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# ELECTROSTATIC PRECIPITATION FOR CEMENT INDUSTRY

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## I. FOREWORD

The history of electrostatic precipitation in cement industries is quite old. Today, electrostatic precipitation, which was originally utilized for kilns, is considered indispensable in cement manufacturing. If a look is taken at the equipment installed during the last two or three years, it will be found that designs based on old concepts in size and configuration of electrode chamber are not rare. Primarily through use of semiconductor power packs, electrostatic precipitators have received many power supply improvements. Also, progress in control technique through saturable reactors, enlargement of electrode plate, adaptation of the excellent magnetic impulse rapper......all of these, together with improved maintainability, have made possible better, more economic, modern precipitators.

Fuji Electric, always the pioneer in precipitator engineering, has directed its effort toward development of power packs and other items. A high value has been placed on unique engineering and particularly excelling qualities have been prominently demonstrated for oxygen steel furnace applications. The high capabilities of the compact Fuji electrostatic precipitators used in cement plants for kiln and raw materials have been well proven. Marking the occasion of a raw material precipitator delivered to and harmoniously operating at the Itoigawa Plant of Myojyo Cement Co. since March 1964, provides the opportunity now being taken to introduce an overall view of the Fuji electrostatic precipitators.

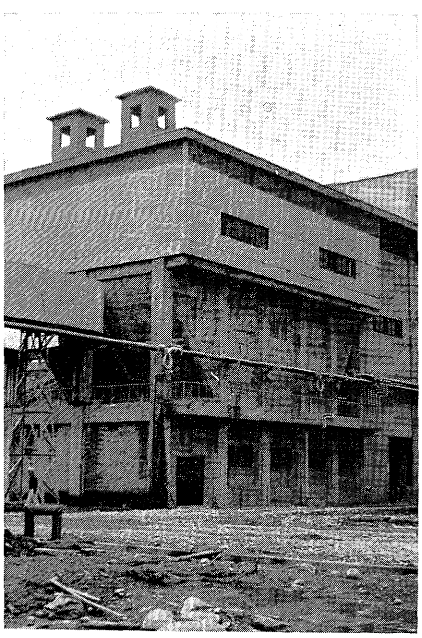


Fig. 1 EP for cray d:yer delivered to Myojo Cement Co.

## II. ELECTROSTATIC PRECIPITATORS FOR CEMENT INDUSTRY

It is said that from several to more that ten percent of the manufactured product at cement plants is dispersed in the air as dust. The majority of this dust is produced during raw material processing and firing. All of this waste can be reclaimed by electrostatic precipitation and, at the same time, air pollution is eliminated.

The raw material, after crushing followed by drying, is fed to the dry kiln when firing cement by the dry process. As a 10 to 15% clinker content is dispersed in the kiln exhaust gas, processing is made by the electrostatic precipitator. The fact that moisture content of the gas is low (with numerous instances of electrical resistivity exceeding $10^{10}\Omega$-cm) presents one reason for difficulty with electrostatic precipitation for dry kiln use. Ordinarily, electrostatic precipitation is also applied to dry processing of raw material. In the numerous wet type long kilns installed this year, to improve the quality of the manufactured cement in relation to the above, the material is converted to slurry and firing is accomplished directly in the long kiln. Dispersion of dust from the kiln is less than that of the dry system and a moderate amount of moisture exists in the gas. Accompanying the enlargement of the kilns, large-scale electrostatic precipitators have been installed, one after the other, and have now become vital elements in the cement industry. With the wet process, electrostatic precipitators for ordinary raw material use are unnecessary.

Recently, the semi-wet type Lepole kiln, due to the excellent heat balance, has been adopted. Raw material processed by the dry process and containing approximately 10% moisture is formed into pellets with a diameter of 10∼20 mm by a pelletizer before entering the kiln. The problem of dust collection does not differ appreciably from that in the wet system. However, electrostatic precipitation is used in the same manner as in the dry system for raw material processing.

As the disposed gas volume per unit is generally large, in the broadly classified cases for kilns described above, problems develop in maintaining high collection efficiency. This must be taken into consideration when distinct changes of dust conditions are involved in relation to operation with raw materials. The use of low cost heavy oil has increased of late. However, the higher sulphur content and the accompanying sulphur attack poses a problem. Precautions are necessary especially for prevention of corrosion and for heat insulating on the inner surface of the casing.

## III. FEATURES OF FUJI ELECTROSTATIC PRECIPITATOR FOR CEMENT INDUSTRY

1) As the power pack is very stable and as this device can be operated at high voltage, very satisfactory collection efficiency is obtained.

The migration velocity in electrostatic precipitation is approximately proportional to the square of the field strength in the precipitating space; thus, as this precipitator is operated from a power pack with high stability and at high voltage, collection efficiency is secured.

2) Most of the dust that deposits on the electrode plates is removed by the magnetic impulse rapper (a very stable device in which the rapping strength and cycle can be adjusted). Partially built-up dust (which may cause a sparking discharge under low voltage) is removed by an electric impulse rapper that utilizes the discharge of a high voltage condenser. Thus, perfect rapping efficiency is achieved, and high collection efficiency can be maintained over an extended period.
3) As the result of thorough research and study of the gas flow and distribution and efforts made to achieve uniform distribution, the electrode chamber was made smaller.

An unsatisfactory gas flow and distribution may not only lower the efficiency (due to partial shortage of the treating time) but also may cause a dust built-up or blockade. Under some conditions, it may even cause instability of the electric charge. At Fuji Electric, a systematic investigation of the gas flow is performed by model experiments and, in some cases, Fuji Electric confirms this investigation by measurements of gas flow and distribution at the site before the start of actual operation. Accordingly, the average gas flow can be raised (in comparison with former types) and the electrode chamber was made smaller.

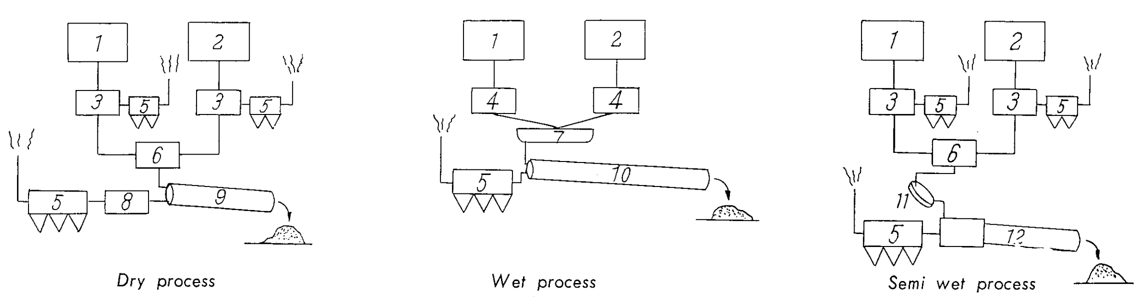
4) Various different standard types of electrode plate and power pack units have been prepared, and they can be selected and combined freely to suit the purpose and conditions. Thus, any desired plan can be readily accommodated.

The electrode plates have been manufactured in various types and sizes which include: corrugated plate, plate with special corrugation, wire net, from the small size of 0.75×1.8 meters up to large sizes such as 3.3×6.6 meters. The power packs have also been standardized, from single phase 5 kva up to 3-phase 100 kva, for use in accordance with the desired operating stability, effectiveness, and cost.

## IV. ELECTROSTATIC PRECIPITATING CAPACITY

### 1. Collection Efficiency Increase Through Increase of Operating Voltage

The relationship between the operating voltage




① Lime stone
② Clay
③ Drying
④ Rough crushing
⑤ E.P.
⑥ Crushing and mixing
⑦ Slurry
⑧ Heat collection
⑨ Kiln
⑩ Long kiln
⑪ Pelletizer
⑫ Leople kiln

*Fig. 2* Electrostatic precipitator for cement industry

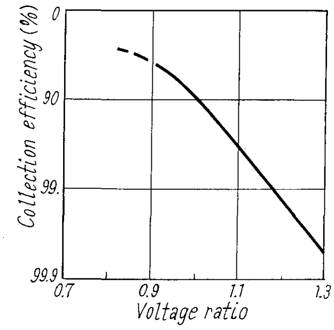



*Fig. 3* Precipitator voltage and collection efficiency

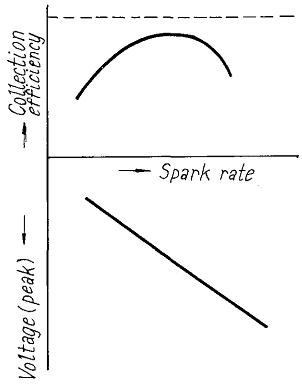



*Fig. 4* Spark frequency and collection efficiency

of the electrostatic precipitator and the collection efficiency is as shown in *Fig. 3*.

In general, the collection efficiency increases as the voltage is made higher. Specifically, the greater the corona current, the higher the collection efficiency. Therefore, assuming that this precipitator is operated while raising the voltage, the maximum voltage will be the voltage that causes a spark-over between the electrode plate and wire. Except under unusual phenomena a spark-over will occur somewhere between the electrodes with an increase of voltage. Then the high voltage side is short-circuited momentarily and, the power pack is usually damaged due to the large short-circuit current. However, if the short-circuit current is suppressed by a current limiting reactor or other device, the operation can be continued, even if such spark-over has occurred. If the voltage is additionally raised, the sparking voltage generally rises together with an increase of the probability of causing the spark-over. In breakdown of a normal insulator, the sparking voltage is almost constant; however, in electrostatic precipitation, it is characteristic that the sparking voltage rises according to the spark rate increase. This tendency is more remarkable in the case of high dust concentration. If the spark voltage rises, the collection efficiency becomes more satisfactory even if minor spark-over occurs.

On the other hand, for each spark-over a certain time is required for the arc quenching and the voltage recovery; thus, if excessive spark-over occurs, the collection efficiency is conversely lowered. Thus, there must be an optimum operating point between these phenomena.

How much the voltage is lowered per spark-over is decided by the time required for arc quenching and voltage recovery. As the time is made less, the spark rate that the power pack can withstand becomes higher and accordingly the collection efficiency also becomes higher. Under the Fuji Electric Standard System, voltage recovery is performed in about 0.03 sec by the functioning of the high voltage condenser.

The spark voltage between the electrodes is also related to the dc voltage waveform. That is, when the dust concentration is not very large and the electrical resistivity of the dust is not considerable, the spark voltage is decided almost entirely by the peak value of the voltage waveform. It is desirable that the peak voltage be as low as possible with an effective dc voltage. Single phase full-wave rectifying systems, in which a usual saturable reactor is used, are very inconvenient from this point of view. In the Fuji power pack a saturable reactor of constrained magnetizing state is used. This, together with the smoothing action of the high voltage condenser, provides an excellent DC voltage waveform (comparable to a 3-phase full-wave rectifying system) with single-phase operation.

## 2. Size Reduction Through Improvement of Gas Flow and Distribution

In an electrostatic precipitator, the gas flow passing between the electrode plates must be uniform. The gas flow in the ducts, at the front and rear of the electrode chamber, is usually 10~30 m/s. Problems occur because the velocity between the electrode plates is about 0.5~3 m/s, which is obtained by lowering the velocity to 1/10 that of the duct. As there is a positive limit to the installing space, it is almost impossible to lower the flow velocity gradually to an ideal condition in which the gas flow does not break away.

Formally, gas flow problems were resolved by relying on experience or by intuition. However, the results were not desirable in most cases. *Fig. 5*

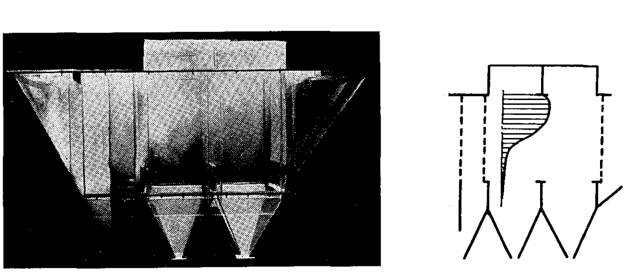


*Fig. 5* Model test of gas flow (Example of unsatisfactory gas flow)

shows an example model test of gas flow in which the gas flow was from the upper portion of the inlet side. It shows that most of the gas flow is passing only the upper half of the electrode chamber (unexpectedly) in spite of the fact that double and single gas-distribution plates are provided, respectively, in the inlet and outlet. In this example, if the gas flow is evenly distributed over the entire sectional surface of the electrode chamber the maximum velocity of the gas is reduced to one half (reentrainment of dust occurs primarily where the velocity of the gas is high). If the collection efficiency is constant, nearly twice the gas volume can be disposed. Further, when the collection efficiency in an unsatisfactory gas flow distribution is assumed to be 86%, if the flow velocity is made even while disposing of the same amount of gas, the efficiency can be raised to as high as 98%. *Fig. 6* shows the change of collection efficiency with the change in gas flow rate. From this figure, it can be understood that the influence of a uniform flow is remarkable, and the volume of the electrode chamber (to insure the same efficiency) can be made smaller by devising further uniformity of the gas flow.

When the distribution of the gas flow is uneven, not only is the efficiency of the dust collection lowered but also a partial dust blockade occurs easily and, in some cases, the operation will become unstable due to the excessive spark-over.

Fuji Electric has been making model tests of the gas flow distribution problem for a long time. In most cases, the model scale is 1/5~1/10 and it is made of a transparent plastic so that the inside flow distribution can be observed. As shown in *Fig. 5*, by flowing smoke, the flow pattern can be observed or, by using an anemometer, the distribution of the gas flow can be measured. As the result of observation of this model the cause of unsatisfactory distribution in the previous example was detected to be the structure of the hopper in the gas distribution plate chamber. After correction, a flow very close to ideal (as depicted in *Fig. 7*) was obtained. Further, for complicated systems, not only the model but the actual precipitator should be checked for the flow distribution at the site.

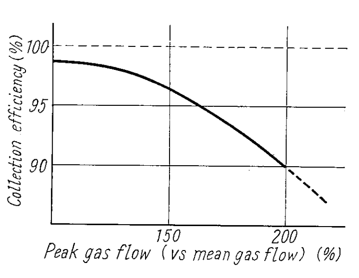



*Fig. 6* Lowering efficiency due to unbalance of gas flow

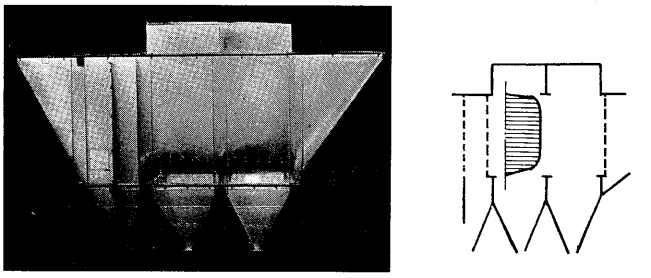


*Fig. 7* Model test of gas flow (the example shown in Fig. 5 was amended)

## 3. Performance of Electrostatic Precipitator for Cement Industry

As explained in the foregoing paragraphs, both the power pack and gas flow distribution have been improved ; thus, the electrostatic precipitators manufactured by Fuji Electric have been made smaller without lowering their capacity, and stability of operation and ease of maintenance have also been improved. *Table 1* is a comparison of the description of the actually delivered precipitator with the usual plan for that precipitator, and *Fig. 8* and *9* are dimensional diagrams for the Fuji plan. For these precipitators, corona current densities of twice those of the former types were planned from the initial design and accordingly the electrode units have been made smaller by 25~35%. For example

*Table 1* Specifications of Fuji Electrostatic Precipitator for Cement Industry

| | For Lepole Kiln | | For Clay Dryer | |
|---|---|---|---|---|
| Specification : | | | | |
| Gas Value | 100,000 cu.m/hr | | 1450 N.cu.m/min | |
| Gas Temperature | At 120°C | | 100~110°C | |
| Collection Efficiency | 98% | | 99% | |
| | Fuji's Plan | Usual Plan | Fuji's Plan | Usual Plan |
| Description of Plan : | | | | |
| Composition | 1 chamber 2 sections | 1 chamber 3 sections | 2 chambers 2 sections | 2 chambers 2 sections |
| Gas through Section | 24.8 sq.m | 25 sq.m | 36 sq.m | 49.5 sq.m |
| Effective Length of Electrode Unit | 5 m | 7.2 m | 4.8 m | 4.8 m |
| Power Pack | 1 $\phi$ Full-wave | 3 $\phi$ Full-wave | 1 $\phi$ Full-wave | 3 $\phi$ Full-wave |
| | Current limiting Electric pulse rapping | Constant-current re-opening of circuit | Current limiting Electric pulse rapping | Unknown |
| | 22.5 kva ×2 | 15 kva ×2 | 22.5 kva ×1 30 kva ×1 | 15 kva ×2 |
| Corona Current Density | Approx. 2 $\mu$a/cm | Approx. 0.9 $\mu$a/cm | Approx. 1.6 $\mu$a/cm | Approx. 0.4 $\mu$a/cm |

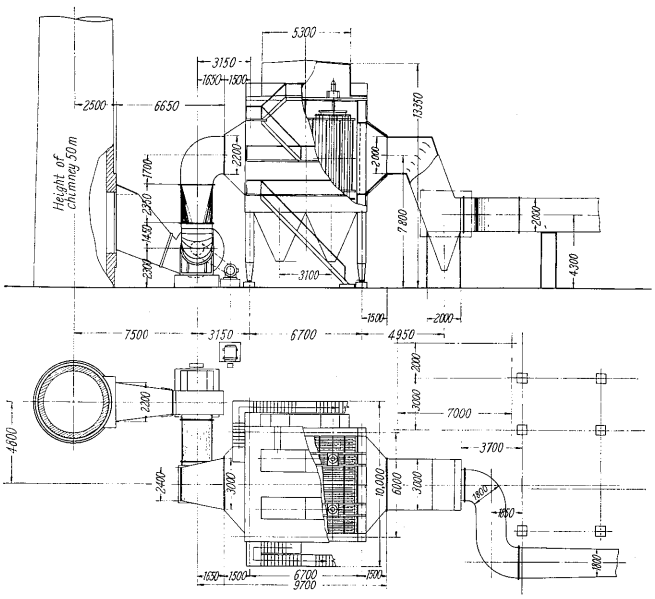
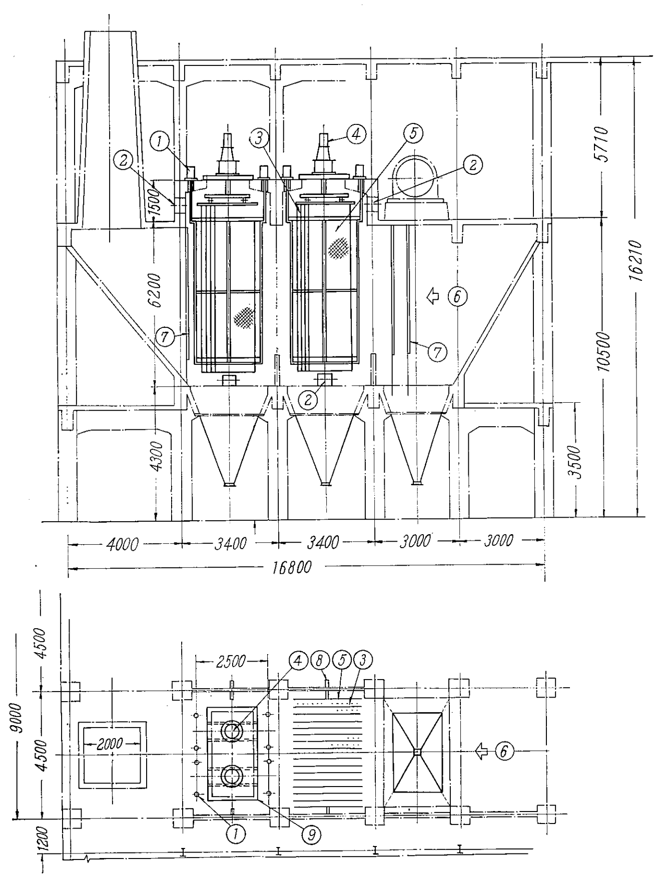


*Fig. 8* Electrostatic precipitator for Lepole kiln



① Collecting electrode hanger
② Manhole
③ Discharge wire
④ High tension insulator
⑤ Collecting electrode plate
⑥ Gas flow
⑦ Gas distribution plate
⑧ Blocking plate
⑨ Header plate

*Fig. 9* Electrostatic precipitator for clay dryer

in the kiln precipitator, the result of the efficiency test, in which 98.7% (which exceeds the planned rate) was measured at 136% of the rated gas volume, proves the superiority of the Fuji Electric technique.

## V. CONFIGURATION OF ELECTRODE CHAMBER

The electrode chamber is a most important part of the precipitator and directly influences the efficiency of the precipitator. Electrode chambers are classified roughly into the tube type and the plate type; however, the plate type is most ofted used in the cement industry. A flat sheet is the fundamental plate type; however, in actual cases, due to considerations of the reentrainment of dust on the electrode or strength of the plate, various types of plate shapes have been devised.

In determining the shape of a collecting electrode, the following points must be considered.

1) Electrical characteristics

The surface squared ratio of the plate in comparison with flat sheet, partial projection or edge effected field concentration, etc.,

2) Mechanical characteristics

The residual stress distortion, heat distortion, mechanical strength, rapping efficiency, etc.

3) Problems of the collecting electrode surface

Gas-flow patterns (keeping the gas flow on the surface of the electrode low for prevention of reentrainment).

4) Economy

Weight, manufacturing hours, and installing hours.

Typical electrodes which provide practical use for cement industries are:

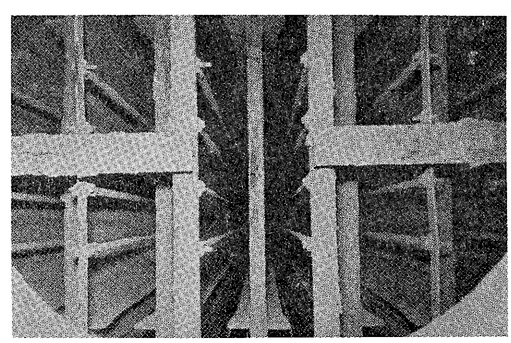


*Fig. 10* Corrugated electrode plate

*Fig. 11* Wire net electrode plate

(1) Wire net type

Normally, through consideration of the material service life, diamond-shaped wire net of 1″ is used. There are two different types of this wire net, one in which the distortion has been prevented by using a reinforcing rib and the other which uses the wire net's own weight for prevention of distortion. The Fuji Electric standard is the latter which does not cause distortion even at high temperatures such as 450°C. When the surface area is not large and the electrical resistivity of the dust is very minor, this type is applied in many cases for cement industries because of its convenience and economy.

(2) Corrugated plate

The surface area is large, and this type is used for a wide variety of purposes; however, as it is subject to distortion when the temperature is high, a proper reinforcing rib is used.

(3) Special types

There are special types, such as the rod type, pocket type, V-type, etc., which are designed for prevention of reentrainment. Generally, these special types are expensive; thus, it is necessary to carefully study the service condition when used. It should be noted that some of these special types easily cause local electric field concentration. The conclusion is that these various types of collecting electrodes should be properly selected and used as based on the service conditions and price.

For the discharging electrode, as long as the necessary corona current is maintained and a proper electric field established, it will be satisfactory; however, it is desirable to finely distribute the corona spot over the length of the discharging wire. Generally, a square discharging wire of 2∼3 mm $\phi$ (or 3∼6 mm) is practical.

The discharging wire often causes disconnection. Unsatisfactory conditions such as cracks, breaks chemical corrosion, electrical wear, insufficient mechanical strength, etc., are pointed out as possible causes. In the normal thimble connecting method, fatigue rupture is frequently caused by mechanical impulse rapping. Under the Fuji standard, a torsion test (performed to detect cracks and breaks, for confirming the method of installation) has been devised to eliminate these causes of fatigue rupture. Further, the most proper material for the existing atmosphere, ranging from soft steel and special stainless steel to Ni-Cr wire is employed.

## VI. RAPPING DEVICE

In the electrostatic precipitator, it is necessary that the dust built-up on the collecting electrode falls into the hopper. Dust on the electrode will, in many cases, disturb the corona discharge or dust collecting phenomenon, and may sometimes become fixed on the electrode depending upon the gas condition or the dust content. Therefore, the quality of the rapping directly influences the collection efficiency.

When the dust is removed from the collecting surface by rapping (if the clot of dust is large), it readily falls into the hopper but, if small, will be reentrained into the gas flow. In this event, even if the rapping is performed more and more frequently, it merely increases the reentrainment and does not work efficiently. In electrostatic precipitators especially, dust deposit is concentrated at the inlet chamber and less exists at the outlet. Thus, it is also convenient to change the rapping cycle, in accordance with dust conditions. Should the dust deposit disturb the collection efficiency, the dust must be removed as completely as possible.

On the other hand, the mechanism by which the dust is built-up on the electrode is influenced by the condition of the dust, gas content, and the temperature; thus, in the practical case, it is advantageous to provide a rapper intensity and cycle that can be adjusted to suit the site conditions. Based on these viewpoints, in the Fuji electrostatic precipitator for cement industries, the following systems are adopted.

### 1. Employment of Magnetic Impulse Rapper

For the mechanical rapper with weight type, it is difficult to adjust the rapping cycle and impulse energy freely at the site. Further, in the pneumatic vibrator, the rapping cycle is large but the acceleration is very small. Therefore, Fuji Electric has made it a standard to employ the magnetic impulse rapper, especially for collecting electrodes.

### 2. Employment of Electric Impulse Rapper

The purpose of the rapping (which provides a mechanical shocking force) is to remove evenly the dust on the collecting electrodes. However, under this system, it is difficult to achieve perfect removal at all over the electrodes and during continuous operation for an extended period, in many cases, a partial dust deposit remains. For these partial deposits, there is a limit to the capability of systems in which the dust is removed by propagating a shock through mechanical rapping. The electric impulse rapping system uses a high voltage condenser to create the discharge at these built-up points and directly remove the dust. Very efficient rapping can be performed in combination with the mechanical rapping method.

The magnetic impulse rapper raises a plunger which is positioned at the bottom in its case, under gravity and a spring force, as shown in *Fig. 12.* The plunger is rapidly dropped, by cutting the exciting current of the coil, and this action raps the electrodes. Because of its mechanism, the life of

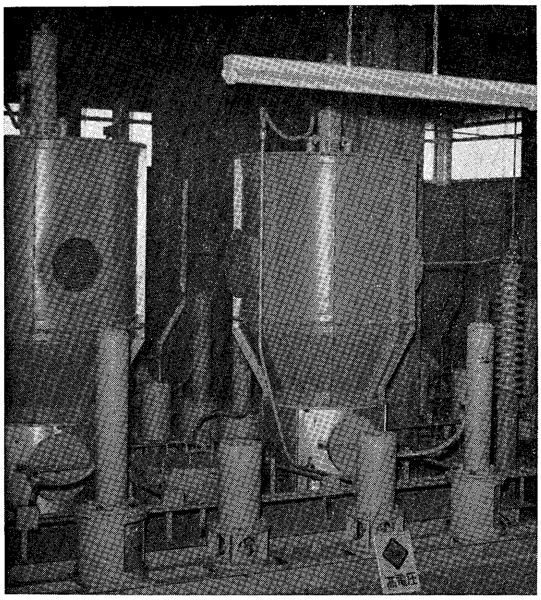


*Fig. 12* Magnetic impulse rapper

this device is extensive and the energy efficiency is very satisfactory.

Adjustment of the energy is smoothly performed by changing the height of plunger rise. *Fig. 13* is the block diagram of the power supply for the excitating source. Together with a Thyristor (SCR) employed in the main circuit, this device consists of a long life transistor timer and a new type auxiliary relay which can withstand 10,000,000 times of switching. Thus, the cycle of rappings and the rest time can be freely adjusted.

## VII. CASING

The casing is normally made of steel frame and plate on which heat insulation is provided or of reinforced concrete. When made of concrete, further heat insulation is sometimes provided.

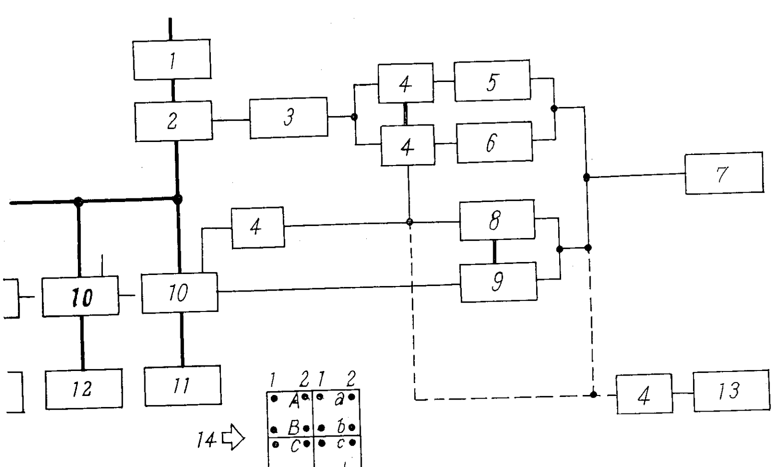
When the casing is made of concrete for a part of the kiln or raw material plant, special caution is required regarding the gas flow. Gas leakage from the casing disturbs the internal gas flow, creates partial dust built-up and shortens the life of the device ; thus, it is necessary to minimize gas leakage as much as possible. At Fuji Electric, a particularly severe leak test is performed.

The recent trend toward use of heavy oil, which is advantageous from the fuel cost viewpoint, presents the problem of corrosion created by the sulphur attack. Most of the sulphur attack becomes $SO_2$ ; however, a part of it becomes $SO_3$. Even if the $SO_3$ content is very minor, a dew point rise occurs when it exists, with the result that, on the inner surface of the casing where the temperature is lower than that of the gas, sulfuric acid is condensed and an unusual amount of corrosion is created. Basically, it is desirable to operate by raising the gas temperature, however, careful treatment of the inner surface of the casing and the provision of tight heat insulation are necessary.

## VIII. POWER PACK

Fuji Electric holds the best performance as a power pack manufacturer since electrostatic precipitators came into practical use in this country. Since the first power pack in which a selenium rectifier was applied was delivered to the Saitama Plant of the Nihon Cement Co., in 1955, the current limiting reactor and other remarkable control devices have been developed by Fuji Electric.

Even the large capacity sets of 5 kva to 100 kva, as shown in *Table 2,* have now been standardized, and the following types of control devices have been




① Transformer 1 ϕ center tap conn
② Thyristor
③ Gate switch
④ Condition
⑤ "On" time setting
⑥ "Off" time setting
⑦ Timer for front chamber
⑧ Timer
⑨ Magnetic contactor forwarding circuit (number of rappings setting)
⑩ Magnetic contactor
⑪ Coil A 1, 2
⑫ Coil B 1, 2
⑬ Timer for rear chamber
⑭ Gas flow

*Fig. 13* Block diagram of magnetic rapper for electric plate

*Table 2* **Standard Capacity of Fuji Power Packs**

| 1 φ 65 kv | | 1 φ 55 kv | | 3 φ 55 kv | |
|---|---|---|---|---|---|
| Capacity (kva) | Output (ma) | Capacity (kva) | Output (ma) | Capacity (kva) | Output (ma) |
| 7.5 | 100 | 5 | 80 | 50 | 650 |
| 15 | 200 | 10 | 160 | 75 | 950 |
| 22.5 | 300 | 20 | 320 | 100 | 1300 |
| 30 | 400 | 30 | 480 | — | — |

manufactured for a free selection based on purpose:

1) Current limiting controlled automatic arc quenching system

   Short-circuit current is suppressed by the current limiting reactor and simultaneously the arc is automatically extinguished.

2) Automatic sparking rate control system

   Electric impulse rapping is not performed; however, sparking rate control is achieved by an analog method.

3) Transistorized sparking count control system

   A fixed value control of sparking rate is performed digitally.

4) Automatic spark rate control system with saturable Reactor and electric impulse rapper

   The most Effective Fuji standard system.

The recent tendency in electrostatic precipitators for cement industries is toward more and more large capacity with an accompanying emphasis on cost reduction. In this situation, it is necessary to provide the many power packs for one precipitator. Fuji Electric has developed the system, shown in *Fig. 14,* applying this method as based on economy. In this system, voltage is furnished to a number of electrode chambers from one large power pack through series resistances. The value of this series resistance can be adjusted to agree with the condition of each electrode chamber; thus, the same effect as that of providing many small capacity power packs can be obtained.

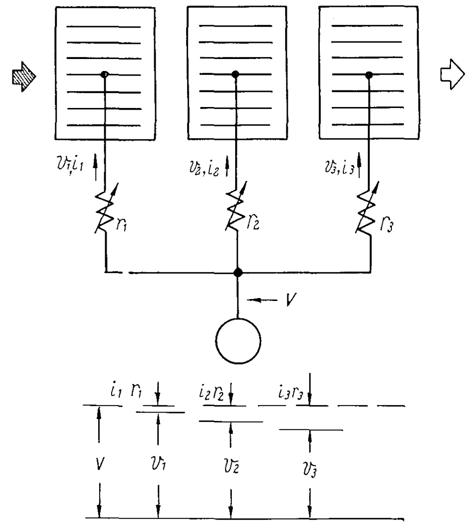



*Fig. 14* Electrical energization through series resistance from a single large capacity source

## IX. CONCLUSION

Features of the electrostatic precipitator, not only for cement use, are essentially to collect the dust electrically by applying high voltage corona discharge. In spite of its excellent characteristics, there still exist many devices which lack adequate precipitation techniques, it is assumed that the problem of public air pollution can be expected to be solved only when economical and superior precipitators are widely used throughout industry. We hope that this report concerning characteristic Fuji electrostatic precipitators for cement use will prove to be a valuable reference to people who are studying the subject of cost reduction in cement manufacturing processes.