PLASMA MELTING TECHNOLOGY OF PCB-CONTAMINATED WASTES

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Abstract
Application of plasma melting technology to PCB(Polychlorinated Biphenyl)-contaminated waste treatment is investigated in experimental manner, using a pilot plant of 1 ton/day capacity. Various types of PCB-contaminated wastes, such as fluorescent light ballasts, carbonless copy paper, wiping cloth waste and sludge are treated in the pilot plant. The result of measurement demonstrated high decomposition ratio of PCB up to 99.999999% and low PCB concentration in both of solid residues and exhaust gas, satisfying Japanese regulations. Moreover, aiming lower dioxins(DXNs) emission in exhaust gas, an enhanced gas treatment system with locating second bag filter after the catalyst tower is also examined. Applying activated carbon powder injection to the second bag filter at lower operation temperature, low exhaust gas DXNs emission compared with Japanese regulation is achieved consistently through repeated measurements.

Introduction
PCB(Polychlorinated Biphenyl) is an inflammable liquid at atmospheric pressure and at room temperature, and has several advantageous natures such as high electrical isolation, high boiling temperature, chemical stableness and heat resistance. Due to such advantages, PCB had been used as electric transformer and capacitor oil, or in carbonless copy paper, and so on, until 1970s.
Due to its toxicity, production of PCB in Japan is banned in 1972, and most of the PCB-containing devices in Japan are left untreated until the end of 20th century[1]. In 2001, "Law concerning special measure against PCB waste" is legislated, and a number of PCB treatment technologies became available by then. Today, several facilities using chemical destruction method are in operation.
Table 1 shows the quantities of PCB waste in stock and in use[2]. Among the table, PCB-contaminated solid wastes(or PCB-contaminated wastes), such as (6)Fluorescent Light Ballasts, (9)Carbonless Copy Paper, (10)Wiping Cloth Wastes and (11)Sludge, shown in Photos 1-4, are not to be treated in the existing facilities using chemical destruction method because of various kinds of their natures, states, materials and products.
The authors applied plasma melting technology to the treatment of PCB-contaminated wastes, and obtained high PCB destruction ratio and lower PCB concentration than Japanese regulations in both of solid residues and flue gas emission.

Table 1 Quantity of PCB-contaminated Wastes in Stock and in Use in Japan (as of March 2001)

	In Stock	In Use
(1) High Voltage Transformers	16 496units	1 689
(2) High Voltage Capacitors	220 345units	30 502
(3) Low Voltage Transformers	30 412units	616
(4) Low Voltage Capacitors	1 146 383units	17 510
(5) Pole-mounted Transformers	1 713 291units	1 967 000
(6) Fluorescent Light Ballasts	4 170 839units	868 256
(7) PCB	12 955ton	55kg
(8) Oil containing PCB	142 261ton	3kg
(9) Carbonless Copy Paper	679ton	—
(10) Wiping Cloth Wastes	215ton	—
(11) Sludge	17 698ton	—
(12) Others	199 873units	42 067


Photo. 1 Ballasts


Photo. 2 Carbonless Copy Paper


Photo. 3 Sludge


Photo. 4 Cloth Waste

Materials and Methods[3]
<u>Principle</u>
Schematic diagram of plasma melting furnace is

illustrated in Figure 1. PCB-contaminated wastes are canned into containers such as drum cans, without shredding or disassembling. Then, the waste container is pushed into the plasma furnace, one by one. For plasma torch, air is used as plasma gas. In the plasma furnace, plasma torch generates high temperature plasma gas so that the furnace temperature is maintained to melt the wastes together with the container itself. The operator observes the inside of the furnace through an ITV camera, and move the plasma torch using torch manipulator to focus the plasma gas jet on a certain target wastes. All the organic substances including PCB is decomposed to CO_2, H_2O and HCl under high temperature atmosphere in the plasma furnace, and the non-organics including metal are oxidized to become molten slag.

Figure 2 shows the block flow diagram of plasma melting furnace system. The exhaust gas from the plasma furnace is introduced into high temperature chamber with retention time of 2 seconds at 1200 degree C, assuring the decomposition of PCB, then quickly quenched to approximately 200 degree C in gas cooling tower. As the exhaust gas pollution control, 2-stage bag filter with lime injection removes dust and acid gas such as HCl and SOx, and then a catalyst tower with NH_3 gas injection removes NOx. At the last stage of gas treatment system, activated carbon adsorption tower is installed as a "safety net" to prevent PCB emission in case of emergencies. Slag and bag filter dust are discharged from the plasma furnace and bag filters respectively, as solid residues.

Pilot Plant

A pilot plant of one ton/day capacity is used to perform the experimental study. In this pilot plant, PCB contaminated wastes are canned in 20-liter pail cans and pushed into the plasma furnace. Photo 5 shows the overview of the pilot plant. Photo 6 shows an ITV image of inside of the plasma furnace.

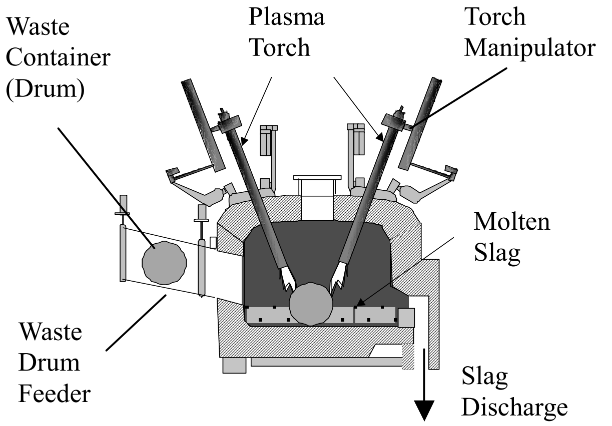

Figure 1 Schematic Illustration of Plasma Melting Furnace

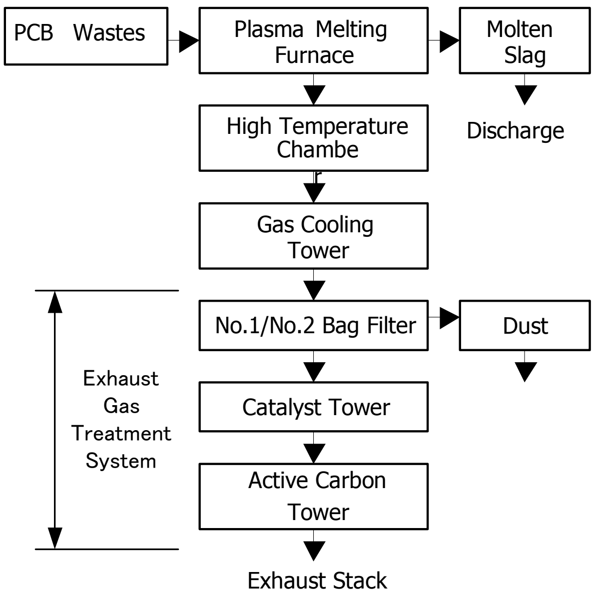

Figure 2 Schematic Flow Diagram of the Pilot Plant

Photo. 5 Overview of the Pilot Plant

Photo. 6 Inside View of Plasma Furnace

Results and Discussion

Mixed Test[3]

The first test series is called "mixed test", various kinds of PCB-contaminated wastes are canned into pail can altogether, namely, sludge 7kg, ballasts 6kg, wiping cloth 0.08kg, carbonless copy paper 0.28kg and concrete blocks(non-contaminated) 4kg. These weight composition is decided to simulate the average of stored PCB-contaminated wastes in Japan, in accordance with governmental statistics(as shown in Table 1). Each can is approximately 20 kg and PCB concentration is 1.3%. Five tests, Run 1 to 5, are carried out in five consecutive days. In each test, 16 cans are treated in 8 hours.
PCB balance in Run 1 is summarized in Table 2. PCB destruction ratio is calculated to be 99.9999% to 99.999999% in five test runs. PCB concentration of exhaust gas is measured to be 1.6 to 19 ng/m^{3}N in five test runs, which is substantially lower than the Japanese regulation, 0.1mg/m^{3}N. For slag and bag filter dust, PCB leaching test results are <0.0005mg/liter, where Japanese regulation is 0.003mg/liter.
For dioxins(DXNs) concentration, Table 3 shows result of Run 1 for solid residues and gas emission. Slag and dusts satisfies Japanese regulations of DXNs emissions, namely, 3ng-TEQ/g. For exhaust gas, DXNs concentration is lower than the regulations of PCB-contaminated waste treatment plant, namely, 0.1ng-TEQ/m^{3}N at O_2=12% equivalent conversion.

Table 2 PCB Balance in Mixed Test

(Note: BF = Bag Filter, Gas Volume is dry basis)

				Run1
IN	PCB Wastes	Amount	kg/8h	319
		PCB Content	%	1.3
OUT	Slag	Amount	kg/h	30.25
		PCB Content	mg/kg	0.000027
	No.1BF Dust	Amount	kg/h	9.68
		PCB Content	mg/kg	0.00016
	No.2BF Dust	Amount	kg/h	11.41
		PCB Content	mg/kg	0.000069
	Cat. Tower Exit Gas	Gas Volume	m^{3}N/h	1790
		PCB Content	μ g/m^{3}N	0.0051
PCB Destruction Ratio			%	99.999998

Table 3 DXNs Concentration of Residues in Mixed Test(Note:BF=Bag Filter, Gas Volume is dry basis)

		Run1
Slag	ng-TEQ/g	0
No.1BF Dust	ng-TEQ/g	0.000031
No.2BF Dust	ng-TEQ/g	0.00000020
Cat. Tower Exit Gas	ng-TEQ /m^{3}N	0.00029
	(@ O_2=12%)	(0.00035)

Non-Mixed Test[3]

The second test series is called "non-mixed test" or "single-species test"; only a single species of PCB-contaminated wastes is canned in the container. This is to investigate the effect of PCB concentration of input wastes. In mixed test, PCB concentration of specimen is 1.3%, which is rather lower than those of sludge and wiping cloth, 27% and 21%, respectively.
Tests for fluorescent light ballasts, carbonless copy paper, sludge and wiping cloth wastes are carried out. PCB balance comparing input and output is summarized in Table 4. Even under high PCB concentration of PCB-contaminated wastes, PCB destruction ratio is more than 99.9999%, and exhaust gas satisfied the Japanese

Table 4 PCB Balance in Non-Mixed Test (Note: BF=Bag Filter, Gas Volume is dry basis)

				Run1 Ballasts	Run2 Copy Paper	Run3 Sludge	Run4 Cloth Wastes
IN	PCB Wastes	Amount	/8h	37kg x 9can	7kg x 28can	10kg x 26can	7kg x 26can
		PCB Content	%	1.5	0.65	27	21
OUT	Slag	Amount	kg/h	63	5.5	5.8	3.8
		PCB Content	mg/kg	N.D.	0.0000028	0.000017	0.0000092
	No.1BF Dust	Amount	kg/h	5.7	6.1	5.5	7.5
		PCB Content	mg/kg	0.00089	0.0071	0.00074	0.0025
	No.2BF Dust	Amount	kg/h	5.2	6.2	5.3	5.8
		PCB Content	mg/kg	0.00018	0.00095	0.0013	0.0082
	Catalyst Tower Gas	Gas Volume	m^{3}N/h	1450	1640	1620	1700
		PCB Content	μ g/m^{3}N	0.019	0.023	0.012	0.024
PCB Destruction Ratio			%	99.9999944	99.999945	99.9999997	99.9999978

Table 5 DXNs Concentration of Residues in Non-Mixed Test (Note: BF=Bag Filter, Gas Volume is dry basis)

		Run1 Ballasts	Run2 Copy Paper	Run3 Sludge	Run4 Cloth Wastes
Slag	ng-TEQ/g	0	0	0	0
No.1BF Dust	ng-TEQ/g	0.0036	0.0038	0.10	0.068
No.2BF Dust	ng-TEQ/g	0.0019	0.00000072	0.016	0.093
Catalyst Tower Exit Gas	ng-TEQ /m^3N	0.041	0.044	0.00023	0.068
	(@O_2=12%)	(0.051)	(0.056)	(0.00031)	(0.089)

regulation of PCB emission. For solid residues, similar to mixed test, leaching test results are <0.0005mg/liter.

In Table 5, DXNs concentrations of solid residues and emission gas are shown. They are also lower than the Japanese regulations of DXNs emissions.

<u>Enhanced Gas Treatment System</u>

To obtain lower level of DXNs concentrations in exhaust gas, an enhanced gas treatment system, which is shown in Figure 3, is examined in another test series. To compare with the gas treatment system shown in Figure 2, No.2 Bag Filter(BF) is located after Catalyst Tower, and active carbon powder injection is applied to No.2BF. In addition, cooling air is introduced at inlet of No.2BF and operation temperature is maintained at 170 degree C to ensure DXNs adsorption by active carbon powder.

Fluorescent light ballasts, small electric devices(capacitors), and capacitor components impregnated with PCB oil are used as PCB-contaminated waste specimen. These wastes are canned into pail cans to feed into plasma furnace. Typical PCB content in each can is from 0.4kg to 1.5kg.

The result of DXNs concentration measurement is summarized in Figure 4. In this diagram, data #1--#3, #4--#7 and #8--#10 are results for ballasts, small electric devices and capacitor components, respectively. This shows consistent low DXNs emission level, compared with the regulation level of 0.1ng-TEQ/m^3N@O_2=12%, is achieved at outlet of No.2BF of enhanced exhaust gas treatment system.

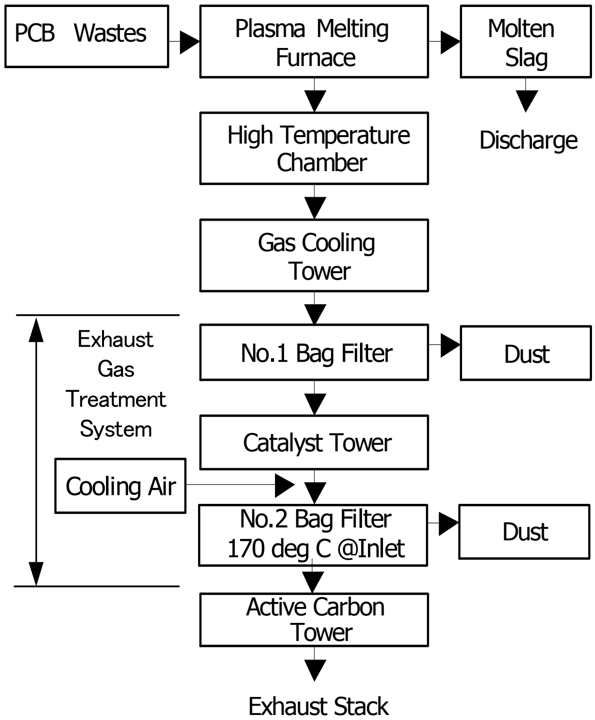

Figure 3 Schematic Flow Diagram of Enhanced Exhaust Gas Treatment System

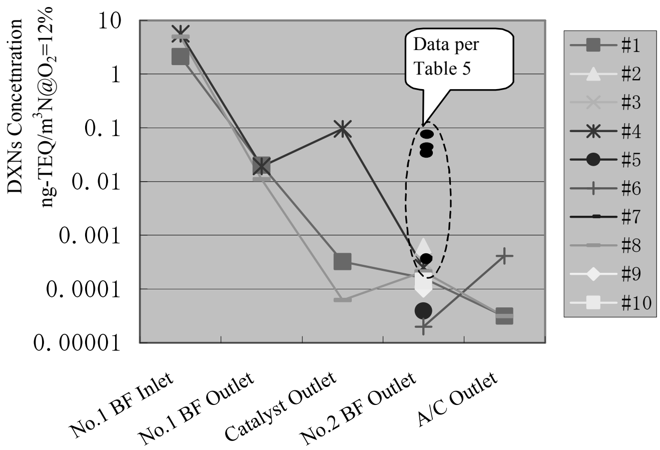

Figure 4 DXNs concentration in Exhaust Gas in Enhanced Gas Treatment System

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