REDUCTION OF DIOXINS FROM A MUNICIPAL SOLID WASTE INCINERATOR BY NATURAL GAS REBURNING

Ryo Takeya, Yasunobu Suzuki*, Yukio Kozai** and Haruhisa Sugiyama***

Energy Tech. Research Institute, Tokyo Gas Co., Ltd., 1-16-25, Shibaura, Minato-ku Tokyo 105-0023, JAPAN *Industrial Sales Dept., Tokyo Gas Co., Ltd., 3-7-1, Nishi-shinjuku, Shinjuku-ku, Tokyo 163-0010, JAPAN **Kawasaki Heavy Industry LTD, 1-1-3, Higashi-kawasakicho, Chuo-ku, Kobe 650-8680, JAPAN ***Kodaira Murayama Yamato Sanitation Association, 2-1, Nakajimacho, Kodaira 187-0033, JAPAN

Introduction

MSW (municipal solid waste) incinerators are increasingly being used, particularly in densely populated urban areas like Tokyo that have little space for landfill. Natural gas reburning technology, which was originally invented to reduce NOx emissions from utility boilers (1-6), has been applied to the reduction PCDDs/Fs emissions from MSW incinerators (7-13). This study highlights an experimental and theoretical study to investigate the effect of natural gas reburning on the reduction of PCDDs/Fs. An existing full-scale MSW incinerator in Tokyo area with the capacity of 105 ton/day was retrofitted to accommodate the natural gas reburning. Detailed measurement of PCDDs/Fs was taken at various key points such as combustion chamber exit, inlet and outlet of an ESP to investigate the effect of reburning on the whole process. Along with PCDDs/FS sampling, temperature and major gas species were measured inside the combustion chamber as well as along the exhaust gas cleaning process. The experimental investigation, numerical method was established to simulate the complex phenomena of flow, heat transfer and combustion in the MSW incinerator (14, 15). Numerical simulation was conducted to optimise the design of the natural reburning and maximise the effect of reburning.

Materials and Methods

Figure 1 shows the schematic of a stoker-fired MSW incinerator accommodating natural gas reburning. Natural gas is injected to create a sub-stoichiometric environment in the reburning zone to reduce NO generated by the combustion of wastes. The flow rate of natural gas is generally set at 5-20% of the wastes on heat value basis. Secondary air is injected into the downstream of the reburning zone to complete the oxidation of CO and possibly unburnt combustibles like dioxins and their precursors.





Figure 2 Schematic of a MSW incinerator with natural

Formation and Sources P149

Figure 2 shows the schematic of the MSW incinerator retrofitted for the natural gas reburning. The combustion chamber was refractory lined. The exhaust gas from the combustion chamber was introduced into a water

quenching chamber to be cooled down to about 300C. After slaked lime injection for HCl removal, the exhaust gas was led to an ESP (electrostatic precipitator). Since it has only 1% of the flow rate of the primary combustion product generated from wastes, natural gas was mixed with re-circulated exhaust gas (EGR) to boost the momentum and promote the mixing with the primary combustion products. Exhaust gas was taken from the downstream of the ESP and mixed with natural gas before being injected into the combustion chamber. Approximately 10-15% of the total exhaust gas was re-circulated. The combustion chamber had two different positions for the injection of the reburning gas, one from the front and the other from the rear. Secondary air was injected from downstream of the reburning zone through the both sides of the incinerator.

Preliminary measurement was conducted to collect detailed operational data that were used for a numerical simulation of the



Figure 3 Predicted distributions of temperature



Figure 4 Predicted distributions of CO

incinerator. Concentrations of O2, NOx, CO and CO2 and temperature were measured continuously at various points inside the combustion chamber. By using the measured data, numerical simulation was conducted to optimise and determine reburning operating conditions for injection position, flow rate and velocity of reburning natural gas. Figures 3 and 4 show the results of CFD simulation. Figure 3 shows temperature. Under the optimised reburning operation, temperature distribution in the reburning zone is more uniform and higher than

under the baseline. Figure 4 shows the distributions of CO concentration. CO can be reduced faster under the reburning operation than the baseline, presumably due to enhabced mixing as well as elevated temperature in the combustion chamber.

Table 1 shows operating conditions for the demonstration test that were determined by the support of the numerical simulation. PCDDs/Fs

ORGANOHALOGEN COMPOUNDS Vol. 41 (1999)

Table 1 Operating conditions

	Conditions	Baseline	Baseline with	Reburning		
	oonaltiono	Baconno	Air	Run 1	Run 2	Run 3
	Waste Feed (t/h)	4.40	3.51	4.07	4.25	4.12
21	Waste LHV					
	(MJ/kg)	8.736	7.422	7.598	9.063	8.217
	(kcal/kg)	(2087)	(1773)	(1815)	(2165)	(1963)
	Primary Air					
	(Nm³/h)	10600	10050	10360	9670	9740
	Ignition loss (%)	2.47%	2.34%	2.62%	3.27%	2.77%
	O ₂ in Comb.					
	Chamber (%)	4.80%	2.20%	2.20%	3.20%	4.60%
	O ₂ at Comb.					
	Chamber Exit (%)	11.20%	10.50%	6.00%	7.00%	7.40%
				Front:6	Front:4	Front:8
	Natural Gas			Rear: 6	Rear: 6	Rear:8
	(Nm ³ /h)	-	-	Total:9	Total:8	Total:6
	74			Front: 820	Front: 230	Front: 000
	EGR			Rear: 690	Rear: 270	Rear: 920
	(Nm ³ /h)	-	-	Total: 9 10	Total: 900	Total:920
		Front: 540	Front: 200	Front: 480	Front: 570	Front:100
	Secondary Air	Rear: 590	Rear: 270	Rear: 620	Rear:650	Rear:140
	(Nm ³ /h)	Total: 330	Total: 670	Total: 300	Total: 220	Total:240
	Flue Gas					
	(Nm ³ /h)	36200	36000	35600	37800	30000
	EP InletTemp.					
	(°C)	262	261	261	261	233

were measured under five conditions: baseline, baseline with low primary air and three reburning conditions. In the reburning operations, Runs 1 and 2 were employed to investigate the effect of the degree of EGR while maintaining the flow rate of natural gas identical. Run 3 was aimed to investigate the effect of lowering the temperature of ESP.

For all operations PCDDs/Fs in exhaust gas were sampled at the combustion chamber exit, cooling chamber exit, ESP inlet and exit. Bottom ashes, cooling chamber ashes and ESP captured ashes were also sampled and analysed. Beside PCDDs/Fs, Chloro-benzenes and Chloro-phenols were sampled and analysed as well.

Results and Discussion

Figure 5 shows PCDDs/Fs concentration in exhaust gas at combustion chamber exit, cooling chamber exit and inlet and exit of ESP. The baseline and baseline with low primary air operation showed PCDDs/Fs of 1.4 and 2.6 ng I-TEQ/Nm3 at the combustion

chamber exit respectively. Reburning operations showed promising results. PCDDs/Fs concentrations at the combustion chamber exit reduced by more that half, down to 0.17-0.54 ng I-TEQ/Nm3. These results clearly demonstrated the positive effect of reburning on the reduction of PCDDs/Fs in the combustion chamber. The oxidation of combustible precursors as well as PCDDs/Fs is expected to be promoted under the reburning process that creates relatively uniform and high temperature distribution in the combustion chamber. As for PCDDs/Fs concentrations at the ESP exit, baseline



Figure 5 PCDDs/Fs in flue gas

and baseline with low primary air operation showed 1.2 and 1.6 ng-TEQ/Nm3 respectively. Under reburning, PCDDs/Fs were reduced to 0.85 and 0.41 ng I-TEQ/Nm3 for Runs 1and 2 respectively. The effect of ESP temperature is also shown in Figure 5. With lowered ESP temperature of 230C for Run 3, PCDDs/Fs concentration was reduced to 0.26 ng I-TEQ/Nm3 at the ESP exit. Clear effect of ESP temperature was observed.

Figure 5 shows somewhat inconsistent behaviour of PCDDs/Fs variation across the air preheater and the ESP. Runs 1 and 3 showed greater increase in PCDDs/Fs between the cooling chamber exit and the ESP inlet and again greater decrease between the inlet and exit of the ESP than the other Runs. Reasons for this behavior is under investigation.

ORGANOHALOGEN COMPOUNDS Vol. 41 (1999) 275

Figure 6 compares total PCDDs/Fs emission including PCDDs/Fs in exhaust gas and ashes at the three different ash collecting points. Runs 1 and 2 resulted in relatively low concentrations of total PCDDs/Fs of 23.5 and 14.9µg I-TEQ/ton of wastes respectively, compared to the baseline and baseline with low primary air operations of 27.4 and 32.8µg I-TEQ /ton. Run 3, reburning with low temperature ESP, resulted in the lowest total PCDDs/Fs emission of 14.5µg I-TEQ /ton. While the mechanisms of formation and destruction of PCDDs/Fs in the reburning process are not yet well-known, the observation here shows somewhat encouraging results on the positive effect of reburning.



Figure 6 Total PCDDs/Fs from incinerator

Acknowledgement

The authors would like to express their

thankful acknowledgement to Takuma Co., Ltd, Hyogo, Japan for its support to the design, planning and execution of this study.

References

- 1. Wendt, J. O. L., Sternling, C. V. and Matovich, M. A., 14th Symp. (intl.) on combust., 1973.
- 2. Myerson, A. L., 15th Symp. (intl.) on combust, 1975.
- 3. Song, Y. H. Blair, D. W. Siminski, V. J. Bartok, W., 18th Symp. (intl.) on combust., 1981.
- 4. Miyadera, T., Kougai, 1987, 22(3), 95.
- 5. Takahashi, A., et al, Mitsubishi Juko Giho, 1980, Vol. 17, No. 6, pp. 65-70.
- 6. Takahashi, A., et al, Mitsubishi Juko Giho, 1980, Vol. 17, No. 6, pp. 71-76.
- 7. Wakamura, Y., et al, Proceedings of the 12th Conference of Japan Waste Management association, 1991.
- 8. Aso, T., et al, 5th Symposium on Environmental Engineering, 1995, pp132-135.
- 9. Aso, T., et al, Japanese Flame Days JFRC 20th Anniversary, 1997, pp. 1-10.
- 10. Sawachi, H. et al, 8th Conference of the Japan Society of Waste Management Experts, 1997, pp. 599-601.
- 11. Aso, T. et al, Thermal Engineering Symposium, 1995, pp. 105-106.
- 12. Sameshima, R. et al, The Thermal and Nuclear Power, 1996, Vol. 47, No. 476, pp. 59-68.
- 13. Sameshima, R., Fuel and Combustion Engineering, 1996, Vol. 63, No. 6, pp. 1-13.
- 14. Takeya, R., et al, 7th ISWA International Congress, 1996, pp. II-221.
- 15. Takeya, R., et al, 4th Intl. Conference on Tech. and Combst. for a Clean Environment, 1997, Vol. 1, pp. 5.2.

ORGANOHALOGEN COMPOUNDS Vol. 41 (1999)

276

Formation and Sources P149

ORGANOHALOGEN COMPOUNDS 277 Vol. 41 (1999)