room containg these enclosed. An air conditioner has been installed in the second floor room by the customer who makes it a principle to regulate the room temperature and keep the room constantly enclosed.

We feel very gratified that the present equipment which is the third contact converter plant in our country and also which has the record capacity has been set in full operation. Further, in the near future, 250 V, 10,000 A equipment for extension for Messrs. Kureha Kagaku Co., 300 V 10,000 A equipment for Messrs. Kanegafuchi Kagaku Co., 125 V, 6,000 A equipment for Messrs. Edogawa Kagaku Co. etc., will all be put into operation one after the other and we are convinced that the contact converter will be the only type of converter equipment for electrolytic source requiring large current at low voltage for future installations.

7,000 HP TWIN DRIVE ILGNER SET FOR KAWASAKI IRON WORKS COMPANY

By

Taiji Gotoh and Keizo Suzuki

(D. C. Mach. Div., Engineering Department)

Synopsis

In July 1953, we delivered 5,000 kW Ilgner set to Nippon Kokan K. K., and in January 1954 4,500 kW Ilgner set to Yahata Iron Works. Recently, we completed 7,000 HP twin drive Ilgner set for blooming mill by the order of Kawasaki Iron Works, which was made by United Engineering Foundry & Co. U. S. A. and installed at Chiba Plant and obtained the unexpectedly excellent results by the test at our works. Here we describe the outline of the set for reference as follows.

I. GENERAL DESCRIPTION OF TWIN MOTOR TYPE

It is well known that main motors for reversible blooming mills are the most severely used ones among the large capacity electric motors. Excess overload and shock is electrically and mechanically sustained because of frequent and rapid accelerating, reversing, and the rolling load. In order to sustain overload, good commutation must be arranged, and to ease rapid reversing, the GD^2 must

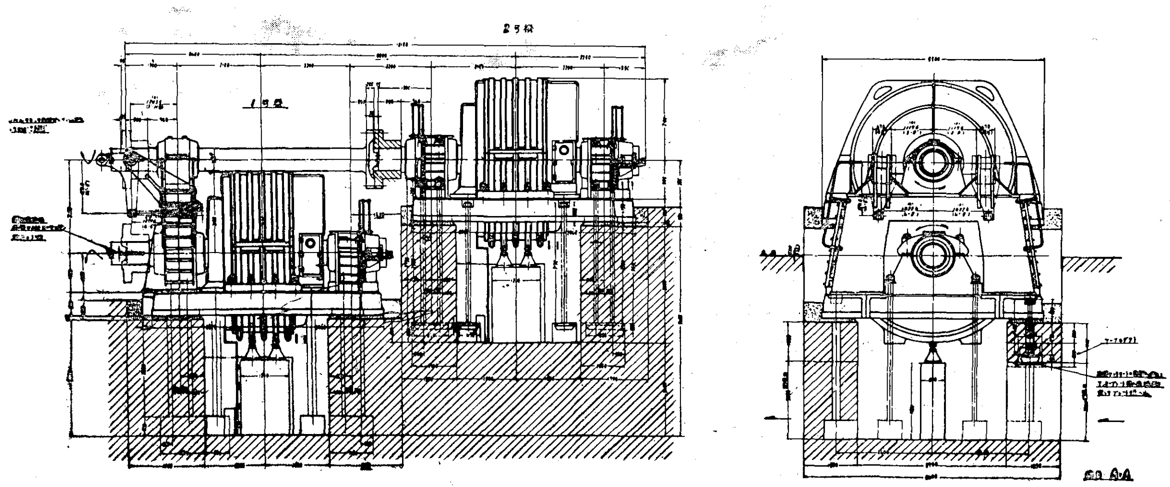


Fig. 1. Arrangement of Twin Drive Main Motor

be made as small as possible.

However, the above conditions contradict each other. Those with a large GD^2, in other words a large armature diameter can have good commutation, but if reversing is done in short order, the accelerating and retarding current increases, and furthermore with the rolling load, causes extreme overcurrents to occur. If the GD^2 becomes smaller, the accelerating and retarding current also become smaller, but from the standpoint of electrical designing, commutation becomes much more difficult. Therefore, the method of operating a rolling mill by a twin motor, commonly called the twin drive and shown in Figure 1, which divides the capacity in two between separate motors directly coupled to the rollers, is replacing the single motor which was used to rotate both the upper and lower rollers by a pinion stand. Of course, with today's technical knowledge, it is possible to safely design a single motor of about 7,000 HP, but considering the recent severe rolling conditions necessary to improve productional efficiency, it is more favorable economically to use the twin drive when requiring over 6,000HP.

The advantages of the twin motor type are as follows:

1) The electrical and mechanical designing is simpler as a result of smaller unit motor capacity made possible by division of the capacity between the upper and lower motor.
2) The total GD^2 of the two units in still far smaller than what it would be had a single motor been used. This reduces the accelerating and retarding currents, then greatly shortens the time required for acceleration or retardation.
3) The pinion stand is unnecessary.
4) The torque and speed of the upper and lower rollers can be minutely adjusted; this enables adjustment of the relative speed of two motors to maintain a certain ratio although some difference in roller diameters may exist. The rollers may be turned, corrected and reused after they are worn, giving them longer life. The speed of both rollers may be differed for some rolling methods intentionally.

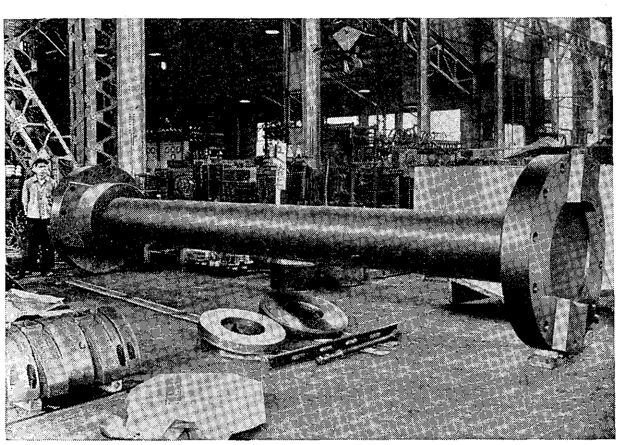


Fig. 2. Intermediate Shaft for Upper Motor

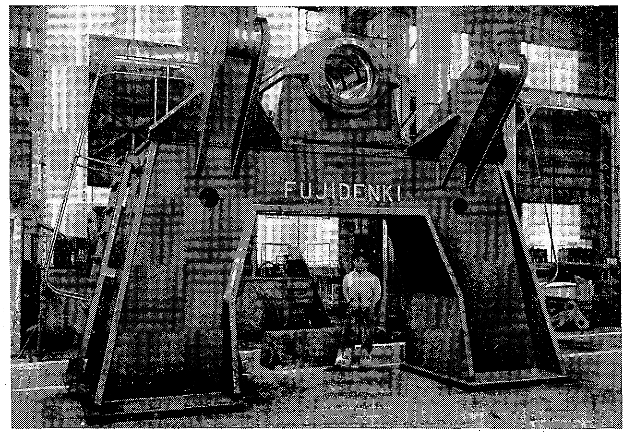


Fig. 3. Bearing Bridge of Intermediate Shaft

Figure 2 shows the intermediate shaft for the upper motor, and Figure 3 the bearing of the intermediate shaft.

II. MAIN MOTOR

As mentioned previously, this motor is a twin type motor for driving 45″×115″ reversible rollling mils, and is rated as follows:

Enclosed, forced ventilation type, single armature, single shaft end.

Type	:	aGM 780/115
Output	:	3,500 HP
Voltage	:	±750 V
Current	:	3,750 A
R.P.M.	:	0–40 RPM Voltage control 40–80 RPM Field control
No. of Poles:		18
Excitation	:	Separately excited by 220 V
Rating	:	Continuous

Maximum operating torque : 143 TM (225%)

Maximum emergency torque : 175 TM (275%)

Figure 4 shows of two these motors directly coupled undergoing factory tests.

III. MOTOR-GENERATOR

Figure 5 shows the Ilgner converter which is very similar to that delivered to the Nippon Kokan Co., and the data of which is as follows:

a. Ilgner generators 2 pieces

Enclosed forced ventilation type, single armature, laminated yoke with current balancing series windings.

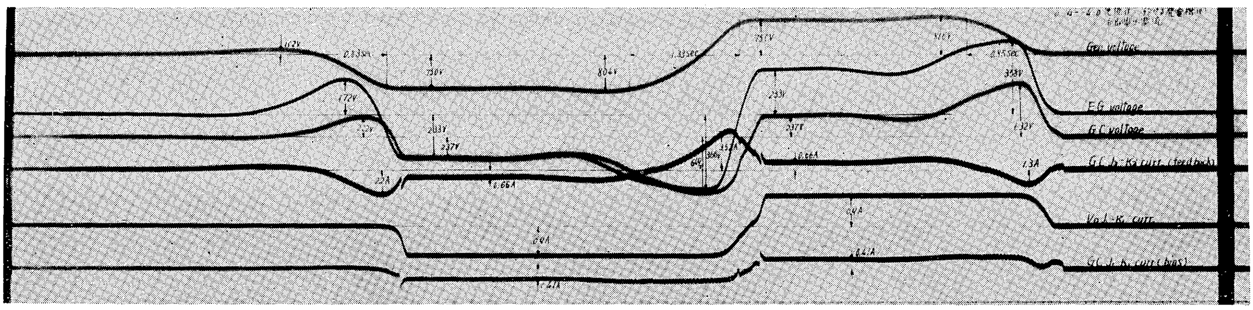


Fig. 9. Oscillogram of Voltage Controlling Circuit

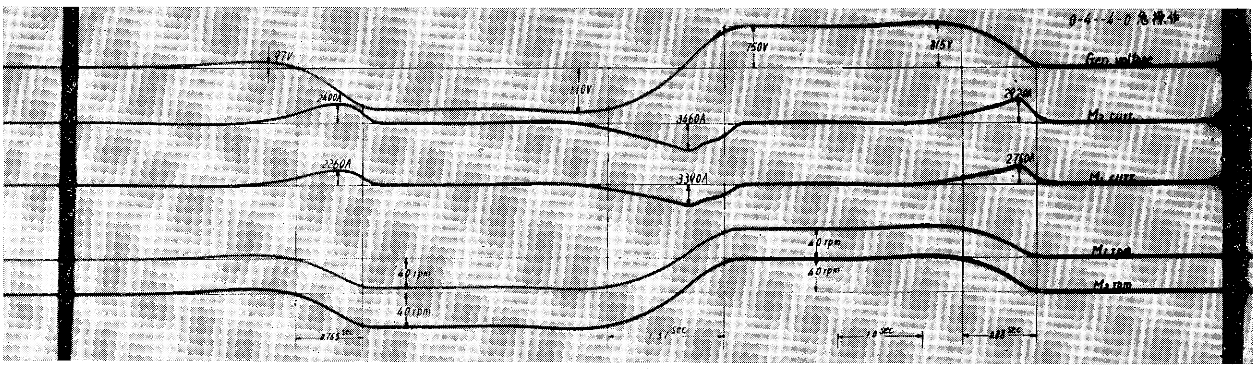


Fig. 10. Rapid Controlled Oscillogram in Voltage Controlling Range

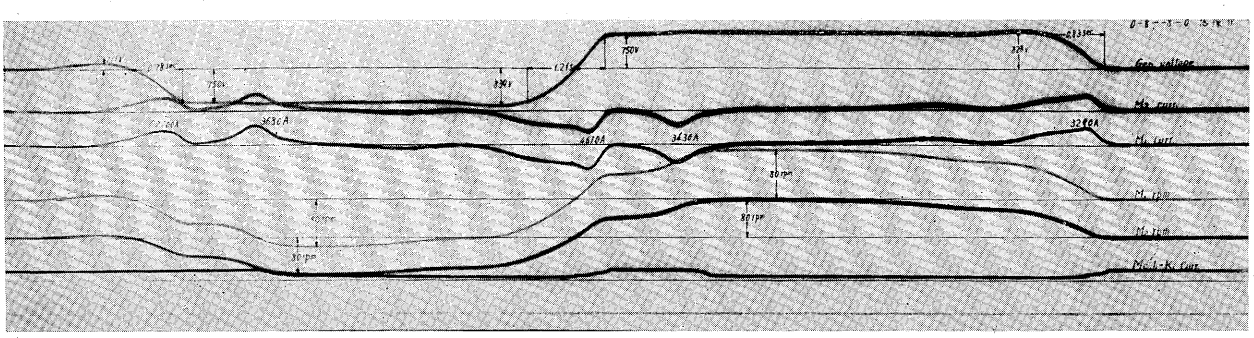


Fig. 11. Rapid Controlled Oscillogram to Field Controlling Range

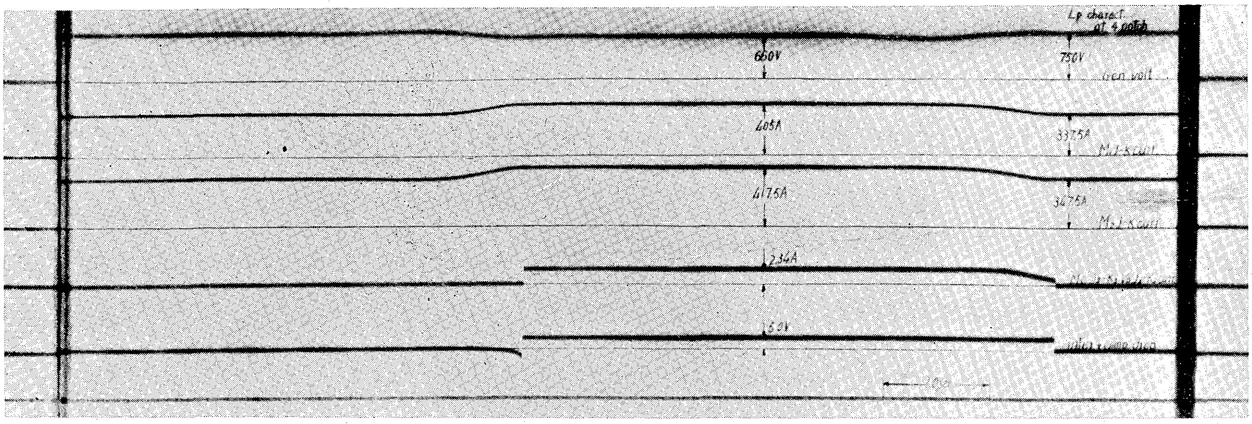
value is feedbacked to the GCJ³-K³ field. Dynamic characteristics are shown in the oscillogram in Fig. 9. This shows the generator voltage, exciter voltage, controlling generator voltage, GCJ²-K² field current, VPJ¹-K¹ field current, GCJ¹-K¹ field current when the master controller is rapidly operated $0 \rightarrow +750$ V $\rightarrow -750$ V $\rightarrow 0$. The GC and EG voltages show very sharp changes in order to enable the generator to change its voltage as quickly as possible. The GC voltage shows that it hits a peak value 2.6 times greater than its steady value. Due to this, increase, reversal and decrease of voltage of main generators can be done in a very short time.

The conditions when raising main motor speed, reversing and stopping within voltage control range are shown in Fig. 10. In about 0.8 seconds the normal base speed + 40 RPM is reached from a standstill, and then in 1.3 seconds it is reversible to the reverse base speed—40 RPM. The fact that even when such rapid speed are effected, the rush current required to give the necessary acceleration and retardation is less than the rated current, shows that the GD² of the main motors is small.

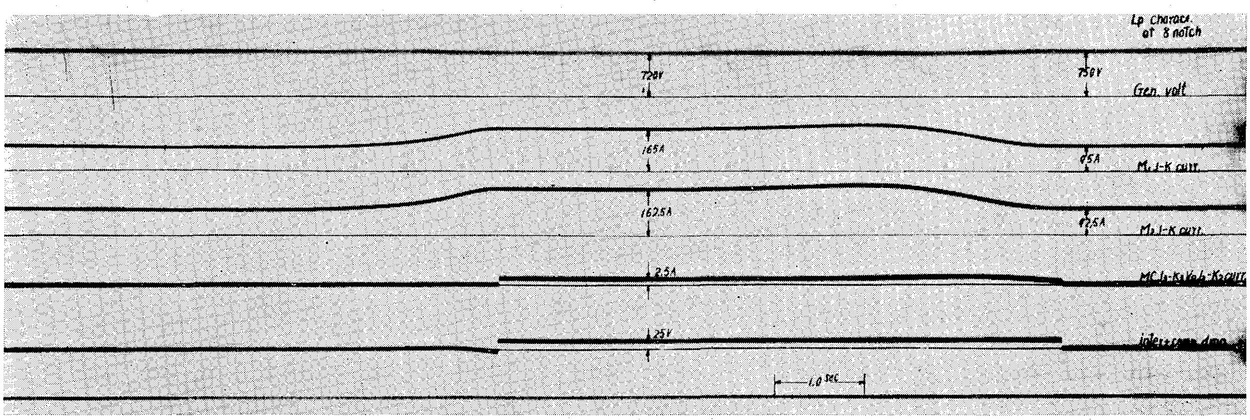
b. Main motor field controlling circuit.

As is clearly shown in Fig. 8, the field current of the main motor M¹, M² are controlled by the field controlling generator which excites the exciters EM¹ and EM². The field current J¹-K¹ of the MC changes accordingly with the field control notches of the master controller, and this field AT is compared with the AT of the MOJ²-K² which is excited by the main motor field current. As this set is of the twin motor type, a load balancing and roller's diameter compensator as will be mentioned later is necessary.

Then the fields of EM¹ and EM² are of 2 circuits and form a bridge. This bridge is perfectly



(a) The Case of 4 Notches



(b) The Case of 8 Notches

Fig. 12. Oscillogram of Over Load Limit Circuit

balanced when in a transient state, not to mention of when it is in a steady state. Unlike the manually operated types, the master controller is operated by foot and the controlling is done entirely by contactors a time relays are on the notch. Fig. 11 is an oscillogram obtained by rapid operation of the master controller which accelerated the main motor to the field control maximum speed of 80 RPM, reversed this and then stopped it. The generator voltage, motor currents, RPMs and the MCJ^1-K^1 field current is shown, and even in this case the maximum value of the current required for acceleration or retardation is only 123% of the rated value.

c. Overload limiting circuit.

When limiting the motor overload, the intercepted torque within the range of field control should be in inverse ratio to the RPM and therefore it is logical to limit the load proportionately to that torque. As can be seen from the connection diagram, when voltage drop at the main motor inter pole windings and compensating windings is greater than the half the voltage generated by the load pilot generator LP, the overload limiting operation is performed by exciting to VPJ^2-K^2 and MCJ^3-K^3 field. The voltage generated by this LP is fixed within the range of voltage control, but the LPJ^2-K^2 field is excited proportionately with the main motor field current to reduce it within the range of field control, and by choosing the ATs of this and the LPJ^1-K^1, any required characteristic can be obtained. When the current flows into VPJ^2-K^2, and MCJ^4-K^4 field, the generator voltage falls, the main motor field is strengthened and the load current is eased by reducing the motor RPM. The opposite effect takes place on the braking current, and the circuit is turned over by the contactors F and B according to the direction of rotation.

The oscillogram shown in Fig. 12 shows the open loop characteristics when at 4 notch 40 RPM, and 8 notch 80 RPM an input equivalent to 275% and 137.5% load current respectively is given. The characteristics that the generator voltage falls and the motor field currents increase can be seen clearly.

d. Main motor load balancing circuit.

In a twin type motor the upper and lower

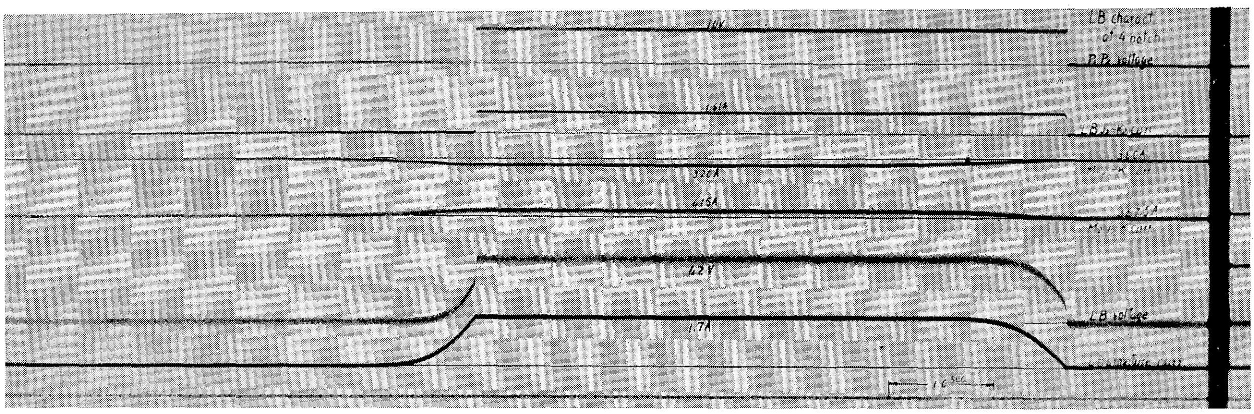


Fig. 13 Oscillogram of Main Motor's Load Balancing Circuit

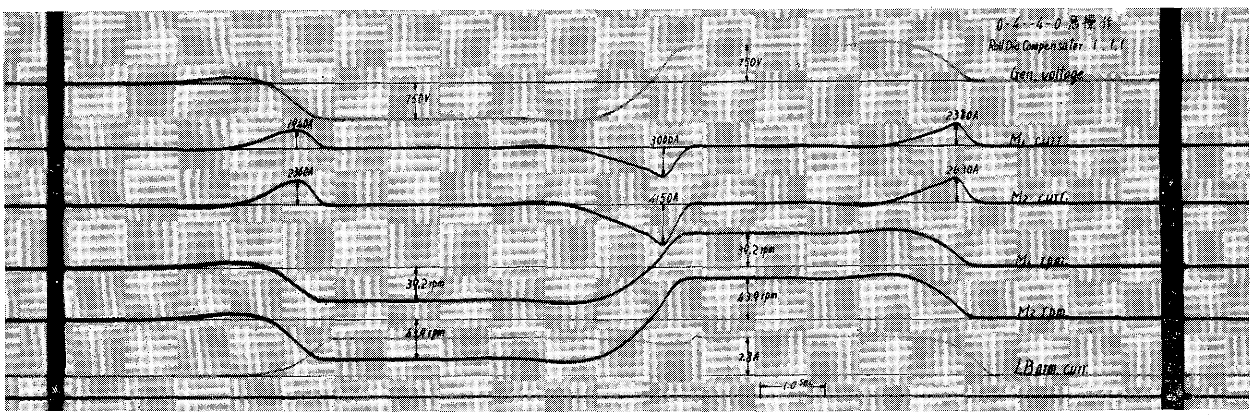


Fig. 14. Rapid Controlled Oscillogram at Roller's Diameter Compensated

motors are connected only electrically, and in this respect the condition differs essentially from single motor pinion stand types.

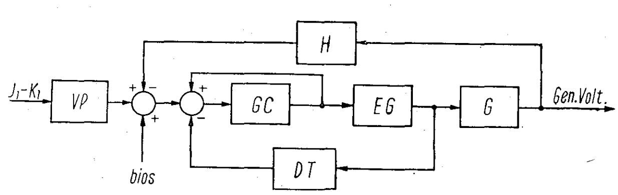
The upper and lower rollers should always do the same work in operation. This can be said even when their diameters differ. When the same voltage is applied to two motors by a common busbar as in this case, it is possible to have them do the same work by maintaning the load current equal ignoring the very slight difference in efficiency. The load balancing generator LB in the connection diagram undertakes this function. When the load current of the main motors M^1 and M^2 become unbalanced, the difference of voltage drop in each of their inter poles windings and compensating windings causes voltage to be appeared between P^1 and P^2, making the current flow into the LBJ^2–K^2 field. This current is quickly and greatly amplified by the amplifying characteristics of LB and flows to the EM^1, EM^2 magnetic field bridge circuit from the symmetry to the MC output. Its directionis determined, for example, in such a mannerthe if M^1 has a greater load than M^2, the EM^1 voltage is raised and the EM^2 voltage reduced. In other words the M^1 is strengthened causing speed reduction, and the M^2 field is weakened to increase speed. Therefore the load balance is regained immediately. In response to the rotating direction of the main motors, the F or B contactors are closed forming its circuit.

Fig. 13 is an oscillogram showing changes in the M^1, M^2 field currents when a voltage equivalent to the unbalanced voltage drop at the M^1, M^2 inter pole windings and compensating windings is given to the LBJ^2–K^2 magnetic field. Of course, in factory tests, it is impossible to load two motors simultaneously, and therefore by open loop characteristics it is still obvious that the M^1 field current increase and M^2 field current decrease is taking place rapidly.

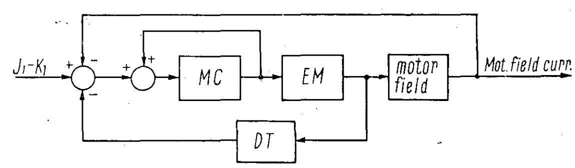
e. Roller diameter compensating circuit.

When a roller is turned and corrected, a difference will arise in the diameter of the upper and lower rollers. Nevertheless, with a twin type motor the rollers may still be used without any difficulty. The RPM ratio of both motors should be prearranged in reverse figures of the diameter ratio. By the way, this mill is designed to enable utilization of a 44 inch diameter roller up to a limit of 39 inches, such long use of rollers proving very economical. Furthermore, depending on the material being rolled, it does not always happen that the torque of both rollers should coincide, it being more effective in some cases to have one moter carry a heavior load than the other. The roller diameter compensating circuit undertakes the above two functions simultaneously.

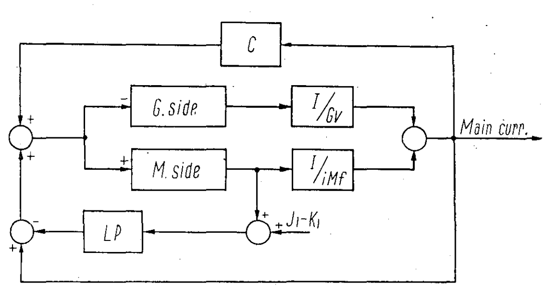
If the certain necessary excitation is previously given to the LB field J^1-K^1 in Figure 8, it will weaken the field of the motor requiring a higher RPM and strengthen the field of the motor with the lower RPM by the same principle as that of the load balancing circuit just mentioned. The LBJ^1-K^1 field current is set y the roller diameter compensator according to the desired RPM ratio, and within the field control range resistors are inserted by opening the contactors, a suitable current thus being maintained. When a certain RPM ratio is pre-arranged by the roller diameter compensator, the speed change characteristics of both rollers pose a problem, shown in the oscillogram of Figure 14. This shows the generator voltage, motor currents RPMs and LB output current when rapid acceleration, reversal, and stopping within voltage control range takes place with the speed ratio set at ca 1:1.1, and it was found that there was perfect agreement in the time characteristics up to when the setting speed was reached. It is logical the a larger rush current was flowed to the M^2 motor which had been set at a greater RPM, because due to a weaker field and a greater setting speed it required a large current to attain the necessary accelerating or retarding torque. Regarding the operating principles of each controlling circuit, a clearer understanding may be gained by the block diagrams grouped together in Fig. 15.



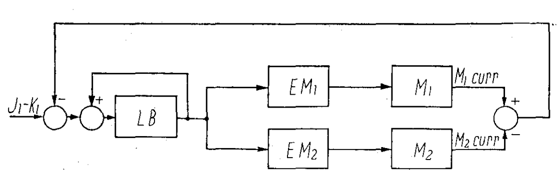
(a) Generator Voltage Controlling Circuit



(b) Main Motor Field Controlling Circuit



(c) Overload Limiting Circuit



(d) Load Balancing and Roller Diameter Compensating Circuit

Fig. 15. Block Connection Diagram of Controlling Circuit

VI. PROTECTIVE APPARATUS

Protective apparatus is built in which protects the mechanism from any accidents, and making possible immediate resumption of operation. Those related to the main motors are the following:

a. Air circuit breaker.
b. Rapid flux reduction of main motors and generator.
c. Overcurrent relay within range of the voltage control.
d. Inverse ratio overcurrent relay within range of the field control.
e. Excess voltage relay.

Besides these, the ground relay, under current relay of main motor field, over speed relay, oil flow relay, temperature relay, are also attached to cope with any emergency which may arise.

VII. AUXILIARY EQUIPMENT

a. Automatic slip regulator.

Fluid resistor for an automatic starting, automatic slip regulating and automatic braking are the main components, which are inserted into the secondary side of the main induction motor. These provide 100% torque starting, 20% continuous slip, 100% torque braking. The fluid is made to circulate through the cooler by a vortex pump.

b. Ventilation cooling apparatus.

The air required for cooling effects amount to 50 m^3/sec, and after this is filtered by the Multi-Duty Automatic Air Filter manufactured by the AAF Co., it is directed through an underground wind channel by a centrifugal, multi-propeller, Sirroco style wind blower operated by an induction motor. The air is also discharged through an underground channel to the exterior of the building.

c. Bearing lubrication equipment.

A high pressure pump is used for the main motor bearings and an oil circulation pump is used for the converter bearings, each having their own oil cooling tanks. The converter pump is automatically switched over to DC operation by storage battery in the event the AC power source is stopped, continuing to furnish a supply of oil to the unit until the converter stops.

VIII. CONCLUSIONS

Thus we close our introductory notes on this set. This electrical mechanism represents the aggregate of our Company's technical achievements in various fields, and we are of firm belief that the above results were obtained only by the close cooperation of each and all of the designing and test sections and plants which participated. This set was immediately disassembled after factory tests, and two of the main motor armatures, fly-wheel and the intermediate shaft bearing bridge which exceeded the limits imposed by rolling stock were delivered by ship, and the remainder by overland transportation to the client, the Chiba Iron Refinery. It is now undergoing installation there, and when it commences operation this August it will be a testing stone for twin drive mills in our country. Undoubtedly, it will contribute greatly to the development of our steel industry.

The rolling manufacturer in this case is the UE Co. (United Engineering & Foundry Co.) of the United States, with our Company supplying the main drive electrical apparatus. Technicians and engineers were dispatched by our Company to hold technical consultations with the UE Co. staff, and today with a perfect organic and synthetic installation completed, we wish to express our heartfelt gratitude to Mr. J. H. Taylor and the many other members of the UE Co.'s technical staff who most willingly shared with us at that time many of their invaluable opinions and ideas.

(30th, May 1944)

ON THE RECENT SMALL INDUCTION MOTORS

By

Yoshio Adachi (A. C. Mach. Div., Eng'g. Dep't.)

Kazuo Hikone (Industrial Div., Mie Works)

Synopsis

It is a great character that the latest induction motor being made small and light by application of new insulating materials and improvement of cooling method, on the other hand, special design have been developed according to several uses. In former, common type motors have been generally used for special purposes of each industries, but the most comfortable motors are designed and constructed recently, by connection between makers and customers. This tendency is seemed to be acceralated more and more in future. We describe special designs and application on small motors.

I. FOREWORD

New insulating materials and improvement in cooling methods have resulted in the latest induction motors becoming much smaller and lighter.

It is now only common sense to use PVF covered round wires for stator coils, and PVF covered flat wires are gradually coming to be used.

It is well-known that the insulation covering thickness of PVF covered wire are the same as enameled wire, thus improving the space factor of copper wire in the stator slot, making possible smaller dimension iron cores than when using double cotton covered wire.

Many new insulating materials and products with various trade names have made their appearance overseas, and it is now relatively simple to obtain these locally. For example, if one brand which is quite strong considering its thinnes, is used for slot insulation, the tendency towards smaller and lighter motors will be stimulated.

Hitherto, enclosed type motors were about the same size as open types, but our company's new type motor has improved cooling efficiency by using a powerful fan of larger outer dimensions, newly devised cooling wind channels, and as a result is 30–40% more light in weight than open types. With such new cooling method devised, enclosed ventilated type general purpose motors