OPERATING EXPERIENCE AND DATA ON REVOLVING TYPE FLUIDIZED BED INCINERATION PLANTS

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ABSTRACT

In refuse incinerators operating by revolving fluidization (Revolving Type Fluidized Bed Incinerator) a broad range of wastes, from low caloric refuse of high moisture content to high calorific value material including a wide variety of plastics, can be incinerated at high efficiency because the unit is outstanding in terms of distribution of waste in the incinerator bed and uniformity of heat. In addition, its vigorous revolving fluidization action is very effective in pulverizing refuse, so even relatively strict emission standards can be met without fine pre-shredding. Residues are discharged in a clean, dry form free of putrescible material. Data on practical operation of the revolving fluidized bed incinerator are presented in this paper.

INTRODUCTION

In the past, the stoker type incinerator has been most widely used for refuse incineration, but in recent years, fluidized bed incinerators have for reasons of superior combustion, cleanliness of residues, etc., greatly increased in popularity. Revolving type fluidized bed incinerators have now been installed in 40 facilities treating municipal solid waste, at eight facilities for industrial waste treatment, and at two facilities handling sewage sludge. Refuse incineration facilities include semi-continuous units with a water spray type gas cooling chamber and continuous units with a waste heat boiler attached. All installed revolving type fluidized bed incinerators are working smoothly. Moreover, at three of the municipal refuse incineration facilities, co-incineration of sewage sludge is undertaken.

REVOLVING TYPE FLUIDIZED BED INCINERATOR

In conventional fluidized bed incinerators, the fluidization of sand consists mainly of a relatively gentle, up-and-down motion. For this reason there is little horizontal distribution of refuse within the sand, and the refuse must be finely crushed. The larger the incinerator, the more essential it becomes to pulverize the refuse in order to assist distribution and uniformity of combustion.

In the revolving type fluidized bed incinerator, shown in Fig. 1, there is lateral rotation of sand added to the regular vertical movement of sand. No mechanical moving parts are required inside the incinerator for this revolving motion, rather it is established by:

(a) Differential flow rate of fluidizing air (with the central portion being more lightly fluidized and estab-

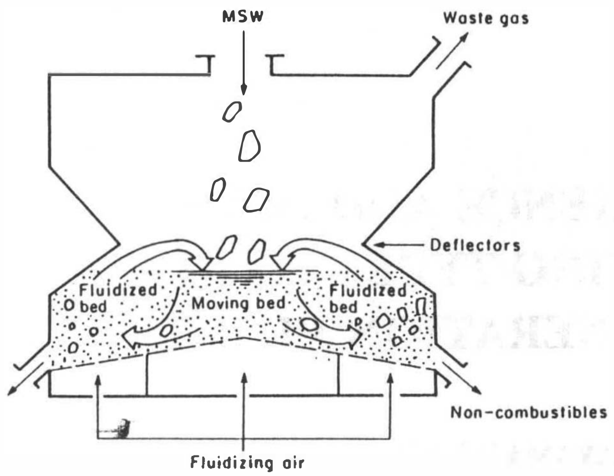

FIG. 1 REVOLVING TYPE FLUIDIZED BED INCINERATOR

lishing a moving bed while each side has a higher flow rate and forms a fully fluidized bed).

(b) Deflectors located above the fluidized bed portions (directing lapping waves of sand over the central moving bed).

(c) An incinerator bed (windbox) inclined towards each side (whereby an airslide effect is produced, directing noncombustibles to the discharge points on either side.)

The mechanism of refuse combustion which takes place in the revolving fluid movement produced by the aforementioned method is as follows.

Refuse fed over the central portion of the incinerator descends through the moving bed, is baked, and all moisture is vaporized as it is passed to the fluidized bed portions. When the refuse reaches the fluidized bed portions, it is caught up in the rapidly moving air-sand mixture, and is disintegrated and thoroughly burned. Noncombustible material similarly sinks in the moving bed and passes to each side where it is discharged together with sand from the noncombustible discharge ports (using a water-jacketed screw conveyor).

Such a combustion system has the following benefits:

(a) The bed combustion rate is high since fed refuse is engulfed and burned in the revolving sand.

(b) Fed refuse is distributed uniformly throughout the bed.

(c) Heat produced by refuse combustion is quickly transmitted to the entire bed, so no localized "hot-spots" occur and stable, uniform combustion is obtained.

(d) Refuse made brittle by heat is pulverized by the revolving motion of the sand and burned, so unpulverized refuse can be treated.

(e) Even relatively large noncombustibles are safely discharged and foreign matter does not accumulate in the incinerator.

Data and experience gained from practical operation of such revolving type fluidized bed incinerators, are presented below.

OPERATIONAL STATUS OF REVOLVING TYPE FLUIDIZED BED INCINERATION PLANTS

Incineration of Municipal Refuse

Revolving type fluidized bed incineration plants for municipal refuse include both the type with a gas cooling chamber attached, found in many small and medium sized facilities, and the type with a waste heat boiler attached, found in many large-scale facilities. Among the 32 incinerators of the type with a gas cooling chamber attached, including those currently under construction, the treatment capacity ranges from 25 TPD (tons per day) (25 t/16 hr by 1 line) to 120 TPD (60 TPD by 2 lines). Among the 8 incinerators with a waste heat boiler attached, the treatment capacity ranges from 120 TPD (60 TPD by 2 lines) to 390 TPD (130 TPD by 3 lines). A typical flow sheet for each of these types is shown in Figs. 2 and 3, respectively.

In the revolving type fluidized bed incinerator, sand heated up to 700–800°C is made to flow vigorously and permeates inside the refuse so that the refuse is heated from the inside and outside simultaneously. In this way, vaporization drying, gasification and combustion take place sequentially in a short time period. Consequently, a wide assortment of refuse, from items containing high percentages of moisture, such as garbage, to plastics and other items of high caloric content, can all be burned under stable conditions. In Japan, general collected wastes other than bulky uncombustibles, such as refrigerators and televisions, and general bulky combustibles such as rolled carpeting and mattresses are fed into the incinerator without fine pre-shredding. Combustion residue is sanitary not only because combustion is thorough, but also because it is retrieved in a completely dry state without the necessity for quenching water. Some of the facilities use a magnetic separator to recover ferrous metal from the residue, and sell it. The volume of dust in the exhaust gas from a fluidized bed incinerator is greater than that of a stoker incinerator, but dust emission standards

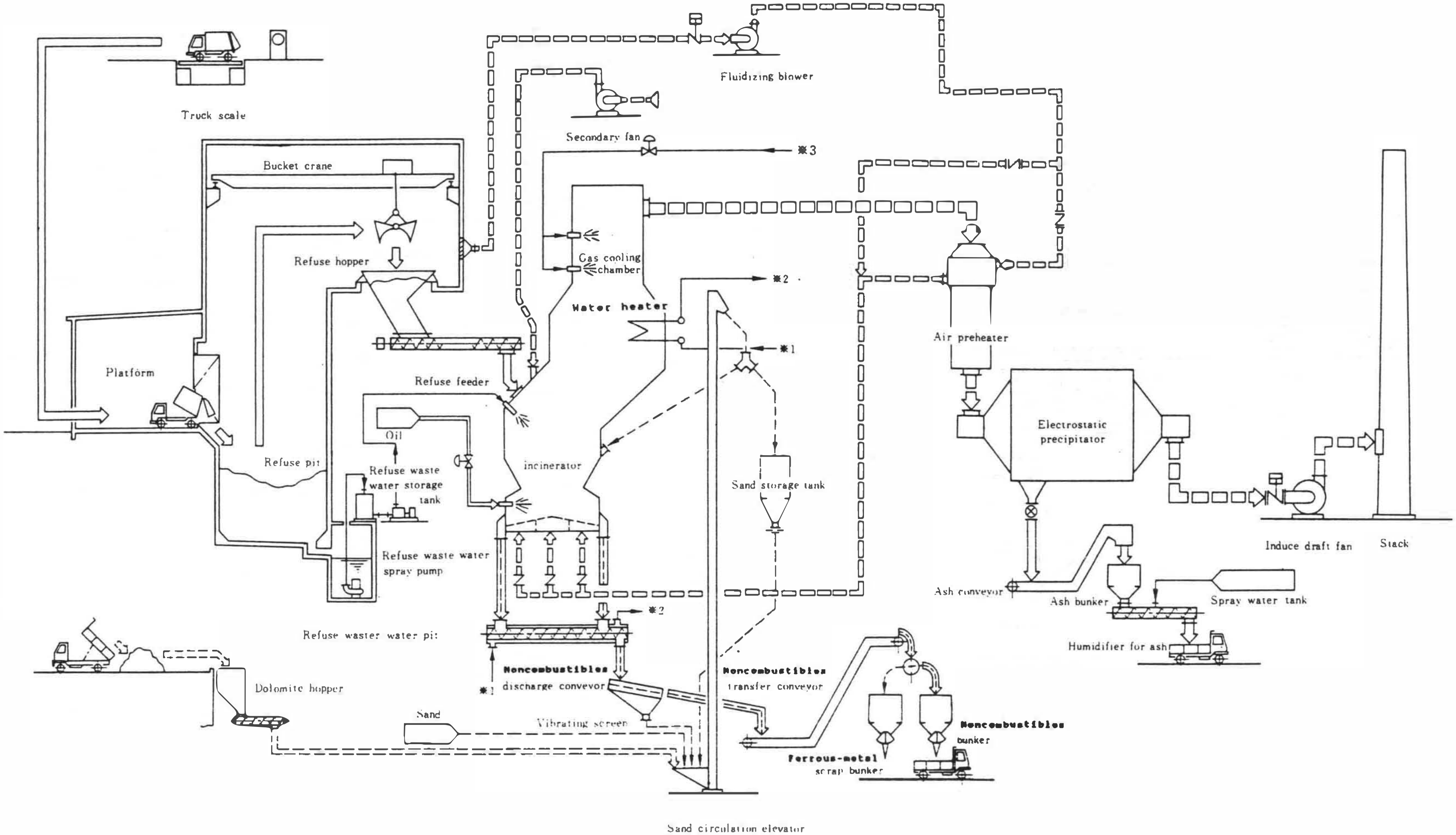

FIG. 2 FLOW SHEET
(Gas Cooling Chamber Type)

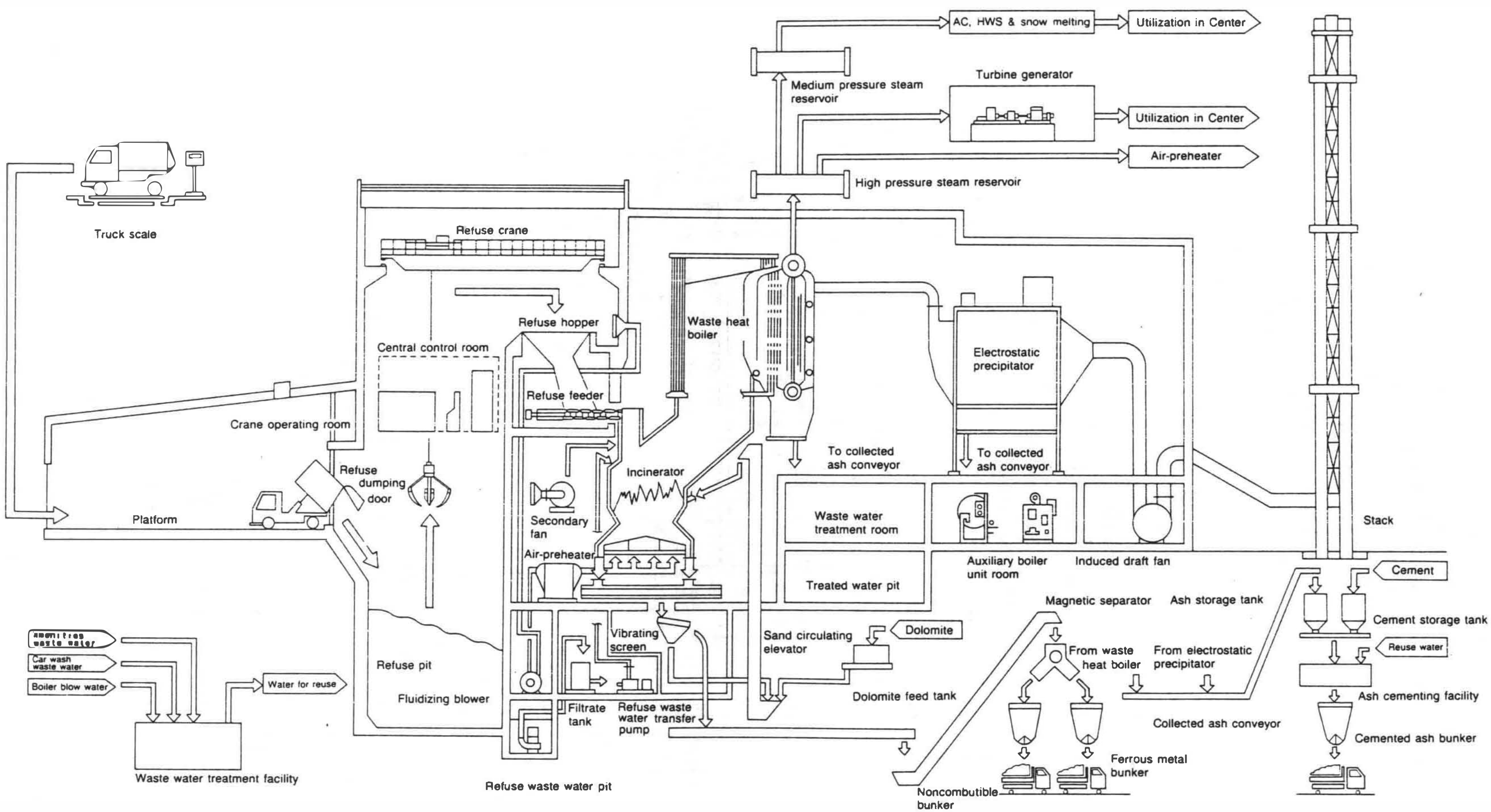

FIG. 3 FLOW SHEET
(Boiler Type)

TABLE 1 DUST COLLECTION BY ELECTROSTATIC PRECIPITATOR

Plant	Capacity t/D	Inlet Dust g/m³ (NTP)	Outlet Dust g/m³ (NTP)	Efficiency %	Regulation g/m³ (NTP)
A	120	16.1	0.024	99.85	0.05
B	150	14.09	0.032	99.77	0.05
C	70	6.07	0.053	99.13	0.1
D	150	6.83	0.035	99.49	0.05
E	80	12.4	0.088	99.29	0.1
F	100	19.5	0.029	99.85	0.05
G	360	8.70	0.03	99.66	0.05
H	327	8.13	0.027	99.67	0.05

TABLE 2 IGNITION LOSS OF COMBUSTION RESIDUE AND FLY ASH

Plant	Capacity t/D	Combustion Residue %	Fly Ash %
a	120	0.05	0.44
b	150	0.03	0.82
c	60	0.04	0.34
d	100	tr	1.15
e	120	0.04	0.51
f	390	0.04	0.6
g	360	0.1	1.06
h	327	0.1	0.3

TABLE 3 ANALYTIC VALUES OF FLY ASH INGREDIENTS

	Concentration (%)
Aℓ	7.9
Mg	5.6
Ca	14.0
SiO_2	24.4
Cℓ	6.0
Cu	0.44
Zn	0.93
Fe	6.4
Mn	0.07~0.15
Na	2.7
K	1.7
Insoluble matter in hot water	70~90

are easily met with an electrostatic precipitator or other dust collector. The results of dust collection by an electrostatic precipitator are shown in Table 1. The ignition loss (i.e., level of unburned combustibles) of residue discharged from the incinerator bed and of fly ash collected by an electrostatic precipitator are shown in Table 2. The fly ash contains ingredients such as sodium chloride which can be easily dissolved in water, and the degree of dissolution in hot water is about 10–30%. In the contents of fly ash, as shown in Table 3, the level of calcium is high, and the PH value is 10–12. Normally, in order to remove HCl from the exhaust gas, dolomite or calcium carbonate is fed into the incinerator, or calcium hydroxide is sprayed into the flue gas stream, though it can be assumed that the calcium already present in the refuse contributes to this reaction. The heavy metals content of the fly ash and the elution test results are shown in Table 4. As shown, hardly any of the metals were eluted, and levels were well within the Japanese national regulations. Table 5 shows elution results after solidification with cement. The type of elution testing performed in Japan consists of mixing fly ash into water in a ratio of 10% of the water weight. The water PH is adjusted from 5.8 to 6.3 and is shook for 6 hr. The amount of heavy metals which elute after this period is then measured.

Normally, the sulfur component of refuse is 0.02–0.2% and over half of this amount appears to remain within the particulates, and less than 30–40 ppm is found in the actual exhaust gas. However, the generation of HCl increases with an increase in the amount of plastic wastes, especially vinyl chloride. There are various systems for removing HCl, with the one most suitable for meeting local emission standards being chosen.

TABLE 4 HEAVY METAL CONTENTS IN FLY ASH AND ELUTION VALUES

	Content mg/kg	Elution mg/ℓ	Regulation mg/ℓ
T－Hg	0.171	N.D	< 0.005
Cd	7.09	N.D	< 0.3
Cr^{6+}	1.6	0.16	< 1.5
Pb	632	N.D	< 3
AS	9.2	N.D	< 1.5
CN	0.5	N.D	< 1
PCB	N.D	N.D	< 0.003
R－Hg	N.D	N.D	N.D
Org－P	N.D	N.D	< 1

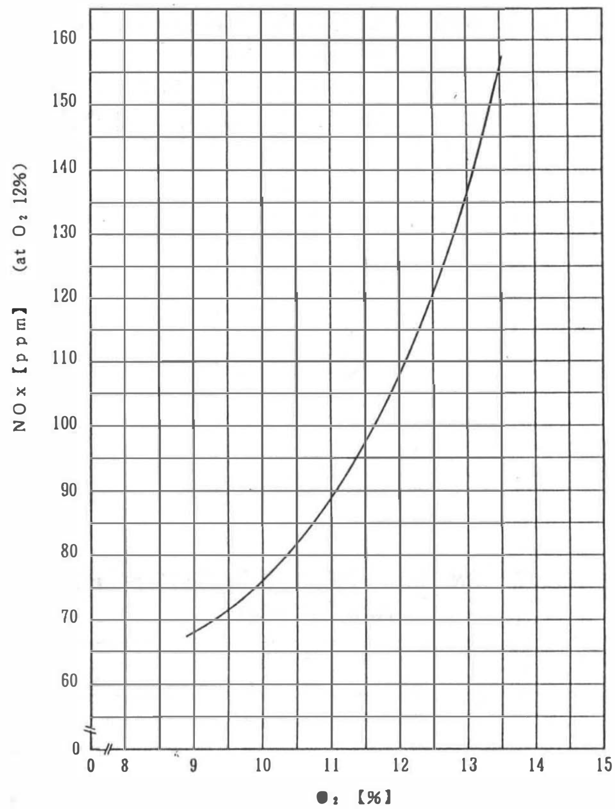

FIG. 4 NO_x AND O_2 AT INCINERATOR OUTLET

TABLE 5 ELUTION VALUES OF CEMENTED ASH

	Elution mg/ℓ	Regulation mg/ℓ
Total－Hg	N.D	< 0.005
Cd	N.D	< 0.3
Pb	N.D	< 3
Cr^{6+}	N.D	< 1.5
AS	N.D	< 1.5
CN	N.D	< 1
Org－P	N.D	< 1

There is little generation of thermal NO_x in the revolving type fluidized bed incinerator because the circulating sand remains isothermic with no localized points of high temperature. As a result of combustion, a portion of the fuel nitrogen becomes NO_x; however the majority appears to undergo self-denitrification and is converted to N_2. Reduction of generated NO_x is also enhanced by the two-stage combustion that takes place in the fluid bed and the freeboard. As shown in Fig. 4, NO_x is greatly affected by the concentration of O_2; the amount of NO_x increasing with an increase in O_2 concentration.

The waste water from refuse incineration plants includes refuse (pit) water, plant waste water and amenities waste water. With the fluidized bed incinerator in general, however, since there is no bottom ash quenching water, there is no need for high-level waste water treatment facilities for treating heavy metals. In facilities employing gas cooling chambers, the balance of water requirements allows a closed system to be employed in which no water is released to the outside.

TABLE 6 HCL REMOVING SYSTEM AND EXHAUST VALUES

	HCℓ Removing System	Exhaust Value
1	Dry System	
	(1) Dolomite or calcium carbonate are injected or sprayed into incinerator.	>150ppm
	(2) Calcium hydroxide is sprayed in flue gas.	150~100ppm
2	Semi-Dry System	
	(1) Calcium hydroxide slurry is sprayed.	100~ 50ppm
3	Wet System	
	(1) Alkali aqueous solution is used in scrubber.	50ppm>

At present, in about 30 plants with gas cooling chambers, water is reused without being expelled.

Since combustion with the fluidized bed incinerator is rapid, incineration is completed within several minutes after feeding of refuse into the incinerator has been stopped, and the oxygen concentration increases. Consequently, no uncombusted remnants remain in the incinerator and there is no need for ash firing, so shutdown is simple. Since the heat retention capacity of the sand is large, and there is little drop in incinerator bed temperature, the facility can be restarted the next day or after a holiday without preliminary heating merely by direct feeding of refuse. Start up and shut down characteristics, and the bed temperature gradient are shown in Fig. 5.

In the typical revolving-type fluidized bed incinerator plant, the incinerator and gas cooling chamber or boiler are combined into a single unit, eliminating duct work, reducing heat loss and conserving space. In facilities with waste heat boilers, the boiler is made integral but positioned eccentrically to prevent excessive heat transfer from the sand bed. Nevertheless, after incineration is stopped, the boiler receives small increments of radiant heat accumulated by the refractory material of the incinerator and from the large volume of heat stored in the sand bed. Consequently, boiler drum pressure is kept high and operational pressure can be maintained over a long period. Figure 6 is a graph of operational conditions, such as boiler temperature and drum pressure, with shut down and restart.

Over a period of 14 hr and 25 min after shut down, the boiler inlet temperature drops from 850°C to 300°C, but the fluidized bed temperature drops only slightly from 800°C. Consequently, when the fluidizing blower is again started and refuse is fed into the incinerator, combustion begins immediately; there is absolutely no need for preliminary heating. Over a period of 11 hr and 10 min, the boiler drum pressure is kept at the normal operating level of 271 psi (1.86 MPa), and thereafter it falls gradually. Even after the unit has been stopped for 14 hr and 25 min, this pressure drops only to 257 psi (1.77 MPa). After restart, regular pressure and steam volume are obtained in about 10 min. Thereafter, the turbine generator is warmed up for 20 min and accelerated for 30 min, and power output can be restored about one hour after the incinerator has been restarted.

With shut-down of a conventional stoker type incinerator, corrosive gas is emitted which damages the boiler tubing. Also, it takes a long time for the unit to be restarted. For these reasons, conventional units as a rule are kept operating continuously, but this system eliminates such problems and provides a much greater freedom of choice in operating patterns, for instance every Sunday stopping operation. In other words, all wastes are combusted within a few minutes of stopping feed. Since no corrosive gas or moisture emanates from the incinerator, no condensation occurs in either the boiler tube or the dust collecting plates of the electrostatic precipitator and corrosion thus rarely occurs.

Incineration of High Calorific Value Waste Products

In recent years, refuse has been increasing in calorific value, and demand has arisen for facilities which can treat such refuse. High caloric refuse in the form of paper and other wood products has a value of 7200–9000 Btu (16.7–20.9 kJ/kg), and that of plastics is 7200–19,800 Btu/lb (16.7–46.0 kJ/kg). In theory, items of high caloric content can be accommodated by recalculation of the grate combustion rate and combustion chamber heat load, but in the stoker incinerator, it is difficult to burn a good many plastics though a small amount of plastics are good because they cause damage to the incinerator during combustion; they are separated out in collecting process from other refuse and buried in Japan. Finding locations where these plastics can be buried thus becomes a problem, along with numerous other problems that arise with this method of disposal. Since the volume of plastic refuse continue to increase, a suitable means of treating this waste must be provided.

Incineration of Plastics

Exclusive incineration of plastics with a revolving type fluidized bed incinerator was conducted in a pilot plant. The refuse materials included various vinyl and

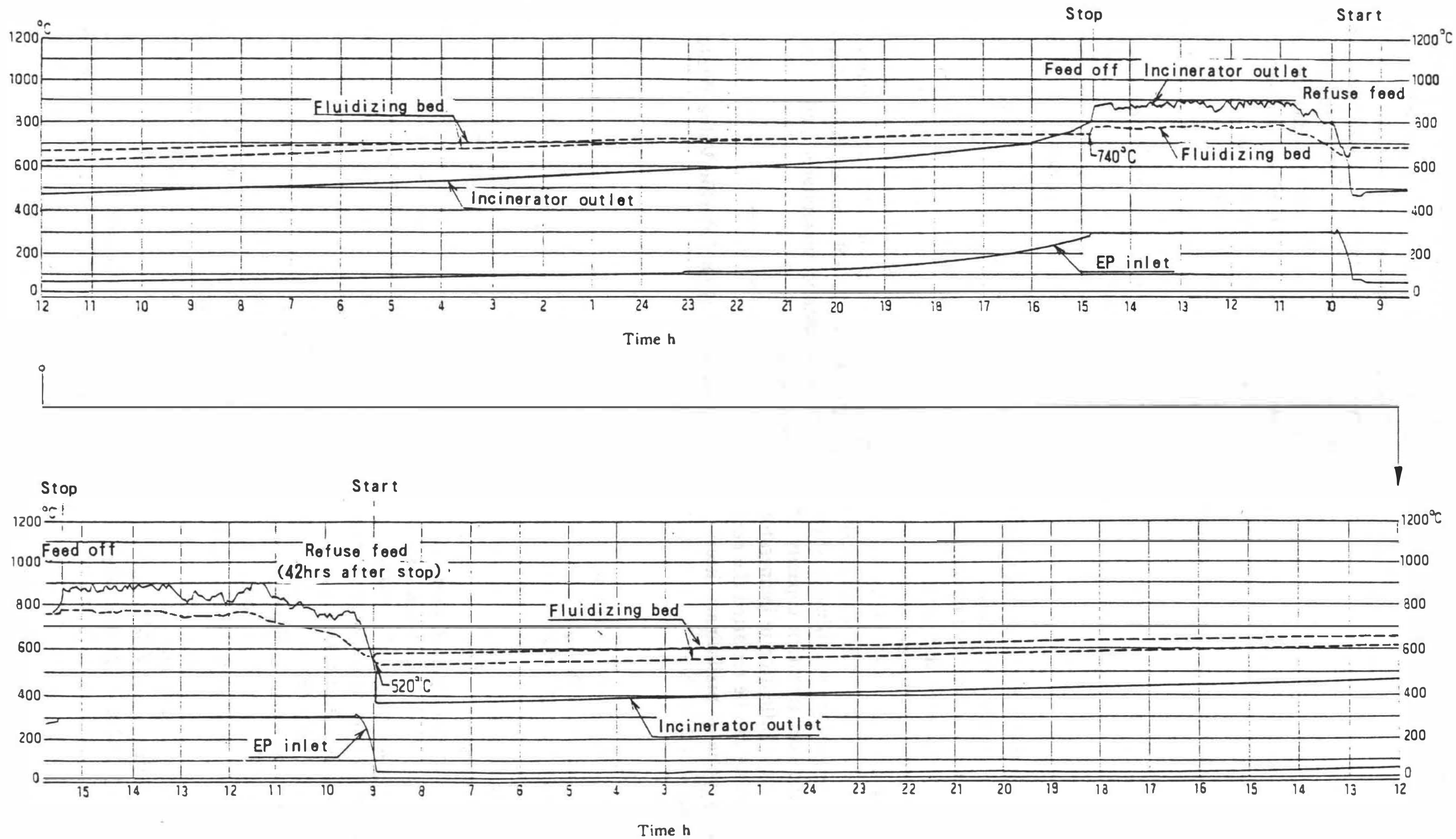

FIG. 5 START UP AND SHUT DOWN TEMPERATURE CHART

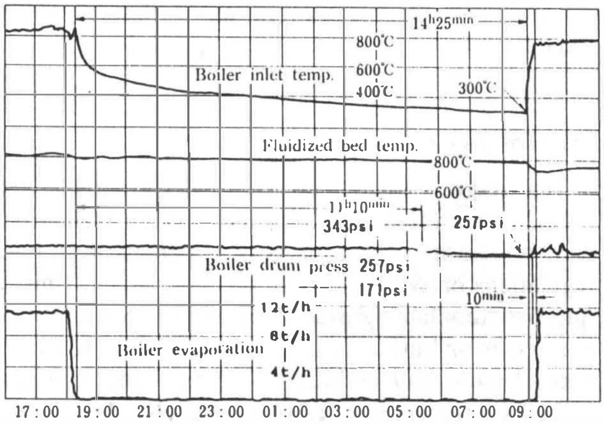

FIG. 6 CHANGE OF OPERATING CONDITIONS FROM SUSPENDED OPERATION TO START-UP

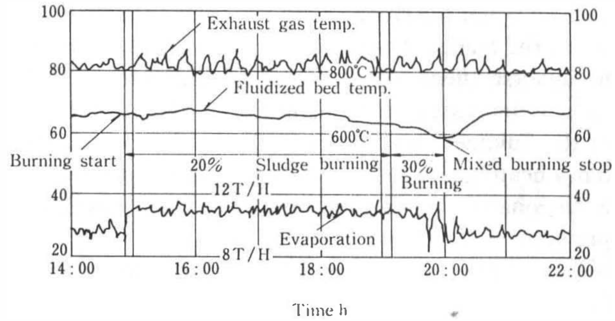

FIG. 7 CHANGE OF OPERATING CONDITIONS DURING MIXED INCINERATION OF MUNICIPAL REFUSE AND SEPTIC SLUDGE

sponge items. The low calorific value of the mixture was 9594 Btu/lb (22.3 kJ/kg) and the moisture content was 2.1%. The concentration of NO_x produced was about 105 ppm. The ignition loss of fly ash was less than 1%. The incinerator bed temperature remained stable at 760–780°C during combustion and there were no clinkers formed. Clinkers result from localized hot spots. In the revolving type fluidized bed incinerator, however, plastics are broken down, combustion heat is properly distributed, and uniform combustion is obtained.

Incineration of Low Calorie Waste Products

Incineration of Sludge

Since substances such as sewage sludge or night soil have a moisture content, they are generally very low in calorific value, at 540–720 Btu/lb (1256–1674 kJ/kg) or less, and their incineration requires auxiliary heating by large volumes of oil or similar fuel. A revolving type fluidized bed incinerator of 30 t/24 hr capacity, exclusively for incineration of sludge from the adjacent sewage treatment plant was constructed in 1982. Treated sludge contains 79% water, and it has a low calorific value of −203 Btu/lb (−473 kJ/kg) [3096 Btu/lb-Dry Sludge (12960 Btu/lb-D.S.)]. The incinerator bed area is 19.6 ft^2 (1.82m^2). The bed temperature is maintained at 650°C and is consistent throughout the bed, and combustion is stable and uniform.

Mixed Incineration of Municipal Refuse and Sludge

In contrast to sludge incineration treatment, which is energy consumptive, combustion of municipal refuse is self-sustaining, and is an energy surplus type treatment from which surplus heat can be recovered and used.

Co-incineration of sludge and refuse can be seen as a means of conserving or more efficiently using energy. No special facilities such as a preliminary drier are required for such co-incineration. With an ordinary fluidized bed incinerator, sludge normally burns within the sand but refuse burns above it, so when the proportion of sludge is increased, the temperature of the sand drops. However, with the revolving type fluidized bed incinerator, the revolving action causes refuse also to be burned within the sand and since the temperature of the sand cannot easily drop, this allows the proportion of sludge to be increased.

At present, there are three facilities where sludge and refuse are co-incinerated. One of these facilities will be discussed as an example. At this refuse incineration plant, the scale of operations is 360 TPD (120 tons/24 hr × 3 lines.) It is equipped with waste heat boilers and a turbine. The calorific value of refuse is 2700 Btu/lb (6280 kJ/kg). Approximately 10 TPD of night soil is generated at night soil treatment centers and it is all hauled by dump truck. The water content of this sludge is around 85% and the calorific value is 27 Btu/lb (63.8 kJ/kg). Hauled night soil is dumped into a reception hopper; and after it has been discharged by a screw conveyor, it is pumped through piping directly into the top of the incinerator. Consequently, maintenance is very simple and the procedures are very sanitary. During regular operation, the ratio of sludge to refuse 4.2%, but Fig. 7 presents data derived when the sludge ratio has been changed. Even when the sludge ratio is increased to 20%, there are no adverse effects on the status of combustion. If the ratio is increased to 30%, however, the temperature of the fluidized sand drops to the level at which auxiliary heating is required. When this mixed combustion is terminated, the temperature of the sand rises to its previous level. If the calorific value of the refuse is higher, the proportion of sludge can be increased even further.

Economic Aspects

Revolving flow bed incineration facilities, in addition to having superior combustibility properties, are also either as economical or more so when they are compared to stoker incineration facilities. Generally the costs are from YEN 15,000,000/waste TPD to YEN 20,000,000/waste TPD. These costs vary depending on factors such as the presence of a gas cooling chamber or boiler and turbine, differences in building specifications and the strictness of anti-pollution control standards.

POSTSCRIPT

The major emphasis of refuse incineration in the past has been volume reduction, but with growing concern in recent years over environmental protection, regulations on pollution have become stricter. This in turn has stimulated greater demand for more thorough and safe incineration, as well as concern for the avoidance of secondary pollution. The revolving type fluidized bed incinerator is a new type of incinerator completely different from the conventional stoker incinerator. It has a variety of distinguishing features. We are confident that it will contribute substantially to waste treatment in the future by satisfying the aforementioned demand.

Key Words: Fluidized Bed; Fly Ash; Heavy Metals; Incineration; Refuse; Residue; Sludge