An Advanced Fluidized Bed Municipal Waste Incinerator for Dioxin Control

Minoru ASAI, Makoto SHIMIZU, Takeichi KONDO,
Yoshio TAKEUCHI, Hiroshi ARAMAKI, and Masanobu NAITO
Ishikawajima−Harima Heavy Industries Co., Ltd.
1 Shin−nakahara−cho, Isogo−ku, Yokohama−shi, Kanagawa, Japan

Dioxins generated by municipal waste incinerators are organic compounds synthesized from a combination of the hydrocarbons that survived combustion and chlorine produced during thermal decomposition of the waste. Complete combustion of the waste is there fore the fundamental means of suppressing their formation. This report discusses the principles and performance of an advanced fluidized bed incinerator installed with an independently controlled secondary swirl combustion chamber. The system we have developed employs a secondary combustion swirl chamber to incinerate unburned combustibles from the initial burning. The combustibles are carried into the secondary chamber via the bed material. Discussion includes promotion of the combustion of char as a typical difficult−to−burn matter, and the successful control of carbon monoxide and dioxin emissions.

Key words : Municipal Waste, Incinerator, Complete Combustion, Dioxin, Carbon Monoxide, Swirl Combustion Chamber, Char Circulation

1. Introduction

The dioxins and their precursors that are emitted from municipal waste incinerators are organic compounds synthesized from a combination of the hydrocarbons that survived combustion and chlorine produced during thermal decomposition of the waste. Moreover, it is known that they are more apt to form in oxidizing atmospheres at temperatures from 300～500°C. Therefore, the primary requisite for preventing dioxin emission is to burn the waste completely while it is still in the furnace. Less apparent though equally important is the need to optimize both the furnace design and combustion method so as to reduce the amount of unburnt matter, typically char, which requires a longer combustion period.

We previously utilized cold model experiments, combustion tests and computational fluid dynamics (CFD) analysis to demonstrate that, of the several furnace designs considered capable of promoting primary combustion gas and secondary air mixture, a design which provides the furnace with a throat (convergence) having secondary air ducts and another that makes use of an independent swirl combustion chamber for secondary combustion are promising configurations.[1)2)] Using the latter design subsequent tests have achieved near perfect combustion. These results are assumed to be attributable to the secondary swirl combustion chamber, where effective classification and combustion of char was observed as well as a high degree of gas mixing.

Encouraged by the test results, we built a 20t/day demonstration plant based on the design for a complete combustion fluidized bed incinerator incorporating bed material recirculation.

This report describes the results obtained with this demonstration plant.

2. Complete Combustion Fluidized Bed Incinerator

Figure 1 shows a composite diagram of the incinerator. Fundamentally, it comprises a fluidized bed, in which decomposition and gasification occur, and a secondary swirl combustion chamber, which was designed based on empirically acquired data to promote complete combustion.

As can be seen from the figure, unburnt gas from the fluidized bed is tangentially injected into the secondary combustion chamber through a convergent flow nozzle where it is mixed with secondary air so as to create a swirling flow. At the same time, the bed material (i.e. a mixture of sand and unburnt material) delivered from the fluidized bed is fed into the swirling gas stream.

The coarse sand in the bed material and char particles from the fluidized bed are separated by centrifugal force, and returned to the fluidized bed through the hopper, thereby constituting an external recirculation loop.

In the meantime, the finer particles ascend in the swirling gas stream slowing and conglomerating at the chamber top as the swirl loses velocity. As they descend down the chamber walls, a very dense film of particles forms, thereby constituting an internal recirculation loop. This high density film provides an excellent environment in which to burn the char at an enhanced rate.

In short, the features of this combustion system are threefold: 1) by establishing external and internal recirculation loops, the char burning period in the furnace is lengthened, 2) the high-density particle film increases the burn rate of the char, thus actualizing complete combustion; and 3) the swirling high-density particle film descending down the furnace walls prevents ash form hanging on the walls.

Figure 2 shows a view of the 20 t/day demonstration plant recently constructed to carry out actual incineration tests, and Figure3 shows the process flow.

In addition to the complete combustion fluidized bed incinerator, the plant features a gas clean-up line which comprises a water spray gas cooling tower, a slaked lime (calcium hydroxide) injector for removal of HCl, and a bag filter for exceptional dust separation.

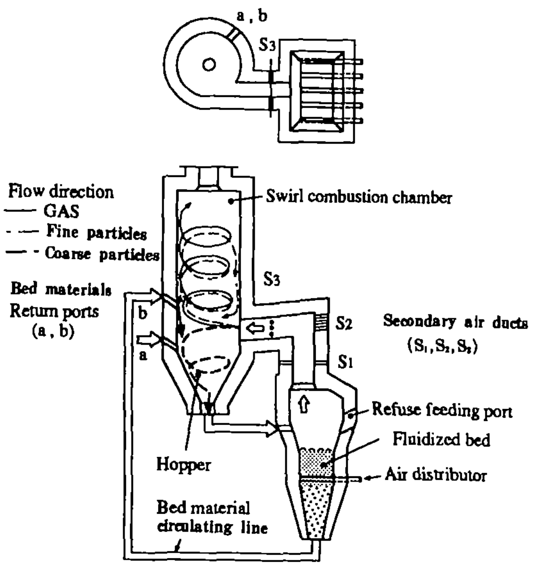


Fig. 1 Fluidized bed incinerator for complete combustion.

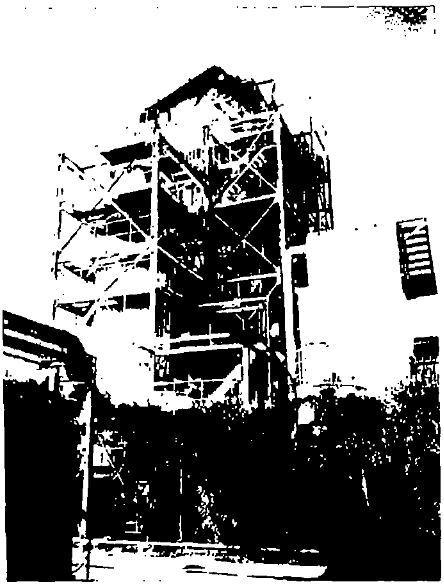


Fig. 2 The incinerator plant.

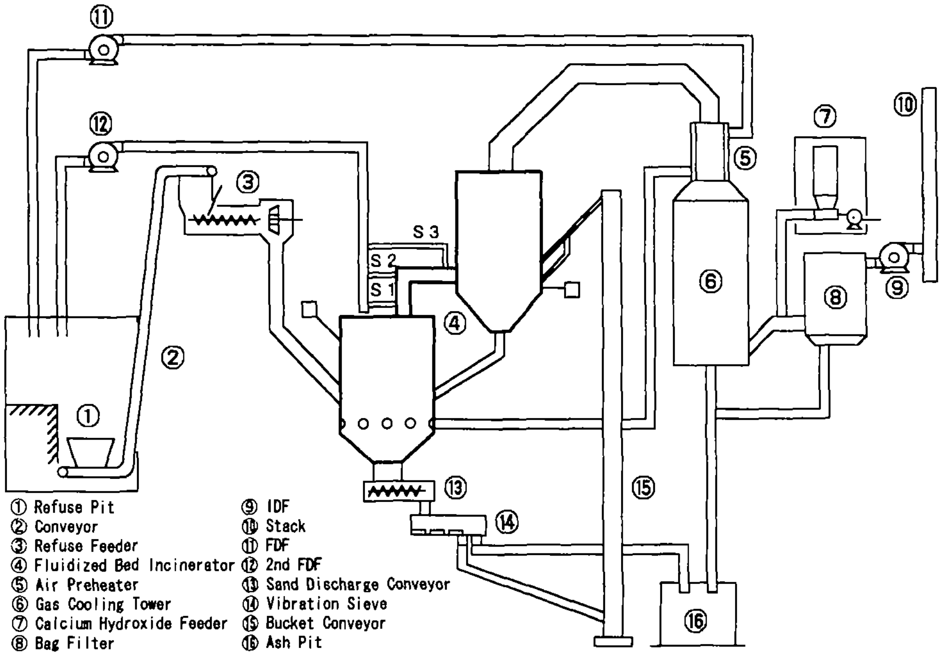


Fig. 3 Process flow diagram.

3. Combustion Test

Model refuse was used to determine the basic performance of the plant in quantitative terms. Vinyl–chloride laminate paper waste(Cl = 0.3 %) was prepared by pulverization and compressed into solid pebbles. This material is known for its property and compositional similarities to real refuse.

With the primary air ratio, combustion temperature and O_2 flue gas as the major parameters, comprehensive plant performance was evaluated. First, the optimum combustion conditions were determined, and then the process of returning the bed material to the swirl combustion chamber was examined to realize the beneficial effect in promoting combustion.

1) Optimization of Combustion Conditions

Figure 4 shows the partial time history of carbon monoxide CO concentration in flue gas as determined at the furnace and gas cooler outlets for three different primary air ratios (λ_1), while keeping the total air flow rate constant. Note in the figure that both the concentration and fluctuation of CO decrease the lower the value of λ_1. This is most likely due to slacking in the fluidized bed, which gives rise to improved combustion.[3)] A CO level of approximately 10ppm measured at the furnace exit for $\lambda_1 > 0.3$ is completely burned when passed through the hot flue, and no CO emission was observed.

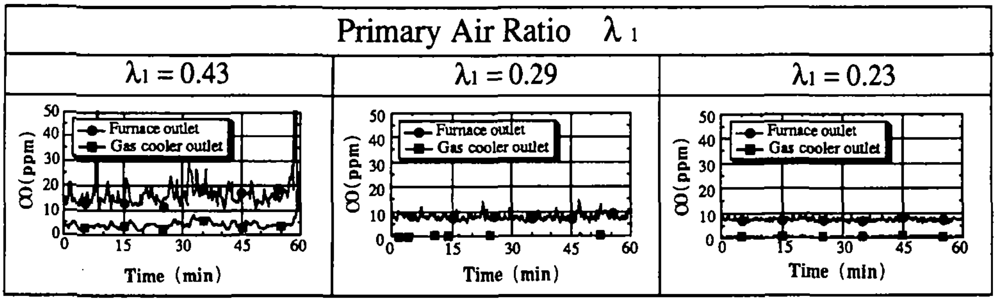


Fig. 4 Effects of primary air ratio on fluctuation and concentration of CO.

The effect of O_2 on the CO in flue gas is shown in Fig.5. The optimum O_2 concentration value that provides the minimum CO concentration is approximately 7.5 % at the furnace outlet end.

The effect of the combustion temperature, which was varied by controlling the amount of secondary air, is shown in Fig. 6. No signs of CO were found in the flue gas when the furnace outlet temperature was 830°C or higher.

Therefore, the optimum setting of combustion conditions is $\lambda_1 = 0.3$, an O_2 of 7.5% at the furnace outlet and a furnace outlet temperature of 830°C or higher.

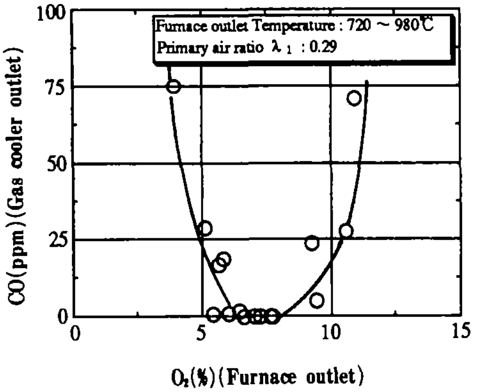


Fig. 5 Relationship between O_2 and CO.

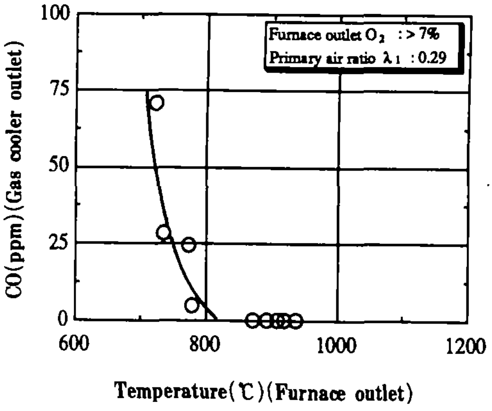


Fig. 6 Relationship between temperature and CO.

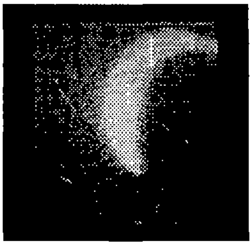
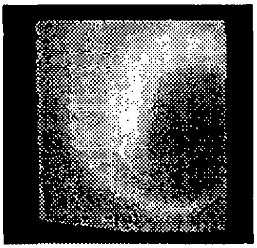
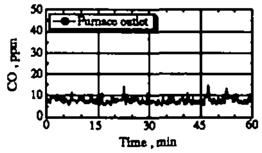
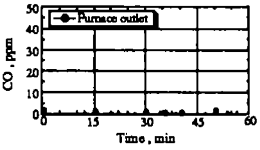
Return position of bed material	a.Hopper	b.Upper part of gas inlet port
Firing condition in the swirl combustion chamber		
CO - Chart (Furnace outlet)		
Unburnt carbon in flyash, %	0.3	0.15
Dioxin, TEQ-ng/Nm^3	0.49	0.18

Fig. 7 Effects of bed material return position on perfect combustion.

2) Effect of Recirculating the Bed Material

It was possible to prove that recirculation of the bed material provides several benefits. Changes in the injection point provided the clearest demonstration of this.

Figure 7 shows two such cases. In (a), the bed material was returned to the hopper of the secondary swirl combustion chamber, whereas in (b) it was injected directly into the primary combustion gas stream from the top of the gas inlet port. It should be noted that where the furnace outlet CO concentration was 9ppm and dioxin 0.49ng/Nm^3 in (a), they were zero and 0.18ng/Nm^3 in (b).

Moreover, it was observed that the amount of unburnt carbon in the flyash was halved, proving that combustion of char in the secondary combustion chamber was markedly improved. This may be understood by comparing the two photographs taken of the swirl(Fig 7). In (a), there is only a slight amount of the bed material rotating along the walls and burning coarse char can be seen all the time, whereas in (b) the swirling bed material is quite substantial and burning char is minimal.

4. Confirmation of Design Performance and Conclusion

Table.1 Example of Emissions at the Bag Filter Outlet.

Gas temperature(℃)	160
O_2(%)	10.9
CO(ppm)*	0
NO_x(ppm)*	80
HCl(ppm)*	4
SO_2(ppm)*	1
Dioxin(TEQ−ng/Nm^3)*	0.09
Particulates(mg/Nm^3)	1.8

＊ 12% O_2 convened

Table 1 presents the flue gas analysis made at the bag filter exit for the optimum combustion conditions of $\lambda_1 = 0.3$, $O_2 = 7.5$ %, and furnace outlet temperature = 900°C, *holding the gas temperature at the bag* inlet at 170°C. We believe this set of data, (i.e. zero CO, 80ppm of NOx, 4ppm of HCl, 1ppm of SO_2, and only 0.09TEQng/Nm^3 (0.25 at the bag inlet) of dioxins) promises highly efficient performance for the swirl combustion fluidized bed municipal waste incinerator when it is upgraded to commercial scale.

Acknowledgment

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