ELECTRIC EQUIPMENT FOR 56″ SEMI-CONTINUOUS HOT STRIP MILL DELIVERED TO THE CHIBA IRON & STEEL WORKS, KAWASAKI STEEL CORP.

By

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I. INTRODUCTION

Along with the continual trial operation for a month since the beginning of April, 1958, this plant has shown its business start in so excellent conditions that we have been desiring. This Article may well explain a brief outline of the equipments, one of our technical accomplishments. The static Ward-Leonard system equipments, employing mercury rectifiers for all power sources of the finishing main motors in the hot strip mill, are not only the first attempt of Japan, but also have the largest capacity of the mercury rectifiers applied to the motor power. The machine parts and components of the equipments have been manufactured by the United Engineering and Foundry Company, U. S. A., and almost all of the electric parts have been made by the Fuji Denki Seizo K.K. except very few auxiliaries. And, all of the assembling and wiring of these electric parts were carried out by the Fuji Denki Kōji K.K. The following sections will be given to the explanation in regard to the general view of the machine parts, electric components of the main body, and auxiliary equipments.

II. GENERAL VIEW OF THE MACHINE PARTS

The arrangement of the machines is to be illustrated in the Fig. 1. Hot iron plants having been roughly rolled by the reversing 2-high roughing mill are to be delivered to the finishing mill yard with the table.

The cutting of the iron plates is made at their edges by the flying crop shear after stopping the running of these plates, which then are to be sent to the finishing roll stands through the finishing scale breaker. The 4-high finishing mill consists of five stands (which are $F_2 \sim F_6$, and the only F_1 will be extended in the future). Any sag of the plates at every stand on the rolling will be stretched by each looper. The thin plate with thickness of 1.6 mm$\sim$3.2 mm approx. coming out of the last stand F_6 is to run on the hot run table at the maximum speed of 10 meters per second approx. to be delivered to the coiler. The thickness of the iron plate is measured by the X-ray thickness gauge fitted at the outgoing exit of the plate of the stand F_6, and the temperature of the plate is

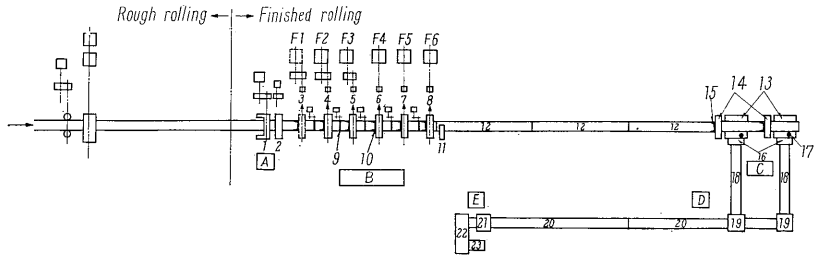

Fig. 1. Arrangement of Machines

1: Flying crop shear
2: Finishing scale breaker
3—8: Finishing mills F_1—F_6 (Mill F_1 will be extended in the future
9: Loopers No. 1—No. 5
10: Finishing mill entry side guides No. 1—No. 6
11: X-ray thickness gauge
12: Hot run tables No. 1—No. 3
13: Down coilers No. 1—No. 2
14: Pinch rolls No. 1—No. 2
15: Down coiller entry side guides No. 1—No. 2
16: Coil unloaders No. 1—No. 2
17: Wrapper rolls No. 1 and No. 2
18: Cross conveyers No. 1 and No. 2
19: 90° transfers No. 1 and No. 2
20: Long level conveyers No. 1—No. 2
21: Weight recorder
22: Down ender
23: V top conveyer
Ⓐ~Ⓔ: Pulpit control desk

to be cooled off to the proper range by the spraying water. The two units of the coiler are operated in the down coiler system with each other, and the strips are to be coiled under a constant tension control with pinch roll and wrapper roll. The coil is to be stored into the coil stock yard through the unloader, cross conveyer, 90° transfer, long level conveyer, weight recorder and down ender; and is to be delivered to the following processes as the hot skin pass, pickling line, cold mill and so forth. The electric parts and components which had been delivered by the Fuji Denki Seizo K.K. are for the composite equipments of the finishing mill from the flying crop shear to the down ender.

III. ELECTRIC COMPONENTS OF MAIN PART

The specification of the main motors for finishing mill is given by the Table 1. Special attention in designing had been paid to the commutation, so that the good records might have been obtained as shown in the non-spark commutating one of the Fig. 2 which was actually measured. The yoke was made of cast steel in a unit; and the stand, bearing support and the startor legs are all of the welded steel plate. The tachometer-dynamo for automatic speed regulating is overhung at the counter-driving side shaft end of the motor and made of such a structure as stopping the rotation of stator with the revolving stop block, in order to prevent

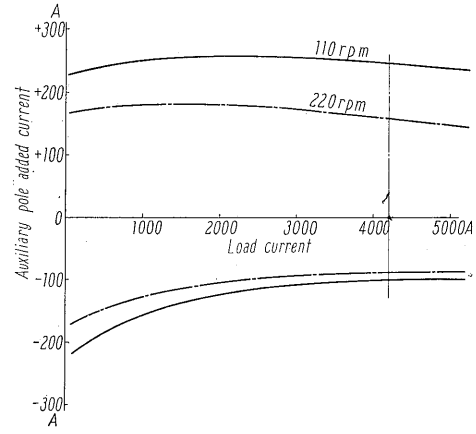

Fig. 2. Non-spark commutating band of 4,000 HP, 750 V, 4,200 A, 110/220 rpm mill motor

rippling as much as possible. The results of test showed only 1/1,000 of the rippling value. The lubrication to the bearings is made both by the forced oil circulation system and by the employment of the oil-ring. The oil circulation system is such that both the upper (on the ceiling) and lower (under the ground) oil tanks are installed in order to circulate the oil in the upper tank around the motor bearings and drop it to the lower tank, and that the oil of the lower tank is to be drawn up to the upper tank by the motor driven pump after cooling it off with the cooler fitted at the lower tank. In this device, 4,600 l of oil is needed and 80 liters per minute of water of 20°C

Table 1. Specifications of main motors for fiinishing mill

Stand No.	Direct current motor						Power source of motor	Mill roll		
	Output (HP)	Speed (rpm)	Voltage (V)	Current (A)	Excitation	Quantity		Diameter of work roll (inch)	Speed of strip (rpm)	Connection
2	4,000	150/336	750	4,200	Separate excitation, shunt wound 220 V	1	3×1,050 kW Mercury rectifier	25	310/695	Gear 3.17:1
3	4,000	150/300	750	4,200	Separate excitation, shunt wound 220 V	1	6×1,050 kW Mercury rectifier	25	516/1,032	Gear 1.9:1
4	4,000	110/220	750	4,200	Separate excitation, shunt wound 220 V	1	6×1,050 kW Mercury rectifier	25	720/1,440	Direct connection
5	4,000	135/270	750	4,200	Separate excitation, shunt wound 220 V	1	6×1,050 kW Mercury rectifier	25	855/1,770	Direct connection
6	3,500	150/342	750	3,680	Separate excitation, shunt wound 220 V	1	6×1,050 kW Mercury rectifier	25	980/2,230	Direct connection

Note: 1) All of the motors are of the enclosed forced ventilation type.
2) Every motor has the automatic speed regulating tachometer-dynamo (overhung at the end of counter-driving side shaft) and other tachometer-dynamo for synchronized operation of auxiliary machines (connected with belt at the end of counter-driving side shaft).
3) The standard NEMA is applied to these motors. The insulation is of class B.
Temperature rising: Not more than 40°C under the continuous load of 100%, not more than 55°C under the load of 125% for two hours. The ambient temperature is not more than 40°C.
Maximum frequently repeated torque: 175% at the base speed, and 160% at the base speed of 200%.
Maximum occasionally repeated torque: 200% at the base speed and at the base speed of 200%.

is required for the cooler: And the motor driven oil pump of 100 liters per minute and 3 kg/cm^2 capacity is employed. The operated motors are shown by the photograph of the Fig. 3. The power source is applied by the static Ward-Leonard system of the mercury rectifier. The skeleton diagram of the power source is to be illustrated in the Fig. 4. The three divided bus line system is employed for this power source, because it has such advantageous points that the d-c short-circuit current can be reduced more than that of the common bus line system on an accident, if any, that the interrupting capacity of the d-c breaker may be smaller, and that the peak current on each rectifier will be modified more than the case of single dividing bus line system on biting the plate. In every bus line, two pairs of one transformer and three rectifier units are connected in parallel. The current balance of three rectifiers being connected to a transformer is to be kept by the anode balancer, and the current balance in the transformer circuit is to be obtained by the current balance control with the magnetic amplifier. The d-c bus line voltage can be varied at 30 V interval and nine taps within the range from 750 V to 450 V by the voltage adjusting transformer.

The specifications of the mercury rectifier and the transformer are as follows:

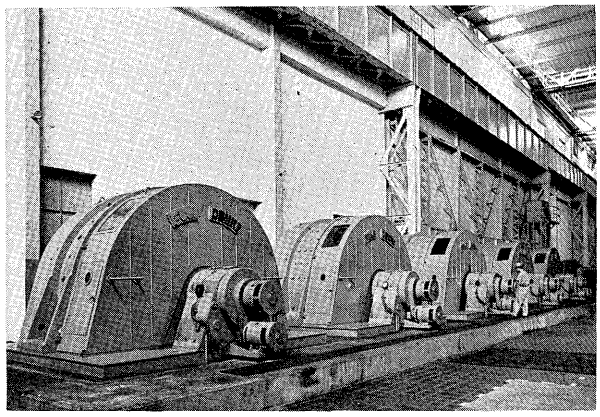

Fig. 3. D-c main motors for finishing mill

1. Mercury rectifier
   - Quantity: 15 (3 more rectifiers will be added in the future)
   - Type: Sealed-off type multi-anode air cooled iron vessel mercury rectifier
   - Model: PSL 2011
     Continuous, 1,050 kW, 750 V, 1,400 A.
   - Rated grid control factor: 75%
   - Overload: 2 hours with load of 125%
     1 minute with load of 200%

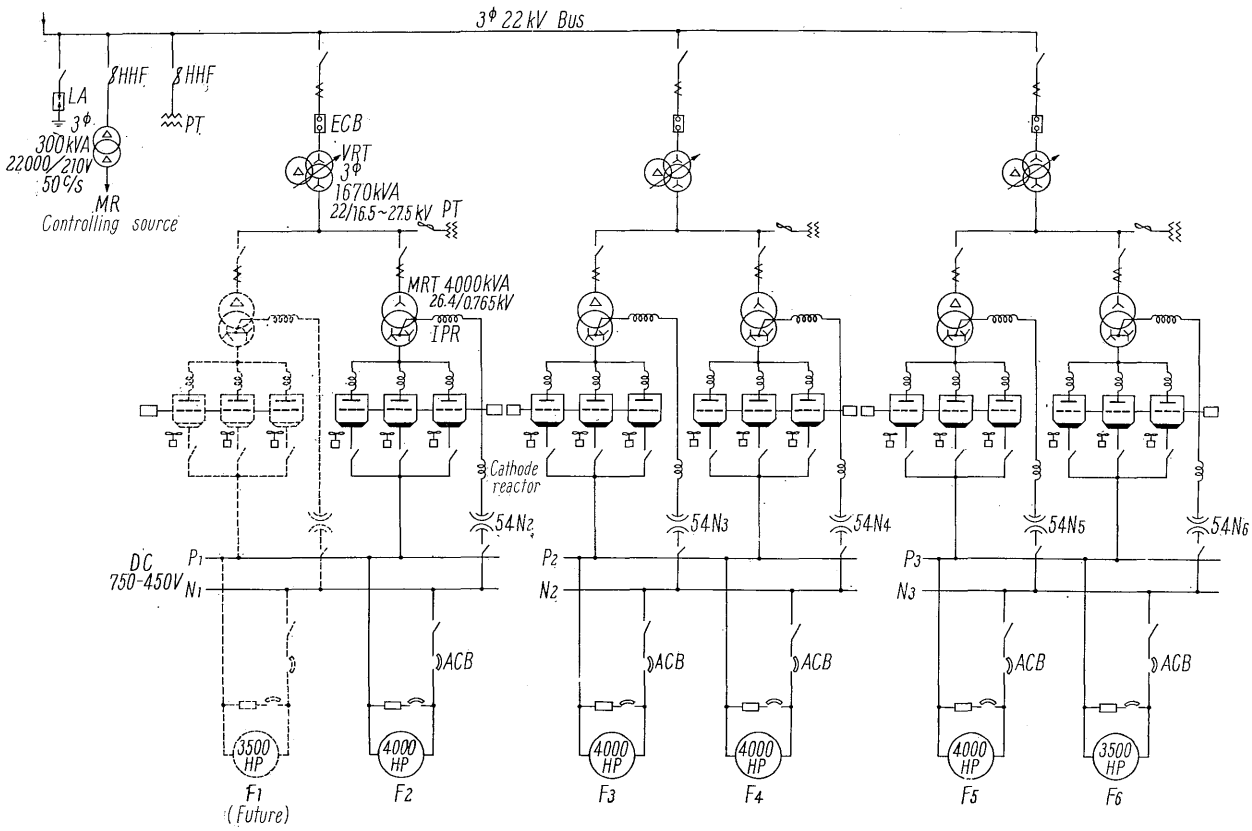

Fig. 4. Skeleton diagram of finishing mill motors

Excitron system, equipped with automatic temperature control device by fan and heater.

2. Rectifier transformer

Quantity : 5 (one more transformer will be added in the future)

Type : Outdoor use nitrogen sealed oil immersed self-cooling type transformer for mercury rectifier Continuous, 4,000 kVA, 26,400/790 V, 50 c/s, 875/1,180 A

Overload : 2 hours with load of 125%, one minute with load of 200%

Connection : 3 transformers △/人−丫, 2 transformers 人/人−丫 fitted with interphase reactor

3. Voltage adjusting transformer

Quantity : 3

Type : Outdoor use nitrogen sealed oil immersed self-cooling type autotransformer for voltage adjustment 3φ, 1,670 kVA, 22/26.4 kV, 50 c/s 210/175 A

Primary tap : 27.5 (F)—26.4 (R) (correponding to d-c 750 V) — 25.3 — 24.2 — 23.1 —22—20.9—19.8 — 18.7 — 17.6 (corresponding to d-c 450V) —16.5 kV

Overload : 2 hours with load of 125%, one minute with load of 200%

All of the above-mentioned transformers, porcelain-clad expansion circuit breakers, metering transformers and other circuit breakers are installed outdoors ; of which appearances are shown by the photograph of the Fig. 5. As for the mercury rectifier, special attention is paid to temperature control by providing it with the particular rectifier's room.

The inner view of the room is shown by the Fig. 6.

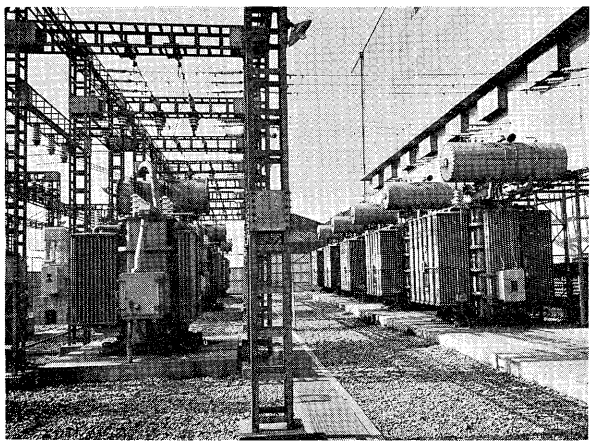

Fig. 5. Outdoor substation for a-c side of mercury rectifier

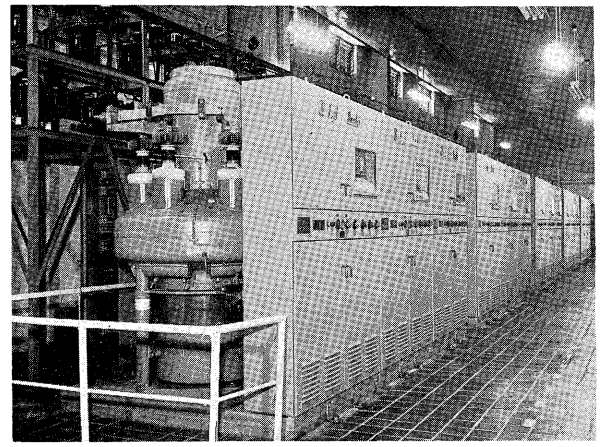

Fig. 6. Mercury rectifier's room

During the rolling operation, the automatic constant speed control of motors is required for preventing the strip among the stands from its excessive stress and for making its loop as little as possible. The speed reduction of the preceeding stand on its biting of the strip must be recovered before the strip arrives at the following stand. For this purpose, employment of a high response control of the good accuracy is needed. In this equipment, two motors are connected in one d-c bus line, so that the constant voltage control (DVR) of a d-c bus line and the constant speed control (ASR) of each motor may become possible separately with each other. The control circuit of the stands F_3 and F_4 is illustrated as in Fig. 7. The control of the stands F_1 and F_2, and of the group F_5 and F_6, are the same with that of the stands F_3 and F_4.

The constant voltage control : The d-c voltage of the bus line can be varied in nine taps at 30 V interval approx. within the range between 750 V and 450 V by the voltage adjusting transformer, and the more fine adjustment in it can be made with the grid phase adjustment, which may also be used for the Ward-Leonard system starting of the motors. The field of the pilot generator ($PG_{1,2,3}$) is to be excited, through the magnetic amplifier, by the adjustment resistor being synchronized together with the tap of voltage adjusting transformer ; of which output voltage is to be in proportion to the output voltage of the voltage adjusting transformer. The potentiometer type adjustment resistor (MRH) is synchronized to the grid phase-shifter of the mercury rectifier, and its divided voltage is to become a reference voltage of the d-c bus line. Therefore, after comparing and amplifying both a reference voltage and d-c bus line voltage by the magnetic amplifier, the phase-shifting saturable reactor of the rectifier grid circuit is to be excited and the constant voltage control of the d-c bus line is to be made. Besides, the current balance and current limitation may be carried out by an application

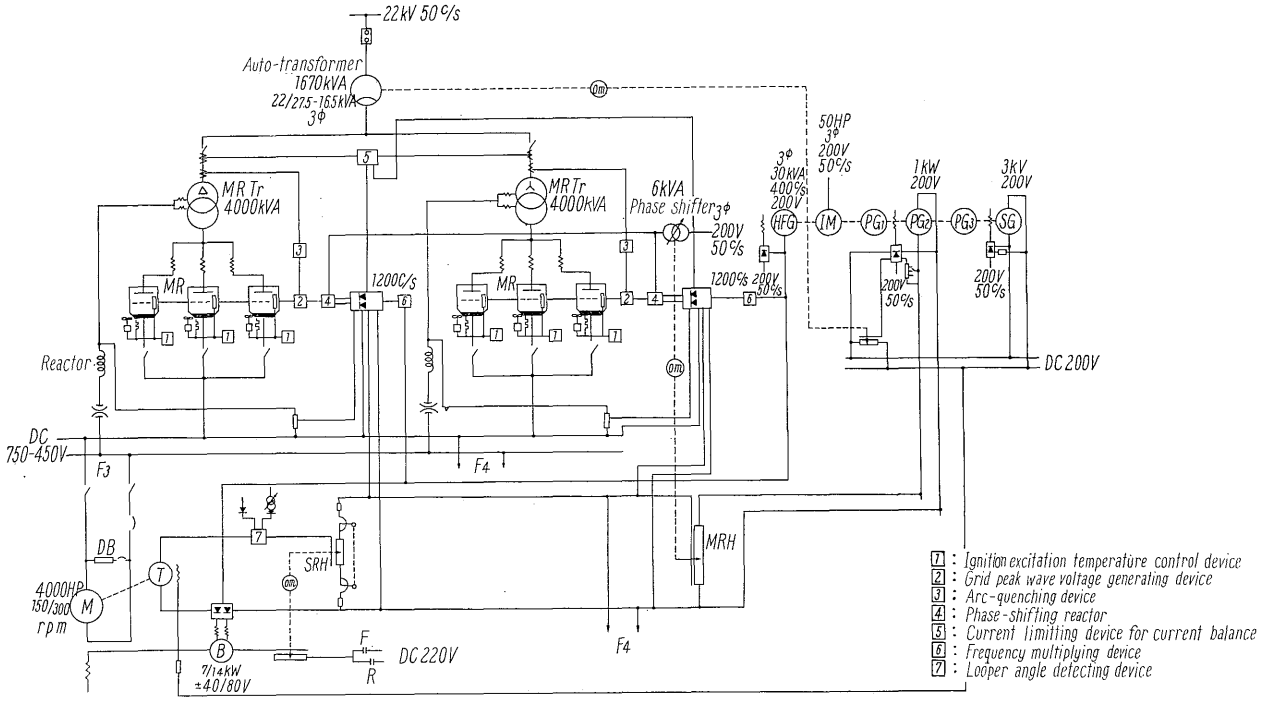

Fig. 7. Control circuit for finishing mill motors

of the above magnetic amplifier which is supplied with the high-frequency of 1,200 c/s, obtained through the static type frequency multiplier, after generated by the high-frequency generator of 3ϕ, 30 kVA and 400 c/s, and which is aimed at encouraging its quick response property and preventing from intervention against the constant speed control system (ASR).

The constant speed control (ASR): As for the reference speed value, the shunt voltage of MRH which is once more divided with the potentiometer type adjustment resistor (SRH) being synchronized with the field adjustor of the motors is to be used for its purpose. As for the actual speed value, it is obtained by using the output voltage of the tachometer-dynamo of the main motor in order to confront the both voltages with each other and by controlling the motor field with the foregoing differential current of the both voltage through the magnetic amplifier and field back booster. The magnetic amplifier power source applies the frequency of 400 c/s. Furthermore, the looper angle detection can also be made together with this automatic constant speed control. This device of detection is to be made by inserting the differential current into the confronting circuit, in order to compare the reference voltage with an output voltage of the induction voltage regulator directly connected to the looper machine shaft, and in order to make such a successive control that, in case of the looper angle of more (less) than a constant value, the speed of the preceeding stands is to be accelerated (reduced) and the speed of the latter parts is to be reduced (accelerated). By adjusting vernier speed regulator on the pulpit control desk, it is possible to control about ± 10 rpm of the speed of every stand. The Fig. 8 shows an operation oscillogram of d-c bus line voltage, motor current and motor speed on the actural operation of the finishing mill. By this oscillogram, the armature peak current of 8,300 A (or 198% of the rated current of the motor), the drop of motor speed at 190 rpm by the percentage of 8.34% and the speed recovering time of 0.456 sec. are made clear.

The jogging speed operation of the mill can be made both from the finishing pulpit control desk and from the mill housing control board, by the bias control of the grid phase-shifting saturable reactor of the rectifier.

The Fig. 9 illustrates the multiple unit control board in finishing mill control room. This board can supervise and control all the operations of main motor oiling system, ventilation system, exciters, mercury rectifiers, a-c power sources and so forth.

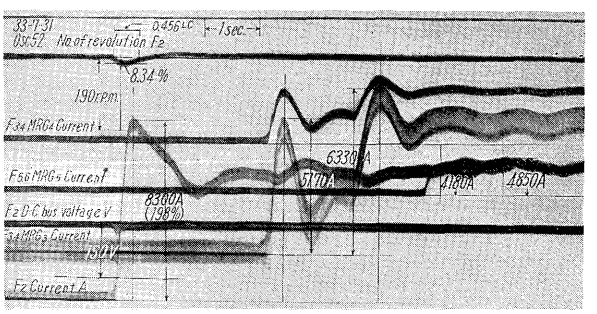

Fig. 8. Operation oscillogram of finishing mill motor

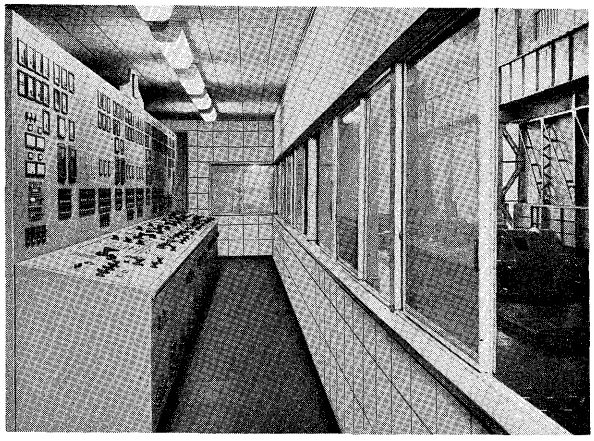

Fig. 9. Multiple unit control board in finishing mill control room

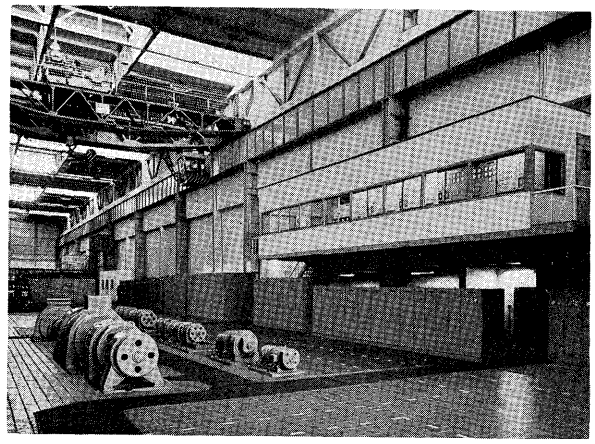

Fig. 11. Main electric room for finishing mill

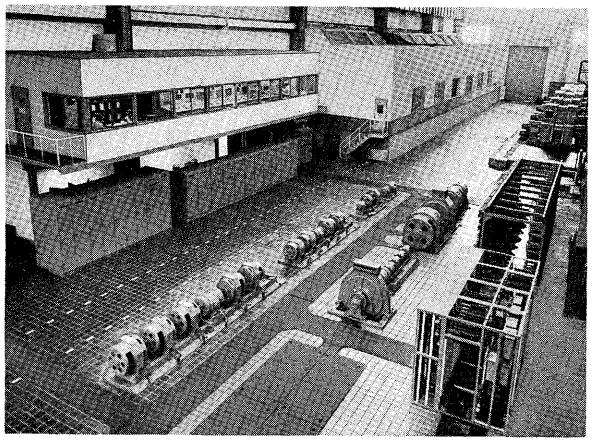

Fig. 10. Main electric room for finishing mill

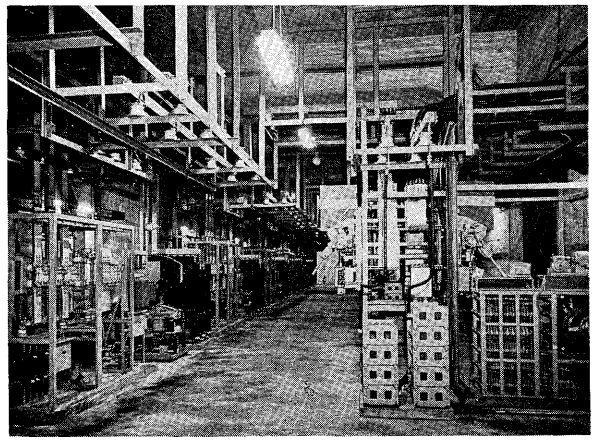

Fig. 12. Basement of electric room

Table 2. Variable voltage d-c motors for auxiliary machines

Use	Direct current motor										Generator	
	Output (HP)	Time Rating	Speed (rpm)	Voltage (V)	Current (A)	Type JEM 1109	Ventilation	Field system	Quantity	Load connection	Brake	Output (kW)	Quantity
Flying crop shear	200	Continuous	420/840	220/440	735	618	Forced	Separate excitation 220 V	1	Gear : 10.5 : 1	Shunt wound	200	1
Finishing scale breaker	35	1 hour	575/1,725	220/660	135	608	Totally enclosed	220 V	1	Gear : 14.7 : 1	—	30	1
Finishing stand looper	236 ft-lb	1 hour	—	8.5	90.2	610	Totally enclosed	220 V	4	Gear : 36.39 : 1	—	5	4
Hot run table	3/3.9	Continuous	750/975	220/282	11.8	Industrial	Totally enclosed	220 V	181	Direct connection	—	250/320	3
Down coiler pinch roll	75	Continuous	515/650	220	280	612	Forced	220 V	4	Upper roll : 2.25 : 1 Lower roll : direct connection	—	150	2
Down coiler mandrel	300	Continuous	375/1,050	220	1,120/1,140	622 Similar	Forced	220 V	2	Gear : 3 : 1	Shunt wound	300	2
Down coiler wrapper roller	25	1 hour	650/910	220	97	606	Totally enclosed	220 V	4	Direct connection	—	300	2

Note : The insulation is of the class B :
Temperature rising is not more than 75°C.
Ambient temperature is less than 40°C.

The inner view of the finishing mill control room is shown by the Fig. 10 and 11. The basement floor of the above room is given by the photograph of the Fig. 12, where the high speed circuit breakers for the mercury rectifiers, cathode reactors, air circuit breakers for motors, and synchronized resistors for the automatic control etc. are installed altogether.

IV. AUXILIARY ELECTRIC COMPONENTS AND APPARATUS

The total quantity of the d-c motor for the auxiliary machines is 229 with 3,025 HP, while that of the a-c motor is 40 with 3,438 HP (excluding the electric machine blower and exciter driving motor). The specifications of the variable voltage d-c motors, the variable voltage Leonard system motor-generators, constant voltage d-c motors and a-c motors, all for the auxiliary machines, are to be given in a list form by the following Tables 2, 3, 4 and 5, respectively.

The total of 181 d-c motors are used for the hot run table, divided in three groups, each of which is under the control of the generator of 250 kW. Every motor is protected with the no-fuse breaker and its overheating may be indicated by the thermostat within the motor itself. The plug is applied for the motor terminals on behalf of the convenience of its replacement.

The three main objects of the down coiler control are as follows:

⑦ To operate the mandrel motor in a high speed, so that it may quickly eliminate the loop on the beginning of the winding of coils, and that it may obtain the so-called Leading Speed as becoming automatically the designated speed after the constant tension recovered.

② To strengthen the motor field against the increased winding of the coil to reduce the rotation, so that the Rapidyne type rotating amplifier inserted into the magnetic amplifier and the motor field may keep the current of the motor constant in order to hold a constant strip tension on its coiling operation.

③ To carry out the attention control in order to prevent the motor from its any excessive speed, as the tension cancelled at the end of coiling and on cutting of the strip.

The Fig. 13 is the diagram of the control circuit of the down coiler. The voltage of the generator G is controlled, in accordance with the signal given to the field J_1—K_1 of the Rototrol CD. In other words, the field J_2—K_2 is excited for the field J_1—K_1 in a proportion to the voltage of G, and it acts to make its difference the minimum at all time by a high gain of CD. The field C—D is a shunt-resonance field and the other field J_3—K_3 is for obtaining a stable state. The field T_4—K_4 is to give, by RH14b, an excitation corresponding to the IR drop against the tension setting current, and is to be excited through RH12 in order to make a Leading Speed.

Table 3. Variable voltage M-G for auxiliary machines

Group	Output (kW)	Time rating	Voltage (V)	Current (A)	Field system	Quantity	Applications
A	200	Continuous	220/440	910	3.5 kW Rototrol	1	200 HP Flying crop shear
	30	1 hour	220/660	136	2 kW Rototrol	1	35 HP Finishing scale breaker
	230	Continuous	220	1,045	Self-excitation, flat compound	1	Constant voltage power source
	Driving motor: 750 HP, 3,300 V, 50 c/s, 117 A, 1,000 rpm, power factor of 0.9 leading. Synchronous motor: One unit, Exciter: 11kW, 40V, 275A.						
B	5	1 hour	50	100	Rototrol	4	4×236 ft-lb Finishing stand looper
	Driving motor: 30 HP, 200V, 50 c/s, 1,470 rpm. One hour rated special cage rotor type 3-phase induction motor: One unit.						
C	250/320	Continuous	220/282	1,135	3.5 kW Rototrol	3	3/3.9 HP Hot run table
	Driving motor: 750 HP., 3,300 V, 50 c/s, 117A, 1,000 rpm, power factor of 0.9 leading. Synchronous motor: One unit, Exciter: 11 kW, 40V, 275 A.						
D	150	Continuous	220	681	2 kW Rototrol	2	4×75 HP Pinch roll 2×300 HP Down coiler mandrel
	300	Continuous	220	1,360	3.5 kW Rototrol	2	4×25 HP Down coiler wrapper roll
	Driving motor: 1,200 HP, 3,300 V, 50 c/s, 184 A, 1,000 rpm, power factor of 0.9 leading. Synchronous motor: One unit, Exciter: 15 kW, 45 V, 334 A.						

Table 4. Constant voltage d-c motors for auxiliary machines

Applications	Output (HP)	Time rating	Speed (rpm)	Current (A)	Type JEM 1109	Field system	Quantity	Magnetic Brake	Control	Remarks
Flying crop shear side guide	7.5	One hour	900	31.5	602	Compound	1	Series winding	RBD+ ASSD	
Finishing mill entry side guide	7.5	One hour	900	31.5	602	Compound	5	Series winding	RBD+ ASSD	
Finishing mill pull back	15	One hour	725	62	604	Compound	6	Series winding	RBD+ ASSD	
Finishing mill screw down	50	One hour	550/980	—	610	Special shunt	10	Shunt winding	Duplex RBD+ ASSD	Made by General Electric Corp., U.S.A.
Hot run table side guide	7.5	One hour	900	31.5	602	Compound	1	Series winding	RDB+ ASSD	
Down coiler table side guide	7.5	One hour	900	31.5	602	Compound	1	Series winding	RDB+ ASSD	
Down coiler stripper	35	One hour	575/1,150	135	608	Shunt	2	Shunt winding	RDB+ ASSD	
Down coiler unloader	35	One hour	575	138	608	Compound	2	Series winding	RDB+ ASSD	
Cross conveyer	15	One hour	725	62	604	Compound	2	Series winding	RDB+ ASSD	
Long level conveyer	35	One hour	575	138	608	Compound	2	Series winding	RDB+ ASSD	

Note: ① Voltage is 220 V. ② Insulation is of Class B. Temperature rising, not more than 750°C. Ambient temperature, less than 40°C. ③ Control code: RDB.....Both directions of rotation, dynamic braking (Both directions of rotation, dynamic braking in "off" or "reverse" positions of the control switch.) ASSD.....Armature shunt slow down. Duplex.....Harmonious operation of two motors.

Table 5. A-c motors for auxiliary machines

Applications	Output (HP)	Time rating	Speed (rpm)	Voltage (V)	Type	Rotor	Quantity	Remarks
Descaling pump	1,500	Continuous	1,480	3,300	Enclosed self ventilation	Wound type	2	
Coil unloader height adjustment	7.5	30 minutes	585	200	Totally enclosed	Special cage type	2	
90° transfer oil pump	40	Continuous	975	200	Totally enclosed	Special cage type	2	
Grease system	1.5	Continuous	1,405	200	Outer fan cooled	Cage type	10	
Morgoil system No. 1	10	Continuous	725	200	Outer fan cooled	Special cage type	2	
Circulating oil system	20	Continuous	730	200	Outer fan cooled	Special cage type	2	
Bearing lubricating system	1	Continuous	1,410	200	Outer fan cooled	Cage type	6	
Circulating oil system	15	Continuous	965	200	Outer fan cooled	Special cage type	2	
Circulating oil system	1.5	Continuous	960	200	Outer fan cooled	Cage type	2	
Roll balance	15	Continuous	1,460	200	Outer fan cooled	special cage type	2	
Down coiler oil pump	5	Continuous	955	200	Outer fan cooled	Cage type	1	
Descaling air compressor	10	Continuous	1,450	200	Outer fan cooled	Special cage type	1	
Morgoil system No. 2	15	Continuous	725	200	Outer fan cooled	Special cage type	2	
Down ender oil pump	75	Continuous	980	3,300	Outer fan cooled	Special cage type	2	
Pinch roll upper roll adjustment	2	30 minutes	955	200	Totally enclosed	Cage type	2	

Note: Frequency is 50 c/s.

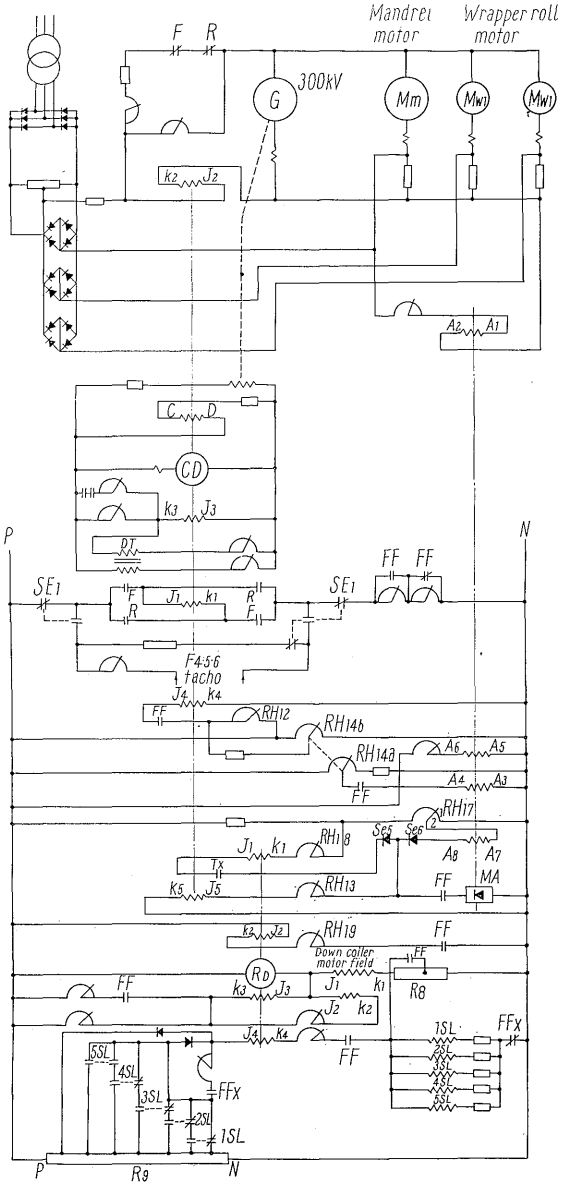

Fig. 13. Control circuit of down coilers

The field J_2—K_2 can also be used for the load current limitation on accelerating, retardating, and operating with over-load of the motors, in order to drop the generator voltage in case where either mandrel motor or wrapper roll motor becomes to bear over-load. The Rapidyne type rotating amplifier is inserted as the booster into the motor field. During its operation, the field J_1—K_1 is excited by the magnetic amplifier MA which amplifies the armature current, and if this armature current is increased the RD gives more voltage in a positive direction to make the field current larger. On the other hand, the field of J_2—K_2 is to give a negative bias current, and all of the dead resistance of the motor field is inserted to secure the minimum excitation at the stopped position of the motor in the main controller. However, it is short-connected with each other in a part of R_8 at the operated position, so that it may, at the same time, give a negative excitation into the field J_2—K_2 through RH19 to secure the minimum excitation current just same as the above-described. And the other field J_3—K_3 is used for stabilization. The J_4—K_3 field is to effect both the suppression of an excessive stirring and over-current, and the attention control of it. A field A_1—A_2 of the magnetic amplifier is to detect the armature current and the field A_3—A_4 is to give AT corresponding to the current value of the required tension by the tension setting regulator RH14a. And, the field A_5—A_6 is to give a bias regulating the operation point, while the A_7—A_8 is to conduct the current when the output voltage of MA is lower than that in 2—1 of RH17 and to hold such a state that, before the current signal from A_1—A_2 attains to the designated value, the output voltage of MA is already to obtain an approximately equal voltage to that of 1—2 of RH17. This value is regulated by RH17 within the range of 0～22 V. The output current of MA is conducted to the field of J_1—K_1 through Se 5 and RH18, only when it overwhelms to 22V of the both terminal voltage of RH17 into the tension adjustment side RD, in order to make its tension adjustment. However, it is conducted to the field of J_5—K_5 of CD through RH13 in itself to the voltage adjustment side, in order to operate and act as a differential power.

Therefore, in case where the voltage of 2—1 of RH17 is zero, the voltage of G becomes high, being added the further voltage to excite through RH12 for the field J_4—K_4 of CD, and increased rotation of the motor about 100 rpm. In case where the above mentioned output voltage of MA exceeds 22V by increasing of the armature current, the excited power by RH12 of the field of J_4—K_4 is extinguished by the field of J_5—K_5, and the designated speed operation will result. As above have been described, the adjustment of the Leading Speed within the range of 0～100 rpm approx. is possible by proper adjustment of RH17. The attention control is to act in such a way that the relays of 1—5SL operate in their order in proportion to the quantity of the motor field current and to connect it with the field of J_4—K_4 of RD through the resistor R_9, and that it is to conduct the current into the field of J_4—K_4 to hold the output voltage of RD constant, even if the motor field current should be reduced by the elimination of the output of MA.

For making the actual winding of the coil perfect, it is quite important to set the speeds being related mutually among the finishing mill last stand, hot run table, pinch roll and wrapper roll. In case where the strip is flowing over the last stand, pinch

roll and mandrel, the distribution of tension is made proper and adequate among these three parts. As soon as the strip departs from the last stand, however, the tension is distributed only between the pinch roll and mandrel, and that of the pinch roll becomes the generator. The pirch rool is to compensate the dropping of IR to make its speed change minimum and also to reduce its speed by several percents, when the two or three turns of strip is coiled on the mandrel to lift up the wrapper roll. When the strip departs from the last stand, the pinch roll is to act as a braking generator by reducing further several percents of its speed with operation of the mill load relay in order to prevent it from drastic and abrupt speed changes. The Table 6 is to give an example of the speed control in the down coilers, which will vary in accordance with the compensation of IR of the pinch roll and the rolling state of the strips.

The Fig. 14 will show the charts of currents of the mandrel and pinch roll motors during operation of strip cooling.

The electric room for the down coiler is separated from the finishing mill control electric room. The Fig. 15 is to give a photograph of the multiple unit

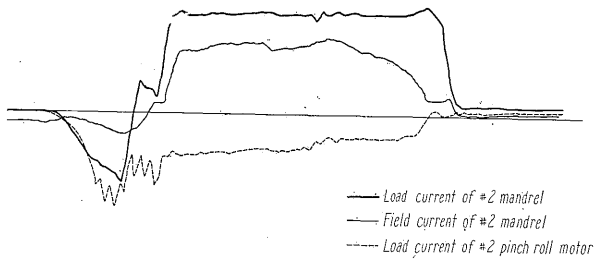

Fig. 14. Load curve of down coiler and pinch roll motor

The mandrel driving motor:
300 HP, 220 V, 1,120/1,140 A, 375/1,050 rpm
The pinch roll driving motor:
75 HP, 220 V, 280 A, 515~650 rpm

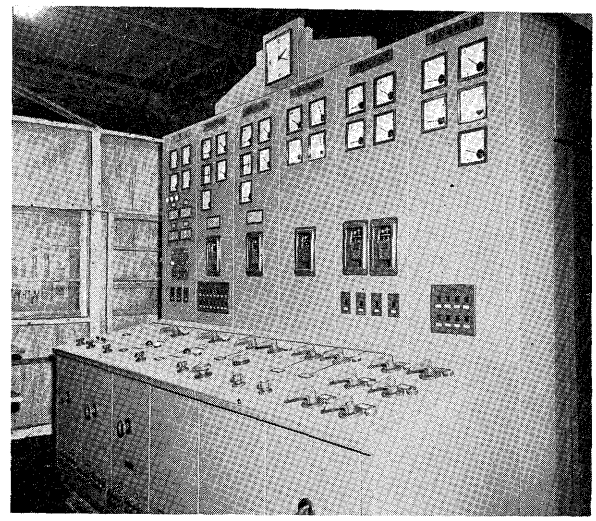

Fig. 15. Multiple unit control board of coiler control room

control board of coiler control room. Both the Fig. 16 and the Fig. 17 will show an inner views of the coiler control room. All equipments for the coil delivery, consisting of two cross-conveyers, two 90° transfers, two long level conveyers, a weight recorder, and a down ender, are to be operated under the four kinds of control, i.e.—the full automatic, the one-pitch automatic, the timer automatic and the

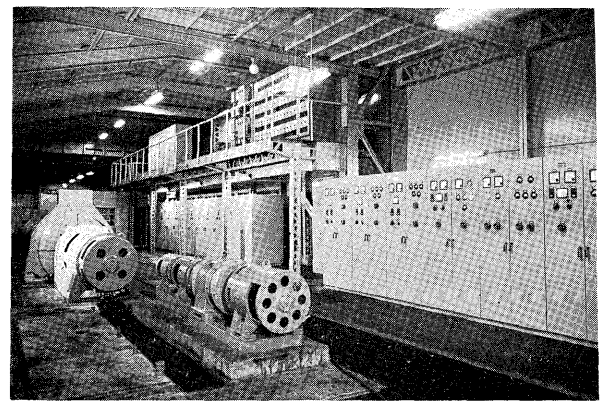

Fig. 16. Coiler control room

Table 6. Speed control example in down coilers

Stable of conditions	Wrapper roll	Closed	Closed	Opened	Opened
	Mill last stand	No load	Load	Load	No-load
Hot ran table No. 1		110%	110%	110%	110%
Hot ran table No. 3		100	110	110	100
Pinch roll		100	105	95	90
Mandrel		120	120	120	120
Wrapper roll		127.5	127.5	127.5	127.5

Note: The above-mentioned figures are given in an assumption under a certain state of conditions, and they don't always accord with the indicated value of the speed meter on an actual operation of the mill.

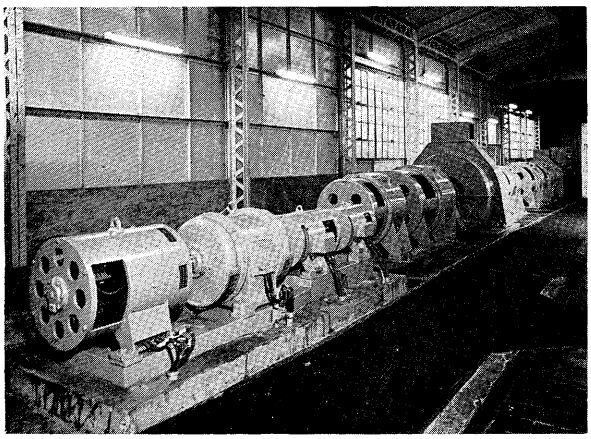

Fig. 17. Coiler control room

manual. In the full automatic operation, the mill can deliver the coil to a pre-designated position without the operator.

V. AUXILIARY EQUIPMENTS

The 3.3 kV power source is illustrated in the skeleton diagram of the Fig. 18. The sealed-off multi-anode air-cooled mercury rectifier is applied to the d-c motor for the constant voltage auxiliary machines and to the d-c 220 V constant voltage power source for the electric crane. The oil circuit breaker of 200 MVA of the rupturing capacity at 3.45 kV is employed, and it is installed within the metal-clad type switchboard.

The ventilation is carried out by the down draft system in the main control room and coiler control room, under which the outdoor air is blown into the control rooms through the air filter and the air is discharged to the mill yard after cooling off the miscellaneous machines and apparatus in the rooms by the induced fan of the forced ventilating machine.

The specifications of air filter :

① For the main control room
type : AAF multi-duty type
one unit : ⇶ 20—144, 111,440 CFM
two units : ⇶ 15—144, 83,580 CFM

② For the coiler control room
type : AAF multi-duty type
one unit : ⇶ 6—88, 16,900 CFM

The specifications of fan :

① For feeding to the main control room
5 units (fitted on the ceiling) : the sirocco type, with capacity of 15 m³/sec at pressure of 30 mm WC, 350 rpm, 20 HP, and 585 rpm.
2 units (fitted on the basement floor) : the turbo type, with capacity of 15 m³/sec at pressure of 40 mm WC, 25 HP and 730 rpm.

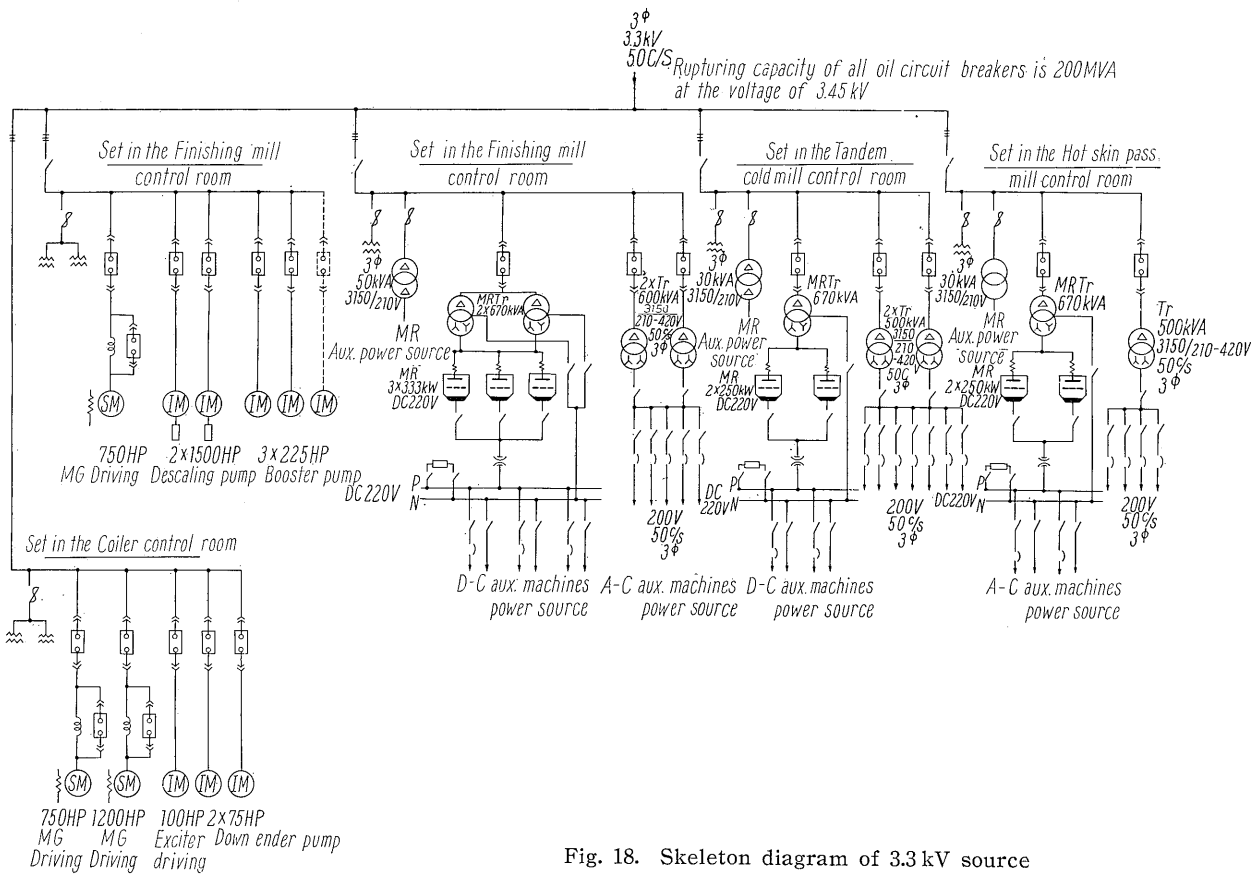

Fig. 18. Skeleton diagram of 3.3 kV source

② For inducing to the finishing mill main motors
3 units: turbo type, with capacity of 9.5 m^3/sec at pressure of 66 mm WC, 25 HP and 950 rpm.
One unit; turbo type, with capacity of 10 m^3/sec at pressure of 60 mm WC, 25 HP and 950 rpm.
One unit; turbo type, with capacity of 8.5 m^3/sec at pressure of 60 mm WC, 25 HP and 950 rpm.

③ For feeding to the coiler control room
2 units; the sirocco type, with the capacity of 4 m^3/sec at pressure of 20 mm WC, 5 HP and 570 rpm.

In addition to the above-mentioned fans there have been installed the four more units of the forced drafting type fans to be used for the d-c motors for the various auxiliary machines.

VI. CONCLUSION

Although the foregoing sections of this Article have only given the readers the brief outline of the electric equipments for the Hot Strip Mill, their controlling system, and their operational characteristics, the author and the Fuji Denki Seizo K.K. would like to take an unexpectable desire that all the readers might excellently understand throughout these equipments. Particularily, the author has an honour of informing that the Company have taken every possible consideration by dispatching the competent engineers and technicians to the U. S. A, in order to accomplish the discussions and negotiations required for their special specification, because the indispensable parts and components had to be imported from the U.S.A. to Japan.

The deep acknowledgements are to be expressed by the author to those kind and suggestive instructions and advices given by the great many engineers, among whom Mr. Fujii, the chief of the Powers Department, Mr. Nakajima, the acting chief of the same Department, and Mr. Yoshida, the chief of the Rolling Department, of the distinguished Kawasaki Steel Corp. are the most unforgettable.