ON THE DESIGN OF SMALL-SCALE INCINERATOR WITH LOW PCDDs / PCDFs EMISSIONS

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ABSTRACT

Complete combustion by improving secondary combustion was tried to reduce PCDDs / PCDFs in small-scale incinerator. Specifically, the turbulence in the secondary chamber was increased for the effective reduction of PCDDs / PCDFs. First, gas flow in the secondary chamber was analyzed with laboratory scale equipment, using the flow visualization technique. Then the combustion efficiency was evaluated using a model gas with standard CO mixing. And then the reduction of PCDDs / PCDFs was confirmed for an actual plant. A significantly reduced level was found by modification of the flow pattern in secondary chamber.

INTRODUCTION

Complete combustion is an effective way for the reduction of PCDDs / PCDFs emissions. With incomplete combustion, dioxin compounds and their precursors are emitted from the incinerator. Especially with small-scale incinerators operated intermittently, combustion of wastes in the primary combustion chamber is easily made unstable[1),2)]. The requirements for complete combustion are based on (1) high temperature, (2) good turbulence, (3) sufficient time and (4) sufficient O_2[3)]. An attempt to keep the temperature high by after-burnning and to increase turbulence by modifying the gas flow in the secondary combustion chamber had been done in order to reduce PCDDs / PCDFs emissions. This report describes the investigation to optimize the gas-flow pattern in the secondary combustion chamber and to confirm the reduction of PCDDs / PCDFs in the actual plant.

EXPERIMENTS

The outline of the research phases and their purposes are shown in Table 1. It has been hypothesized that the gas flow in existing small-scale equipments was close to a laminar flow, and there was little turbulent flow within the secondary chamber. For the complete combustion of pyrolyzed gas and soot, it was thought to be important to thoroughly mix the gas with O_2 and to eliminate any short-pass. We would then try to modify some gas flow configurations at the gas inlet and outlet of the secondary chamber. The research had 3 phases, (1) the cold model: visualization of the gas flow pattern; (2) the hot model: evaluation of combustion efficiency using a model gas; (3)the pilot model: confirmation in the actual plant.

Table 1. Research phases and their purposes

	Research phases	Object gas	Purpose	Evaluation index
1	Cold model	air	*to investigate the optimization of gas flow turbulence*	visualized picture of gas flow
2	Hot model	mixed model gas with CO	to evaluate the CO combustion efficiency and mixing quality	•CO concentration •gas velocity in section
3	Pilot model	actual combusted gas	to confirm the improvement in the actual plant	PCDDs / PCDFs, CO concentration

RESULTS AND DISCUSSION

(1) Cold model

The Smoke-Wire Method was used to visualize the gas flow[4)]. Fig 1 illustrates the setup for this method. A wire is stretched horizontally across the section, and it is coated with oil. An increasing electric current is applied through the wire to generate white smoke. After a predetermined delay a strobe light illuminates the smoke pattern and photographs are taken. In this experiment, the state of the gas-flow were observed when the gas-inlet patterns were changed into concentric and eccentric and when the several types of baffle plates were settled. Representative pictures of the gas flows are shown in Fig 2. Flow A is the case of a concentric inlet without baffle plate (this was formerly the present configuration). In this case, there is little turbulence. Flow B is the case of an eccentric inlet without baffle plate. In this case, the gas-flow is observed to revolve. And Flow C is the case of an eccentric inlet and a doughnut-shaped baffle plate near the cylinder outlet. Two items, an eccentric gas-inlet and a doughnut- shaped baffle plate near the cylinder outlet, are effective in stimulating turbulence.

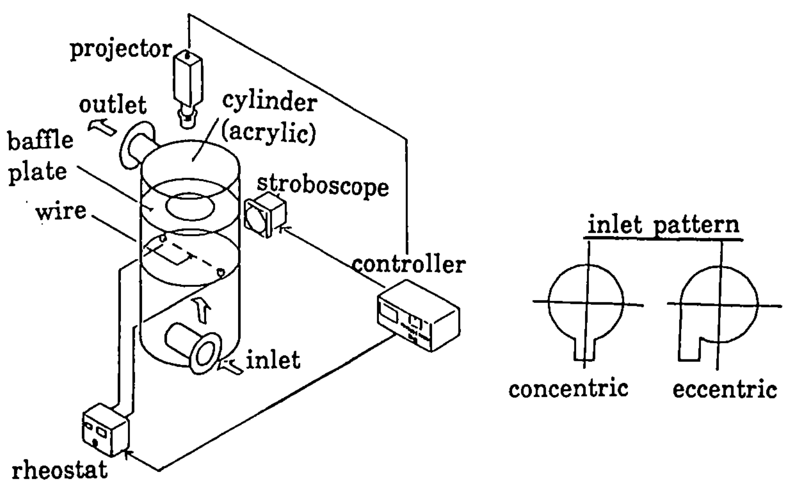
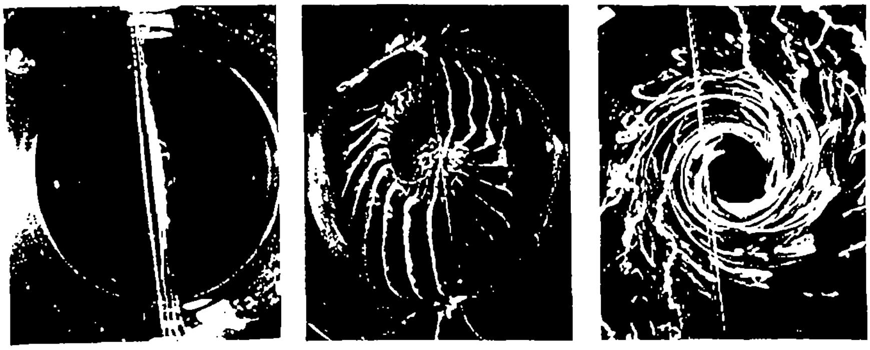


Fig 1. Smoke-wire Method setup



Flow A Flow B Flow C

Fig 2. Photographs of gas flow

(2) Hot model

In this test, first the gas velocity in the section was measured, and then the efficiency of CO reduction was studied. Fig 3. is a conceptional illustration of this model .This test used the model gas that was prepared by mixing of standard CO gas and hot gas by combusting propane. In this test, an axial-flow outlet is used instead of a baffle plate. The gas velocity distribution pattern is shown in Fig 4. With the concentric inlet, gas velocity is low throughout the whole section. With an eccentric inlet and orthogonal outlet, high velocity flow is seen in the outside area of the section, but there is low velocity flow in the center area. On the other hand, with an eccentric inlet and an axial-flow outlet, there is high velocity vortex flow throughout the section. The amounts of CO reduction in the three cases are shown in Table 2. In the case of the concentric inlet with little turbulent flow, the output concentration of CO was 105 ppm. In the case of the eccentric inlet and axial-flow outlet the level was about one-fifth of that, 20 ppm. This shows that high turbulent flow results in a significant reduction in CO.

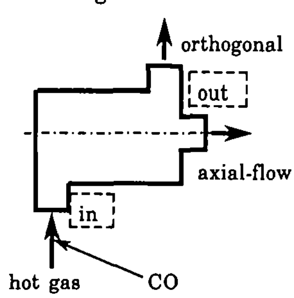


Fig 3. Conceptional illustration of hot model

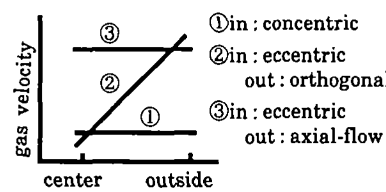


Fig 4. Cross-section distribution of gas velocity (in the middle area of cylinder)

Table 2. CO reduction effect in each case

Inlet	concentric	eccentric	eccentric
Outlet	orthogonal	orthogonal	axial-flow
Output CO concentration	105ppm	38ppm	20ppm

Experiment condition
- Inlet CO concentration : 10,000ppm
- Inlet gas temperature : 700°C
- Retention time : 1.9 sec

(3) Pilot model

In the previous test, combustion efficiency have been evaluated by using a model gas. Pilot model had an aim to simulate the actual municipal solid waste incinerator. Table 3. shows the value of PCDDs / PCDFs and CO concentration at the secondary combustion chamber outlet. The use of an eccentric inlet and an axial-flow outlet results in good combustion quality.

Table 3. PCDDs / PCDFs and CO in each case (all figures at 12% O_2)

		CO (ppm)		PCDDs / PCDFs (ng / Nm^3)	
Inlet	Outlet	Mean value	Maximum peak value	Total	I-TEQ
concentric	orthogonal	38	1,000	210	2.3
eccentric	orthogonal	5	120	39	0.69
eccentric	axial-flow	<2	<2	8	0.05

Next are the results for an actual plant with an eccentric inlet and axial-flow outlet. A schematic of the facility and the sampling points are shown in Fig 5. The sampling points are at the outlet of the incinerator, air pre-heater, gas cooler and fabric filter. The measured values at each points are shown in Table 4. Although PCDDs / PCDFs increased considerably at the air pre-heater and at the gas cooler, the actual facility with an eccentric inlet and axial-flow outlet had a low level emission of PCDDs / PCDFs in the exhaust gas from the incinerator.

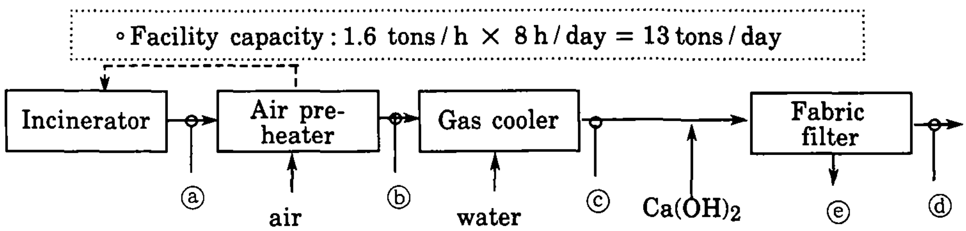


Fig 5. Schematic of the facility and the sampling points (ⓐ~ⓔ)

Table 4. Results of measurement in he facility

		ⓐ	ⓑ	ⓒ	ⓓ	ⓔ
Temp. (°C)		820~910	570~620	210	190	--
O_2 (%)	range	6.0~11.1	6.3~12.4	6.7~12.7	10.1~14.4	--
	mean	9.1	9.6	9.6	12.3	--
CO (ppm)		<2	→	→	<2	--
PCDDs*) / PCDFs	total	8	48	205	200	1.23
	I-TEQ	0.05	0.79	2.52	2.60	0.013

*) ng / Nm^3 in gas(ⓐ~ⓓ), ng / g in fly ash(ⓔ)

CONCLUSIONS

Regarding the ability to increase turbulence by changing the gas flow in the secondary combustion chamber, an eccentric inlet creates a revolving gas flow and an axial-flow outlet creates a vortex flow. This increased turbulence reduces PCDDs / PCDFs emissions from the incinerator. Though small-scale incinerators operate intermittently to exhibit unstable combustion of wastes in the primary combustion chamber, after-burnning with high-turbulence enables the stable and effective combustion of organic gas .The reduction of PCDDs / PCDFs emissions was confirmed by the modification of gas flow on the actual small-scale incinerator. It will be necessary to continue a research to suppress the increase of such emissions at exhaust gas treatment equipment.

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