ample dimensions. The number of contacts and shape of the cams are determined in accordance with the programme it is desired to carry out. Further, it is an easy matter to change the moment at which the contacts function and adjust the length of time each contact is closed and open to the needs of the control. This design is particularly attractive as it allows quick adjustment of the equipment and perfect setting of the automaticity.

The *servo-motor* is of the *vibrating-armature type* having neither commutator, brushes nor flexible current leads. It functions very reliably. An interesting characteristic of this motor is its independence of the temperature. Even overloads which may occur have only a slight influence on it. This latter property is very advantageous especially for complicated programmes to be carried out automatically.

In most cases, the programme switch controls the performance of the plant through the intermediary of contactors.

The magnetically controlled switch, or "contactor", plays a big part in automatic controls of many types. The many applications of the contactor according to what kind of current is available, what type of plant is being controlled and what diagram of connections is used etc., makes it necessary that it should be very adaptable besides being very reliable, both mechanically and electrically.

Contactors of the air break type, as used in automatic conveying plants and in all controls with frequent switchings, often gave trouble, on account of wearing out too quickly. For many years efforts have been expended towards eliminating these difficulties by improving the design.

After exhaustive tests, both on industrial plants and in laboratories, Brown Boveri have brought out a contactor which does away radically with these disadvantages. The rebound of the contacts at the closing of the contactor is suppressed and a high closing velocity attained. This reduces wear on the contacts to a minimum and ensures a long life to all the moving parts. A frequency of switching of the order of 1500 switchings per hour (Fig. 4) is now allowable. We would add that the main contacts are very accessible and easily replaced in a minimum of time, which shortens stoppages of the plant.

According to the surroundings in which the apparatus has to work, the contactors can be mounted open on iron frames, in ventilated cubicles or totally enclosed in boxes. In most cases, all the contactors required to carry out an automatic control are lodged in a common cubicle which also holds the programme switch, the protective switches for the motors and the

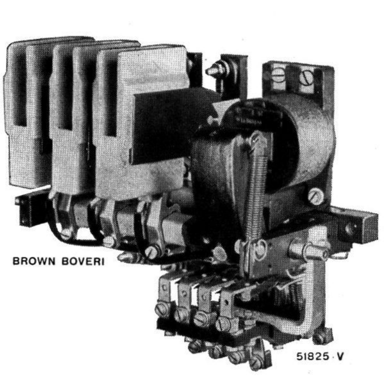

Fig. 4. — Three-pole contactor for alternating current with air-break contacts.

A modern design ensuring long life, very little and simple upkeep. These qualities make the contactor especially suitable for automatic controls in which frequent switchings take place.

auxiliary apparatus (Fig. 5). The cables between all these different pieces of apparatus can be mounted in the shops and this arrangement allows of trying out the entire equipment before despatch, which simplifies matters on site.

When the surrounding atmosphere is particularly injurious, it is necessary to protect the apparatus more completely. In such cases *oil-immersed contactors*

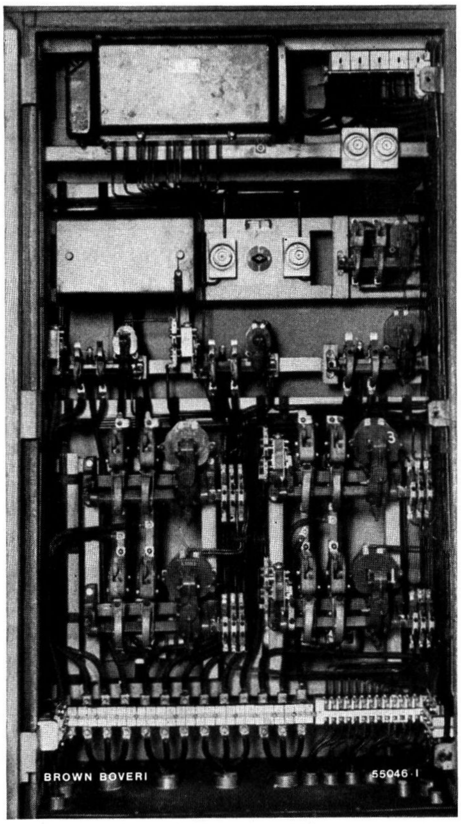

Fig. 5. — Cubicle for contactors built of structural iron parts with sheet-iron panels and door at front.

The layout of the switching devices and leads simplifies supervision and increase operating reliability.

are used. As Fig. 6 shows, this apparatus comprises a light-metal case holding the terminals and, eventually, the thermal relays for motor protection. The coil and the contacts are lodged under it in a tank and are entirely immersed in oil. The same applies to the auxiliary contacts.

The tank is easily lowered to allow of supervision and replacement of the contacts. The joints between cover, tank and metal case are made splash-water proof and dust tight.

This apparatus can also be mounted on a switchboard panel or in totally enclosed switching batteries. This latter arrangement is often resorted to for simple automatic plants working in an injurious atmosphere.

A big number of conveying plants (conveyors, elevators, etc.) always work in the same running direction while others such as hoists, buckets and trucks run in alternating directions. At the end of each travel, the mechanism must be stopped by a *mechanical brake* which remains applied during the whole stop to prevent sudden restarting. These shoe or band brakes are held applied by a spring or, what

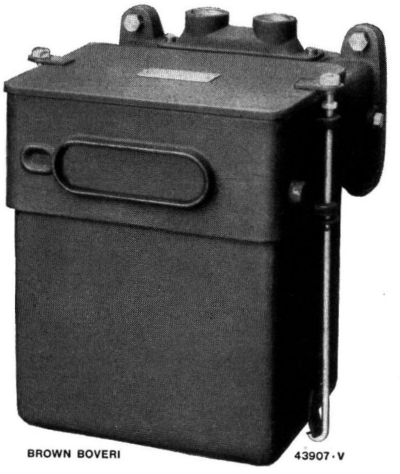

Fig. 6. — Three-pole oil-immersed contactor totally enclosed and therefore very suitable for mounting in injurious atmospheres.

is better, by a counter weight. The brake is released by an electro magnet. The latter comprises a cast iron frame, a fixed armature and a moving one, which operates on the brake mechanism. When the coil is put under voltage, the moving armature is attracted by the fixed one which action releases the brake. When current is cut off, the brake is blocked by the action of the spring or counter weight.

Unfortunately, experience shows that brake-releasing electro-magnets working with alternating current have certain defects. They work in jerks which stresses the brake and the mechanism. The coils absorb a big closing current. Thus, it is impossible to give suitable protection to the coils. If a brake-releasing electro-magnet fails to draw up its moving armature completely, due to some slight overload or a mechanical defect, the current remains as strong as in the beginning and the coil will burn out. This means stoppage of operations with all its accompanying inconveniencies.

This is the reason why Brown Boveri replaces the brake-releasing electro-magnets, whenever possible, by another apparatus, termed electro-hydraulic thrustor, which has none of these defects, and the qualities of which go far to increase the reliability of operations.

This apparatus comprises a centrifugal pump driven by a small squirrel-cage motor mounted above the tank. The thrust pistons are grouped round the motor on the top of the tank and are connected together by an armature which transmits the thrust to the mechanism of the brake, directly. As soon as the motor begins to revolve, the pump delivers a fluid under pressure to the cylinders and continues to do so until the pistons have reached the end-travel position. In this position, the pump ceases to deliver but maintains constant pressure under the pistons so that the brake counter-weight is maintained raised. If the motor is cut out the pump stops and exercises no more pressure; the pistons fall back to their original position driving the fluid into the tank again. There is an adjustable damping device which can be made to intervene at any desired point on the down stroke of the pistons and which allows of obtaining a time-stroke characteristic with a sharp bend in it, which is an object often sought for in the case of powerful brakes. It is also possible to regulate the strength of the damping factor by means of a throttle valve. Thanks to the simplicity of its design, the electro-hydraulic thrustor is very reliable and works smoothly and, pratically, noiselessly. Contrary to what occurs with electro-magnets, the motor of the thrustor only takes a low current at switching in, which allows of providing it with suitable protective devices. An overload of the motor due to excessive mechanical stressing, i. e. a counter-weight which is too heavy or too powerful springs etc. cannot occur, here. The smooth action protects the thrustor from strain as well as the mechanical part of the plant and its electrical equipment.

Fig. 8 gives an example of a winch mechanism belonging to a conveying plant which is equipped with an electro-hydraulic thrustor. This apparatus, seen in the background, releases the service brake, which is of the shoe type. A second brake is seen in the foreground; this is the emergency brake and is also of the shoe type. Both brakes act on separate drums. The counter-weight of this latter brake is raised by a crank. It is maintained in its upper position by a small electro-magnet. If trouble occurs, as, for example, over speed, or end-travel switches being overrun or excessive vibration of cables, the little electro-magnet is immediately cut out and the winch is blocked by the emergency brake.

We said before that the servo-motor of the programme switch got the necessary current impulses from the manœuvring switches which allow of operations taking place according to the desired programme. According to the layout of the plant, these manœuvring switches can be push-button switches, diaphragm apparatus placed in the silos or hoppers or again interlocking switches or end-travel switches, governed by mechanical devices which ensure the conveying process. Thus, Fig. 9 shows a manœuvring switch placed on the rail track followed by a coal bucket of hinged-bottom type just at the beginning of an incline. This switch is actuated when the bucket passes it, through the agency of a small actuating rail on the side of the bucket. In the plant in question this switch fulfils an important function:— the speed of the bucket on the incline is lower than on the level, for mechanical reasons, and the change in speed required when the incline changes, either in travelling in one direction or the other, is carried out

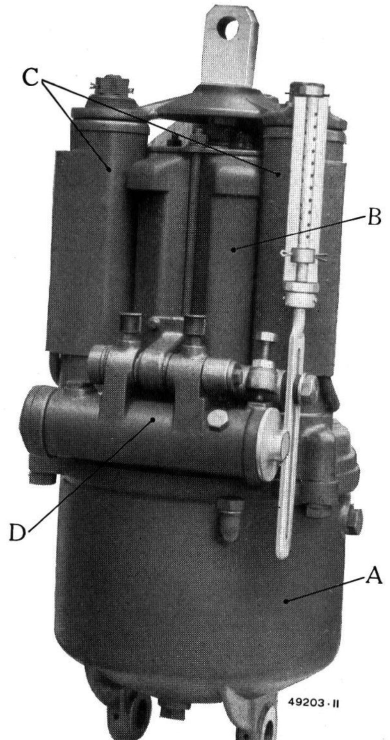

Fig. 7. — Electro-hydraulic thrustor with adjustable damping effect.

The brake releaser for automatic brakes of hoisting gears and conveying plants. It is taking the place of brake releasing electro-magnets on account of its outstanding advantages.

A. Oil tank. C. Cylinders.
B. Motor. D. Damping device.

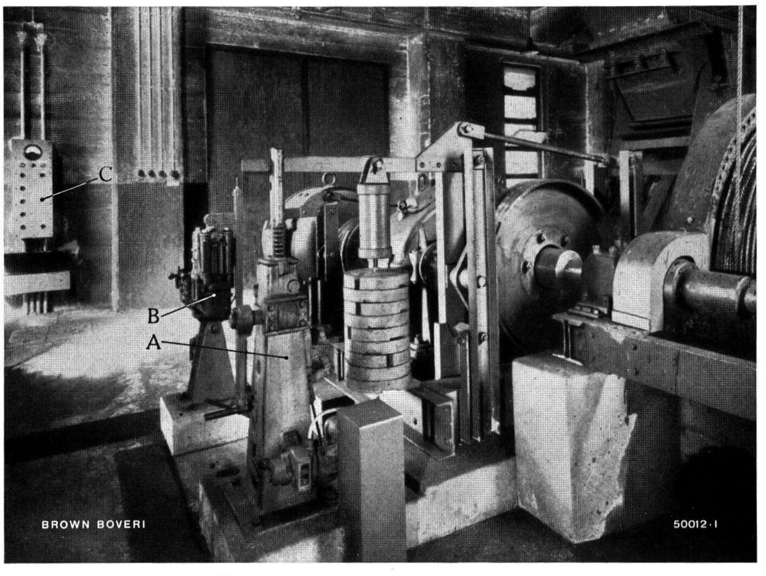

Fig. 8. — Winch gear of an automatic conveying plant.

A. Safety brake. B. Service brake controlled by an electro-hydraulic thrustor.
C. Control panel for manual or automatic service.

by the switch, which acts, according to what has been said, on the programme switch.

Fig. 10 shows an *end-travel switch* for auxiliary current, much used in conveying plants either as a

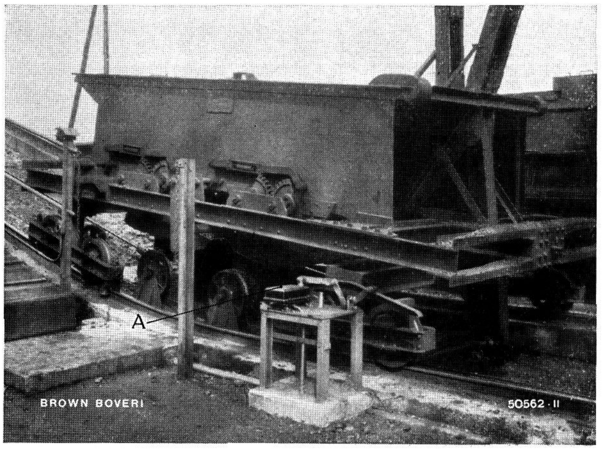

Fig. 9. — Coal bucket in an automatic conveying plant, with end-travel switch and device for actuating it, designed so as to protect the switch from shocks when the bucket actuates the switch.

A. Manœuvring switch with special actuating gear.

manœuvring switch or as an interlocking switch. This design is characterized by light moving parts and is, thus, particularly suitable for frequent switchings, up to about 600 per hour.

The apparatus has hammer contacts, controlled by cams, which give perfect contact and, consequently, very reliable service. The shape of the cams can be altered on site which allows of adapting the apparatus to any programme.

These switches are controlled by means of a lever or fork designed specially to suit the frequent switchings to be carried out and the heavy mechanical stresses resulting therefrom. They can either be placed in the open air or in dust- or fume-charged atmospheres.

This study would be incomplete without mention being made of an interesting control device now commonly found in important plants; this is the *light diagram.* It is particularly suitable for conveying plants in which several working programmes are carried out. It allows the operators to ascertain at any moment what programme is being worked to and what parts of the plant are working. It also signals any trouble or stoppage and thus increases the simplicity of supervision. Fig. 11 shows the control desk of a coal silo with a light diagram in the vertical panel above it. This diagram shows the 5 silo compartments with their respective conveyors and elevators, as well as the coal crusher and hinged-bottom bucket for discharging the coal. The same diagram is reproduced in colour on the upper part of the desk on which is mounted the apparatus necessary for choosing the working programme, as well as for starting the plant or stopping it.

In its standard design, the light diagram works in the following manner:— once the conveyance programme has been chosen, the diagram lights up in flickering light signals which appear on the diagram. The operator can thus check whether the preparations he has made are the right ones and sees exactly what the working programme chosen is going to perform. He thus avoids mistakes and, even serious accidents which may result from starting some device in course of repairs, for example. By depressing the starting push-button, the motors driving the different devices

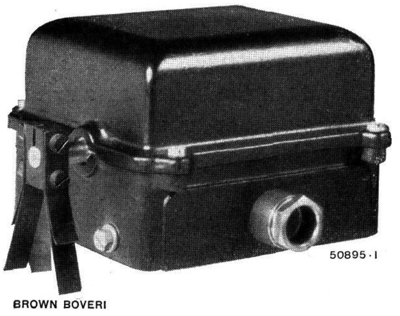

Fig. 10. — Auxiliary-current end-travel switch with hammer-type contacts, compact design, protected against weather and dust-tight.

The moving parts of the switch are light and give great service reliability while being very rapid in action.

are all switched in in proper sequence by the programme switch. Every time a motor is switched in, the flickering light of its respective symbol on the light diagram changes to a steady white light.

Fig. 11. — Light diagram of a coal bunker plant.

The optical signals simplify putting to work and attendance and help considerably in keeping the vital coal conveying plant always ready for service.

If trouble occurs, as for example when the overload on some motor causes its relays to cut it out, all the devices working in front of it are cut out as well to prevent material being carried along and collecting at one point. On the light diagram, the defective part appears in a red light and an acoustical signal draws the operator's attention to the mishap. The symbols of the devices placed before the defective one now appear in flickering light, meaning that they also have stopped but can carry on again as soon as required. Of course, all other parts of the conveying plant unaffected go on running and are represented by steady white lights in the light diagram. This signalling of the defective element allows the operators to localize the fault simply by looking at the light diagram and thus avoids the necessity of carrying out long investigations in the plant. Thus, stoppages due to defects in the mechanical or electrical gear are made as brief as possible.

IV. PRACTICAL APPLICATION.

In order to make clearer how the principles set out above are applied in practice, we describe, summarily, a characteristic automatic conveying plant. This is the *coke elevator in the Geneva gas works.*

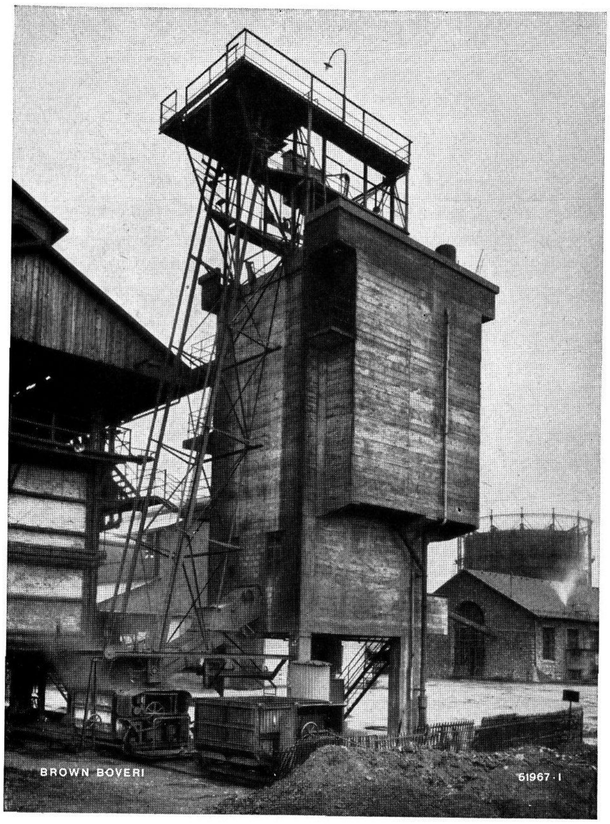

Fig. 12. — Dry coke-extinction plant of the Geneva Gas Works.
On the left, the coke elevator and coke bucket car; the cloud of dust in which the switching devices have got to operate will be noticed.

This plant which is an up-to-date one was put to work recently and has given very satisfactory results thanks to the devices just described.

The Châtelaine works of the Services Industriels de la Ville de Genève supplies the greater part of the Canton of Geneva with gas. Recently, this plant has been completed by the building of a plant for the process of the dry extinction of coke, which was delivered by Messrs. Sulzer Bros., Winterthur, acting as general contractors. This plant utilizes the caloric energy contained in incandescent coke to generate steam and it works in the following manner (Fig. 12).

Hinged-bottom buckets mounted on motor trucks are loaded with incandescent coke supplied from the ovens after the gas has been extracted from the coal and these buckets travel to the foot of an extinction tower. Here, they are taken over by an inclined elevator track which is seen on the left, and are carried up to a position above the loading aperture in the upper part of the tower; they are then emptied into the extinction chamber. The empty bucket now descends to the motor truck, which is then ready to fetch another load.

The boiler and its accessories are located inside the tower, in its lower part. After the heat has been entirely extracted, the coke collects in a discharge channel and is loaded on discharge buckets.

Messrs. H. Hübscher, Maschinen- und Stahlbau in Schaffhouse (Switzerland) built the mechanical part of the equipment which comprises a metal structure resting on the concrete tower and on which runs a crab with hoisting gear. The loaded coke buckets coming to the foot of the tower are suspended to a beam which has wheels engaging in the rails of the inclined elevator.

Weight of empty coke bucket with beam	2·2 t
Capacity of bucket	2·0 t
Hoisting speed	18·5 m/min
Travelling speed of crab	25 m/min.

The plant is supplied with three-phase current 380 V, 50 cycles. The *electrical equipment* supplied by Messrs. Brown, Boveri & Co., Limited, Baden, comprises a hoisting motor of slip-ring type, 26 kW, 975 r. p. m. and a travelling motor of the squirrel-cage type, 1·5 kW at 920 r. p. m. for the crab. These machines have got to work in an atmosphere charged with coke dust and are totally enclosed, with *external cooling*; they meet all requirements perfectly. Fig. 13 shows the winch-gear motor with stop brake and the corresponding winch drums.

Based on Fig. 14, which gives a simplified form of the diagram of connections, we will now describe the apparatus and how it works.

The winch motor 1 is switched in for hoisting or lowering by contactors 7a or 7b. It starts with the

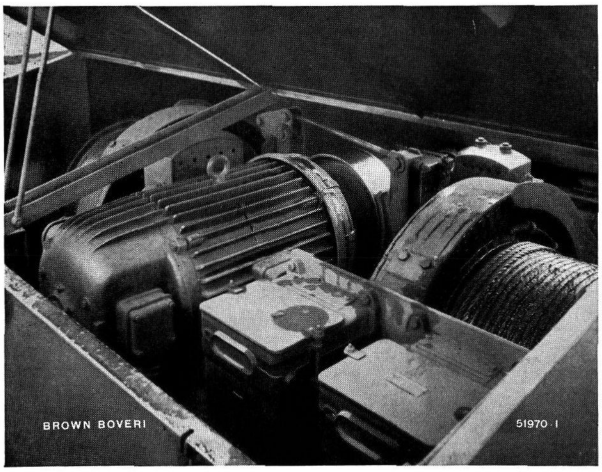

Fig. 13. — Winch gear of coke elevator in the Geneva Gas Works.
Totally-enclosed motor with external cooling and oil-immersed contactors ensure perfect service despite the dust-laden atmosphere.

help of resistance 2, the two steps of which are short-circuited one after the other by contactors 3a and 3b. The motor 5 displacing the crab is controlled by contactors 8a and 8b. The end-travel positions of bucket and crab are limited by the end-travel switches 13. Main switch 11 allows of cutting out the whole plant.

The various contactors are controlled by the programme switch 9, according to the principle already laid down.

Let us assume that bucket B, loaded with incandescent coke, has just been secured to the carrying beam. By depressing push-button 10a, the operator switches in the programme switch, the drum of this switch revolves from position 0 to position I. During this rotation, hoisting contactor 7a and then contactors 3a and 3b close one after another. The bucket moves upwards.

When it reaches its highest point, it causes the corresponding end-travel switch to act which cuts out contactor 7a. The programme switch having got a new current impulse from an auxiliary contact of contactor 7a, rotates from position I to position II. In this position, contactor 8a closes and the crab motor is put under voltage and the crab with the bucket moves towards the filling hopper D. The lowering and raising of the bucket, its return journey and the descent of the empty bucket on to truck C are effected by a similar process. At each stop brought about by the corresponding end-travel switch, the programme switch 9 gets a new current impulse and moves on to the next position, switching in the contactor or contactors which cause the motor in question to run in the desired sense.

Control of the whole plant is very simple as a single depression of push-button 10 suffices to bring about a complete cycle comprising 6 different movements of the bucket and the crab. Thanks to the programme switch, the different movements always take place in proper sequence and according to the programme chosen; there is no possibility of faulty switching being carried out. Thus service reliability is absolute.

We would add that the complete apparatus was tried out and adjusted in the shops. This reduced the time necessary for setting to work on site to a minimum, indeed the whole driving gear was thus ready for service exceptionally quickly and has worked ever since most satisfactorily. Its reliability and simplicity are much appreciated by the client.

(MS 777) *G. Rochat. (Mo.)*

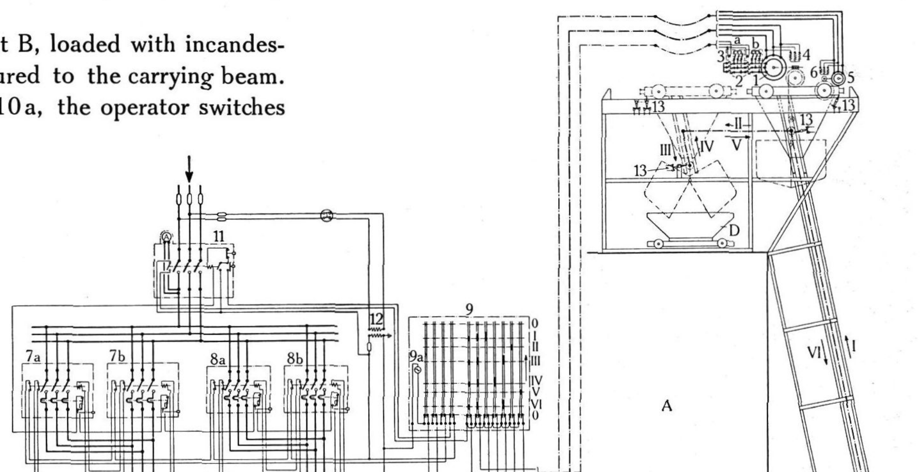

Fig. 14. — Diagram of the electrical drive of the coke elevator in the Geneva Gas Works.

1. Three-phase, slip-ring winch motor.
2. Starting resistance.
3 a, b. Rotor contactors.
4. Three-phase brake-releasing magnet.
5. *Three-phase squirrel-cage crab motor.*
6. Three-phase brake-releasing magnet.
7 a, b. Three-pole reversing contactors of winch motor.
8 a, b. Three-pole reversing contactors of crab motor.
9. Programme switch.
9a. Driving motor of programme switch.
10. Push-button switch: a. "in". b. "out".
11. Main switch box.
12. Single-phase auxiliary transformer.
13. End-travel switch.
A. Cooling tower.
B. Coke bucket.
C. Bucket-conveying motor truck.
D. Filling hopper.

BRIEF BUT INTERESTING

New trolley-buses for the town of Zürich.

As is the case in most countries, the number of trolley-bus lines is continuously increasing in Switzerland. Thus, in Zürich, a first trolley-bus line was started in 1939 and now a second one has been put into operation. This new trolley-bus line (Albisriederplatz—Spyriplatz), like the first one, replaces a motor-bus service. The line presents some stiff gradients, of up to 80 ‰. On the downward trip there is, indeed, one of 110 ‰.

Roomy coaches to hold about 80 passengers at rush hours were ordered for this line. These are characterized by considerable improvements when compared to the

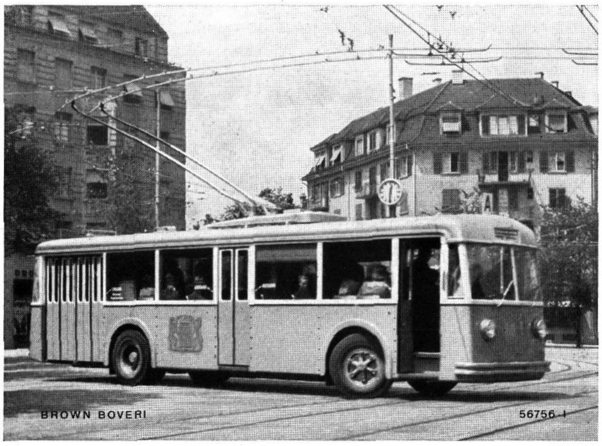

Fig. 1. — 110 H. P. trolley-bus to carry 80 passengers for the Zürich Tramways, with electrical equipment based on fundamentally new principles.

Big acceleration, high commercial speed with low power consumption.

buses running on the first trolley-bus line. The electrical equipment comprises some exceptional advantages. The 110 H. P. motor is so designed that it delivers full power at low speed and permits of speed increase without losses over a wide range by field modification. Thus, this motor economizes current in service, which brings down running costs in urban service with its numerous starts. The motor has two commutators and has proved very reliable even when subjected to the sharpest emergency brakings. Control by contactors, with the latest type of contactors, proved very advantageous. There are ten resistance steps at starting. For travelling proper, there are eleven steps, of which one at full field strength and ten further ones for regulation of the travelling speed by field weakening without loss. There are eleven steps available for electric braking. A big lighting battery allows of covering short stretches independently of the contact wire and with lowered current collector, in emergencies. There are two doors, one in front, one in the middle of the coach, so passengers can leave the bus comfortably and quickly. A third wide door at the back is reserved for passengers boarding the bus.

(MS 869) *M. Hiertzeler. (Mo.)*

The influence of seam and spot welders on the supply system.

In order to prevent the piece being welded from getting too hot, seam welders are not designed to operate continuously, but to produce a great number of separate spot welds (multi-spot welding). In these seam welders, rollers form the electrodes and these keep the work moving progressively at a speed which can be adjusted as desired. These electrodes and the work itself short-circuit continuously the secondary winding of the transformer which is built into the welder. Therefore, the requisite interruptions in the current supply must be looked after by a mechanically controlled contact, which is on the primary side of the transformer. The duration and frequency of the current impulses as well as the moment at which the current is switched in and out on the alternating-current wave are the factors which determine the magnitude of the current tapped from the supply system. It was usual, up till now, to actuate the rupturing contact by means of an induction motor which had a determined slip with regard to the frequency of the supply system. The switching in and out of the welding transformer thus took place at undetermined and continually changing points on the alternating current wave. Experience showed that this produced undesirable current surges. The result of measurements carried out with a control device driven by an induction motor are recorded in Fig. 2 and these show that current surges of as much as 960 A peak value can occur on a 500-V supply, as compared to the rated primary current of only 53 A.

By means of the *Brown Boveri synchronous switch* (Fig. 1) it is possible to make the instant of closing and opening the primary circuit coincide with the most advantageous point on the alternating current wave, so that the undesirable current peaks which were formerly experienced are entirely done away with. This allows of practically sparkless welding under low current consumption.

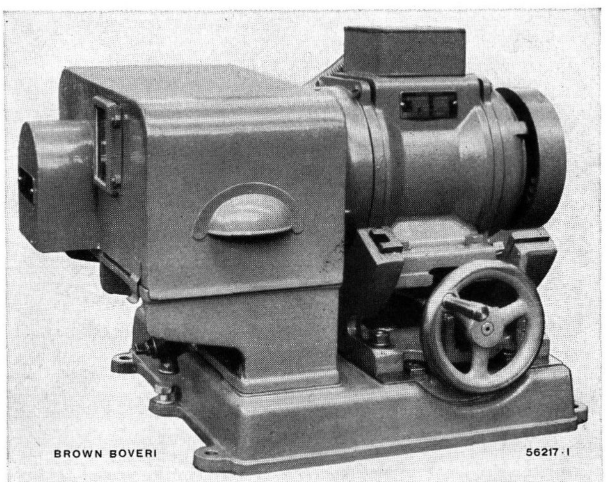

Fig. 1. — Synchronous switch for the suppression of inadmissible current surges when switching in seam welders. The life of the contacts is, practically, unlimited thanks to the sparkless rupturing process.

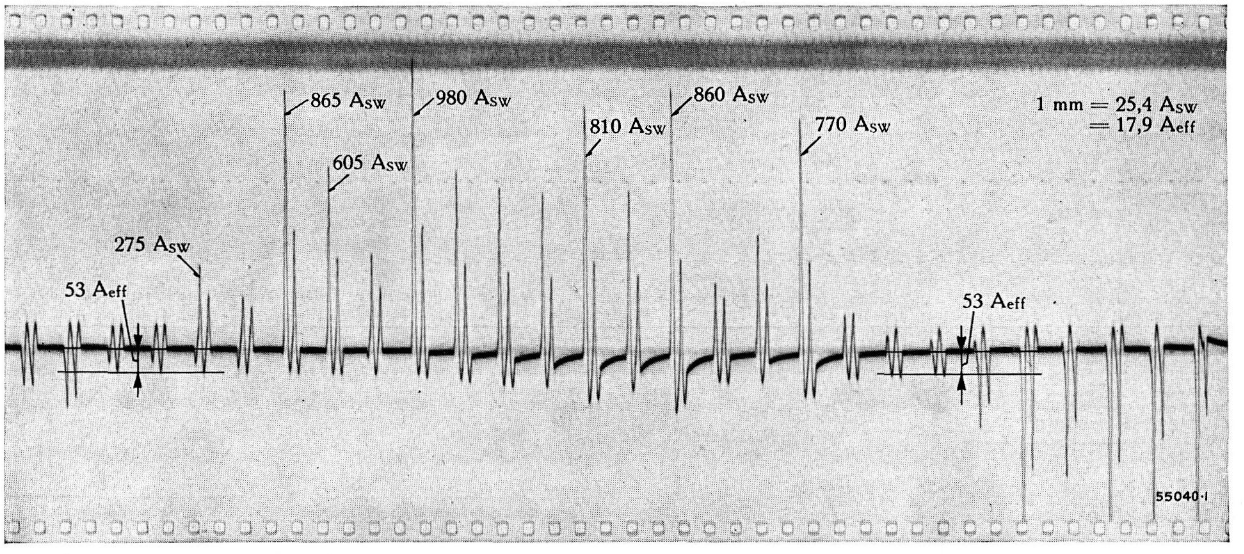

Fig. 2. — Characteristic of the primary current of a seam welder controlled by an ordinary current making and breaking device.
The current peaks at switching in exceed 900 A on a 500-V network. The maximum output of the machine corresponds to a rated current of 53 A.

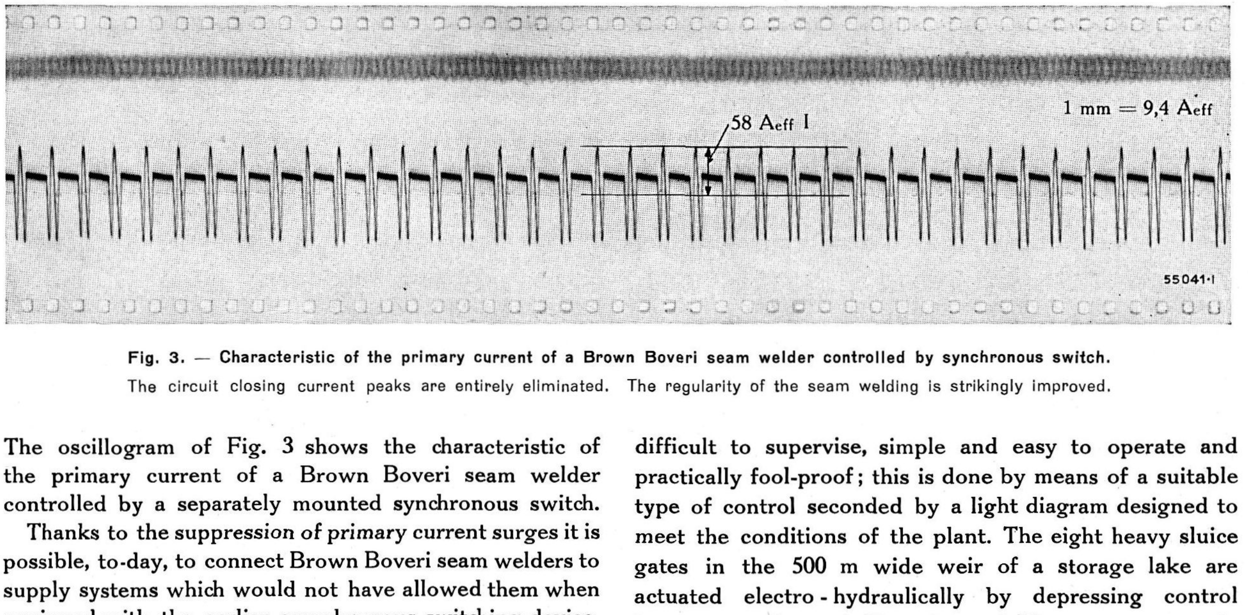

Fig. 3. — Characteristic of the primary current of a Brown Boveri seam welder controlled by synchronous switch.
The circuit closing current peaks are entirely eliminated. The regularity of the seam welding is strikingly improved.

The oscillogram of Fig. 3 shows the characteristic of the primary current of a Brown Boveri seam welder controlled by a separately mounted synchronous switch.

Thanks to the suppression of primary current surges it is possible, to-day, to connect Brown Boveri seam welders to supply systems which would not have allowed them when equipped with the earlier asynchronous switching device.

The advantages which have accrued from this happy solution of the constructive problems offered by the seam welder have benifited the spot welder as well. Brown Boveri is in possession of a patented device which allows of limiting the circuit-closing current surges of these machines to a maximum value of twice the rated current.

This clever device, thanks to which the dreaded heavy current surges are entirely suppressed, will certainly help to widen the field of application of resistance welders (spot and seam welders) in the metal industry.

(MS 873) *A. Balmas. (Mo.)*

A collaborator who never fails.

THE light diagram shown in Fig. 1 is an interesting solution of the problem of how to make plants, which are difficult to supervise, simple and easy to operate and practically fool-proof; this is done by means of a suitable type of control seconded by a light diagram designed to meet the conditions of the plant. The eight heavy sluice gates in the 500 m wide weir of a storage lake are actuated electro-hydraulically by depressing control buttons on the switchboard panel. There are two main pump sets or one emergency set to generate the oil pressure of 165 kg/cm^2 necessary to raise or lower the different big sluice gates either under ordinary conditions or in an emergency. The light diagram control equipment not only allows of reliable operation of the different gates from a remote position but also permits of ascertaining at a glance which pump set is connected up and put to work, into what pipe system the pumps are delivering, what positions the sluice gates move into and what order impulses have been given out from the different observation posts in the plant.

The remote control and supervision apparatus combined to form a whole, as shown in Fig. 1, makes it possible to control with ease the plant from a single control post and to ascertain the operating conditions at any moment,

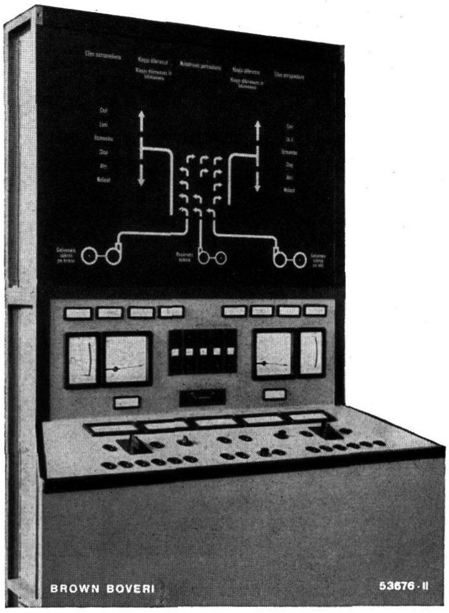

Fig. 1. — Light diagram equipment for the electro-hydraulic remote control and supervision of the sluice gates of a big storage-lake plant.

A suitably chosen layout allows of making, even those plants which are difficult to supervise, easy to operate, without committing any errors.

The simple and logical layout combined with various interlocks allows of thoroughly reliable control with only a few operators and even with unskilled labour.

(MS 852) *E. Altschul. (Mo.)*

A striking demonstration.

ANYONE associated with electrical industrial devices asks, on visiting Baden, to be shown the demonstration panel for industrial apparatus seen in Fig. 1. This is no inanimate exhibition but is apparatus in action, the functions and effects of which will fascinate the visitor.

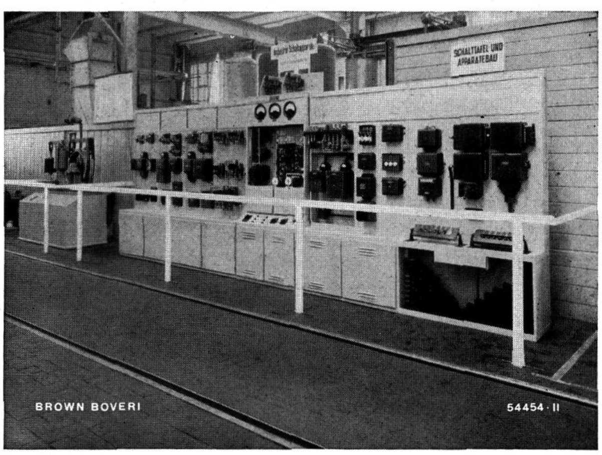

Fig. 1. — Demonstration panel for industrial apparatus in the shops of Messrs. Brown, Boveri & Co., Limited, Baden (Switzerland).

The visitor can follow the working process of the different pieces of apparatus and grasp the manifold duties which they are able to perform.

You, yourself, can operate switches and contactors; see — and hear — the difference between contactors which rebound on making contact and those in which this undesirable feature is eliminated. You follow the working process of a thermal release and cannot help being convinced that it possesses the action lag which makes it suitable for protecting motors, while acting instantaneously when it is necessary that it should do so. You, yourself, adjust the voltage at which the "fault voltage trip" acts to eliminate dangerous accidental contact. You can follow switching processes of the original star-delta switch and can satisfy yourself that the starting current of a squirrel-cage motor is kept low, it being, further, impossible for you to make a switching error. In a few minutes you learn this and that fact which, otherwise, you would probably only have acquired after laborious reading.

(MS 850) *S. Hopferwieser. (Mo.)*

A boring mill which works automatically.

THE precision boring mill shown in Fig. 1 is an example of how the working process of a machine tool can be improved by making proper use of the possibilities offered by electrical drive.

A brief pressure on a push button suffices to bring the drill-spindle carriage rapidly into the working position, after which the drill spindle begins to rotate of itself and the feed is slowed down simultaneously. At the end of the bore, the spindle is stopped and the drill-spindle carriage rapidly brought back. Thus, once adjusted, the whole working cycle develops automatically after one single brief depression of a control button.

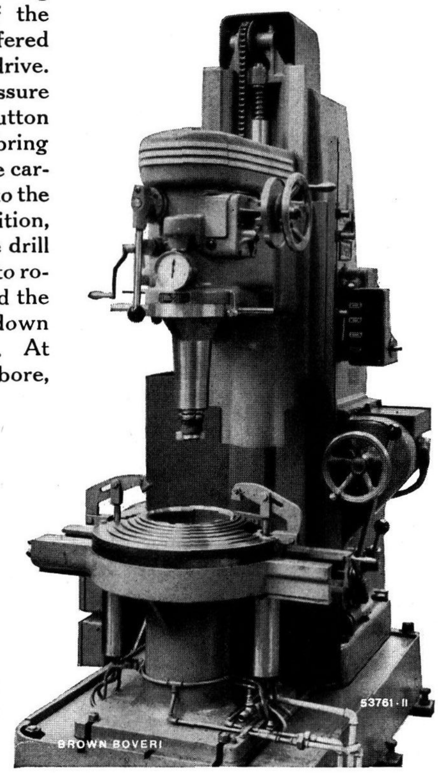

Fig. 1. — Automatic two-motor Brown Boveri drive for a precision boring mill built by Messrs. L. Kellenberger & Cie., St. Gall (Switzerland).

The electric drive so improves the machine and simplifies its use that even unskilled operators can get mass production of the highest precision from it.

The automatic feature can be cut out and any of the partial processes "lowering", "boring", "raising" can be carried out independently as long as the push-button belonging to the respective motion is depressed.

(MS 851) *S. Hopferwieser. (Mo.)*

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