UDC 621. 313. 2-585. 3: 676. 2. 052

ELECTRICAL EQUIPMENT FOR LINE SHAFT DRIVE OF BOARD PAPER MACHINE

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I. FOREWORD

This board paper machine is a large scale model. The line shaft is driven by one 900 kw dc motor, and is equipped with 14 helper motors of various types.

This equipment was installed at Soka works, Jujo Board Paper Mfg. Co., Ltd. As this type of paper machine with top wire units is new to our country, we carefully determined the control system of its helper motors. The results were very good and the machine functions smoothly.

In the following paper, an outline of this machine is given.

II. DESCRIPTION

The specifications of this paper machine are as follows ;

Type : Inverform

Wire width : 3760 mm

Speed : 360–90 m/min

Raw material : Raw plaster board paper and jute liner.

Table 1 shows the roll names and driving sources.

This paper machine is of the Inverform type with its wire part consisting of 5 sets of top wire units installed on the botton wire (of the 5 sets, 1 is for future installation). This is the part in which layers of paper are pressed into one thick sheet ; it is capable of producing board paper of fine quality in high speed operation.

The line shaft drive system is employed ; the main roll of each part is driven through flat belts and air clutches by the line shaft.

Differences of speed between each part (called draw) are made by cone pulleys of the belts.

Auxiliary rolls of each part of the machine are driven by auxiliary motors (called helper motors) shown in *Table 1*.

Table 1 **Roll Names and Driving Sources**

Part No.	Roll Name	Driving * Source
1	Wire turning	L
	Suction couch	H
	Wire return	H
	No. 1 top wire	H
	No. 2 top wire	H
	No. 3 top wire	H
	No. 4 top wire **	H
	No. 5 top wire	H
2	No. 1 press top	L
	No. 1 press bottom	H
3	No. 2 press	L
4	No. 3 press	L
	Wringer	H
5	No. 4 press	L
	Wringer	H
6	No. 1 dryer	L
7	No. 2 dryer	L
8	No. 3 dryer	L
9	Breaker fixed	L
	Breaker swing	H
10	No. 4 dryer	L
11	No. 5 dryer	L
12	No. 6 dryer	L
13	Size fixed	L
	Size swing	H
	Expander	H
14	No. 7 dryer	L
15	No. 1 calender	L
16	Calender dryer	H
17	No. 2 calender	L
18	Reel	L

* L : By line shaft H : by helper motors

** For future installation

III. ELECTRICAL EQUIPMENT

1. Specifications of main components

(1) Line shaft drive motor

Open pipe-ventilated type shunt dc motor ...1

900 kw, 750 v, 1200 rpm, continuous rating, B-class insulation

Speed control range : 1200–300 rpm (Constant torque by Leonard control)

(2) Static Leonard power source for the above motor

Multi-anode air-cooled sealed-off mercury arc rectifier................................2

485 kw, 750 v, 647 amp, special rating, rated output control factor 10%.

Indoor-type, oil immersed self-cooled transformer for mercury rectifier 1

1275 kva, 3/2×3ϕ 3150/810–327 v (6 taps)

50 cps special rating. connection : delta-star conversion/double star type

(3) Helper motors and their motor generators (See *Table 2*)

(4) Auxiliary generator

Constant voltage exciter : Open dc generator 1

30 kw, 220 v, 1480 rpm

High-frequency generator for the power source of the magnetic amplifier : Drip-proof types single-phase ac generator 2

30 kva, 200 v, 350 cps 28-pole 1500 rpm

These generators are driven by 350 kw induction helper motors which are used to drive the helper motor-use generators.

2. Structure and control of electrical equipment

1) Line shaft drive system

Fig. 1 is a skeleton diagram of the line shaft drive motor. It has static Leonard control with a mercury rectifier as its power source. The field of the motor is excited by the constant voltage exciter (used also for exciting the helper motors) equipped with the automatic voltage regulator.

Its automatic speed regulator is a system which checks the shaft speed by reading the voltage of the pilot generator connected directly to the line shaft, comparing with the standard voltage, adjusting the voltage of the mercury rectifier thus maintaining the line shaft speed at a constant value. The cascade control system, our unique technique, is employed in this system, providing a voltage control unit inside the speed regulator loop (main loop) to regulate the voltage of the rectifier to that of the speed desired. In the case of the conventional speed regulator which lacks a voltage control unit, a voltage variation of ac power source results in a speed variation and is adjusted by the regulator at this stage. On the other hand, when the voltage control unit is provided, the voltage variation is adjusted within the unit and does not affect the speed. That is, the voltage variation is detected and adjusted as it is prior to changing to the speed variation.

Moreover, it contributes to stabilization, rapidity of response and accuracy of the entire control system.

The speed setting range is 1:4, with Leonard control by changing the output voltage of the mercury rectifier. A voltage selector tap is installed on the transformer for the rectifier to insure high power factor and stable operation.

The tap voltage selector is a no-voltage electrically-operated switching device. Sudden engagement of the clutch of the dryer part, which has particularly large GD^2, causes excessive torque of the motors, resulting in overcurrent and possible tripping. To prevent this, a current limiter circuit is installed to lower the voltage of the rectifier when overcurrent occurs.

Speed changing must be performed gradually and delicately. For this reason, the variable resistor for speed setting has 450 notches. This resistor is a dual-purpose type, serving for variation of setting of both speed and voltage. In case of emergency, the motor is stopped by dynamic braking with all parts remaining connected.

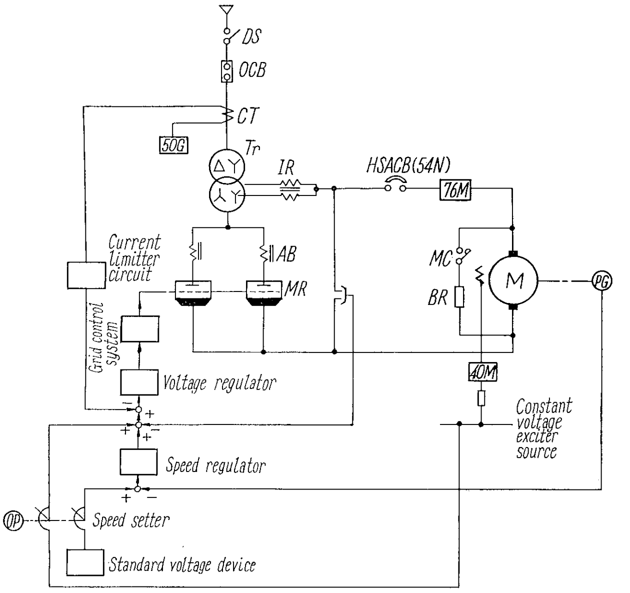

Fig. 1 **Skeleton diagram for line shaft drive motor**

2) Helper motors

(1) Basic explanation

Each part of the paper machine consists of rolls of various sizes. In the wire and press parts, these rolls are connected by endless wires and felts, and hence should be rotated at the same peripheral speed. Of these rolls, the main roll is driven by the line shaft and rotates at a constant speed. Small rolls are driven by the main roll via wire or felt, but larger rolls cannot be driven in this way as it causes large tension to the wires and felts. Power transmission by belts and gears from the main roll is also not feasible because roll wear causes gradual change of peripheral speed. For these reasons, these rolls are equipped with individual motors to provide a constant torque. These motors are called helper motors because their speed is decided by the main roll, and they only help the driving of each part by providing a constant torque for them.

The method generally employed for constant torque control of helper motors is to adjust the armature voltage to provide constant armature current with the motor excited at a constant

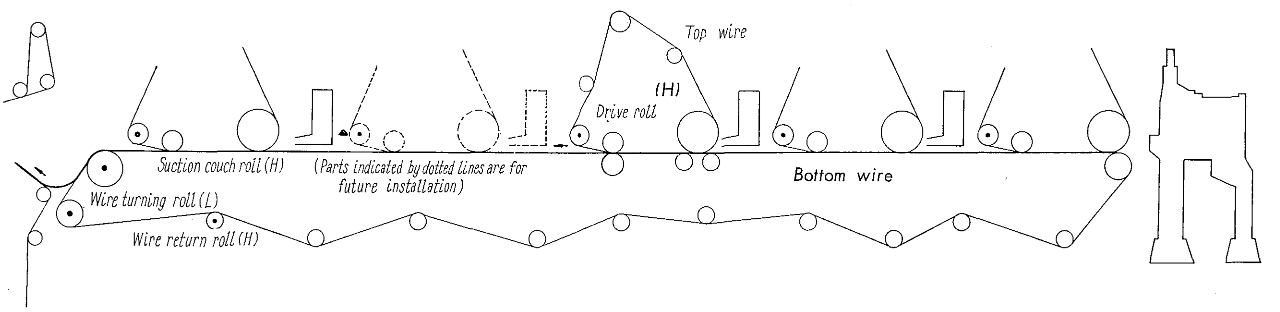

Fig. 2 Wire part

rate. Another method is to adjust the field current to maintain constant armature current by feeding it from a main source which has approximately proportianal voltage to the main roll speed. A similar constant torque property can be obtained by connecting a motor with approximately 10% drooping characteristic to such a main source which has approximately proportional voltage to the main roll speed.

This method does not require any current regulater. Selection is made from these methods with consideration given to motor output, conditions of use, main roll drive system (line shaft or sectional drive) and economy. These helper motors have other uses, which will be discussed later.

(2) Bottom wire

Fig. 2 shows the distribution of rolls of the wire part.

An explanation of the bottom wire control system is indicated in *Fig. 3*.

A generator is installed for two helper motors, its current being automatically regulated to a constant rate. As each motor has drooping characteristic and operates at the same speed, they share the current of the generator in a certain proportion. To change this current distribution proportion, the separately excited field current of the wire return roll helper motor is changed slightly. A manual field adjuster is installed on the machine side control board to accomplish this.

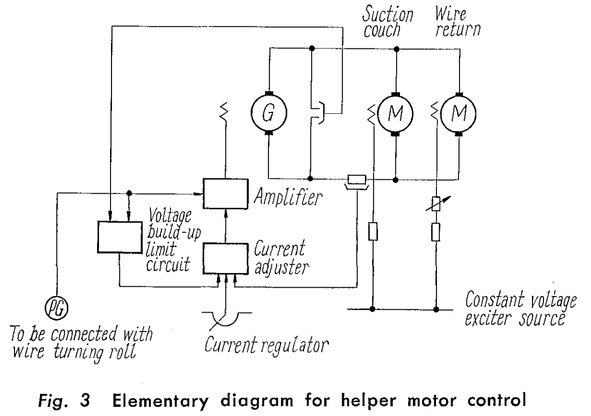

Fig. 3 Elementary diagram for helper motor control (bottom wire)

Upon starting or speed shifting of the bottom wire, the speed of the helper motor must smoothly follow that of the main roll.

For this purpose, a pilot generator is connected by gear to the main roll, its output voltage added to the bias winding of the magnetic amplifier, so that the voltage of the generator changes approximately in proportion to the speed of the main roll.

When excessive current is given beyond the torque transmission capacity of rolls to the wire, slipping is liable to occur, which would cause over-speeding. Therefore, a voltage build-up limit circuit is installed to prevent the voltage of helper motor generator from exceeding that of the main roll's pilot generator. Further, an adjuster is provided to reduce the torque of the helper motors when the wire is free of white water, and to increase the torque when loaded with white water.

The method is to detect through the use of a vacuum meter with alarming contacts the increase of the vacuum rate of the suction box which occurs when the wire is loaded with white water, effecting 3-stage variation of helper motor torque automatically.

Upon starting the bottom wire, action for the air clutch engagement to connect the main roll to the line shaft automatically actuates the hleper motors prior to clutch engagement.

(3) Top wire unit

After starting the bottom wire, each part is actuated individually and dropped to touch the bottom wire. In this case, it is necessary to synchronize the speed of the top wire with that of the bottom wire accurately to prevent damage to the wire. For this purpose, speed regulatory control is performed prior to touching, and by sensing the touchdown with the limit switch, speed regulation is switched to steady current characteristic operation, utilizing the drooping characteristic of the motor.

Fig. 4 shows an elementary diagram for helper motor control (top wire). One generator is installed to serve 5 helper motors, with its voltage automatically regulated. The voltage of the pilot

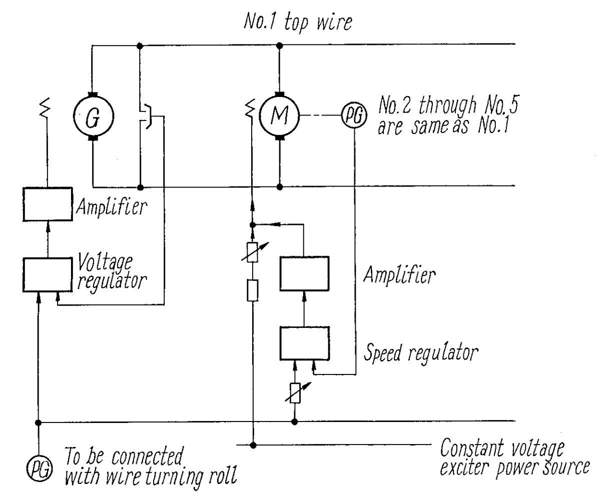

Fig. 4 Elementary diagram for helper motor control (top wire)

generator connected by gear to the wire turning roll is used for the standard value of voltage control, and it is adjusted so that the speed of helper motors is synchronized with the speed of the wire turning roll. The speed regulation of each motor is controlled by comparing the voltage of the pilot generator directly connected to each motor with the voltage of the pilot generator connected by gear to the wire turning roll. The field magnet coil of the motors is single-wound; the magnetic amplifier output current is added to the fixed exciter current, providing variation of the motor exciter current.

(4) No. 1 press

The distribution of rolls from No. 1 press to No. 4 press is shown in *Fig. 5*. Both rolls of the No. 1 press are actuated separately and touched together after starting.

Fig. 6 shown an explanatory diagram of its control system. With the speed of top roll as the standard, the voltage of the helper motor generator is controlled so that the current approaches the steady current characteristics, taking advantage of the helper motor drooping characteristic.

If steady current control is employed, the helper motor speed will become excessive when the main roll is separated. However the above method precludes this hazard. Therefore, this system is employed for all parts involving separation of rolls in this equipment.

(5) No. 3 press and No. 4 press

The control system is same as that of the bottom wire, automatically adjusting the current of the helper motors.

(6) Breaker stack

Distribution of rolls of this part is as indicated in *Fig. 7*. The swing roll is touched after starting. The control system is same as that of No. 1 press.

(7) Size press

The distribution of rolls is shown in *Fig. 8*.

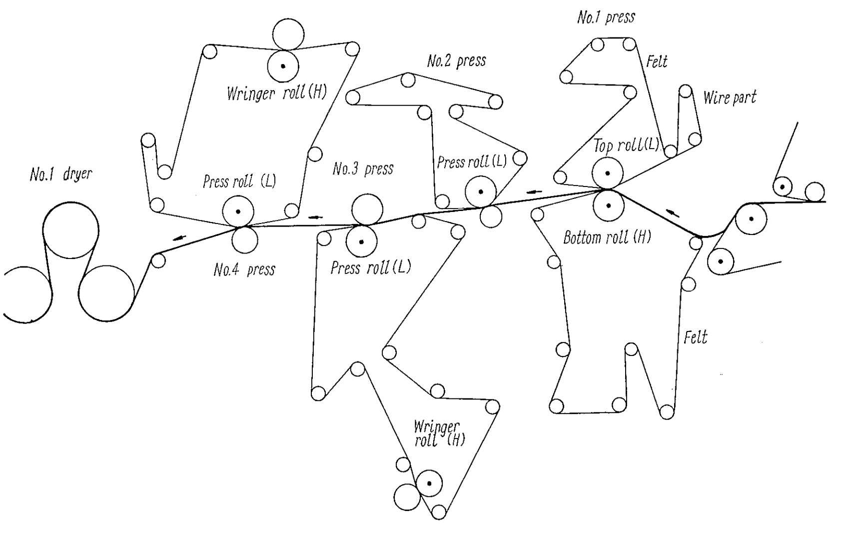

Fig. 5 Press part

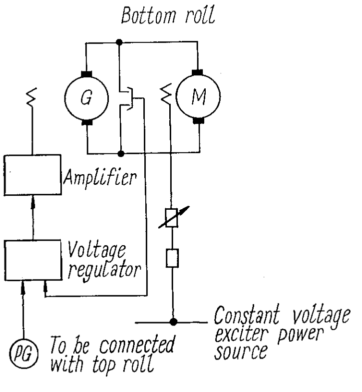

Fig. 6 Elementary diagram for helper drive control (No. 1 press)

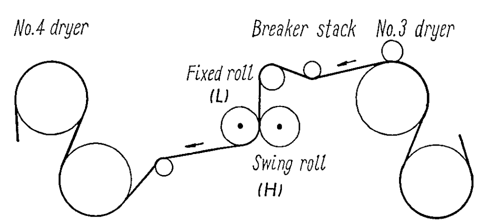

Fig. 7 Breaker stack

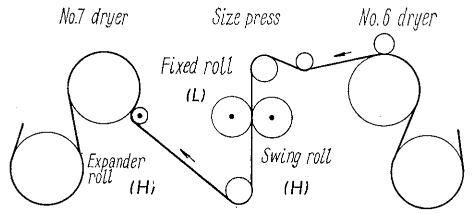

Fig. 8 Size press

The swing roll is touched after starting. A generator is provided for 2 helper motors, its voltage being regulated to the standard speed of the fixed roll; the current of each helper motor is made close to the steady current characteristic by utilizing its drooping characteristic.

(8) Calender dryer

Because of the difficulty of driving the line shaft of this part due to its position, it is driven by individual motors with speed regulation. These are also called helper motors because of their low output compared to the line shaft drive motor. *Fig. 9* shows the control system of this part. With the voltage of the pilot generator connected by gear to the No. 2 calender roll as the standard, the speed is regulated by comparing it with the voltage of the pilot generator directly connected to the motors driving the calender dryer.

3. Explanation of main components

1) Dc motor

Fig. 10 shows the motor for line shaft drive. The paper machine is installed upstairs and the motor downstairs; the power is transmitted by the belt. The motor has shaft ends at both sides, to which the line shaft is directly connected. Helper motors are connected to the rolls by gear. The 1.5 kw motor is the enclosed type, while the others are the open pipe-ventilated type, which are ventilated through branched lines from two turbo-fans.

To maintain approximately 10% drooping charac-

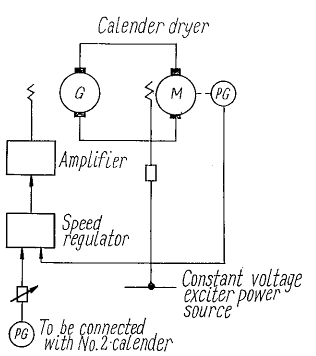

Fig. 9 Elementary diagram for helper drive control (calender dryer)

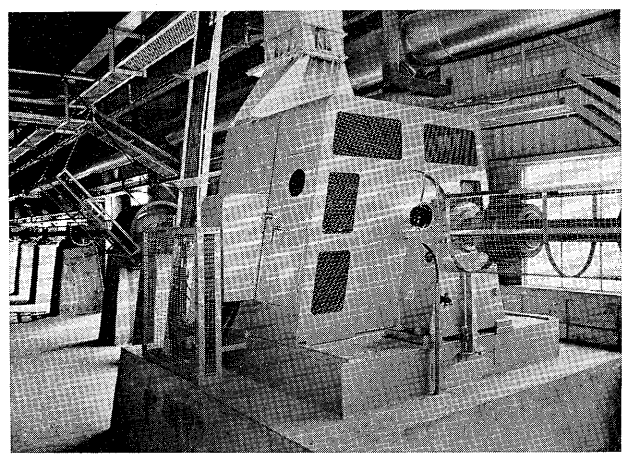

Fig. 10 Dc motor for line shaft drive

Table 2 **Helper Motors and their M-G Sets**

Part Name	Purpose	Dc Motor	Dc Generator	Induction Motor for Driving Generator
Wire	Suction couch	55 kw 220 v 1140/1260 rpm	81 kw 225 v 1480 rpm	350 kw 3150 v 4 P 50 cps 1480 rpm Squirrel-cage rotor type (direct starter) Remarks: 3 generators for control are also driven by this motor
	wire return	15 kw 220 v 1140/1260 rpm		
	No. 1 top wire	22 kw 220 v 1140/1260 rpm	135 kw 225 v 1480 rpm	
	No. 2 top wire	22 kw 220 v 1140/1260 rpm		
	No. 3 top wire	22 kw 220 v 1140/1260 rpm		
	No. 4 top wire	22 kw 220 v 1140/1260 rpm		
	No. 5 top wire	22 kw 220 v 1140/1260 rpm		
No. 1 Press	Bottom	22 kw 220 v 1140/1260 rpm	26 kw 225 v 1475 rpm	250 kw 3150 v 4 P 50 cps 1475 rpm Squirrel-cage rotor type (direct starter)
No. 3 Press	Wringer	55 kw 220 v 1140/1260 rpm	63 kw 225 v 1475 rpm	
No. 4 Press	Wringer	55 kw 220 v 1140/1260 rpm	63 kw 225 v 1475 rpm	
Breaker Stack	Swing	9 kw 220 v 1140/1260 rpm	12 kw 225 v 1475 rpm	
Size Press	Swing	15 kw 220 v 1140/1260 rpm	20 kw 225 v 1475 rpm	
	Expander	1.5 kw 220 v 800/900 rpm		
Calender Dryer		22 kw 220 v 1140/1260 rpm	26 kw 225 v 1475 rpm	

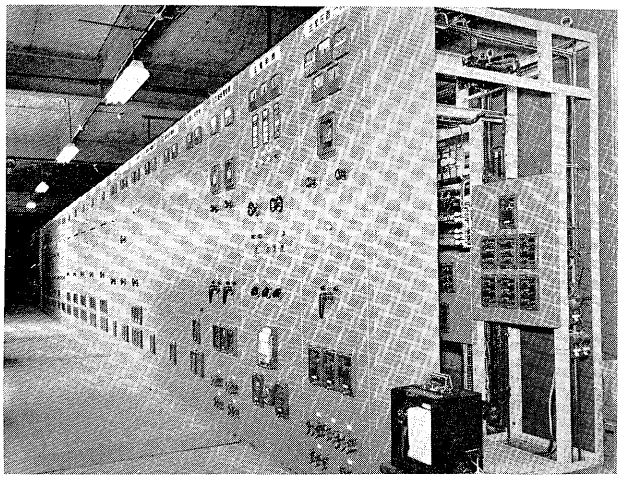

Fig. 11 Main switchboard

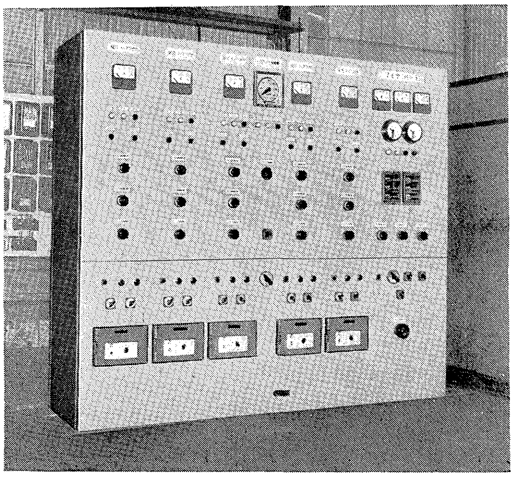

Fig. 12 Control cubicle for top wires

teristic, auxiliary series-wound field magnetic coils are affixed.

2) Pilot generator for speed detection

The pilot generator for speed detection of the line shaft is connected to the shaft end of the line shaft at its reel side. Due to the requirment for high accuracy and stability, a permanent magnet type ac generator equipped with silicon rectifier is used. Its lack of exciter power source and rectifier brush precludes errors due to them. It has 20 poles and its coil is 3-phase, which undergoes full-wave rectification.

This keeps rectification ripple to a minimum so that no trouble is caused by this.

3) Regulator and amplifier

A PID regulator of the magnetic amplifier type is employed, its output being amplified by a magnetic power amplifier for excitation of the field magnets of generators and motors. All power sources are high frequency (350 cps).

The ac generators for the high frequency power source are equipped with automatic voltage regulator depending on 50 cps magnetic amplifier.

4) Standard voltage device

The standard voltage device for regulating the speed of the line shaft employs a transistor power source based on Zener diodes.

5) Speed difference meter

Upon touching those rolls driven by helper motors, it is necessary to adjust their speeds to that of the main roll.

A speed difference meter is required for this purpose. The system is such that the frequency of each dc generator, which is gear-connected to both rolls, is converted to dc current and a minute dc voltage resulting from the difference operates an electric tube type automatic balance meter. It indicates the speed difference in rpm.

6) Switchboard

The main switchboard is a self stand open type board, with meters, relays and switches installed on the front, and magnetic amplifiers, resistors and dc low voltage apparatus on the back frame.

7) Machine side control panel

The control panel consists of one board for the line shaft, one board for the wire part (See *Fig. 12*) and six boards for the helper boards.

IV. CONCLUSION

We have given above an outline of this equipment. Future development of this type of equipment will include thyristors as the Leonard power source and regulators consisting of transistor. Our company is adequately prepared to meet these technological developments.