ELECTRICAL EQUIPMENT FOR NEW CEMENT PLANT

By

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I. INTRODUCTION

The Nozawa Asbestos & Cement Co., Ltd. has recently completed their first stage new cement plant at Taga Factory, Hikone City into satisfactory service. The cement plant was designed and constructed by F.L. Smidth of Denmark, which is of the very latest, up to date, cement plant of its kind. It is the wet-method ecomonical long-kiln plant, and having a output capacity of about 40,000 tons of cement of high quality per month.

Our Company has manufactured and delivered most of the electrical equipment used in this plant. This includes erection and wiring works, from 70 kV extra-high voltage receiving and distribution equipment, to motor load ends, under the closed technical cooperation with the Nozawa Asbestos & Cement Co., Ltd. and F.L. Smidth Co. Outline of the equipments is introduced here. The construction of the new plant's second stage is now under way and is to be as large as the first stage plant. This plant was installed separately at the Taga Main Factory and the lime stone department.

The main equipment delivered to this plant are as follows:

- 70/3.45 kV 12,000 kVA extra-high voltage receiving and distribution equipment.
- 250 kVA independent electric power.
- Motors and speed reducers for motors.
- Motor switchgears (including unit substation and control center)
- Totalized control equipment (main factory lime stone department).

Making the approximate total number of various electrical equipment in use at this plant to 150 motors including 1,300 kW ball mill motor with the total capacity of 8,500 kW, 120 sets of high tension cubicle and 100 units of control center. These are guaranteed long-run operation for 8,000 hours per year. The plant schedule was made consistently under the detailed whole plant.

Reducers, except imported ones, were delivered by the Seiki Kogyosho through our Company.

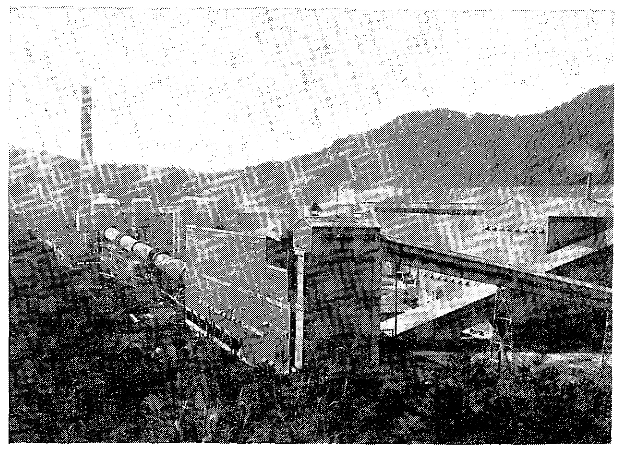


Fig. 1. General view of Taga Factory

II. PROCESS

The arrangement of the Taga Factory is shown in Fig. 2. Fig. 3 shows the main process.

III. RECEIVING & DISTRIBUTION EQUIPMENT

The substation was of the outdoor 70/3.45 kV extra-high voltage with power supplied from one incoming over-head line. Installation in the substation was a 12,000 kVA 3-phase power transformer with no-load tap-changer, a high porformance 1,500 MVA expansion circuit breaker for 70 kV main circuit and OCB for 3.45 kV main feeder. The 3.45 kV side switchgears were of metalclad type. Power supply is transmitted to the lime stone mining on a 6.6 kV over-head line by a 3,000 kVA transformer, which was installed in this substation, from a distance of approximately 5 km. This power is also supplied to 4 intermediate belt conveyor rooms which are located between the substation and the lime stone mining. Thus, the lime stone long distance belt conveyor rooms are supplied the power. For power factor improvement, in the lump, static condensers were installed on the 3.45 kV bus of the main substation. These had 5 banks of 500 kVA condenser, i.e., total capacity was 2,500 kVA

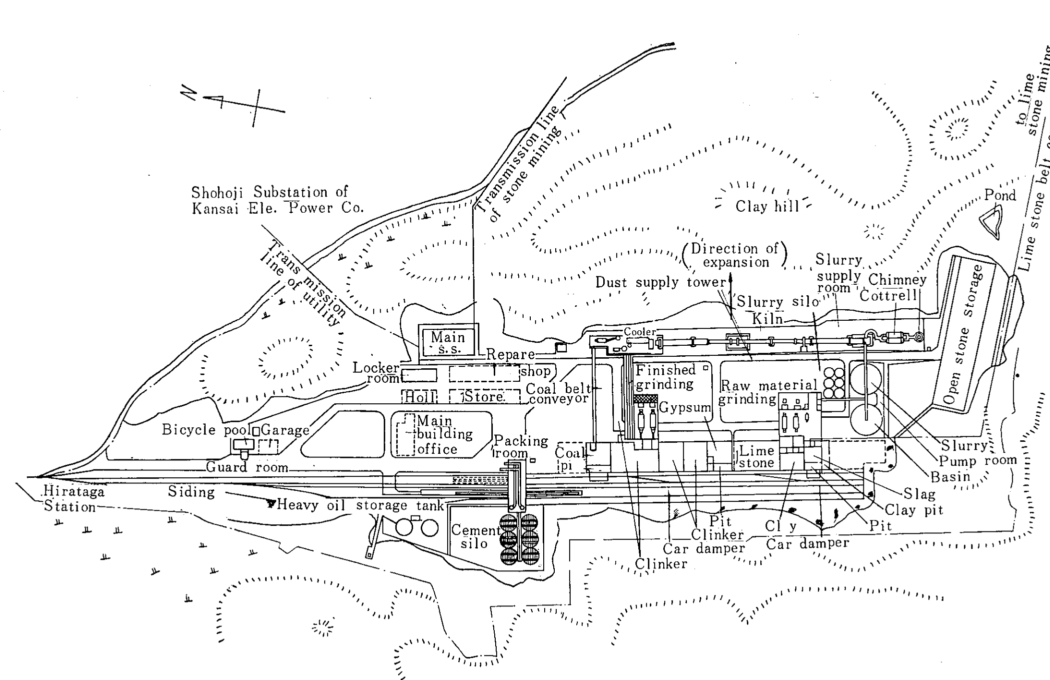


Fig. 2. Arrangement of Taga Factory

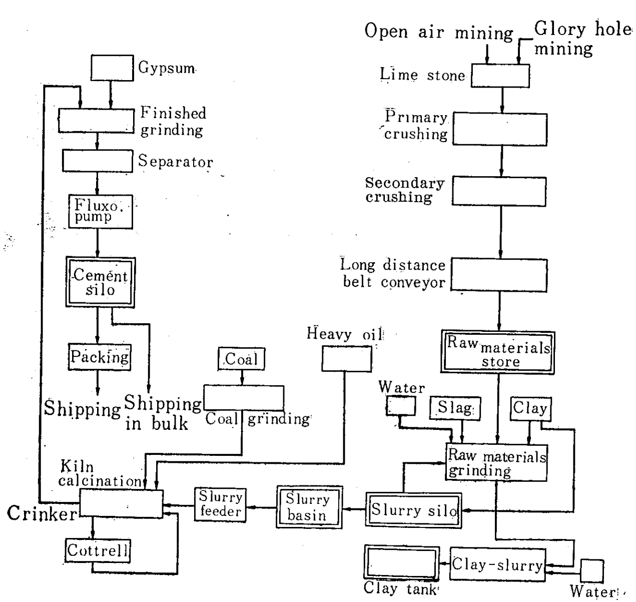


Fig. 3. Flow sheet of cement plant

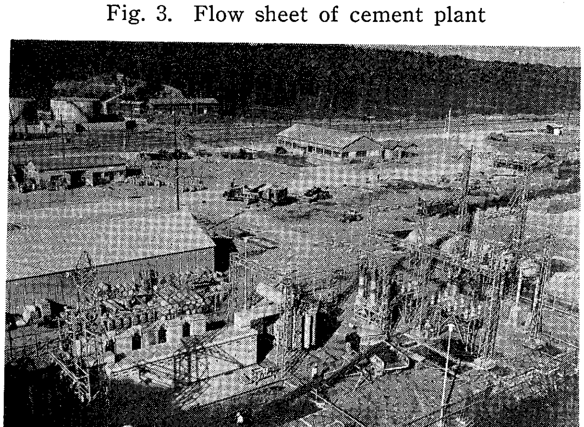


Fig. 4. 70/3.45 kV main substation

and the working capacity can be adjusted in accordance with its load desired, 3.45 kV network was of the un-grounded-cable distribution system and each of its main feeder was furnished with a sectional grounding protection relay.

IV. INDEPENDENT POWER SUPPLY

The generator is driven by a diesel engine made by Fuji Diesel Co., Ltd. having capacity of 300 HP 600 rpm. and is a self-compound synchronous generator, which supplies its power to a 3.45 kV bus of the main substation. This generator set can supply power within 30 seconds after stop in the receiving power by a automatic starting facility.

Because this power must be prepared as a complete continuous power supply, for instance, in case for emergency kiln drive, a special independent wiring can be considered for just such a incident to supply the power, but this system would be too expensive and complicate. Therefore, it was concluded that the emergency power was to be supplied through the ordinary power distribution line. But in this case, the independent power supply room, the main substation control panel and motor controlling panel were separately installed. For this reason, it is imposible to know if the voltage return to normaly is from utility power or from emergency power. So, if all motors were switched on by emergency power, the emergency power would be impaired. Accordingly, an automatic interlocking device was installed between the main substation and each totalizing control room.

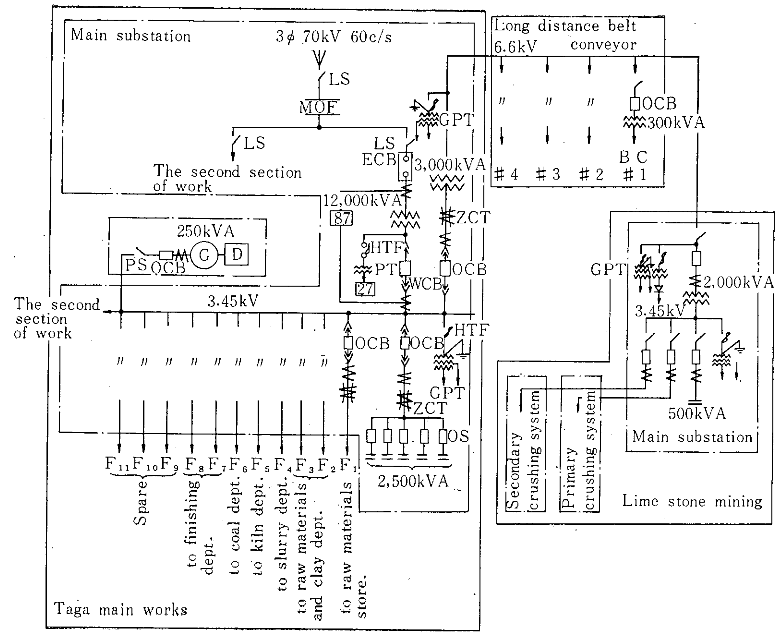


Fig. 5. Skeleton diagram of Taga Factory

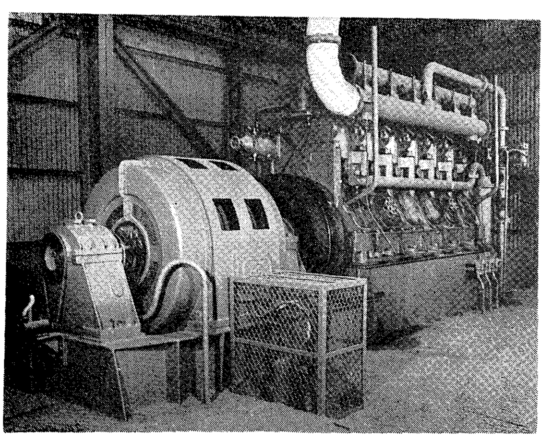


Fig. 6. Diesel generating set

V. MOTOR SWITCHGEARS

1. Basic arrangement of switchgear

Fundamentally, high tension motor cubicles were installed near the motors. The low tension magnetic switch were of the control center system, which were located near the totalizing control panel in each control room. This means the main feeder of high tension must be extended as much as possible, and connected to a unit substation type motor control cubicle located near the motor. The following things must be studied throughly, the number ratio of high and low tension motors, relative locations for both center control paneles and motors, required installing space, channels to be used for wiring the main feeders, before final decisions can be made in the composition of the switchgears, for each manufacturing part and each operating system.

On the other hand, a special electric room for these switchgears were not required under this plan. For this reason, the dead space in the manufacturing machine room was completely and effectively utilized, and when it become impossible to install the switchgears indoor, they were designed for outdoor use.

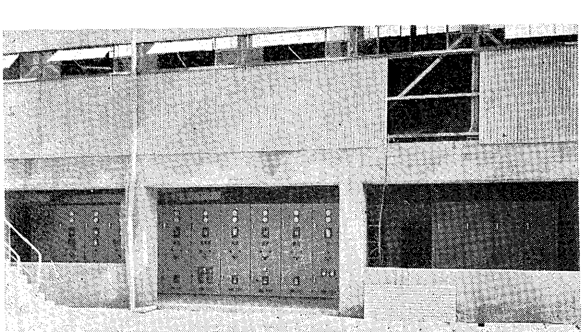


Fig. 7. Switch gears for kiln department

2. Circuit breaker

Interrupting capacity level of 3.3 kV class OCB is 150 MVA and the combination starter of NFB (no-fuse breaker) was adopted for AC 220 V and DC 110 V circuit. The % Z of 220 V step-down transformer was so designed that the interrupting capacity would not go over that of the upper limits of the NFB. Accordingly, no master ACB (load center) was required.

The motor starting systems used, are listed as follows : Cage motors were of the direct start system, and the DC motors were of the one stage or two stage-contactor-automatic starting system, and wound motors were of the circuit limiting automatic starting system by liquid rheostat. For protection of both high and low tension motors, it was provided with double protection, i.e., over-load and short-circuit.

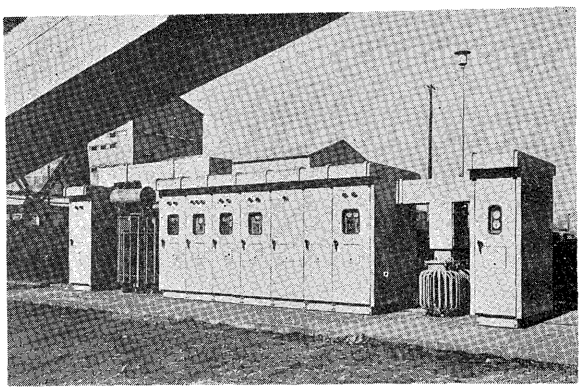


Fig. 8. Outdoor use switch gear for raw material store

VI. INTENSIFICATION OF PLANT OPERATION STABILITY

1. Complete separation of operating system

First of all, the main feeder was divided into each manufacturing department. Further more, in each manufacturing department, a motor power and the auxiliary power (lighting, heating, welding, etc.) were completely separated. In the case of the mill grinding, where there are two lines, this was further divided to minimize loss or prevent unlucky whole stop caused by any unforeseen damage. The separation of the abovementioned systems were throughly studied and discussed, regarding the minimum number of operators, maintenance, totalizing circuits into units and sequence test.

2. Prevention of dropout caused by instant voltage drop

The motor control was furnished with a trip hold circuit under condition that no battery would be furnished. The back power of this plant is not large, and is the same as any other cement plant. So the electric source can be greatly effected by any mishaps, inside or outside of the plant. And by this, the stability of plant operation would be strongly effected.

For OCB, DC no-voltage condenser trip-free was adopted, as shown in Fig. 9. Here-to-fore in use, the applied voltage system, that is, the capacity trip system have been used. Whereas, this system must have a low voltage detecting relay, so, if the condenser were abnormal, and even if the tripping were reguired at a certain time, the tripping would fail. Therefore, this new system was adopted to prevent a one in a million chances of just such a trouble to occur. According to test results, it was confirmed that, in the case of a 2,000 μF condenser, it is possible to hold during for approximately above 0.5 seconds, from the precise time of no-voltage. For this condenser, an electrolytic capacitor is sufficient being of low price, compacted and mounted on the OCB,

The low tension magnetic switch is controlled by a selenium rectifier with a DC relay. If the control relay is designed to have suitable RC time constant, it is possible to hold for approximately 0.5 seconds, and the required capacity of this condenser, is 30 μF, and is built in the relay.

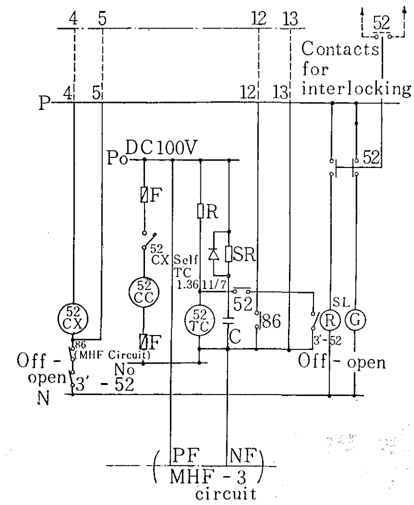


Fig. 9. OCB control circuit

VII. MOTORS

1. Selection of motor type

Fundamentally, the induction motor was adopted, including 1,300 kW and 1,200 kW wound rotor type induction motor for mill. The speed of symmetro-gear center drive type ball mill, produced by F.L. Smidth, has a fairly high speed. So, there is little difference in characteristics compared with other synchronous machines, such as with price, controlling, easy maintenance. Besides, power factor can be compensated separately. This being the case, the wound rotor was adopted.

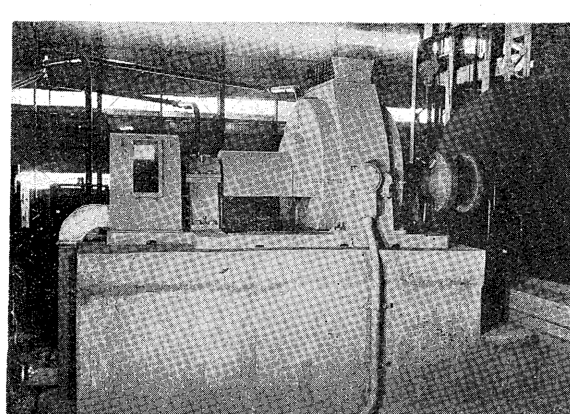


Fig. 10. 1,300 kW wound motor for finishing ball mill

2. General construction of motor

1) Enclosed self ventilation type was fundamentally adopted for motor cooling system, but for mill motors, open drip-proof was constructed with a stator movement device. Geared motors (under 37 kW) were of totally enclosed fan cooled type.

2) For both high and low tension motors, the primary incoming cables was constructed to a dust-proof terminal box. Cables leaving the slip ring case were passed through a conduct pipe.

3) The slip ling for all small wound rotor motors provide brush-continuous rating. This was to simplify totalizing control and to eliminate complicated construction and operation.

4) And for other, insulation class, especially mill motors as B class, kiln motors were H class, and for motor above 370 kW, resistance thermo-elements were embedded in the stator and bearings for remote temperature measuring.

The rating of main motors are shown in Table 1. For power over 37 kW is 3,300 V, below 37 kW is 220 V, DC 110 V.

Table 1. Rating of main motors

Use	Q'ty	Output (kW)	Speed (rpm)	Reduction gear (rpm)
Raw material mill	2	1,200	500	500/18.8
Kiln	2	140	700~234	700/7.65
Coal mill	1	370	705	705/128
Induced draft fan	1	370	705~530	705/415
Primary fan	1	120	1,160~870	Direct coupled
Finishing cement mill	2	1,300	500	500/17.4

VIII. MOTOR SPEED CONTROL

1. Classification

The speed control of various manufacturing machines differs according to its needs.

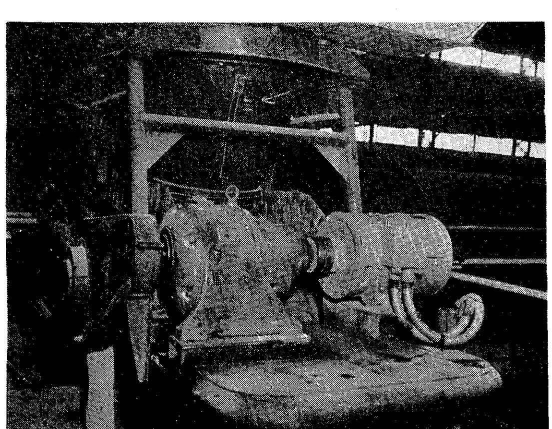


Fig. 11. DC motor and reduction gear for feeder service

1) Feeder and conveyor

For feeder and conveyor motors, DC motor which is of the self-excited shunt field adjusting type was used. The motor's power is between 0.45 kW~22 kW, speed control range is 1 : 3. It is possible to consider another control system, but as described here-in-under, the system is not as favorable as the abovementioned system, because of the following reasons :

(1) The cost for adopting a shunt commutator motor is very expensive, and also, maintenance and adjusting are very difficult.

(2) If cage motor with eddy current coupling are to be used, each motor must be mounted with a tachometer feed back control equipment, further complicating the control circuit. Also, if numerous type of small motors are used, the cost would be very expensive in adopting this system. Therefore, in this plant, the DC motors were adopted, because of its excellent shunt characteristics. As a common electric source, the selenium rectifier with AVR was used.

2) Fan

Fan control is carried out by means of secondary resistance control of wound rotor type induction motor, and speed control range is approximately 30%.

3) Rotary kiln

Rotary kiln control is carried out by means of secondary resistance control of wound rotor type induction motor with ASR control (automatic speed control).

For the application of this motor, the DC motor or AC commutator motor having shunt characteristic were essentially preferable for its load torque characteristics, but the price is very expensive, and also, because this plant made it a point of operating at top speed, the wound motor was adopted.

2. Automatic speed control of rotary kiln

1) Feature of rotary kiln

The most important part of this plant is the rotary kiln. Now, the diameter and total length are 5 m and 180 m respectively. And this is driven by two 140 kW motors, i.e., twin drive, and this mammoth kiln has a total weight of approximately several thousand tons. In the case of slurry inserting amount is constant, the required torque is almost constant in the speed-torque characteristic, but at the starting time, the starting torque would be required up to 200% because of the large static friction. The relation between the quantity inserted slurry and torque is theoretically given as (specific friction-torque) : (torque required, when the inserted amount of the slurry is 100%)$\fallingdotseq {}^1/_7 : {}^6/_7$. Now, according to the data, when the range of controlling speed is between 50~100%, the above formula

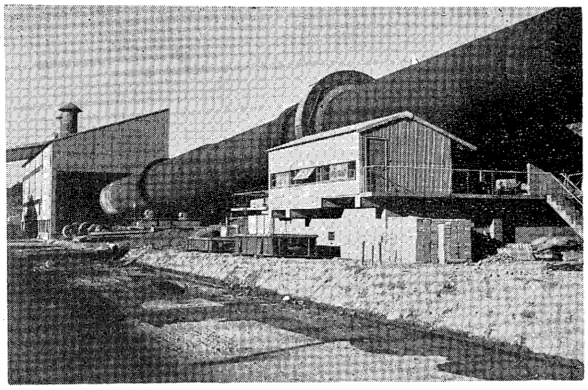


Fig. 12. Outer view of rotary kiln and motor rooms

was confirmed correct.

It is only common that when the kiln is still new, there is little or no torque variation, and the use of automatic control is not necessary during this time, but after many years of long operation, the kiln will bend and the slurry will not flow uniformally inside the kiln, making the torque run abnormally. Because of this, it is only natural that the quality can not be kept the same, and both the life of the kiln itself, and the fire bricks will be badly effected. Therefore, it was necessary to adopt an automatic speed control.

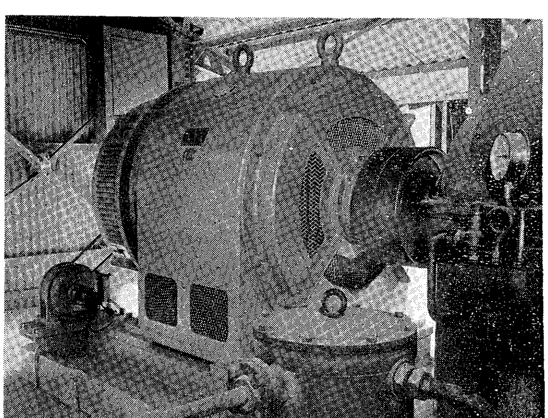


Fig. 13. Motor for rotary kiln

2) Speed control system

As shown in Fig. 14, with the operation of one speed pilot, it will control at the same time two L. R. sets in a constant speed by MA→Thoma regulator. If load unbalance should occur, this will be correct by an automatic load balance equipment. Accuracies of automatic speed control are ±2% of static error and ±5% of dynamic error on the condition of input power supply being 3,300 V ± 5%, 220 V ±10%, 60 c/s ±3%.

The difinition of dynamic error is based on the following: When the speed control is aim at to set at 70% of synchronous speed, the motor is to be loaded a composed torque which is super imposed

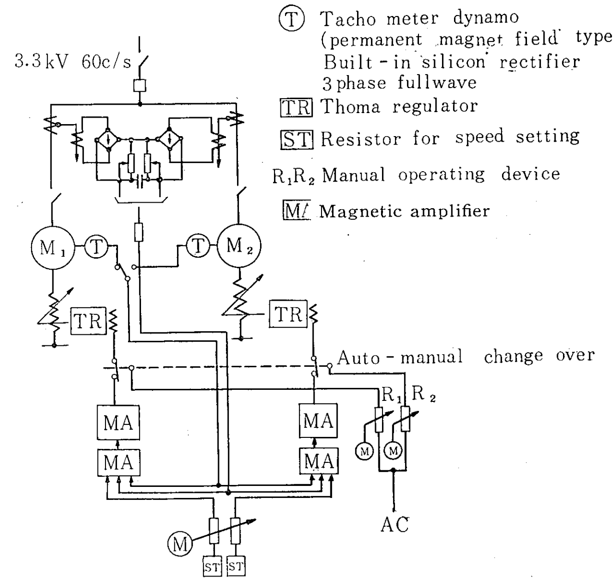


Fig. 14. Control system for kiln speed control

±25% sine wave (one cycle is approximately 80 seconds) on the 75% of the motor rated torque (DC component of load torque).

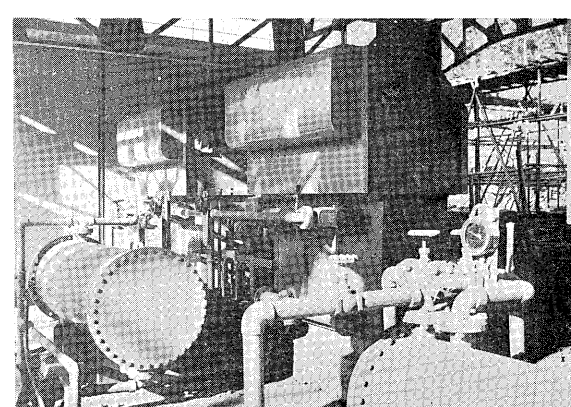
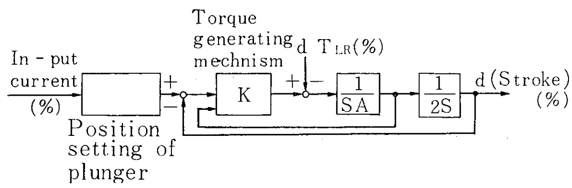


Fig. 15. Thoma regulator drive liquid rheostat

3) Characteristics of the Thoma regulator control

Now, the special feature of the speed control of this kiln is that the Thoma regulator (oil servo motor) manufactured by us was used for this L.R. operation.

The Thoma regulator is that which both a moving speed of a servo cylinder and its position are controlled with a unity feed back system. The servo cylinder is operated with oil pressure through a plunger (for setting the stroke's position), the plunger's input is a state of current of very small. Fig. 16 shows the block diagram. An operation time is to be required 2 seconds to get 100% stroke (90°) at 100% input (AC 200 mA) except the time to be required to turn to the position, and an operation is required 20 kgm at the load torque T_{LR}.



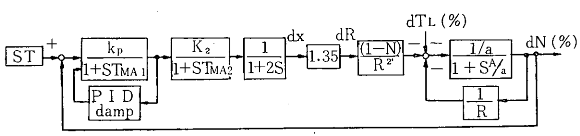
T_{LR}: Load torque of output shaft (100% = below 20 kgm)

A': $\frac{GD^2}{375} \cdot \frac{1\ (\text{kgm})}{1\%\ T_{LR}\ (\text{kgm})} \cdot \frac{1\%\ n\ (\text{rpm})}{1\ (\text{rpm})}$

GD^2: Moment of inertia of output shaft (kgm^2)

n: Actuating speed 100% (rpm)

Fig. 16. Block diagram of Thoma regulator



A: $\frac{GD^2}{375} \cdot \frac{1\ (\text{kgm})}{1\%\ T_M\ (\text{kgm})} \cdot \frac{1\%\ N\ (\text{rpm})}{1\ (\text{rpm})}$

T_M: 100% torque of motor

N: 100% speed of motor

R: Resistance of secondary controlling resistor (%)
In case of $T_M = 100\%$, $N = 0$, it should be 100%

GD^2: Equipment total GD^2 value (kgm^2) on the motor shaft

Fig. 17. Block diagram for control loop

We assume, $dT_{LR} \fallingdotseq 0$

$$\frac{dx,\ \text{position}\ (\%)}{\text{input current}\ (\%)} = \frac{1}{1+2S+S^2 \cdot 2A'/K}$$

when A'/K is neglected, for it is very small,

$$\text{input current}\ (\%) \rightarrow \boxed{\frac{1}{1+2\,S}} \rightarrow \text{position}\ (\%)$$

This final control element regards as transfer function of a single time constant.

Therefore, the block diagram of the control loop can be shown in Fig. 17.

But now, we assumed, that the load machine has friction torque T_{LO}, $T_{LO} = ao + aN$, the reactance of the motor is neglected, and the relation between LR electrode shaft stroke x and LR resistance R is corrected to linear characteristic, besides, the maximum value of secondary resistance is selected so as to be able to control 67.5% speed for 50% T_M, and load balance circuit is abriged.

As, for special constant load torque T_L, $(1-N)/R$ is constant = 1, then, for special T_L, setting deviation ΔN would be $1/1+K$, where K is loop gain. And as A is very small, we assume $A \fallingdotseq 0$, the relation between the Thoma regulator's input (mA) operating amount x and R, N can be shown in Fig. 18.

4) The outstanding features of this control system are as follows.

(1) As the Thoma regulator is a kind of amplifier, input power is extremely small, accordingly, the pre-amplifier can also be small.

(2) As the Thoma regulator can be regarded as a transfer-function of the single time constant as a final control element, it is not necessary to equip it with a electric minor loop.

Here-to-fore, it was necessary to equip it with a complicated motor-operated electric minor loop.

(3) It is small and compacted, light and economical. And as the pressure pump was built in the dust proof robust case, any kind of oil source or its piping was not required, so the handling is very easy.

(4) As GD^2 is extremely small as a final control element, no brake is required. Here-to-fore, there was the problem of operating motor's inertia when motor operating system was applied.

(5) Operating mechanism of LR is very simple. The necessary accessory was a interlock rink only which is prepared for changing electric output angle (90°) of the Thoma regulator to electric operation angle (60°).

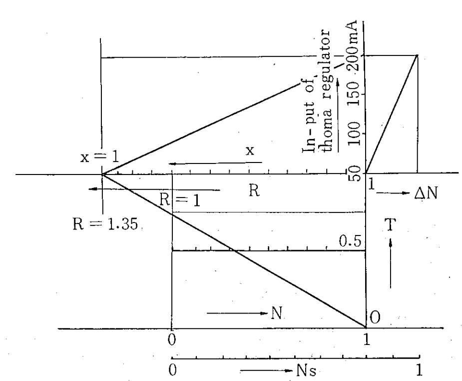


Fig. 18. Relation between x, R, N, T

IX. TOTALIZED CONTROL

This plant can be divided into following series, that each has a center totalized control board :

(1) Mining department—primary crushing series.

(2) Mining department—secondary crushing series.

(3) Lime-stone transfer long distance conveyor series.

(4) Raw material series.

(5) Clay series.

(6) Slurry series.

(7) Kiln coal series.

(8) Finishing series.

(9) Packing series.

Of these series, (1) and (2), the first case for our country, are of the no-contact relay system (time delay start) using the transistor for totalized control (4)~(5), (7)~(9) are of the centralized push button control system, (6) is carried out only by remote control, (3) can be carried out by a time delay interlocking system made by the customer. Two

(2) Secondary crushing system on lime stone mining

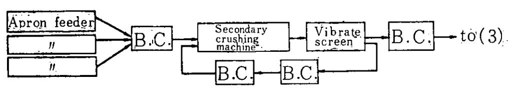


Fig. 19. Totalized control series

(4) Raw material system

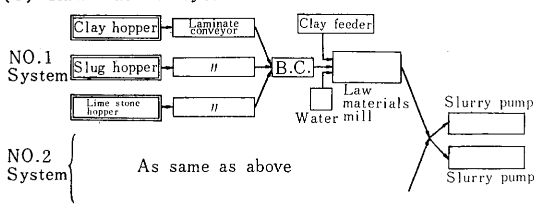


Fig. 20. Totalized control series

examples of control system are shown in Fig. 19 and 20, (7), (9) are equipped with control paneles imported from F.L. Smidth being after modified by our Company to obtain the required ability. Fig. 22 shows kiln and coal departments.

1. Transistor system totalized control

Main functions are listed as follows:

1) Each machine can be switched over to [interlocked-individual] at the machine side.

2) Automatic time delay start by a transistor timer (push button start is also possible).

All equipment should stop after conveyors are unloaded.

3) Prevention of drop-out caused by instant voltage drop.

4) Emergency simultaneous stop, interlock stop at the machine side (during interlocking).

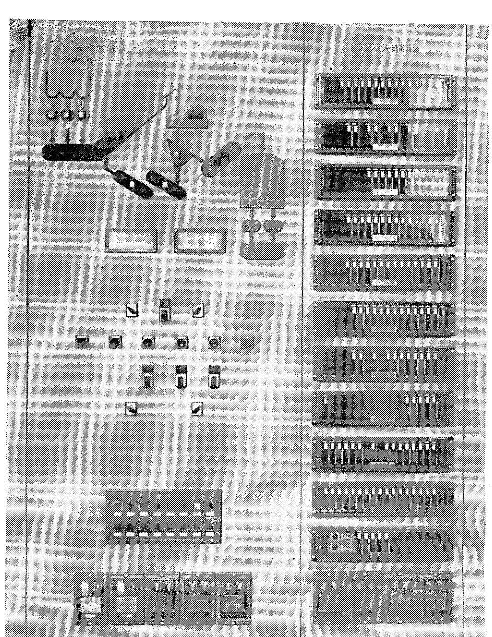


Fig. 21. Transistor system totalized control panel

5) Luminous flow diagram and signal device.

6) Fault indicator and alarming.

When the motor is not properly functing, a pilot lamp frickers on the panel, besides, a start delay indicator is also functioned.

7) Test of control circuit before starting.

8) Sequence test can be carried out under the condition that the incoming disconnecting switch of the main circuit is open.

Fig. 21 shows control panel. As the details of the transistor equipment has already been published in Fuji Jiho (Fuji Electric Journal) Vol. 33 No. 6 so the details will not be described here.

In case of operating wires for motor interlock are to be used only for series connection, four wires are sufficient for common use. In case the interlocks are branched out, 4 wires are also required for each branch as much as common line.

Moreover, one transistor equipment would be sufficient for the total member of branches. The feature becomes more effective, the further the distance between motors, the more effective it becomes. The time delay starting order would be transmitted alternately by two transistor timers through two wires of these 4 common operating wires, the third wire would be used as impedance measurement for operating indication, and the remaining wire is used as a return wire.

2. Multi-push button switch system totalized control

1) Main features are as follows:

(1) [interlocked—individual] can be switched over on the center control panel all at once.

(2) [interlocked] ⇄ [individual] can also be changed over even if the load is in continued operation.

At the starting time, machines are individually controlled by the side of the machines. When the machines have obtained their suitable conditions, the plant can be changed over from [individual] to [interlocked] all this while, holding their suitable conditions. The aim of this change over is so that this procedure can also be reversed and operated.

This would be very effect for kiln, coal departments, etc., that is, especially for processes requiring thermo constituent parts.

(3) The machine side switches in [individual] operation can be locked when these are in "off" position. Therefore, the machine side operation is very safe and convenient when the plant's operation is changed over [interlock] [individual] at the center.

(4) Prevention of dropout caused by a instant voltage drop.

(5) Pre-check before starting in a check circuit. (For instance, for low tention motor, a pilot lamp

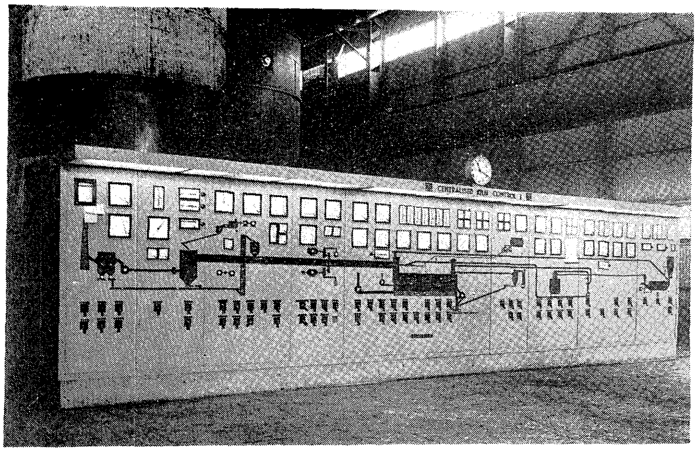


Fig. 22. Totalized control panel for kiln and coal departments

would switch on if the followings are all right, an operation indicator—a magnetic switch coil—thermal relay contact—returning lock contacts of a machine side switch, they are connected in series).

(6) Sequence test can be carried out. It is possible by, only, opening a incoming disconnecting switch of the main circuit in each control system.

(7) Emargency simultaneous stop, machine side interlock stop (duaring interlocking) are possible.

(8) Luminous flow diagram and indication device. All motors to be required totalized control are furnished with an ammeter which are assembled in the main board.

(9) Fault indication and alarming.

For damaged motor, its signal lamp will flicker on the diagram board. For detailed reason of failure of high tension motor, it is indicated on a assembled fault indicator equipped on the front of each high tension cubicle.

2) Preparation of control source

According to the abovementioned separation of operation system, each system furnished with unit source itself, i.e., selenium rectifier to supply the power for throw-in trip of OCB, each operating, coils of magnetic switch to be required totalized control, AC and DC sources of relays for totalized control. This source also supply the power for low tension magnetic switch's AC coils, so, in 220 V main circuit of the control center belonging to the controlled motor, the protection will be carried out by means of under valtage detecting relays and phase-absence detecting relays.

3) Combination of the standard unit circuit

Individual control circuits of motors (Fig. 9 shows a example) and interlocking circuits regarding motors except when motors are located at before and behind, right and left of process flow (Fig. 23 shows a example), can be made into unit, according to its kind and controlling system. And the circuits required are obtained by combining these unit according to the flow sheet.

X. CONCLUSION

Salient points of this plant are described in the above. Because this kiln was imported by customer, we did not include measuring instruments, but we are in a position to design and manufacture, not only said heavy current machine but process instrument.

Hence, it is our desire to contribute to further the developing and expanding of this field.

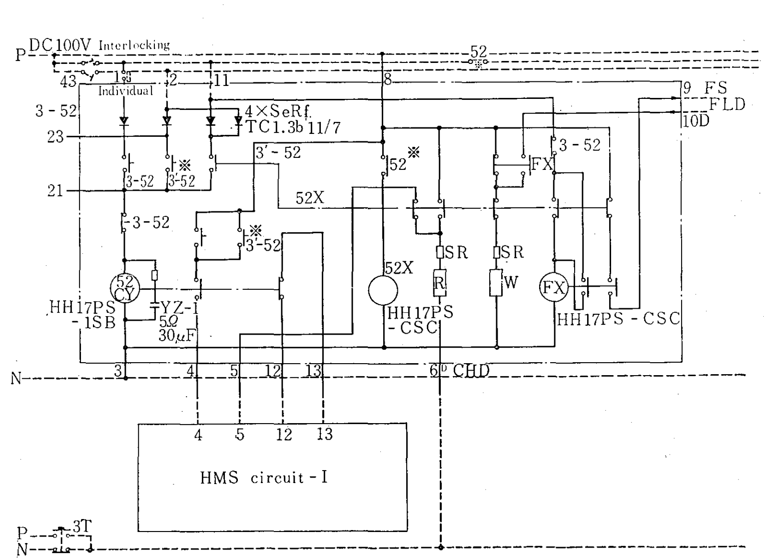


Fig. 23. Interlocking circuit