

# NEW HCl REMOVAL PROCESS FOR MSW INCINERATORS

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## ABSTRACT

A new dry process for HCl emission control has been developed. Slaked lime powder is blown into the flue duct, and its unreacted particles are captured in a moving bed, which is integrated with an electrostatic precipitator, to react with HCl once again. An HCl removal rate of 95% has been obtained for a  $\text{Ca}(\text{OH})_2/\text{HCl}$  equivalent ratio of 3 with a pressure drop of less than 50 mm Aq; 98% removal has been achieved at a ratio of 3.5. The construction and test results are described.

## INTRODUCTION

Of acid gases contained in the combustion flue gases that are exhausted from a municipal solid wastes (MSW) incinerator, hydrochloric gas arising from the decomposition of organic chlorides, particularly of plastics, is of special concern. Though the exhaust concentration of HCl varies greatly with the quality of the wastes, it is usually in the order of 400 ppm, but can become as high as 1000 ppm when the situation is adverse.

In Japan, the Atmospheric Pollution Prevention Law stipulates that the HCl effluence be  $700 \text{ mg}/\text{Nm}^3$  (about 430 ppm) maximum. However, local autonomous governments can, and often do, impose stricter ordinances, so that there are instances where a con-

centration as low as 50 ppm or even less is demanded of newly constructed incinerators.

Although dry, semiwet, and wet processes are available, the limitations of HCl removal by conventional dry and semiwet methods are generally believed to be about 80 ppm and about 50 ppm, respectively. To meet the cited requirements, therefore, a wet method is usually adopted.

However, these methods are not without inherent deficiencies. Those are, for the wet process, the need for waste water treatment and for prevention of a plume, and for the semiwet processes, frequently recurring problems in the slurry handling line and clogging of nozzles. Therefore, emission control systems with better HCl removal capability, and less prone to trouble, are in demand.

This report introduces a new, dry, HCl removal process capable of attaining HCl removal rates as high as those of the wet ones. In the present process, powdered, slaked lime is blown into the flue duct to react with HCl. Unreacted lime is captured in a moving bed, upstream of the electrostatic precipitator, where it reacts with HCl again.

## PROBLEMS IN CONVENTIONAL METHODS AND COUNTERMEASURES

The methods employed, the features of, and problems found with HCl removal processes in commercial

use today are summarized in Table 1. In that table, the two semiwet processes have been excluded from the dry category, even though the SEMIWET 1 is sometimes called the "dry scrubber", because both utilize lime slurry. Yet they are not quite in a class with the wet process, because elimination of HCl to much less than 50 ppm is difficult.

Moreover, it will be noted in Table 1 that a common problem with the semiwet methods is clogging of nozzles. The dry method avoids this problem, and avoids at the same time the annoyance of having to treat the waste water—a problem which is always associated with any wet method. To compete with conventional semiwet processes, the HCl removal rate will have to be at least 95%, and the apparatus must be compact, simple, and easy to operate.

The dry method, the one that involves blowing slaked lime into the flue duct, i.e., DRY-1 in Table 1, is noted for simplicity, which should be retained. However, the HCl removal rate is not more than about 80% for a  $\text{Ca(OH)}_2/\text{HCl}$  equivalent ratio of 3. Slightly higher HCl removal rates can be achieved by increasing the quantity of in-blown slaked lime, but such a practice entails an increase both in running costs and in the dust load on the electrostatic precipitator. It was thought then that this problem might be overcome by providing a moving sand bed downstream of the scrubber in which to capture the unreacted lime particles and let them work on HCl once again.

Moving sand beds are sometimes used for dust collection. Experience has shown that, when the dust concentration or the gas flow velocity becomes too high, the pressure loss increase inordinately; so much so that the operation becomes unstable, or even impossible. For this reason, the DRY-2 in Table 1 has its large vessel installed downstream of the precipitator to hold down the gas flow velocity and the dust concentration.

System simplification was attempted by incorporating a moving bed and an electrostatic precipitator into an integral unit. Specifically, a moving sand bed of the same sectional area as that of the precipitator would be installed in front of, and integrally with, the latter.

This calls for a new type moving sand bed, such that it is able to operate under a high dust load and at a same gas flow velocity as that in the electrostatic precipitator, which is about 0.6 m/s. For the dust load, the slaked lime that is coming from the flue duct unreacted has to be added to the dust usually present in any fluidized bed type MSW incinerator, which is about 10 g/Nm<sup>3</sup>.

The usual method of retaining sand in a moving bed, using punched metal sheets was thought inadequate

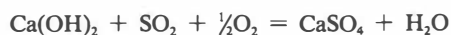
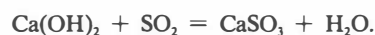
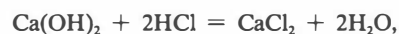
TABLE 1 COMPARISON OF HCl REMOVAL PROCESSES

Type	Method	Features and Problems
DRY-1	To blow slaked lime powder into exhaust gas duct, there to react with HCl.	Structurally simple and easy to operate, but the removal rate is low.
DRY-2	To let pebbles of quick lime descend through the moving bed, there to react with HCl.	High removal rates (to < 50 ppm) but the bed must be enlarged to keep the pressure loss low, holding more lime than is necessary.
SEMIWET 1	To spray slaked lime slurry by high pressure air into a reactor, there to react with HCl.	Structurally simple, but because of slurry spray, nozzle clogging and formation of scale are inevitable.
SEMIWET 2	To pack reactor with balls, spray slaked lime slurry from above, and blow the exhaust gas from below to react with the lime in between the balls.	High removal rates, but structurally complex, meaning equipment and running costs are high; scale formation is inevitable.
WET	To spray alkaline aqueous solution into the reactor, there to react with HCl, the waste solution to be treated afterwards separately.	High removal rates, but the waste water must be treated, needing high initial and running costs.

for these service conditions, because the openings would soon clog with dust. Therefore, an attempt was made to make use of opposing double louver construction by which to absorb the dust in a downwardly moving bed of sand without unduly increasing the pressure loss. As will be discussed in detail later, this method was proved in a pilot test, using simulated gas, to be able to operate continuously and stably, free of clogging by dust, and to achieve the HCl removal rate set forth.

## REMOVAL REACTIONS

As mentioned earlier, the slaked lime blown into the flue duct reacts with HCl, and also with SO<sub>2</sub>, in the duct and again in the moving sand bed. The reactions are as follows:



The reaction products and dust are carried away on the sand, and are taken out of the system through a classifier, which returns the sand to the moving bed. That part of the reaction products and dust which is blown out of the moving bed is collected by the electrostatic precipitator and taken out of the system.

It is generally known from experience obtained in operating commercial MSW incinerators that the concentration of SO<sub>2</sub> in the exhaust is usually in the range of 20 ~ 100 ppm, and that of this SO<sub>2</sub>, 50 ~ 60% can be removed simply by blowing slaked lime into the flue duct. Because of this, and since other acid gases are of even lower concentrations, other acid gases are left out of consideration.

## RESULTS OF TESTS

### Selection of HCl Removal Agent

To select an HCl removal agent, or absorbent, from popular ones, slaked lime, quick lime, lime stone, dolomite, and magnesia of compositions shown in Table 2 were tested. Tests were conducted by filling a Pyrex reactor (40 mm i.d. × 600 mm) with sample, placing it in an electric furnace to heat it to the desired temperature, and then flowing HCl gas through the reactor. The testing conditions were as follows:

Air flow rate:	1.5 Nl/min
HCl concentration:	1000 ppm
Reaction temperature:	300°C
Quantity of absorbent:	50 g (except for the slaked lime, which was 2 g, and its reaction time was extended by the mass ratio)
Size of absorbent:	0.177 ~ 0.297 mm (except for the slaked lime, which was less than 0.125 mm)

The results, which are shown in Fig. 1 in terms of HCl absorption rate and reaction time, gave the following order: slaked lime, quick lime > lime stone > magnesia, dolomite.

From this, and in consideration of the ease of blowing operation, slaked lime was chosen as the HCl absorbent.

### Design of Moving Bed

To summarize, the basic design requirements for the moving bed are as follows:

(a) What remains of the absorbent must be brought into the bed in such a way as to react with HCl again.

TABLE 2 COMPOSITIONS OF CANDIDATE HCl ABSORBENTS

	(in wt. %)							
	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO	Na <sub>2</sub> O <sub>2</sub>	Ig Loss	Notes
Slaked Lime	0.19	0.12	0.06	74.17	0.69	-	24.6	1
Quick Lime	0.33	0.18	0.11	95.87	0.88	-	2.35	2
Lime Stone	0.21	0.10	0.05	55.33	0.50	-	43.78	
Dolomite	1.46	0.11	0.09	34.33	18.13	-	45.85	
Magnesia	0.44	0.12	0.44	2.07	91.48	1.25	3.17	3

1: Ca(OH)<sub>2</sub> = 97.2, CO<sub>2</sub> = 0.46; 2: CO<sub>2</sub> = 0.47; 3: K<sub>2</sub>O = 0.95

(b) The bed must be able to deal with high dust concentrations, because the bed is to be installed upstream of the electrostatic precipitator.

(c) To make the vessel as compact as possible, the sectional area of the bed must be the same as that of the precipitator, so that the gas flow velocity through the bed will be equal to the empty space velocity of the precipitator.

For these requirements, the opposing double louver design was adopted to let the downwardly moving sand absorb dust, in the hope that this construction would forestall blocking of the moving bed by dust even when the dust concentration in the gas is high. If the carrier sand stagnates between two louvers when it is passing through them, however, clogging can take place because of accumulation of dust. This problem was solved empirically, and optimum design parameters, such as inclination, interdistance, and arrangement, were determined as illustrated in Fig. 2.

In Fig. 2, it will be seen that symmetrical arrangement of the double louver, shown as the cases A and B, leaves a lot of sand standing between the louvers, while allowing the center part of the sand to simply descend straight through. This could not be corrected by offsetting the 45 deg. louver rows to each other in the vertical direction so as to give rise to a snaking motion to the descending sand, as shown in C.

The problem was solved, as shown in D, by setting the louver angle to 60 deg. and by closing up the distance between the two louver rows, on top of vertical offsetting.

### Selection of Carrier Size

The pressure loss in a moving bed increases as the carrier absorbs dust contained in the gas as it passes through the bed. This increase in pressure loss can become a significant problem if the carrier is too fine. This is shown in Fig. 3 for various carriers tested,

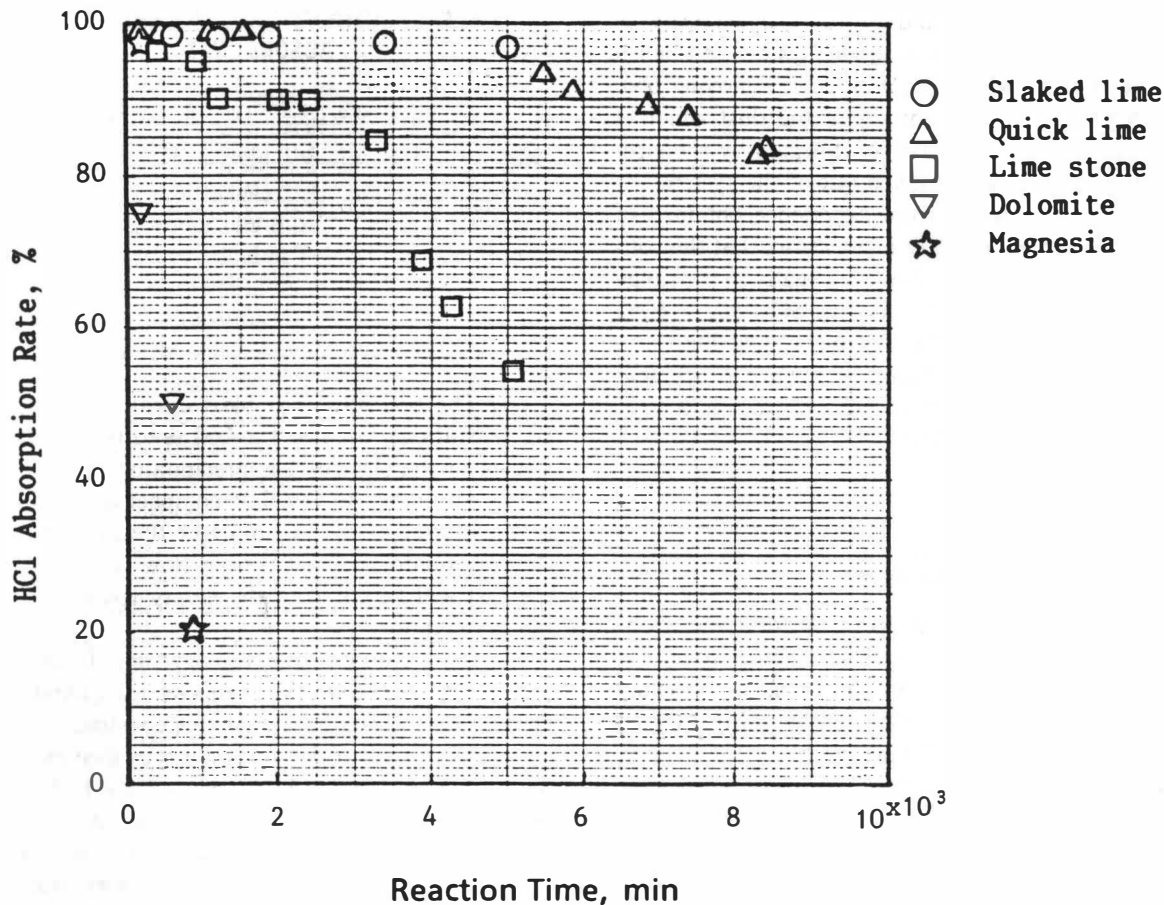


FIG. 1 RELATIONS BETWEEN ABSORPTION RATES OF HCl REMOVER CANDIDATES AND REACTION TIME

whose properties are shown in Table 3. The test was conducted in a cold model with air containing dust.

Although not shown in the figure, the No. 2 silica sand showed an abrupt increase in pressure loss after several minutes of operation. On the other hand, an abrupt increase in the pressure loss did not take place in the No. 1 silica sand until about 50 minutes. Furthermore, the pressure increase was prevented by eliminating the fine particles with a 3.36 mm sieve, i.e., by using the 3.36 mm plus particles. The pressure loss can be held low and stable by resorting to large particles such as the 4 ~ 7 mm silica sand or the 5 mm alumina balls owing to their large void rates.

The pressure loss should, of course, be low and stable, but to ensure high HCl removal rates, the void rates are also desirably low. For these considerations, the 3.36 mm plus class of the No. 1 silica sand was chosen.

TABLE 3 PROPERTIES OF CANDIDATE CARRIERS FOR MOVING BED

	No.2 Silica Sand	No.1 Silica Sand	No.1 Silica Sand, 3.36 mm plus	4-7 Silica Sand	5 mm Alumina Ball
True Specific Gravity (g/cm <sup>3</sup> )	2.67	2.70	2.65	2.70	3.74
Apparent Specific Gravity* (g/cm <sup>3</sup> )	1.44 (1.49)	1.50 (1.52)	1.47 (1.52)	1.39 (1.42)	—
Angle of Repose (deg)	32.0	35.3	33.7	33.3	—
Ig. Loss** (mass %)	0.07	0.15	0.07	0.30	0.01
Size Distribution	5.66 mm plus	0	0	57.29	—
	4.76 mm plus	0	5.46	29.53	—
	3.36 mm plus	2.83	78.21	92.50	—
	2.83 mm plus	50.26	15.56	0	—
	2.00 mm plus	46.34	1.60	0	—
	1.68 mm plus	0.35	0.05	0	—
1.68 mm minus	0	0	0	0	—

\* Figures in parentheses designate the apparent specific gravities as tapped.

\*\* 400°C, 2 hrs

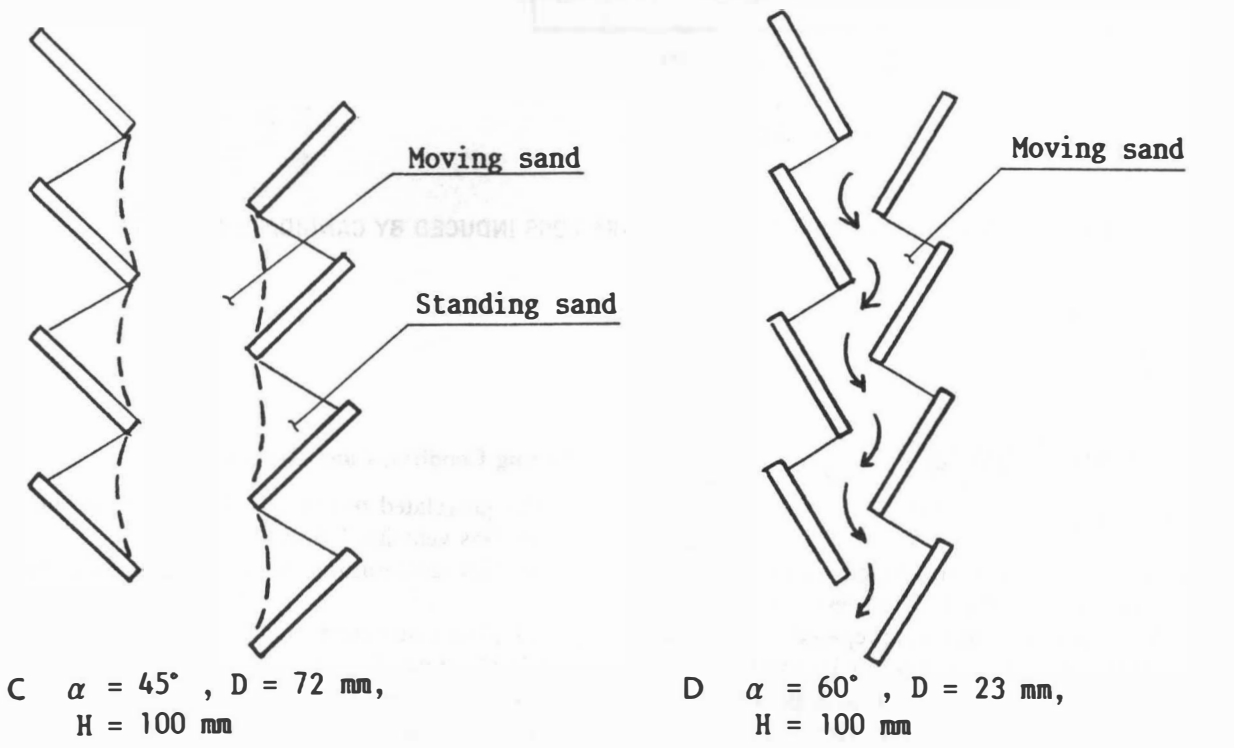
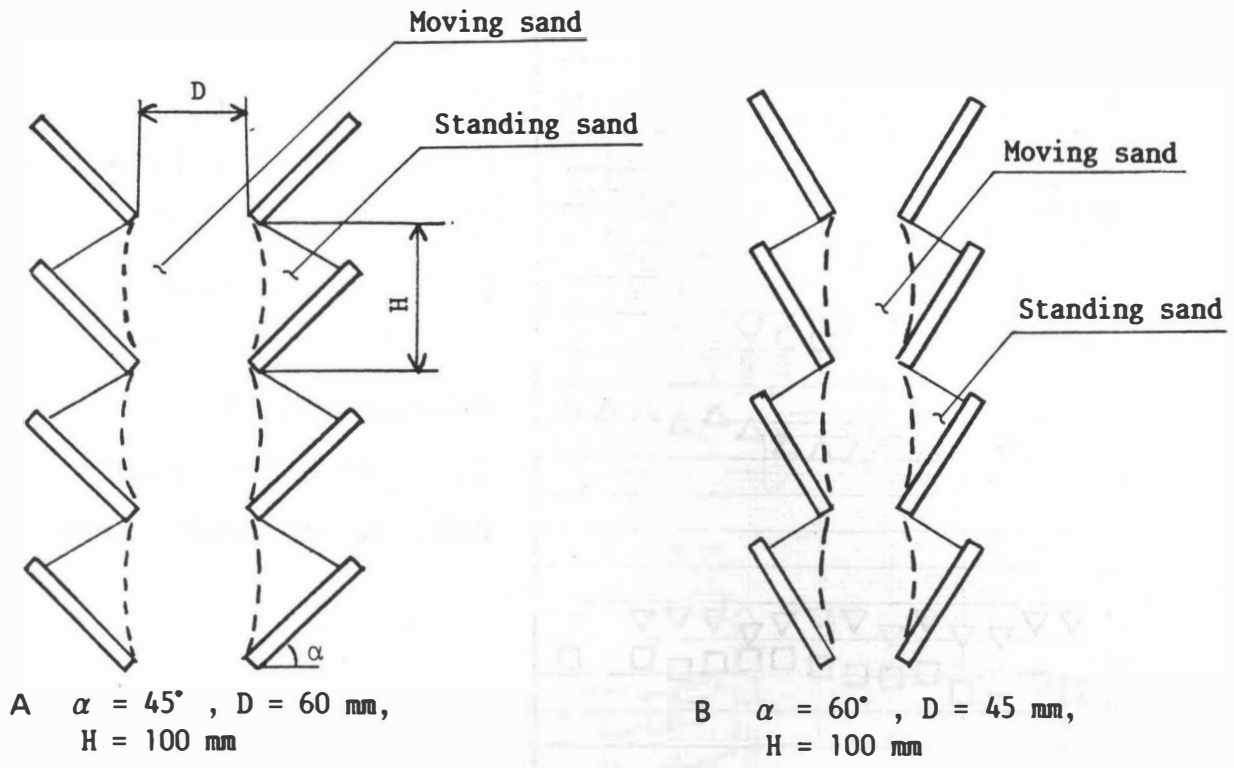


FIG. 2 ARRANGEMENT OF OPPOSING DOUBLE LOUVER

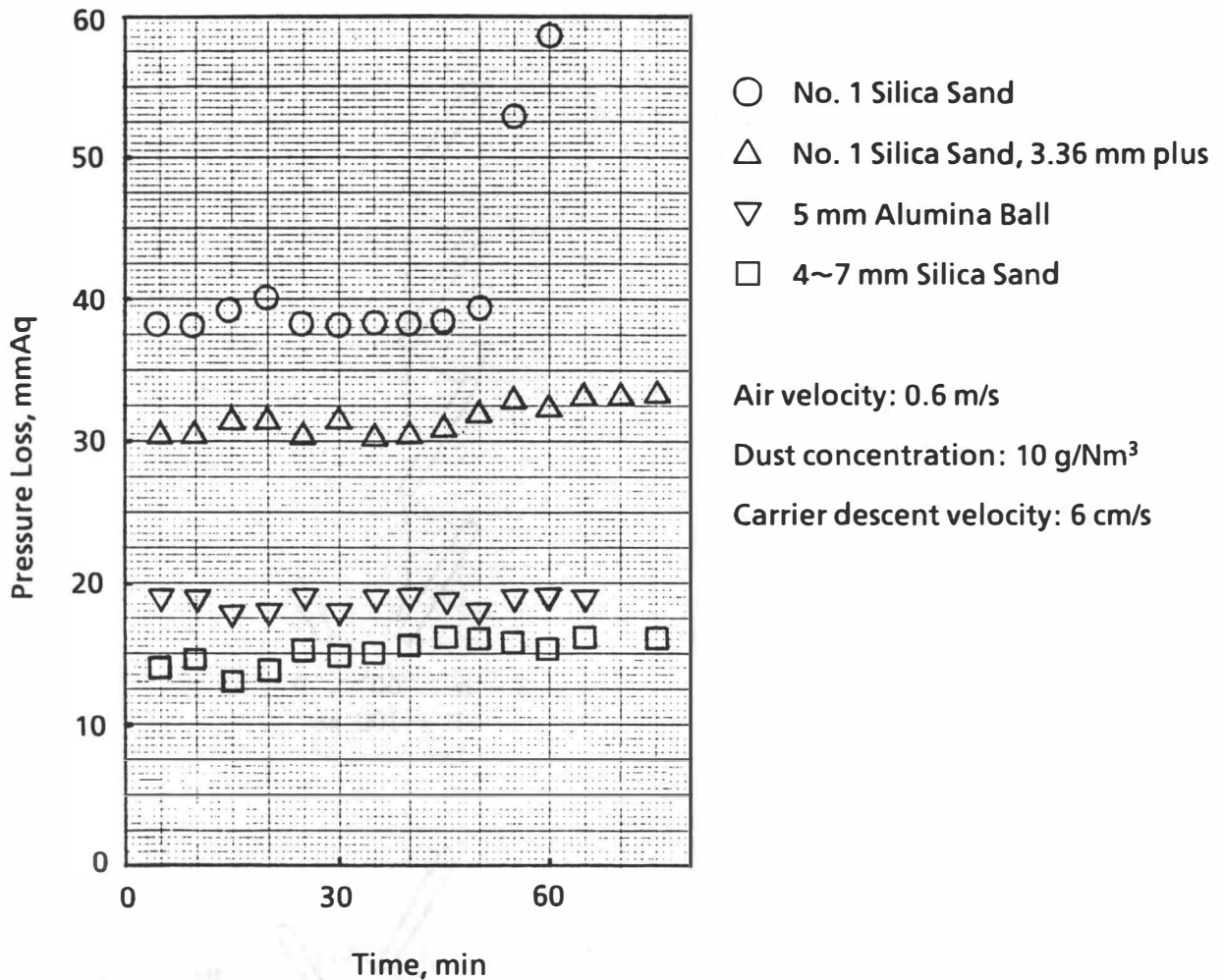


FIG. 3 HISTORIES OF CHANGES IN PRESSURE LOSS INDUCED BY CANDIDATE CARRIERS

## PILOT PLANT TESTING

### The Pilot Plant

Pilot plant tests were conducted using a synthetic exhaust gas. A flow chart of the test plant is shown in Fig. 4. The synthetic gas was prepared to adequately simulate real MSW incinerator gas by spraying water in the air heated in a hot air generator and adding HCl gas and dust to it. The moving bed is located downstream of the slaked lime feeder, and the electrostatic precipitator is installed downstream of, and integrally with, the moving bed.

### Testing Conditions and Results

The gas-related testing conditions were as follows:

- (a) Gas velocity: 0.6 m/s
- (b) Gas temperature: 300°C (at the moving bed inlet)
- (c) Dust concentration: 10 g/Nm<sup>3</sup>
- (d) Moisture: 10 vol. %
- (e) HCl concentration: 900 ppm
- (f) Sand and size: No. 1 silica sand, 3.36 mm plus
- (g) Sand descent velocity: 9 cm/s

The pressure loss across the moving bed during continuous operation remained at around 25 mm Aq as



Instrumentation Notations

- T<sub>1</sub> - 6 : temperatures
- P<sub>1</sub> - 5 : pressures
- H<sub>1</sub> - 3 : HCl concentrations
- F : flow rates

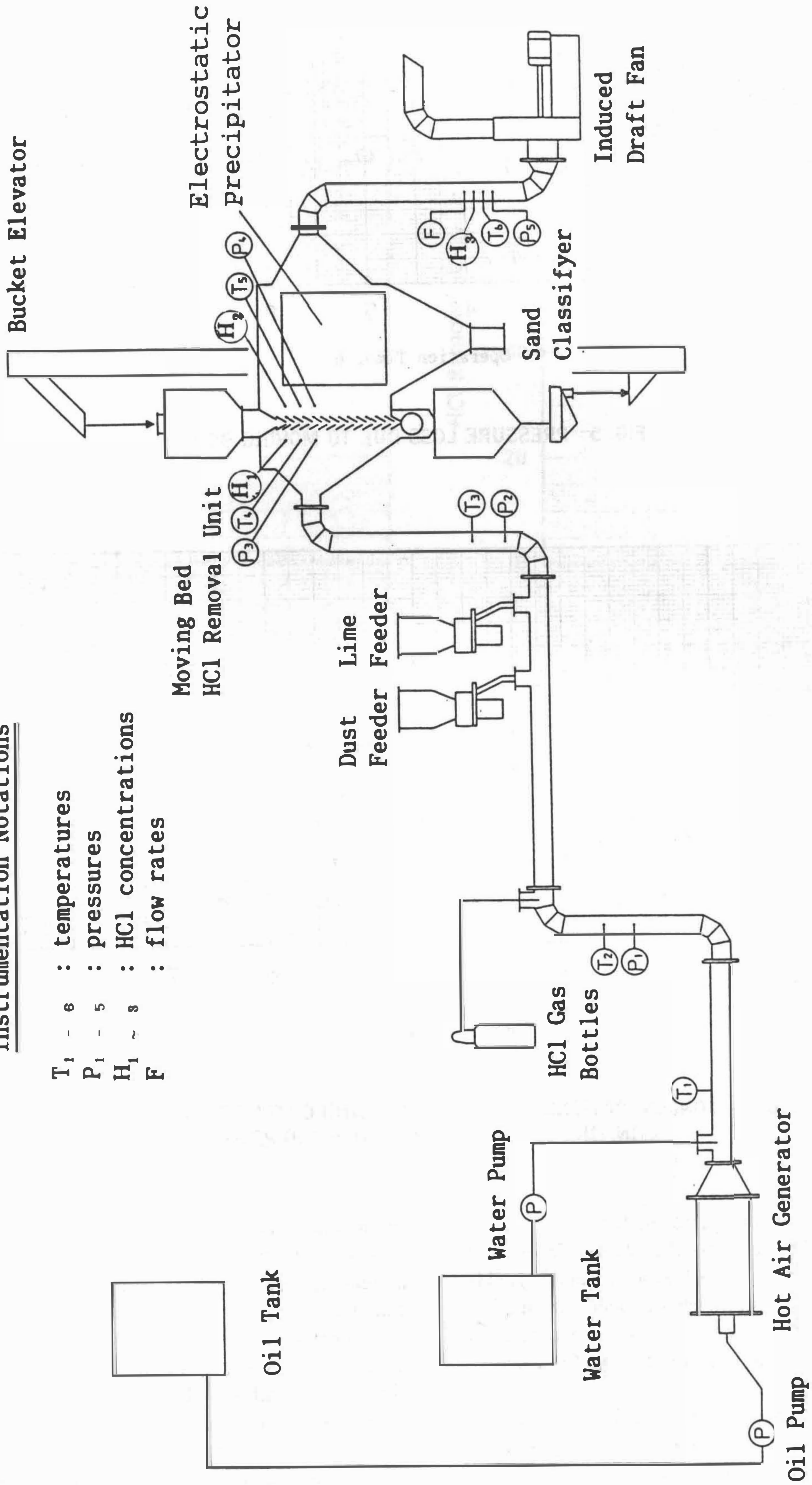


FIG. 4 PROCESS FLOW CHART OF TEST PLANT

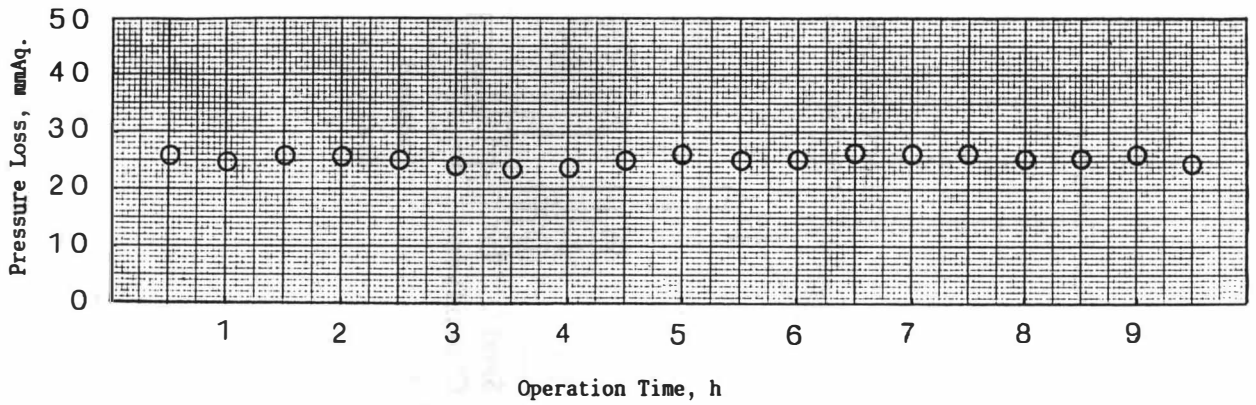


FIG. 5 PRESSURE LOSS DUE TO MOVING BED

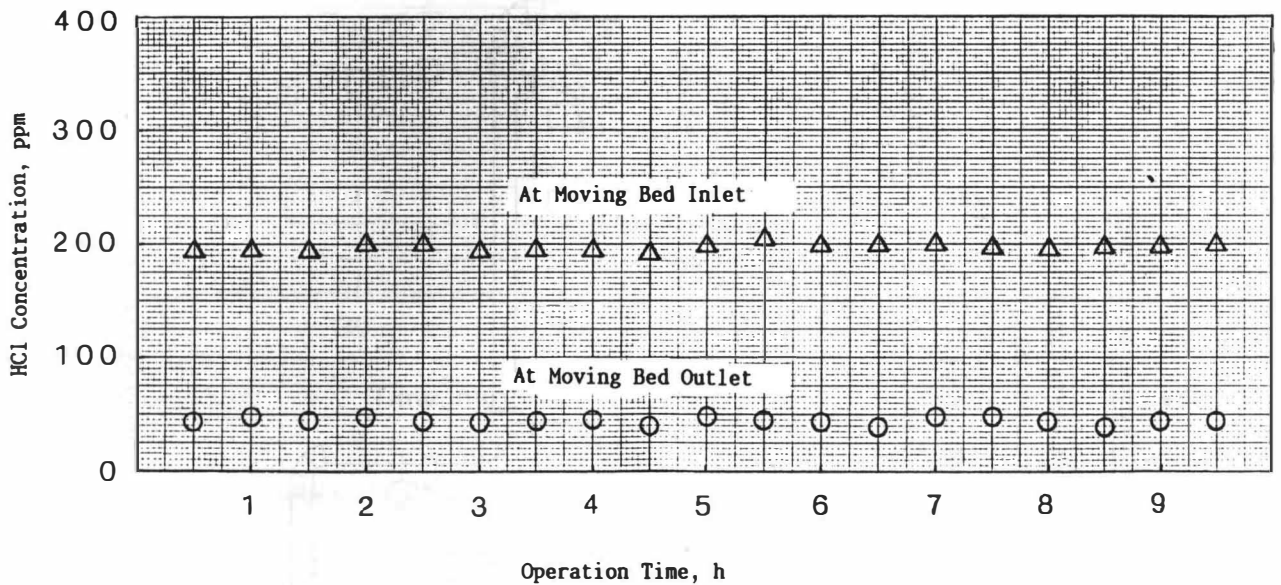


FIG. 6 CONCENTRATIONS OF HCl AT INLET AND OUTLET OF MOVING BED (INITIAL HCl CONCENTRATION = 900 PPM)

shown in Fig. 5. Typical performance of the moving bed is presented in Fig. 6 by the HCl concentrations at the inlet and outlet of the bed at a  $\text{Ca(OH)}_2/\text{HCl}$  equivalent ratio of 3 and an HCl concentration of 900 ppm. It is to be appreciated that the bed outlet concentration of HCl is held to below 50 ppm for a removal rate of better than 95%.

The effects of equivalent ratio on HCl removal are depicted in Figs. 7-9, respectively for the gas stream (in the flue duct), the moving bed, and overall removal.

In the gas stream part, i.e., at the flue duct, the HCl removal rate is improved as the equivalent ratio is increased, but in the moving bed, it remains little changed in the 70 ~ 90% range, irrespective of the equivalent ratio. This is due to the presence of additional slaked lime which has been brought into the moving bed and adsorbed on the recirculating carrier sand. The fact that the two data points exhibiting low rates (solid circles) were both obtained immediately after renewal of bed sand verifies this reasoning.



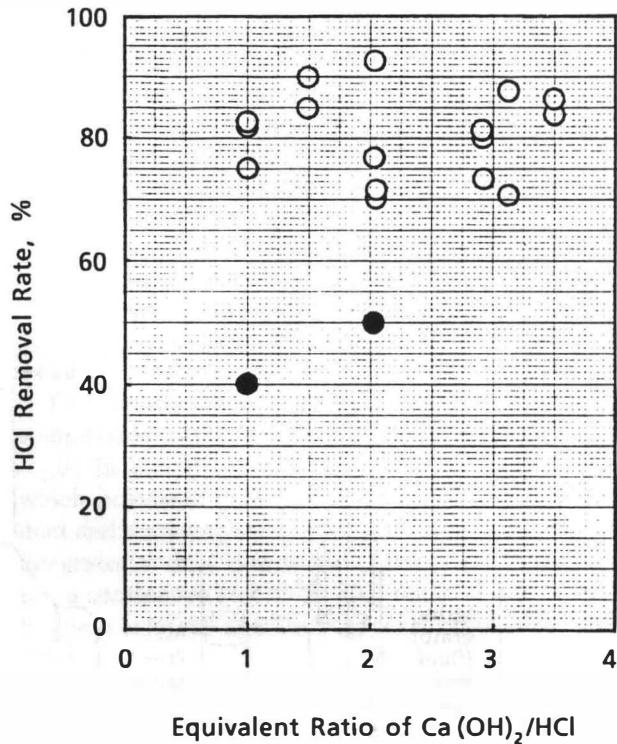
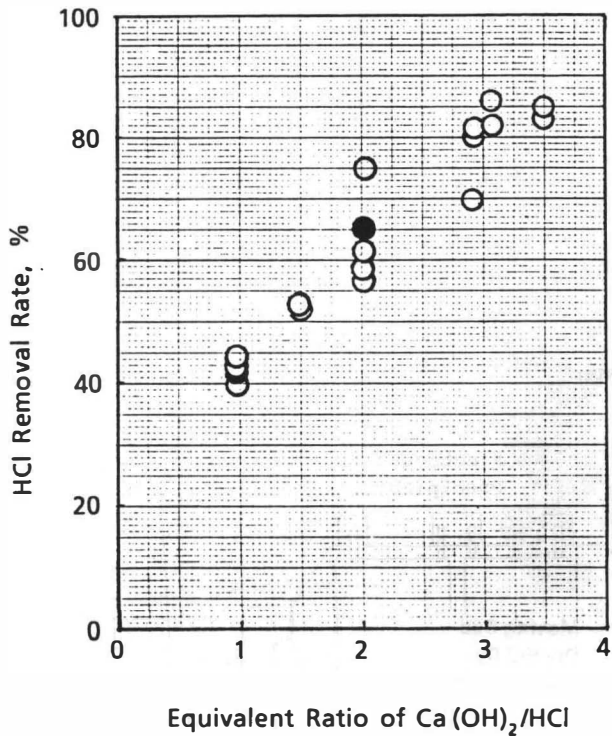


FIG. 7 HCl REMOVAL RATES IN GAS STREAM AS A FUNCTION OF Ca(OH)<sub>2</sub>/HCl EQUIVALENT RATIO

FIG. 8 HCl REMOVAL RATES AT MOVING BED AS A FUNCTION OF Ca(OH)<sub>2</sub>/HCl EQUIVALENT RATIO

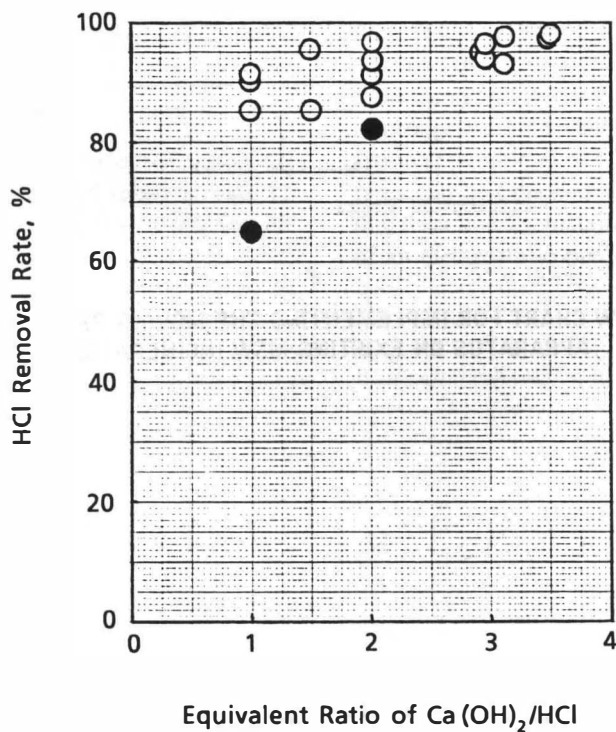
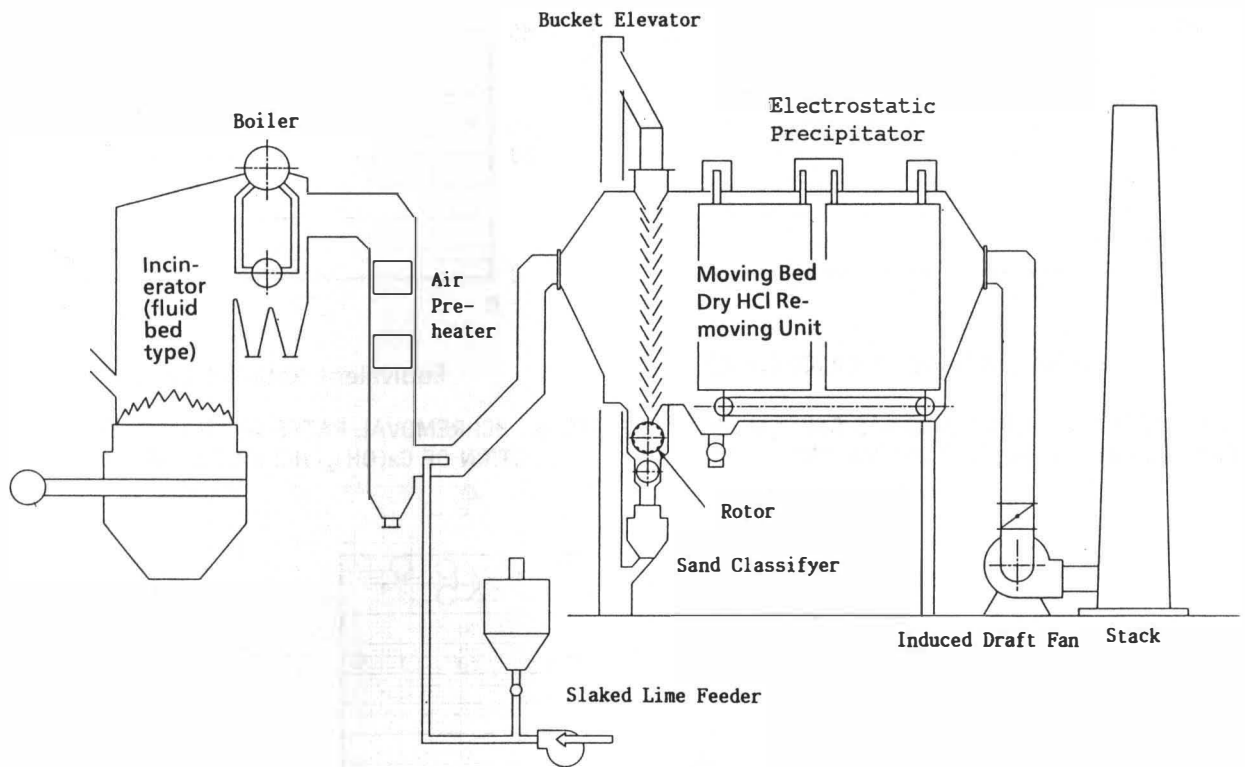


FIG. 9 OVERALL HCl REMOVAL RATES AS A FUNCTION OF Ca(OH)<sub>2</sub>/HCl EQUIVALENT RATIO



**FIG. 10 PROCESS FLOW CHART FOR IMPLEMENTING THE MOVING BED TYPE DRY HCl REMOVAL APPARATUS ON EXISTING MSW INCINERATORS**

## IMPLEMENTATION ON EXISTING INCINERATORS

The process described above can readily be implemented on existing MSW incinerator plants in a form illustrated in Figs. 10 and 11.

## SUMMARY AND CONCLUSIONS

The results obtained in the present work may be summarized as follows:

(a) In a compact dry HCl removal apparatus, in which powdered, slaked lime is blown into the flue duct and a moving sand bed is located in front of, and integrated with, a downstream electrostatic precipitator, a continuous and stable HCl removal rate of 95% has been achieved at a  $\text{Ca}(\text{OH})_2/\text{HCl}$  equivalent ratio of 3.

(b) Although developed for MSW incinerator plants, this process should be applicable to any emission control system for HCl or other acid gas.

(c) For dry scrubbers, provision of a downstream moving sand bed in the manner described above can improve the HCl removal rate.

(d) For existing plants equipped with either a slaked lime feeder at the flue duct or a dry scrubber, the addition of a moving sand bed in front of the electrostatic precipitator, in the manner described above, can improve the HCl removal rate. Even when no HCl removal equipment is provided, high HCl removal rates can be obtained by blowing slaked lime into the flue duct and by installing a moving sand bed in front of an electrostatic precipitator.

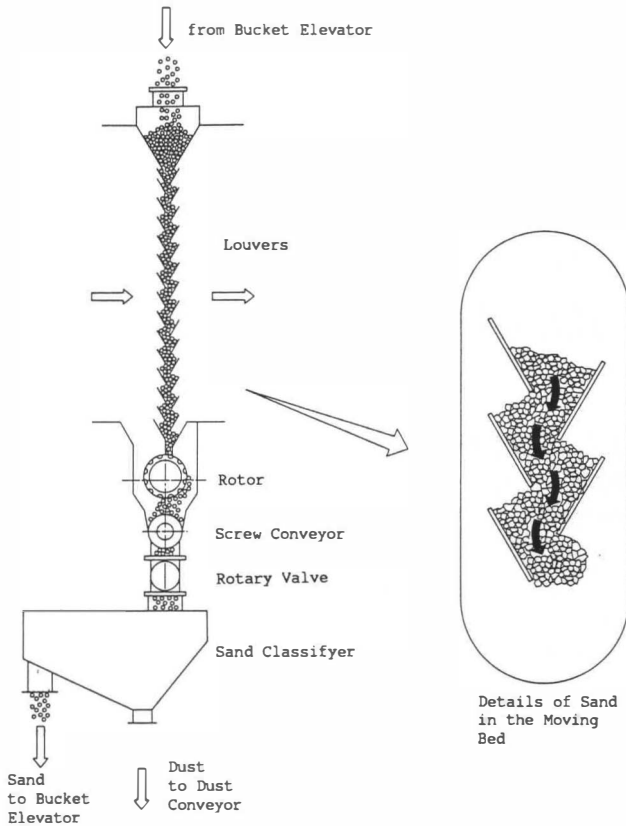


FIG. 11 DETAILS OF THE MOVING BED PART OF THE DRY HCl REMOVAL APPARATUS

Thus, high HCl removal rates have been realized with low equivalent ratios: an HCl removal rate of 95% for an equivalent ratio of 3; and 98% for an equivalent ratio of 3.5.