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ELECTRICAL EQUIPMENT FOR WIRE ROD AND BAR MILLS

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I. INTRODUCTION

Wire rod and bar mills in these days are designed for faster rolling speeds from the viewpoints of improvement in productivity and of reduction in temperature difference between top and tail during roll ing. Some wire rod mills is provided with a block mill in the finishing train and realize a delivery speed of faster than 50 m/sec. Mills are designed with heavier coil weight for better productivity, more labor saving, and increased yield. Some mills can produce coils weighing 2 tons.

Basing on the above background, electrical equipment for wire rod and bar mills also has greatly advanced. New control systems, reflecting advancement in control engineering, have been actively introduced for automation, labor saving and product quality improvement. This article introduces Fuji Electric's electrical equipment for wire rod and bar mills, taking examples from installations recently manufactured equipment.

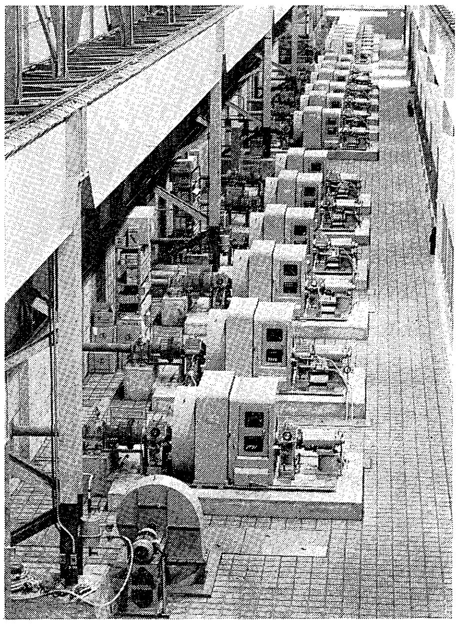

Fig. 1 Mill motors

II. EXAMPLES OF ELECTRICAL EQUIPMENT FOR WIRE ROD AND BAR MILLS

Major electrical equipment manufactured by Fuji Electric for wire rod and bar mills are listed in *Table 1*.

The electrical equipment the Fuji manufactured for No. 6 wire rod mill of Kobe Steel, Ltd. in 1965 was for the loop rolling with a delivery speed of 35 m/sec. This electrical equipment employed transistorized controllers, a high responsible loop position detection system, realizing a high speed loop rolling and the whip prevention control system.

For No. 7 wire rod mill of the Kobe Steel, Ltd., which was constructed in 1969, the Fuji manufactured an electrical equipment which was fully thyristorized with flat-packaged type high capacity thyristors and which employed a digital control system for automation and labor saving. This facility em ployed a Schloemann type block mill for its finishing train and produced 7 mm dia. products at a delivery speed of faster than 50 m/sec. This facility employed a two-tandem block mill system. The machine was so desinged that eight rolls were mounted on one block frame, and six of them (the first block) were driven with a 2,500 kW motor and the remaining two rolls (the 2nd block) were driven with a 1,000 kW motor. Between the two mechanically isolated blocks, non-loop rolling is performed. Since the distance between the two blocks is very small and the inter-block speed is as fast as more than 35 m/sec, fast-response high-accuracy control is employed in order to prevent breakage of rolled product due to excessive tension between blocks and to prevent looping due to compression.

The major technical problem the authors are dealing with today is how to grasp the rolling mills, electrical equipment and operators as a single system in order to persue operation rationalization and synthetization, and how to realize a system which will answer the requirements of higher productivity and higher product accuracy from the viewpoint of mill operation. The more sophisticated the control systems are becoming, the more advanced are the technology. Various phases, some of which are mentioned below, are required to be taken into consideration in designing a system.

Table 1 **Supply list of electrical equipments for wire rod and bar mills**

No.	Customer	Installation	Product dimension (mm)	Max. rolling speed (m/sec)	Mill motor: Number	Mill motor: Reted capacity (kW)	Mill motor: Rated voltage (V)	Mill motor: Rated speed (rpm)	Mill power (kW)	Control system	Completion
1	Kobe Steel, Ltd.	No. 3 wire rod mill	5.5 φ~25 φ	20	9	660	750	750/1,100	Mercury rectifier 3×1,000 2× 750	Electron tube and magnetic amplifier	1956
2	Kobe Steel, Ltd.	No. 3 wire rod mill (Expansion)	5.5 φ~25 φ	20	8	450	750	750/1,100	Mercury rectifier 2×1,000	Magnetic amplifier	1960
3	Kobe Steel, Ltd.	No. 5 wire rod mill	5.5 φ~13 φ	20	10 10	660 450	750 750	750/1,100 750/1,100	Mercury rectifier 6× 750 4×1,000	Magnetic amplifier	1961
4	Nippon Koshuha Steel Co., Ltd.	Wire rod and bar mill	8 φ~36 φ	10	3	660	750	750/1,100	Mercury rectifier 3× 693	Magnetic amplifier	1964
5	Kobe Steel, Ltd.	No 6 wire rod mill	5.5 φ~8 φ	35	2 2 6 2 6 6	750 660 450 550 225 200	375 750 750 750 440 440	650/900 750/1,200 750/1,200 750/1,200 900/1,800 1,200/2,400	Mercury rectifier 2× 825 6× 900 12× 260	TRANSIDYN with thyristor excitation	1965
6	Tokushu Seiko Co., Ltd.	Wire rod and bar mill	5.5 φ~50 φ	20	2 7 3	750 660 450	375 750 750	650/950 750/1,200 750/1,200	Mercury rectifier	TRANSIDYN with thyristor excitation	1966
7	Certain Co.	Wire rod and medium section mill	5.5 φ~100 φ	20	2 6 2	750 660 450	375 750 750	650/900 750/1,200 750/1,200	Mercury rectifier 2× 825 2×1,000 2× 900	TRANSIDYN with thyristor excitation	1966
8	Nakayama Steel Product Ltd. Corp.	Bar mill	D 13~D 41	10	1 4	900 300	600 600	400/800 500/1,000	Thyristor 1× 970 4× 320	TRANSIDYN with thyristor excitation	1968
9	Mitsubishi Steel Mfg. Co., Ltd.	Bar mill	12 φ~52 φ		1	900	600	300/600	Thyristor 1× 970	TRANSIDYN with thyristor excitation	1968
10	Kobe Steel, Ltd.	No. 7 wire rod mill	12 φ~32 φ	23	6 8 6	500 600 600	750 750 750	350/800 450/1,000 650/1,500	Thyristor 2× 440 10× 550 8× 660	TRANSIDYN with thyristor excitation	1969
11	Kobe Steel, Ltd.	No. 7 wire rod mill (Expansion)	7 φ~	More than 50	1 1	2×1,250 1,000	750 750	1,000/1,400 700/1,400	Thyristor 1×2,700 1×1,070	TRANSIDYN with thyristor excitation	1970
12	Otani Heavey Industry Co., Ltd.	Bar mill		8	4	650	600	900/1,500	Thyristor 1×1,000 2× 660	TRANSIDYN with htyristor excitation	1970
13	Tosa Steel Works, Ltd.	Bar mill	13 φ~25 φ	15	1 1 1 1 2 1 1 1 1	250 600 850 1,000 1,000 600 450 550 450	3,300 3,300 750 750 750 600 600 600 600	600 (12P) 600 (12P) 300/500 300/500 300/450 500/850 400/650 500/750 600/950	Thyristor 1×4,200 2×2,250	TRANSIDYN with thyristor excitation	1971

(1) Electronics equipment such as the automatic control equipment, digital control equipment, should be desinged with IC's in order to improve reliability and to make the equipment maintenance-free.

(2) In introducing an automation system, the ease of operation by the operators should be given the basic importance. In actual operations, unforeseen rolling schedules, and machine operation modes are required in most cases. Therefore, the system should be designed with as high flexibility as possible. Fixed circuitry should be avoided whenever avoidable.

(3) Wire rod and bar mills involve a number of very

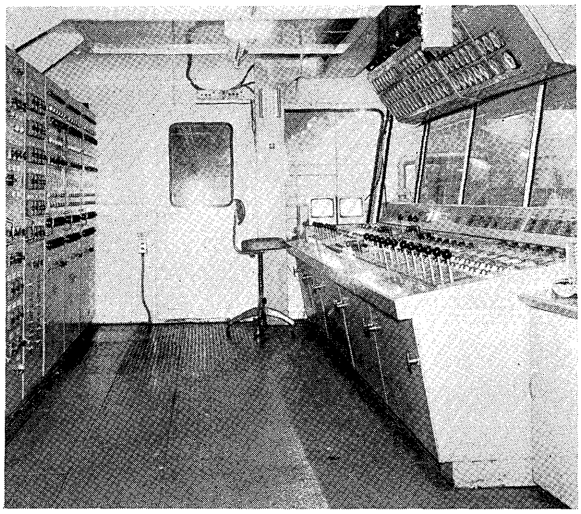

Fig. 2 Operator's pulpit

important auxiliary machines, such as shears and loop former machines, which give indirect aid to high speed flow of rolled product. Since these auxiliary machines operate in obedience to instructions given by detectors of rolled material, it is essential that these hot metal detectors are of a proven reliability. The Fuji employs the minimum necessary number of detectors which suit best the application conditions and are of a proven reliability.

III. MAIN DRIVE

1. DC Mill Motor

In the non-loop rolling process, the accuracy of products can be improved by reducing the impact speed drop in the rolled material bite process. From this viewpoint, the DC mill motor is designed for a large mechanical time constant and a small armature resistance drop and a small electric time constant. The limit of temperature rise and overload capacity are determined as per JEM 1157–2 (similar to Standard NEMA–MG1), and as for insulation, class F is employed in general.

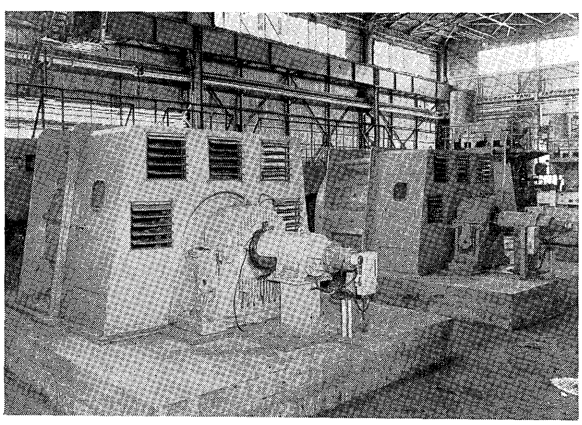

Fig. 3 Mill motor 1,000 kW 750 V 300/450 rpm

Since the wire rod mills require a fast response, static Leonard systems are used in general. These power supply system require attention for commutation and overheat. The Fuji's equipment is provided with special attention for reactance voltage, transient commutation, commutation segment voltage, brushes, and commutators.

Armature voltage generally is 750 V, 600 V, or 440 V, meeting the motor capacity of each installation. The most suitable voltage is selected taking various factors into consideration such as arrangement of stands, the number of stands, the construction and location of the electric room, motor capacity, rolling speed, price, influence on converter and control equipment, receiving voltage, and wiring route.

To improve the speed control performance, it is desirable to make as small as possible the output ripple voltage of the tachogenerator and to make zero the time constant of the filter which is used to eliminate the ripple voltage. The Fuji supplies high-precision DC tachogenerators which are most suitable for this type of high-accuracy and fast-response speed control systems. Regarding the coupling method with the motor, a direct coupling method with a special coupler is employed instead of the conventional overhang method. The new method is very effective for reduction of the output ripple voltage. Specifications of these tachogenerators are 2,000 rpm, 200 V, 500 mA, and permanent magnet excitation type.

2. Thyristor Converter

Of most of wire rod and bar mills, motor capacities are of a range of several hundreds kW to 1,000 kW per stand and overload capacities are of 175% load frequently (when motors designed as per Standard JEM 1157–2 are employed). Since the capacities are not very large as above, a forced air cooling system is suitable for equipment cooling.

Although the motor capacity per stand of a wire rod and bar mill is not very large as above, the overall DC motor output often exceed 20 MW since the number of stands is very large.

In designing an converter facility for such a large unit, effects caused by the converter of the AC power supply must be taken into consideration. Since the thyristor converter has no energy storing function different from the MG converter, a current which is in a relationship of 1 : 1 with respect to the load current flows in the AC line and the power factor is proportional to cosine of the gate control angle α. For the case of wire rod and bar mill, both magnitude and duty as of peak load imposed on the AC line is not so severe for the case of the hot reversing mill. The reasons for this are that acceleration is made under the no load state and that biting of rolling products into the rolling mills and throw out of rolling product tail are not simultaneously made for all stands. For this reason, a thyristor

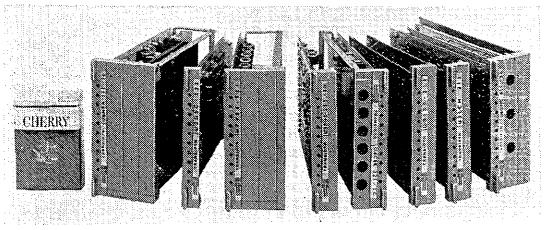

Fig. 4 IC-TRANSIDYN controller

switched static capacitor system will be suitable as for the power factor improving equipment.

As the thyristor converter operates, a higher harmonic current appears from the converter into the power source system. When the harmonic frequency has become tuned with or has become close to the proper resonant frequency of the system, a very large voltage of the resonance frequency is superimposed on the fundmental frequency. In order to prevent this, attention must be paid in designing a large converter system to that less harmonic components leaks into the system. The harmonic current can be reduced by increasing the phase number of rectification. To make use of this fact, delta/delta and delta/star connection transformers are used mixedly and a 30° electrical phase angle shifting system is employed, making the converter to be of a 12-pulse rectification system with respect to the AC line.

3. Automatic Control Equipment

" Maintenance-free " is the basic design feature of the automatic control equipment. It also is required to be compact and is of a strong withstand voltage and a high reliability. These features can be well realized by employing Fuji TRANSIDYN which are designed with IC. As shown in *Fig. 4*, the TRANSIDYN consists of units for individual functions. Each unit is housed in a standardized housing. Controls and check terminals for testing circuit waveforms are mounted on the front panel of each unit, thereby facilitating adjustment and maintenanc. The analogical circuit employs high-performance highreliability linear-IC's and the digital circuits employs digital-IC's, which has anti-noise characteristics.

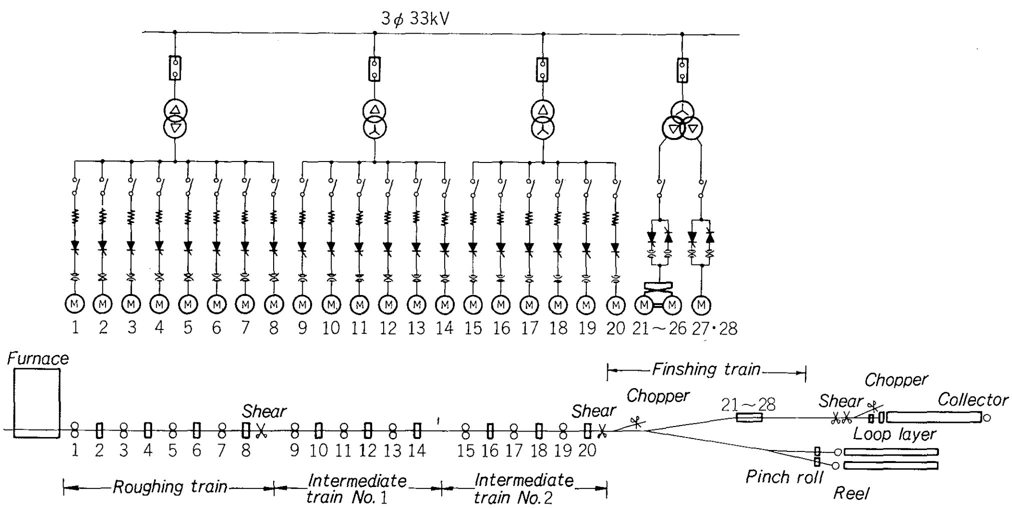

Fig. 5 Power supply of wire rod mill

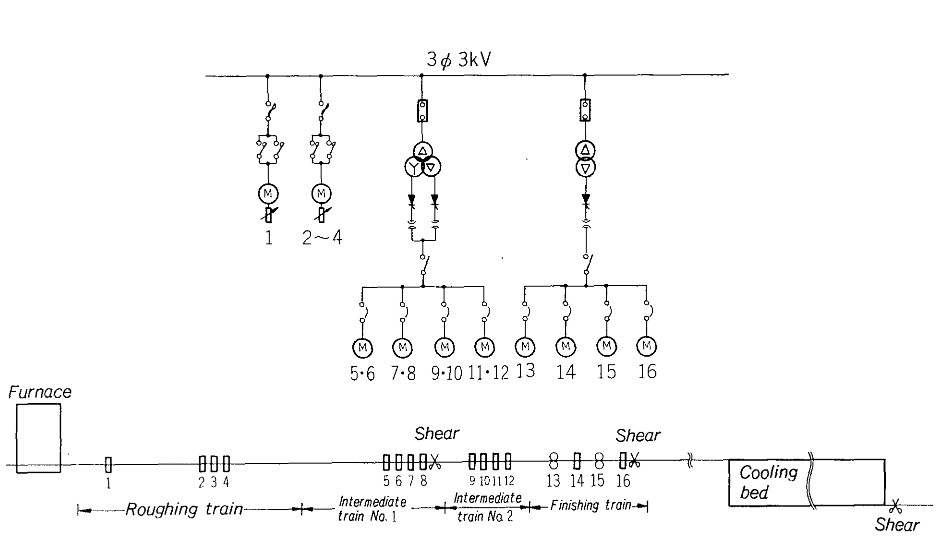

Fig. 6 Power supply of bar mill

4. Mill Power Supply

The mill power supply is constructed by attaching the highest importance to their functions It is unit-constructed with respect to mill train. An example of a power supply for a wire rod mill (an individual power supply system) is shown in *Fig. 5*, and that for a bar mill (DC bus-bar system) is shown in *Fig. 6*. Comparing the two system, it can be known that the individual power supply system has advantages over the DC bus-bar system on the following points:

(1) The impact speed drop is small and the recovery time short.

(2) The current limiter positively operates and, therefore, trip of the DC circuit breaker due to overload during rolling operation can be eliminated.

(3) Motor speed range is adjustable for a wide range and, therefore, the rolling schedule is adjustable with a high flexibility.

The individual power supply system with a common transformer in *Fig. 5*, is of which is supplied through an AC reactor and a thyristor (AC bus bar system) for each motor. This system provides the same speed control performance with that attainable to a system which employs transformers for individual thyristor convertors. This system is more economical and requires less floor space.

IV. COOLING AND VENTILATION SYSTEM FOR ELECTRICAL EQUIPMENT

Industrial development has caused environment pollution which today has become the most serious social problem. In the field of the electrical equipment also, as more electronic control apparatus have become to be used, more attention has become to be required to be paid against sulphuric acid gas, fluorine gas, and other corrosive gases. The compartment of an electrical equipment room which houses thyristors, automatic control equipment TRANSIDYN, digital control equipment (F-MATIC) and other electronic apparatus should be sealed against corrosive atmosphere and should desirably be protected with a recirculation system having an air-conditioning facility.

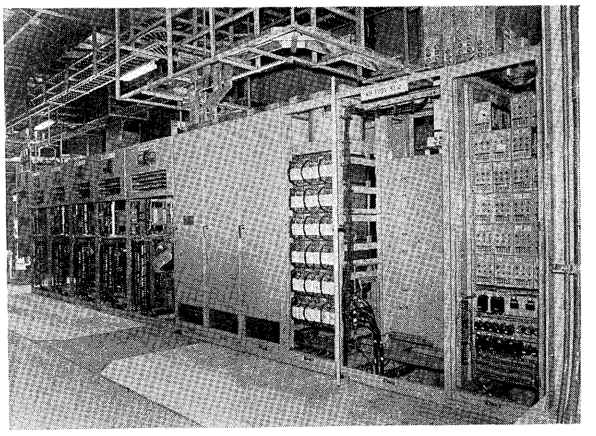

Fig. 7 Leonard control cubicle of DC bus-bar system

Transformers, high-tension switchgears, and other power apparatus are protected in a conventional cooling system which employs air filters and forced air ventilation fans. For the future, protection against corrosive gases will be required for these power

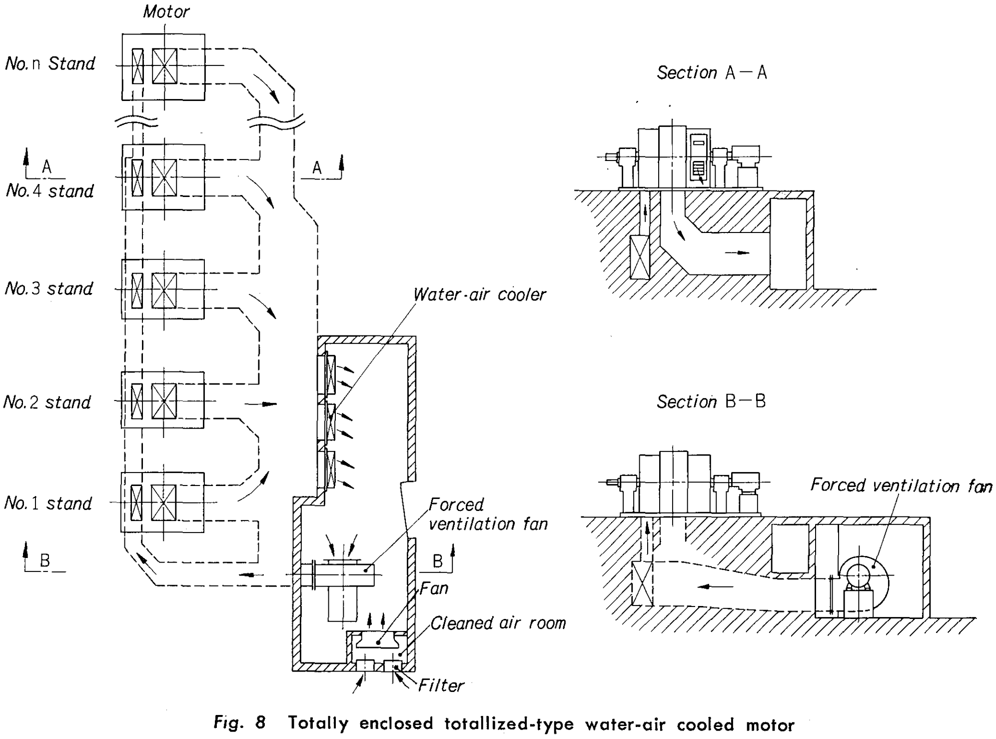

Fig. 8 Totally enclosed totallized-type water-air cooled motor

apparatus also.

For DC mill motor cooling, a totally enclosed water-air cooled system is becoming to be widely used in addition to the conventional updraft system and downdraft system. As for water-air cooled system, the Fuji employs a totally-enclosed totalized-type water-air cooled system with a view to reduce the initial cost and to facilitate inspection and maintenance. An underground air pit is provided in common for stands of each group of machines such as the roughing mill train, intermediate mill train, and finishing mill train. A forced ventilation fan, a water-air cooler, and a makeup filter and fan are in the underground air pit. The cooling air recirculates through the closed-loop circuit consisting of the common forced air ventilation fan, motor, water cooler, and returning again to the common forced air ventilation fan. The makeup fan has a function to intake atmospheric air to makeup for air leak from the recirculation path. In this case the intaken atmospheric air is cleaned with a gas-eliminating filter. As for the cooling water, either industrial water or sea water is required. A flow detector is employed to detect any abnormal state of the water path and to safeguard the mill operation.

V. DIGITAL CONTROL AND COMPUTER CONTROL

As the reliability of counting elements has become sufficiently high, digital control systems for wire rod and bar mills have become to be generally employed. In recent years, demands are rising for a higher delivery speed to improve productivity and for a wide speed range to handle various kinds of steel. The digital technique is highly instrumental as it rapidly calculates running speed of the rolled material and rolled distance and, basing on the calculation result, rapidly determines a new rolling schedule. The technique also provides a very easy means of operation setting.

The wire rod and bar mills, as compared with other rolling mills, require highly accurate speed setting. The digital setting technique is advantageous in that it provides a speed setting with high accuracy and that the setting operation is easy. Due to these advantages, the digital speed setting technique has been playing an effetive rolling in wire rod and bar mills. In recent years, some new systems have been developed. These include a scanning system which sequentially sets a number of rolling mills, a system which performs an effective voltage-frequency control when a successive speed control method is employed, and a control system which memorizes the optimal set speed within the stable states after the biting of the rolling product to the roll in loop controlled mill. Proper control of drive timing of the loop former in the loop forming operation is important to eliminate miss roll. Especially when the rolling speed is changed in a high speed mill, drive timing of the loop former is changed automatically.

For the control of the drive timing of the loop former, methods as mentioned below have been developed.

(1) A system to compute the distance for which the rolled product has advanced.
(2) A system which computes the time, after detecting the speed of the rolled product.
(3) A system which computes both items mentioned above, and memorizes the computed result for the following rolled products (adaptive control).

Using these systems, the drive timing is automatically controlled optimal irrespective of drive speed.

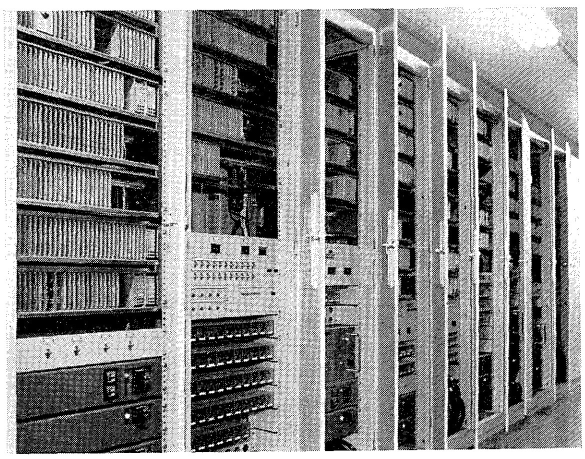

Fig. 9 Digital control cubicle (F-MATIC)

When a miss roll is caused, it must be immediately detected and the material must be cut by each shear and extraction of the following rolled product must be stopped. Detection of miss roll is made by computing the time required by the material to travel between detectors located at different positions on the line or by computing the distance the material has travelled in a unit time.

Cutting miss of the crop end by shear causes miss rolling. Long crop ends reduce the yield rate.

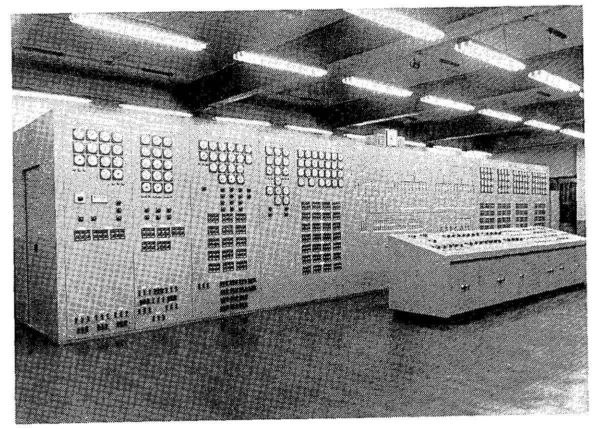

Fig. 10 Supervisory panel

Cutting length control hitherto has generally been made using a combination of a timing relay and hot metal detectors. However, as the rolling speed has become fast and rolling schedule become wide setting of time relay has become difficult. When compensation for shear accelerating process is taken into consideration, the time setting becomes very difficult. In such a case too, as is the case for the control of loop former, the cutting length can be set irrespective of rolling speed change by computing the distance or time.

Although the above control method incorporating computation of the rolled product speed and distance is quite effective for rolling schedule change, the method requires attentions with regard to input/output changing. That is, multi-point changeover switches or program board must be provided so that switching can be easily preset.

As coil unit weight has become heavier, a lift system is employed for the reel machine with a view to prevent scraps of the coils. With this type of reel, after the coil is reeled, a fork is inserted beneath the coil receiving plate and the coil is removed by raising the coil from the coil receiving plate. Therefore, a control system for positioning of the coil receiving plate is required. To meet this requirement, a high-precision position control which is a combination of a digital automatic position control and a stopping device by inching control is employed.

In recent years, for full continuous mills including section mills and billet mills, tension-free rolling systems for non-loop rolling stands have been developed. In such systems, motor current variation is regarded as tension variation and speed correct control is made basing on the motor current variation.

This control system is advantageous in that variation detection can be very easily made. However, it is disadvantageous in that it makes an erroneous correction operation in response to skid mark and, in order to prevent this, it requires a compensation provision for such erroneous operation.

The demand for improved finished product accuracy has promoted application of AGC system (automatic gauge control system) under direct connection with a gauge detector. Different from the sheet rolling, the section rolling (3-dimensional rolling) involves a number of problems yet to be solved. When development of rolling theories is fully advanced in the future, the AGC system will become to be fully applicable to the section rolling also.

Demands are rising for computer control for production control of wire rod and bar mills, for automatic combustion control of furnaces, for optimum rolling, and for automation and labor saving in the finishing process. Taking an example from a new bar mill, denoting the personnel for furnace operation and rolling adjustment and operation excluding off-line processes such as roll grinding adjustment to be 100%, the personnel for cooling bed operation, inspection, and finishing stages is approximately 400%. This fact indicates that the finishing stages involve many phases which cannot be easily automated for labor saving. Developments of automation and rationalization of computer controlled automation systems which may handle these phases are required. On the other hand, in the rolling process phase, an automation system which enables the one-man control of the process is practicable. Computer application in this phase is meaningful as it will provide automatic optimum setup or adaptive rolling.

The Fuji hitherto has manufactured electrical equipment for a number and various types of wire rod and bar mills and have collected know-how on rolling technique. The Fuji, basing on these technical assets, will actively develop new techniques to provide more effective electrical equipment for wire rod and bar mills for the future.