

# ELECTRICAL EQUIPMENT FOR SECTIONAL DRIVE OF PAPER MACHINE SUPPLIED FOR KUSHIRO MILL OF JUJO PAPER MFG. CO., LTD.

By

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## I. INTRODUCTION

A paper machine has been installed by the Jujo Paper Mfg. Co., Ltd., for use in its mill in Kushiro, to produce news print paper. This Company can will be proud of the fact that, this equipment is in scale, the largest in the Orient. All electrical equipment for sectional drive was manufactured by our Company. An accurate co-operative running control (to control speed differences between parts, i. e. draw control) is required of a paper machine which is to be operated continuously, day and night, (approximately for 2 weeks). Therefore, it was necessary for its electrical equipment to function with high accuracy and have stability. The necessity is more for wide and high speed machine as this plant. Because of the above mentioned reasons, it was necessary to concentrate on recent techniques and also apply our long experience, all the while, consulting with our customer, before actual steps could be taken, in the design of the installation and production started.

For co-operative running control, we, too, have a technique of a pure electrical controlling system, in which permanent magnet type brushless-DC pilot generators with silicon rectifiers, a magnetic amplifier type high accuracy standard voltage regulating device and magnetic amplifier type integral amplifiers are used. But in this case, a differential gear type draw regulator had to be adopted, based on the system applied for the Sakamoto Works. This technique was published in our issue of Fuji Denki Review Vol. 4, No. 1, 1958.

This installation started satisfactory operation during July of 1960, and great attention was focussed with regards to this installation. This is why, it is our sincere desire to explain here, our outline of electrical equipment.

## II. PAPER MACHINE

Width :	6,960 mm (274 in)
Paper making speed :	700-350 m/min (2,296-1,148 ft/min)

Kind of paper :	news print paper
Specification of each part :	refer to Table 1

Paper processing is shown in Fig. 1, white water (furnish) is flowed from the head box and formed into wet paper, dehydrated, pressed, dried and calendared; and then, the finished paper can be obtained continuously and automatically. An outline of this is shown in Fig. 3, 4. Local control desk, DC motors and reduction gears to drive each section, are installed on the front and back of the paper machine, respectively. Primary white water pump is connected to secondary white water pump in series through pipe line, which is the last stage, as pump to transfer the white water into the head box of the paper machine.

## III. CONSTRUCTION AND CONTROL OF ELECTRICAL EQUIPMENT

A skeleton diagram is shown in Fig. 2. DC motors (section motors) to drive each section of the machine are supplied with power from the mercury rectifiers, as a common source, except for 11 kW and 3 kW motor. The bus voltage is automatically controlled to the constant tension, according to preset paper making speed. The other hand, the exciter is also equipped with an automatic voltage regulator, even if AC voltage or frequency should change, speed of all section motors should be constant. But, because of load variation of each section motor, these motors might be vary in their speed, to compensate this main circuit booster generator is connected to each part, accurate speed control can be achieved by raising or lowering the main circuit voltage. This control can be achieved by a draw regulator having a differential-gear type speed-difference detecting mechanism. That is, this mechanism detects the speed difference between the standard speed and the speed of the synchronous motor, supplied power of AC three phase from the slip ring built in the section motor. Signal voltage, of the control transformer connected to this differential shaft (generating the voltage nearly in proportion to rotation angle),

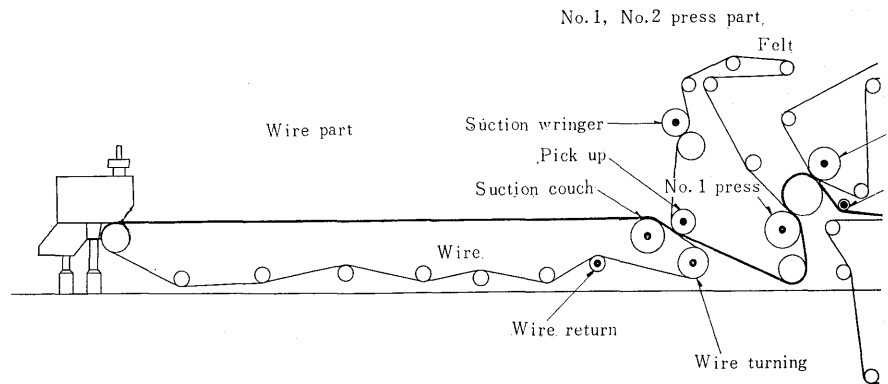


Fig. 1. Side view for paper machine

and of DC pilot generator (generating the voltage nearly in proportion to speed), are fed into a magnetic amplifier, this amplifier controls the field of the booster generator, and in this way, the speed of the section motor can be kept constant. Draw regulation is made by adjusting the speed transmission ratio of every cone pulley, which are set up between middle

of the master shaft and the differential gear of each part. In this system, the speed of the section motor can be controlled so as to completely meet with the standard speed, offset error should be zero. This figure is very suitable for a paper machine, which is required to keep a constant speed difference set exactly between parts. The DC pilot generator

Table 1. Specifications of each part of paper machine

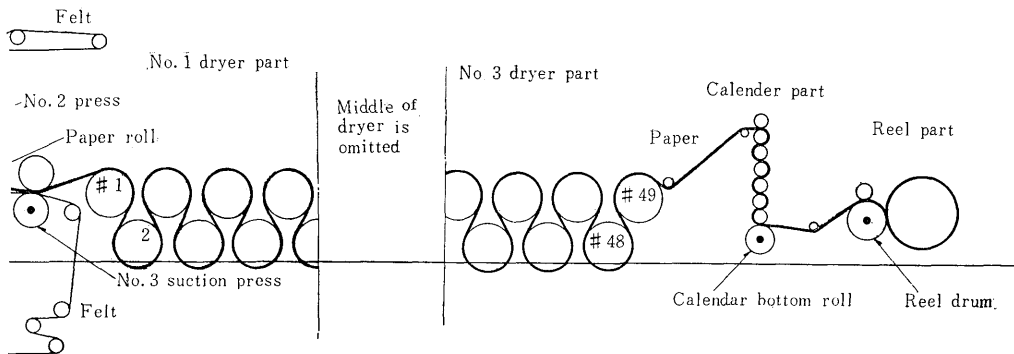
Name of part	Name of machine being driven by section motor	Standard draw (%)	Rated output of motor (kW)	Ratio of reduction gear
Wire	Wire turning roll (D)	0	350	5.44
	Suction couch roll (H)	—	350	6.25
	Wire return roll (H)	—	11	3.39
No. 1, No. 2 press	No. 1 suction press roll (D)	2	160	6.17
	Suction pick-up roll (H)	—	75	4.55
	Suction wringer roll (H)	—	160	4.58
	Suction felt roll (H)	—	75	4.55
	No. 2 suction press roll (H)	—	160	6.17
	Paper roll (H)	—	3	1.88
No. 3 press	No.3 press bottom roll (D)	2	160	6.17
No. 1 dryer	No. 1 dryer driving pinion (D)	0	350	8.71
No. 2 dryer	No. 2 dryer driving pinion (D)	0	350	8.71
No. 3 dryer	No. 2 dryer driving pinion (D)	0	350	8.71
Calendar	Calendar bottom roll (D)	0	350	5.44
Reel	Reel drum (D)	0	75	6.52
Secondary white water pump	—	—	420	—

Remark: 1. Standard draw is to be the value which is set at designing. Above-mentioned draw is determined based on No. 3 dryer's speed as follows;

Draw= 
$$\frac{(\text{circumference speed of back part roll})-(\text{circumference speed of front past roll})}{(\text{circumference speed of roll in No. 3 dryer part})} \times 100 (\%)$$

The speed of driving motor of each part can be controlled independently within ±5% of upper and lower limit of speed being decided by the standard draw.

2. In the above table, (D) and (H) mean to be driven by driver motor and and helper motor respectively



coupled to the differential shaft, in case of speed variation, is to quicken response of controlling by generating DC voltage in proportion to its error speed. Therefore, it can be said, this system is a position control system with a differential action.

The AC pilot generator is directly coupled to the master motor which operates the master shaft. Its generated frequency is detected by means of a extremely high sensitive frequency detector which is made by a combination of special magnetic amplifier having a synchronous rectifying action and the double T type frequency bridge, and it controls the Leonard-generator, then an accurate speed control is carried out. This system is the same as for electric governor of Fuji water turbin generator (refer to Fuji Denki Review Vol. 3, No. 2, 1957). Setting speed for paper machine can be changed by a four ganged resistor which varies with interlock motion a resistance of the static field of Leonard-generator and three resistors used in the frequency bridge circuit. The four ganged resistor is turn by a DC motor, and has approximately 700 notches (arranged in a spiral) to set a paper making speed closely.

The helper motor being connected to the speed control booster generator in parallel with the driver motor, in the case of draw regulating, the speed of the helper motor is smoothly controlled according the speed of the driver motor. Moreover, the booster generator is connected in the motor field circuit to automatically keep the load current of the motor constant. At the wire part, there are a number of rolls with endless wire, three of them are driven independently by motors. The wire turning roll is literally a main roll to drive the wires, and is driven and controlled in speed by the driver motor. The reason a suction couch roll is equipped with the helper motor, is to decrease the wire tension between two rolls by distributing loads so that it lengthens life of the wire. In case of load variates, it is desired that loads of both motors change with keeping same rate, so total current of both are detected by means of DCCT, and this is utilized as the standard value

of an automatic current control of a motor which drives the suction couch roll. The private Ward-Leonard generator is available for 11 kW helper motor which drives the wire return roll, as the power source. This roll is ready to give a back-tension with draw-regulating to the wire. As the constant field of the generator is excited by the terminal voltage of the main motor, the speed of helper motor is nearly in accordance with the speed of the driver motor. Moreover, load current can be controlled into constant value. At No. 1 and No. 2 press part, No. 1

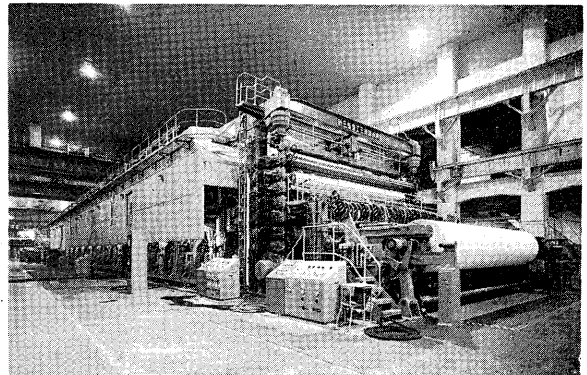


Fig. 3. Paper machine (front side)

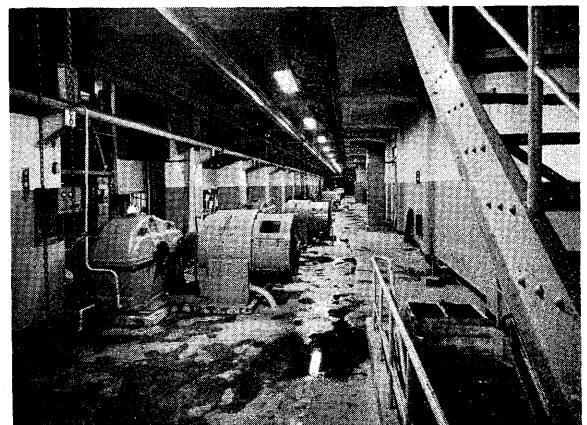


Fig. 4. Paper machine (back side)

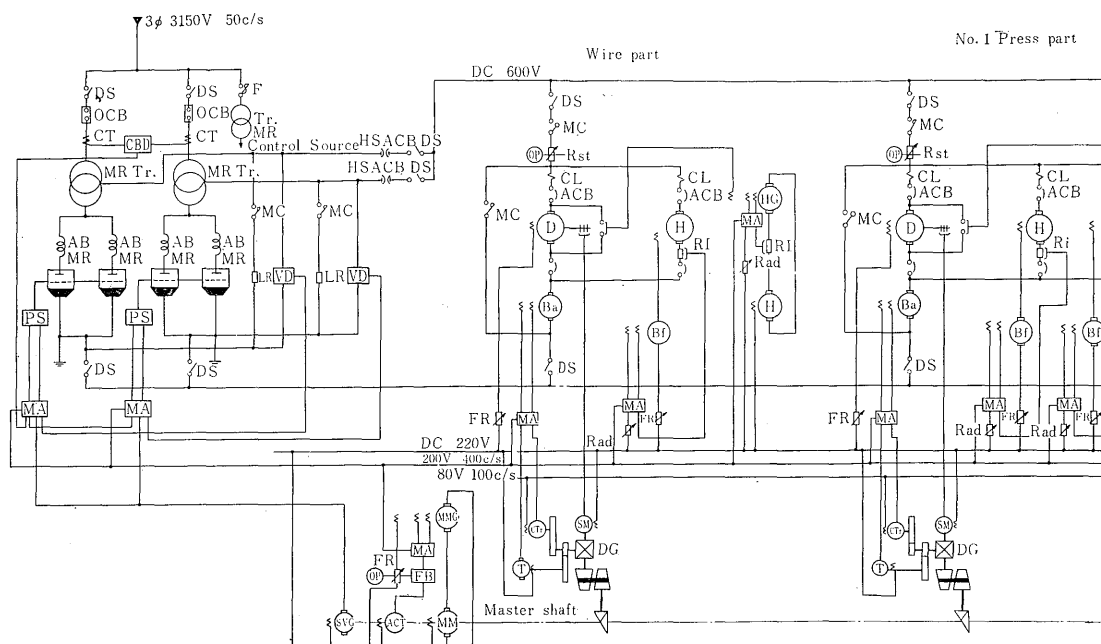


Fig. 2. Skeleton diagram for sectional drive

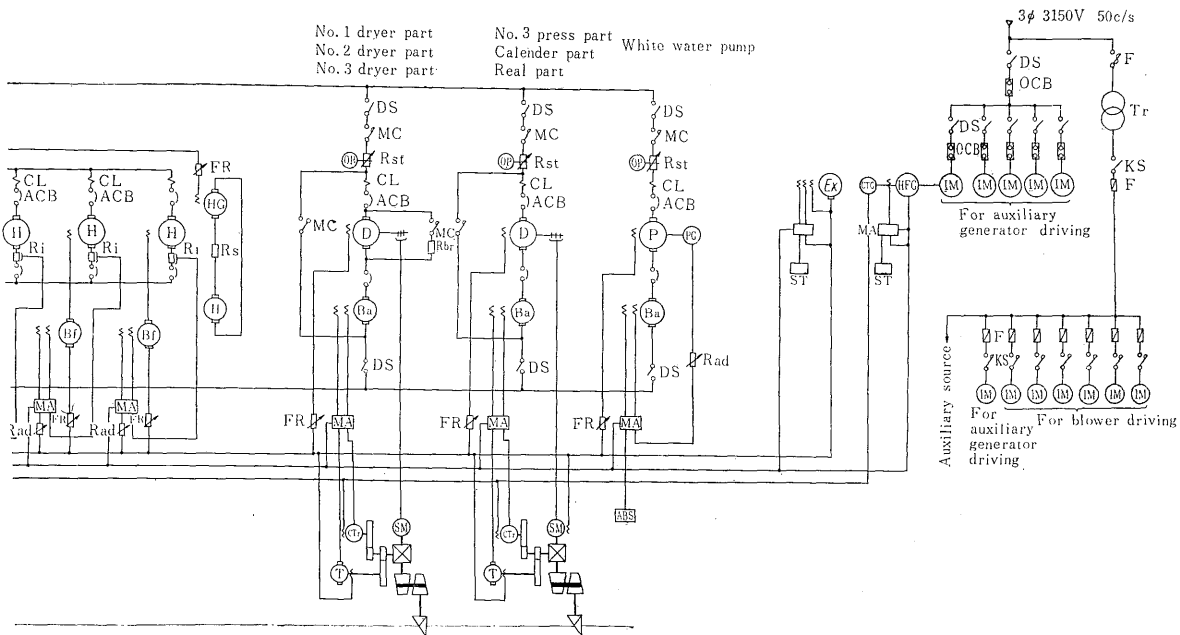
press roll is driven by the driver motor, with help of four helper motors. Because each roll has its own driving motor, tension on the felt is extremely small compared with one roll drive, so fine quality felt being superior in hygroscopic is available, these helper motors are all controlled into constant load respectively. The paper roll driving motor is supplied with power from the Leonard-generator which is excited by a terminal voltage of the driver motor, and runs with a speed-drooping characteristics obtained by use of series resistance.

All automatic control equipment used in the above installation are magnetic amplifier. For this source, the 400 c/s high frequency generator is used. Push-pull type one is utilized as magnetic amplifier so as to raise accuracy, moreover, the high frequency generator is also equipped with the magnetic-amplifier automatic-voltage regulator (self excited 400 c/s, single type).

Regardless of the rectifier's bus voltage, slow running of the section motor can be achieved, because the circuit is composed of the main circuit booster generator to control speed which functions as a Leonard-generator. Speed is adjustable from 30 to 60 m/min. by means of the generator's field regulator. At the time of starting, the motor field is forcibly excited in parts of the dryer and calendar. Slow running is especially valuable for cleaning or repairing wire and felt, regardless of other sections. Besides, this has merit that the machine can be operated without the necessity of the mercury rectifier even during holidays. To increase the speed, the section motor is connected to the bus of the rectifier,

through the main circuit booster generator of each part and the starting resistor. Each current limiting relay is capable of detecting the rush current of each motor has attenuated, the short circuit notches of the motor-operated starting-controller then proceed. In the part, which has the helper motor, such as, wire part, No. 1 and No. 2 part, what has 18 notches is used, to eliminate speed unbalance during starting of the motors. When an acceleration is finished, the source of magnetic amplifier for current control of the helper will be switched on. After that, if the speed of the differential shaft of the draw regulator is below the standard, the source of magnetic amplifier for speed control is switched on, consecutively, DC pilot generator—control transformer is connected to the differential shaft. As mentioned above, a speed control can be carried out with a small rush current. And for stopping, the dryer part is stopped with a dynamic brake, because of very big  $GD^2$  of this part. As mentioned above, the sectional drive has merit that it provides easy smooth slow-running and high-speed-running for each and every part.

Even if paper making speed kept constant, when the speed of the secondary white water pump varies, it is undesirable the thickness of the paper be affected by this. So this pump is also driven by DC motor and controlled automatically. As a DC source, the mercury rectifier bus is used, but, as the pump speed can not be changed very much and not in proportion to the paper macking speed, a control system being different in the case of the section motor is used. The speed of this is detected by the permanent-magnet type brushless-DC pilot generator



- DS: Disconnecting switch  
 OCB: AC oil circuit breaker  
 CT: Current transformer  
 CBD: Current balancing device  
 MStr: Rectifier transformer  
 AB: Anode balancer  
 MR: Mercury rectifier  
 PS: Phase shifting grid control device  
 MA: Magnetic amplifier  
 F: Fuse  
 Tr: Transformer  
 MC: Magnetic contactor  
 LR: Base load resistor  
 VD: Voltage divider  
 HSACB: High speed air circuit breaker  
 Rst: Starting resistor  
 OP: Driving motor  
 CL: Current limiting relay  
 D: Section motor (main)  
 H: Ditto (helper)  
 ABC: DC air circuit breaker  
 Ba: Main circuit booster generator  
 Bf: Field circuit booster generator  
 FR: Field regulator  
 RI: Current detecting resistor  
 Rad: Adjusting resistor  
 MM: Standard speed motor  
 MMG: Generator for above  
 ACT: AC pilot generator  
 FB: Frequency bridge  
 SVG: Standard voltage generator  
 SM: Synchronous motor  
 DG: Differential gear  
 CTr: Control transformer  
 T: DC pilot generator  
 HG: Generator for helper  
 Rs: Series resistance  
 P: Motor for white water pump  
 PG: Special pilot generator  
 ABS: High accurate standard device  
 EX: Exciter  
 ST: Standard device  
 IM: Induction motor  
 KS: Knife switch  
 DCCT: DC current transformer

amplifier type high-accurate standard device, and then the main circuit booster generator is controlled. Setting of speed is made by a adjusting resistor manually. Though the section motor is used on the condition that, the booster generator voltage is around zero, but in this case, as the generator is to be run with generating voltage, the magnetic amplifier is used with keeping down it's sensitivity at the starting time of an automatic control so as to prevent a rush current.

#### IV. DC MOTOR AND AUXILIARY MOTOR-GENERATOR

The specifications are listed in tabled 2 to 4. Enclosed air ventilated type is adopted not only for DC motors that are used on condition of high-temperature and high-moisture, and provide the speed control up to  $\frac{1}{2}$  of rated speed at constant torque, but for DC generators that are installed in the electric room to protect the commutator from dust. The cooling air is distributed through distribution air ducts by blowers (4 sets for section motors, 2 sets for DC motors).

And for all driving motors of auxiliary motor-generator, enclosed self-ventilated 3 phase cage-rotor type induction motor are used. Fig. 5 shows the group of auxiliary motor-generator.

#### V. DC POWER SOURCE

(silicon rectifier is built in this) connected to the motor, the detected speed is referred to the magnetic-

The power source is composed of two banks made

Table 2. DC motors

No. of set	Output (kW)	Voltage (V)	Current (A)	Speed (rpm)	Use
6	350	600	630	1,200	Couch, wire turning, No. 1 dryer, No. 2 dryer, No. 3 dryer, calendar
4	160	600	290	1,200	Wringer, No. 1 press, No. 2 press, No. 3 press
3	75	600	136	1,200	Pick-up, felt suction, reel
1	11	220	58	1,200	Wire return
1	3	220	16	1,200	Paper roll
1	420	600	750	1,200	Secondary white water pump

up of one transformer and two rectifiers. The specifications of each equipment are as follows;

Pumpless air-cooled multi-anode mercury rectifier  
4 sets

1,140 kW 600 V 1,900 A A class rating  
rated output control ratio 15 %

Indoor use oil-immersed self-cooled rectifier  
transformer 2 sets

3,100 kVA 3/6 phase 50 c/s delta/double star  
connection

primary 3,150 V

secondary 682-410 V 9 taps (at primary with  
built-in type inter-phase reactor)

Both banks have the grid control device. The grid control can function so that output voltage is kept constant based on the voltage of the standard voltage generator being coupled to the standard speed motor. This control device is not of Toulon circuit heretofore in use, but employs up-to-date system which is based on the fact that, trapezoidal voltage applies for the saturable reactor, and the phase to saturate the reactor will vary according to an exciting current. This system can control quickly and accurately.

The mercury rectifier has many merits compared to the motor-generator set, that easy erection, easy maintenance, noiseless and high efficiency etc. In the case of common source, the bus voltage will vary caused by DC load variation, and the speed of the section motor will be disturbed. But when mercury rectifier is used, because of quick voltage control, this disturbance will be extremely small. This is a big merit.

Two banks are always operated in parallel, an automatic current balance circuit is furnished, so as to prevent an unbalance current among both loads. A temperature control of the rectifier is made by temperature relays; heater switch on and off, blower start and stop, and the speed of the blower is automatically controlled in accordance with the load. These auxiliary control cubicles are installed on the common bed and on the front; back and sides are

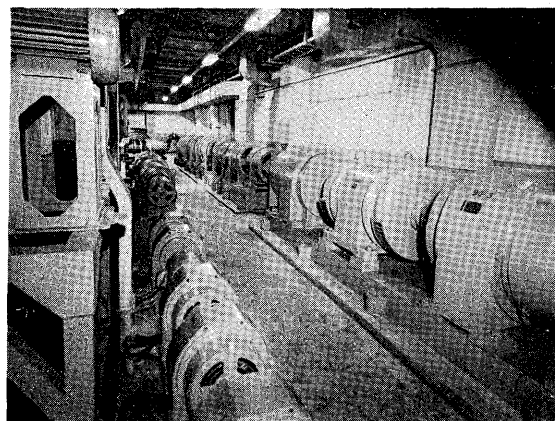


Fig. 5. Auxiliary M-G sets

covered by steel sheets to rise the effect of temperature control (refer to Fig. 6, 7).

According to the applied paper making speed, the voltage control is between 600 V and 300 V. This control is by the tap changer of the transformer

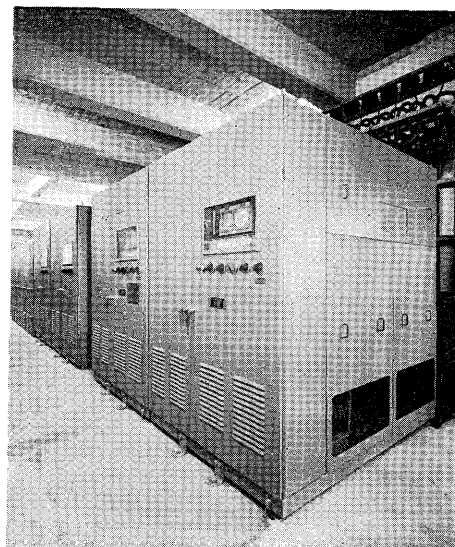


Fig. 6. Mercury rectifiers

together, to keep high operating power factor. For this, the transformer has the manual-operated no-voltage tap-changer. The most suitable tap position must be set before starting. In the rectifier bus, a

base load resistance is connected to prevent voltage up, even if the load is zero, but for economizing power, these resistances will be cut off automatically when any section motor is connected to the bus.

Table 3. DC motor-generator

Group	No. of set	Output (kW)	Voltage (V)	Current (A)	Speed (rpm)	Field	Use
A	2	90	70	1,285	980	2 winding push-pull mag. amp.	Main circuit booster generator's wire, each part of No. 1, 2 part
	Driving motor 220kW 3,150 V 50 c/s 6 pole 980 rpm						
B	4	45	70	642	1,470	2 winding push-pull mag. amp.	Main circuit booster generator, No. 1 dryer, No. 2 dryer, No. 3 dryer, calendar, each part
	1	21	70	300	1,470	Do	Do, but for No. 3 press part
	1	10	70	143	1,470	Do	Do, but for reel part
	Driving motor 250 kW 3,150 V 50 c/s 4 pole 1,470 rpm						
C	1	1	110	9.1	1,450	2 winding push-pull mag. amp.	Field booster generator couch,
	2	0.65	110	5.9	1,450	Do	Do, but for wringer & No. 2 press
	2	0.45	110	4.1	1,450	Do	Do, but for pick-up & felt suction
	Driving motor 5 kW 200 V 50 c/s 4 pole 1,450 rpm						
D	1	35	220	159	1,470	self-excited and controlling 2 winding push-pull mag. amp.	Constant voltage exciter
	1	13.5	225	60	1,470	DC 600 V and controlling 2 winding push-pull mag. amp.	Generator for wire return
	1	4	225	17.8	1,470	DC 600 V	Generator for No. 1 paper roll
	1	7	220	31.8	1,470	DC 220 V and controlling 2 winding push-pull mag. amp.	Generator for standard speed motor
	Driving motor 75 kW 3,150 V 50 c/s 4 pole 1,470 rpm						
E	1	54	70	771	1,470	2 winding push-pull mag. amp.	Main circuit booster white water pump
	Driving motor 65 kW 3,150 V 50 c/s 4 pole 1,470 rpm						

Table 4. AC motor-generator

Group	No. of set	Phase	Output (kVA)	Voltage (V)	Current (A)	Speed (rpm)	No. of pole	Frequency (c/s)	Field	Use
A	1	Single	30	200	150	1,500	32	400	1 winding S mag. amp.	Source of mag. amp.
	1	Single	0.5	80	6.3	1,500	8	100	Permanent magnet	Source of control transformer
	Driving motor 45 kW 3,150 V 50 c/s 4 pole 1,500 rpm (synchronous speed)									

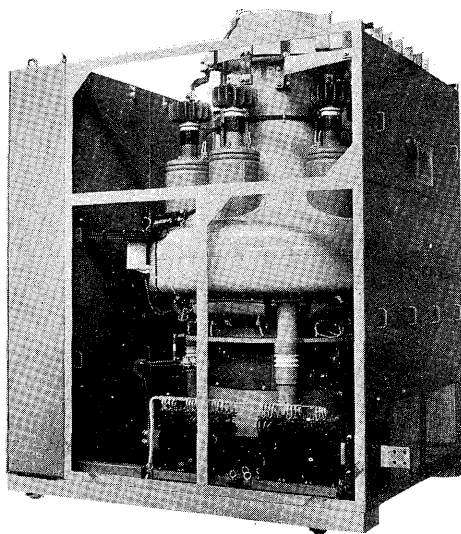


Fig. 7. Main body of mercury rectifier

## VI. DRAW REGULATOR

Fig. 8 shows the outside view of a draw regulator which is the main part of co-operative running. This equipment is made up eight parts, and adding the reserve is nine, which is installed on a common bed, each part section is coupled to the master shaft and is driven by a 6kW standard speed

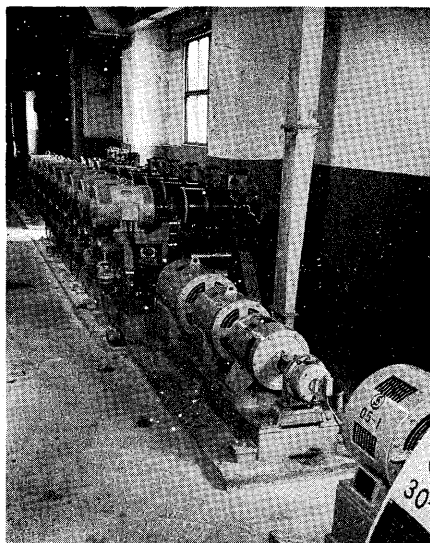


Fig. 8. Draw regulator

motor. The construction of one part is as shown in Fig. 9, and is constructed to the base board of the frame. Inside of the upper cone pulley there is a planetary gear type differential mechanism. The inside-teeth gear is fixed to the cone pulley and the sun gear is directly coupled to the synchronous motor. The planetary gear's axial is known as the differential axial. Moreover, a rotary switch is fixed

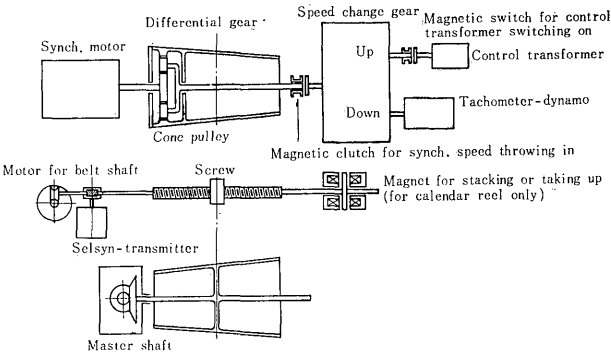


Fig. 9. Construction for draw regulator

to the differential axial to check the revolution difference. Change of draw can be made by shifting a belt-tension pulley with the aid of a shifting screw mechanism operated by electric motor. The revolution of the screw shaft is also sent to the selsyn-transmitter and a setting position can be indicated on far off receiver.

Wire part and No. 1, No. 2 press part are required for draw change that, when the suction pick-up roll slacks and contacts, changing speed on these two parts must be made is the same ratio. Because of this, it is necessary to couple the draw-changing device drive-shafts of these two parts by a magnetic clutch. In this way, the draw change of both parts are jointly operated. Both calendar and reel parts are equipped with a take-up and a slacking device, standard speed can be varied by moving some distance the belt-shifting screw shaft if necessary. Because of this, 2 pcs. of magnets are prepared, the armature fixed on the screw shaft will be attracted if either of these is excited, so that draw change can be given.

## VII. SWITCH BOARD

The switchboards which control each machine of this installation are justifiably constructed depending on its use. All equipment other than section motors, are controlled and supervised through the main switch-board which is installed in the electric room. AC high tension circuit breakers are grouped together as a AC high tension cubicle.

As shown in Fig. 10, main switchboard for section motor ; meters, relays and switch for stops, etc. are fixed on the front of this, a magnetic amplifier for speed control is built in this. Relays are administrated in a case so that there will be no faulty contact due to dirt or dust. Magnetic contactor (for start-stop use), air circuit breaker (for over-current protection on motor circuit), etc., which are connected to the bus of mercury rectifiers, are grouped together on a DC high tension board and hidden from view



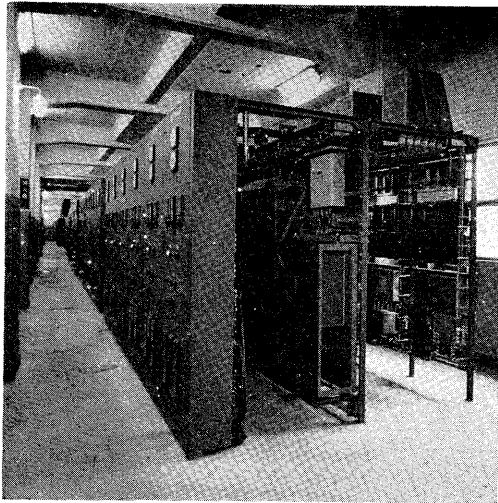


Fig. 10. Main switchboard

by wire screen. Operation of section motors for each part can be carried out directly at the place of operation by a control desk. With this, there are push buttons for slow-speed, high-speed, stop, draw increase, draw decrease (calendar part and reel part have these take-up and slacking device), and also, belt position indicator, draw indicator (later explained), load ammeter and each kinds of pilot lamp (besides No. 3 drier part there is a speed indicator), so that operating conditions can be watched. In the sectional drive machine there are various electrical equipment in use, and each are equipped with protecting devices, so fault indicators are prepared to classify, note and a bell or a buzzer sounded depending on the importance of accident. Also on the corrective recording panel AC voltage, frequency, DC bus voltage, exciter voltage, standard voltage generator's voltage and No. 3 dryer drive motor's speed can at the same time be recorded. Moreover, in this installation a draw measurement device later explained is equipped between parts to ensure to supervise co-operative running.

### VIII. DRAW MEASUREMENT DEVICE

The draw measurement device is installed as shown in Fig. 11. A set (will measure eight draws at the same time) will measure a speed difference between parts and between wire-turning roll and pick-up roll. B set (will measure eight draws by turns) will measure a speed difference between each part and the master shaft by turns. This measurement device is capable of accurately metering a speed

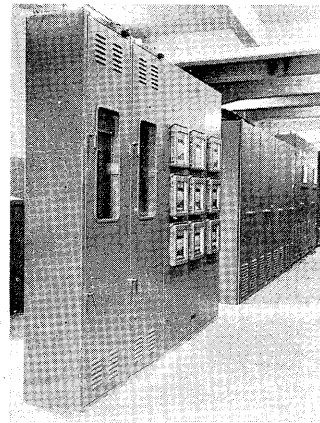


Fig. 11. Draw meter

difference by way of frequency difference produced by two high-frequency generators, each is coupled to a section motor. This draw is measured in percentage based on the speed of the part ahead of this part. Then we have,

$$\text{Draw} = \frac{(\text{circumference speed of back part roll}) - (\text{circumference speed of front part roll})}{(\text{circumference speed of front part roll})} \times 100\%$$

The full range of this meter is up to 6%. B set is prepared for metering variation of a speed in each part based on the master shaft. These draws are continuously recorded on the recording pannel. And A set can, by remote, indicate to the control desk installed at the site. The recorder (full range  $\pm 3\%$ ) between the wire-turning roll and the pick-up roll has upper and lower limit switches (whole range is adjustable with 0% as center), if a draw goes over this range, it sends order to the pick-up roll so that the roll is lifted up and off from the wire.

### IX. CONCLUSION

On beginning the manufacture of this equipment, we took great efforts to produce a sectional drive set of a paper machine which would be of the our highest standard. With the completion of this equipment, we were well awarded with our efforts.

In conclusion, we would like to pay our courtesies to the staff of the Jujo Paper Mfg. Co., Ltd., for their kind and generous co-operation.