Emission Control of Dioxin Compounds in Plastic Waste Incineration

Kazuaki Watanabe, Keisuke Tsukamoto
Environmental Plant Department, Ebara Corporation
1-6-27 Kohnan, Minato-ku, Tokyo 108, Japan
Collaboration with Plastic Waste Management Institute (Japan)

1. Introduction

Even in Japan where the bulk of all wastes are disposed of by incineration, there is a reluctance to incinerate plastic waste. Following are the main reasons:

1) Since plastics have a high calorific content, they will produce high combustion temperatures, thereby causing damage to the incineration furnace.
2) In event plastic wastes contain polyvinyl chloride (PVC), they will generate highly concentrated hydrogen chloride (HCl), therefore leading to corrosion of the incineration facility and emission of toxic dioxin compounds (PCDDs, PCDFs).

The present study has demonstrated that the combustion of classified urban plastic wastes generally land-filled in reclamation sites in practical scale incineration plants under steady combustion states has led to an effective emission control of dioxin compounds.

2. Experimental

Fig. 1 is an outline of the incineration plant in this study which has a fluidized-bed incineration furnace. To achieve stable combustion , the secondary air flowrate and the waste feeding rate were automatically controlled on the basis of the flame sensor output and oxygen consumption rate. The combustion gas was divided between the main line and the branch line at the center section of the furnace top and the waste heat boiler, with the combustion gas flowrate in the branch line being 1500Nm^3/h. For heat exchange and cooling, the combustion gasses pass through the boiler, air heater, and quench chamber. The heating medium boiler in the branch line uses an alkyl benzene as heat carrier and is designed to prevent dust deposition. Concerning exhaust gasses treatment , the highly concentrated HCl gas is removed in the scrubber located after the fan while the toxic substances, in particular dioxin compounds, are eliminated in the bag house and through an activated coke filled bed.

As shown in Table 1, the waste materials in this study consisted of sorted urban plastic wastes land-filled in reclamation sites. After sorting and collection, these plastic wastes were treated with heating and compression for volume reduction. In order to stabilize the feeding rate, these were finely shred before entering the furnace. Fig. 2 shows the conditions of the plastic wastes before and after shredding.

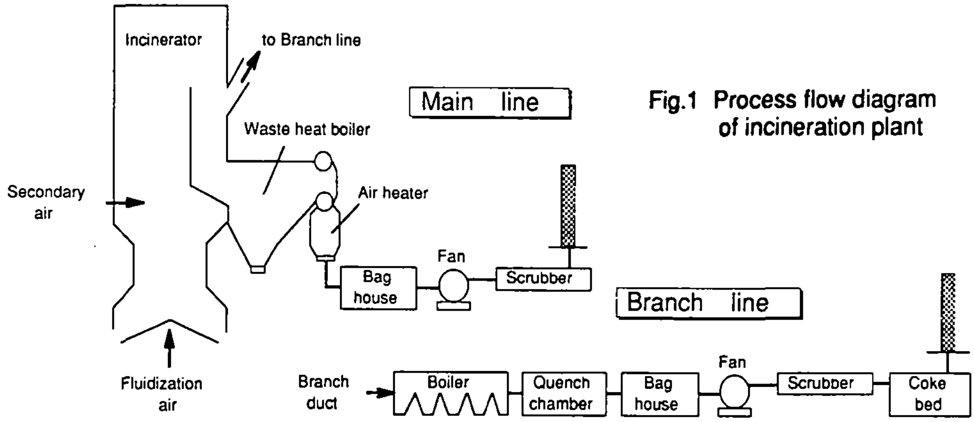

Fig.1 Process flow diagram of incineration plant

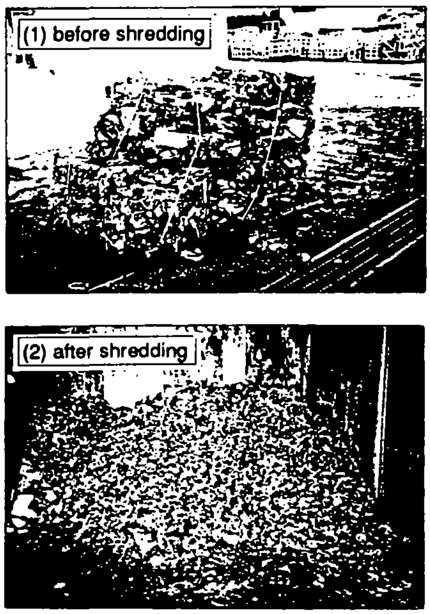

Fig. 2 The condition of the plastic waste

Table 1 Profile of plastics waste

Municipal solid waste treated with heating and compression for volume reduction	
Plastics content : 80 wt%	
Element composition [wt%]	
C	69.2
H	9.2
O*	10.45
N	0.3
volatile Cl	3.12
combustible S	0.03
others	7.7
Calorific value : 7740 kcal/kg	

* : calculated value

3. Results and Discussion

Table 2 shows the operating conditions in the test. The feeding rate of the plastic waste material was maintained at a practically uniform level of 530kg/h. As a result of appropriate control of the secondary air admission rate, it was possible to maintain the free board temperature generally at 800℃ or above. This also led to a low CO concentration being achieved, a typical sign seeing that the presence of CO is indicative of incomplete combustion.

The HCl concentration prior to passing through the scrubber was in the order of a few thousand ppm, and it is clear that the operating conditions in this plant favored the formation of dioxin compounds. The means to control dioxin emission can be classified in terms of where the reduction takes place: the waste material incineration process, the combustion gasses heat exchange / cooling process, or the elimination process from the exhaust gasses. It is generally considered important to minimize the unburned component as best in order to control the formation of dioxin compounds during combustion. In other words, it is crucial to ensure complete and stable combustion. The operating conditions for the incineration furnace in the present study may be described as favorable in this respect.

Table 2 Incinerator conditions during the experiments

Waste feed [kg/hr]	530
Fluidization air flow [Nm3/hr]	2800
Secondary air flow [Nm3/hr]	2800 - 6900
Free board temp. [℃]	760 - 850
Oxygen (B.H.inlet) [% d.b.]	11.5
CO (B.H.outlet) [ppm]	22
HCl (B.H.inlet) [ppm]	1750 - 2100
Fly ash (B.H.inlet) [g/Nm3]	0.27

B.H. : Bag house
d.b. : Dry basis

Fig. 3 shows the rate of regeneration of the various chlorinated dioxins at the boiler outlet, using the dioxin concentration at the boiler inlet as the reference standard. The dioxin concentration, including both PCDDs and PCDFs were observed to increase in the boiler. It represented the regeneration of dioxins by so-called "de-novo synthesis" through the combustion gas heat exchange / cooling process. The extent of regeneration was lower in the branch line boiler than in the mainline boiler, and this was true for both PCDDs and PCDFs. In the mainline, the rate of regeneration tended to be higher for the more chlorinated compounds whereas the regeneration trend for the branch line was the exact opposite.

It has been pointed out that the unburned carbon and heavy metals, especially copper, contained in the fly ash play an important role in the regeneration of dioxin compounds. Vogg and Stieglitz et al.[1)-4)] have conducted a series of laboratory experiments to study the formation of dioxins. Their results suggest that dioxin synthesis is promoted at temperatures of 300℃ and 470℃. Fig. 4 shows the residence time / temperature profile for the combustion gasses in the mainline and branch line boilers. The residence time in the range of 300 - 500℃, that is the temperature region believed to promote the formation of dioxins, was 3 seconds in the main line but only 1 second in the branch line. The above results suggest that the suppression of dioxin regeneration in the branch line boiler may be attributed to the differences in dust deposition in the boilers and also to the effect associated with the rapid cooling of the combustion gasses.

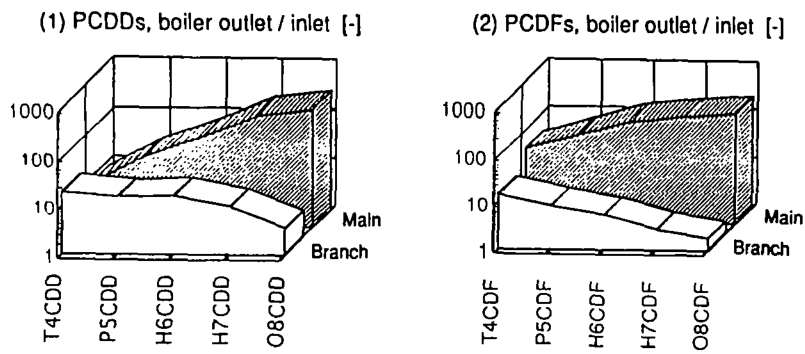

Fig. 3 Regeneration of PCDDs and PCDFs in boilers

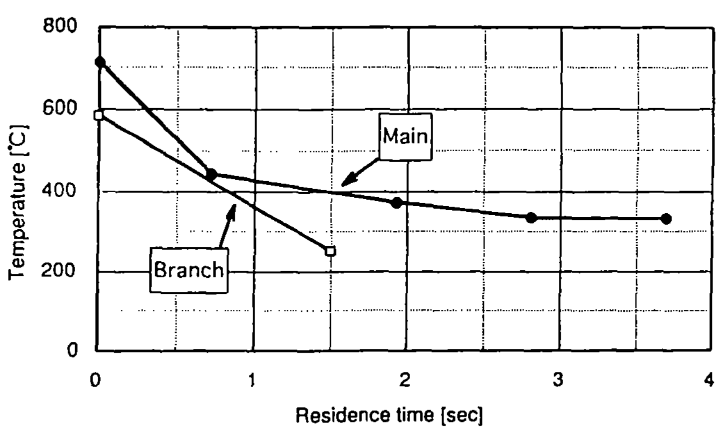

Fig. 4 Residence time / Temperature profile of combustion gas in boilers

The removal of dioxins from the exhaust gasses has been found to be the most effective countermeasure of dioxin emission in a practical incineration plant. Fig. 5 presents the test results. It can be seen that the concentration at the bag house outlet of the branch line was 0.6ng/Nm^3 I-TEQ, once increased through the scrubber [5], and then decreased to 0.13ng/Nm^3 I-TEQ at the outlet of the activated coke filled bed. The dioxins at the bag house outlet consisted of approximately 90% of PCDFs, with PCDDs accounting for only about 10%. At the coke bed outlet, however, the proportion of PCDFs was substantially reduced and the dioxin emission consisted of practically equal proportions of PCDFs and PCDDs.

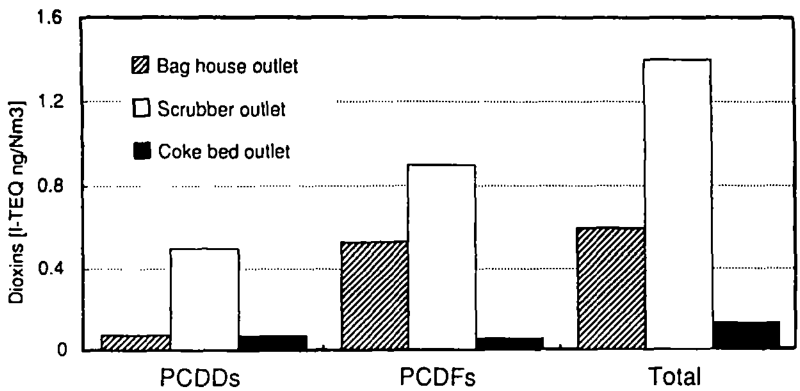

Fig. 5 Dioxin concentrations after exhaust treatment

The above results indicate the possibility of not only incinerating plastic wastes which have been considered unsuitable for incineration so far, but also clearing the government guidelines on the prevention of dioxin emission. This is substantiated by the achievement of complete and steady combustion, the prevention of dust deposition in the boiler, the rapid cooling of the combustion gasses, and the appropriate treatment of the exhaust gasses.

4. Conclusions

The present study has confirmed the following results:

1) It has been established that stable combustion of plastic wastes can be achieved as the result of a steady waste feeding rate and appropriate combustion control.
2) Efforts have been made to effectively reduce the regeneration of dioxins using a branch line boiler designed to prevent dust deposition.
3) With the rapid cooling of the combustion gasses in the branch line boiler, it was possible to suppress the formation of highly chlorinated dioxins.

4) The dioxin compounds contained in the exhaust gasses are effectively removed in the bag house and through the activated coke filled bed, leading to a low dioxin concentration of only 0.13ng/Nm^3 after advanced treatment.

Based on these experimental findings, further research will be made in an effort to establish a suitable incineration process for plastic wastes with the effective emission control of dioxin compounds.

5. References

1) H.Vogg, L.Stieglitz : Thermal Behavior of PCDD/PCDF in Fly Ash from Municipal Incinerators, Chemosphere, Vol.15, Nos.9-12, pp.1373-1378 (1986)
2) L.Stieglitz, H.Vogg : On Formation Conditions of PCDD/PCDF in Fly Ash from *Municipal Waste Incinerators, Chemosphere, Vol.16, Nos.8-9, pp.1917-1922* (1987)
3) L.Stieglitz, G.Zwick, J.Beck, W.Roth, H.Vogg : On the De-Novo Synthesis of PCDD/PCDF on Fly Ash of Municipal Incinerators, Chemosphere, Vol 18, Nos. 1-6, pp.1219-1226 (1989)
4) G.Schwarz, L.Stieglitz, W.Roth : Formation Condition of Several Polychlorinated Compounds Classes on Fly Ash of a Municipal Waste Incinerator, 10th Int. Symp. on Dioxin, Vol.3, pp.169-172 (1990)
5) S.Marklund, I.Fangmark, C.Rappe: Formation and Degradation of Chlorinated Aromatic Compounds in an Air Pollution Control Device for MSW Combustor, 11th Int. Symp. on Dioxin, S49 (1991)