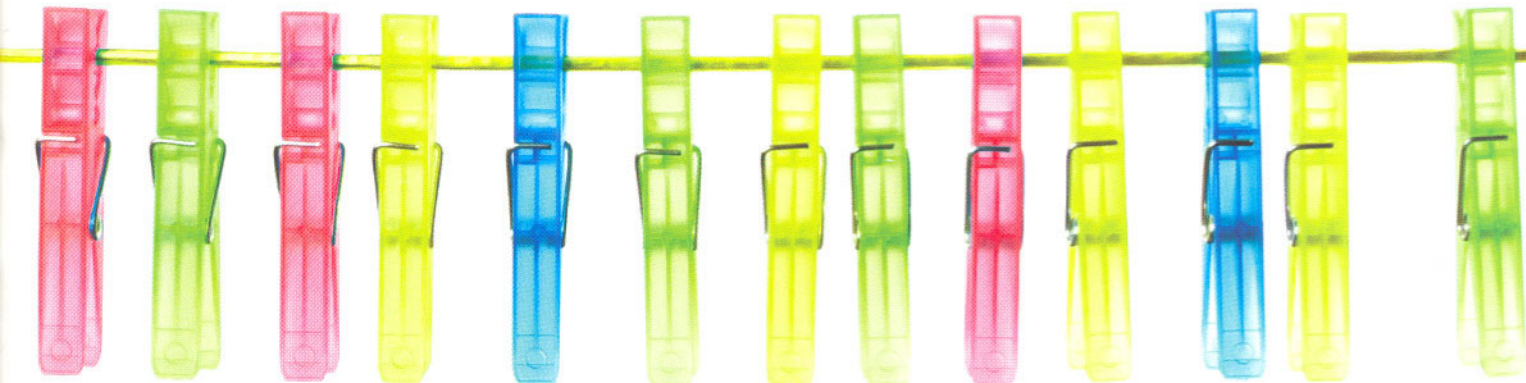


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## POSTER EXHIBITION



# Waste Plastic Treatment by Thermoselect Gasification and Reforming Process

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## Abstract

The Thermoselect process is a completely new solid waste treatment process which achieves pollution-free recycling of municipal waste and industrial waste by a high temperature gasification and reforming process. The process effectively recovers fuel gas from waste and recycles metal and the byproducts as resources. Using the Thermoselect furnace, the Chiba Recycling Center at Chiba Works completely recycles industrial waste from Chiba Prefecture and the surrounding region, as well as waste plastic collected under the Containers and Packaging Recycling Law, as fuel gas for the steelworks. In April 2001, it entered the plastic recycling business licensed for plastic gasification. As of March 2005, a cumulative total of more than 270 thousands ton had been received. This report is also described to demonstrate fuel gas recovery, outstanding dioxins decomposition performance and direct reduction by-products.

## Introduction

Japan has made various laws related to recycling of waste, beginning with the Basic Law for Establishing a Recycling-based Society, the Law on Promoting Green Purchasing, and others aimed at creating a recycling-based society. The general purpose of these laws is to reduce waste discharges, promote reuse, and prevent illegal disposal. Reducing discharges and material recycling are essential. However, since some remaining wastes are difficult to recycle as materials, development of an appropriate treatment method for these types of waste is also an important task.

The Thermoselect process\*1) is a gasification and melting technology which uses a gas reforming process\*2) to recover purified synthesis gas from municipal waste and industrial waste by gasifying the waste and reforming the gas obtained. While minimizing environmental impacts, the process also realizes chemical recycling.

In 1997, the former Kawasaki Steel (now JFE Group) was licensed with the basic technology from Thermoselect S.A., and in 1998, with the financial support of New Energy and Industrial Technology Development Organization (NEDO), began construction of a 300 t/day scale plant called the Chiba Recycling Center (Waste treatment capacity: 150 t/day 2 lines, Photo 1) at the present JFE Steel's East Japan Works (Chiba District). In FY 1999, as part of joint research with Chiba Pref. and Chiba City, the plant completed a demonstrating operation of municipal waste treatment in this facility for a continuous period of 93 days and a total of more than 130 days. \*3,4) This was the first demonstration in Japan of a gasification, reforming, and melting equipment on an actual plant scale. Based on these results, Japan Waste Management Association issued a summary of technical verification and confirmation. \*5) In FY 2000, the plant began an industrial waste treatment/fuel production business which treats industrial wastes on consignment, producing fuel gas for power generation in the steel works. In 2000, the Thermoselect process

became the first gasification and melting plant to receive New Energy Award. In Jan. 2001, the Chiba Recycling Center was transferred to Japan Recycling Corp., a subsidiary of JFE Steel specializing in waste treatment. Now in Japan, five plants of this type are in operation and two plants are under construction.

This paper describes the results of a performance study of municipal solid waste including plastics treatment at the Thermoselect process Chiba plant, the condition of the industrial waste treatment/fuel gas business, including the characteristics and use of the gas, and a newly developed gas engine electric power generation system suitable for use with smaller-scale Thermoselect waste treatment plants in areas without major fuel gas-consuming industries.

## 2. Outline of Thermoselect Technology

### 2.1 General Process Flow

The standard treatment flow of the Thermoselect process is shown in Fig. 1. Wastes are compacted without pretreatment, followed by drying and pyrolysis by indirect heating in the degassing channel. The pyrolyzed waste product is then charged into the high temperature reactor, where it is melted at high temperature by reaction with oxygen and pyrolyzed carbon to form gas. This gas passes through the gas reforming/quenching/refining process and is recovered as a clean synthesized fuel gas.

### 2.2 Features of Process

The features of the Thermoselect process are described in outline below.

#### 1. Extremely low emission of dioxins and no generation of fly ash are possible.

Generated gas is held at 1 200°C for 2 sec. or longer, followed by quenching to approximately 70°C in an oxygen-free condition, to suppress the generation of dioxins to an absolute minimum, and is then recovered as fuel gas.



Photo 1 Chiba Recycling Center



## 2. 100% recycling of wastes is possible.

100% of waste input is converted into purified syn-thesis gas or recovered in the form of granulated slag, metals, metal hydroxides, S, mixed salts, and other substances which can be used effectively as resources, resulting in zero landfill disposal.

## 3. Clean gas can be recovered by gas reforming.

Since the main components of the recovered synthe-sis gas are  $H_2$  and  $CO$ , the gas can be used not only as a fuel for power generation, but also as a chemical feedstock. The fuel gas is applicable to a wide range of power generation methods, including gas engine, fuel cell, gas-fired boiler, and gas turbine combined-cycle power generation, allowing the user to select an optimum generation method from the view points of equip-ment scale and site conditions.

## 4. The process offers excellent economy.

The Thermoselect process utilizes the energy con-tained in waste to perform melting and eliminates the need for separate treatment processes for diox-ins and fly ash with high heavy metal contents. As a result, the total cost is lower than the conventional "incinerator ash melting". Moreover, because the Thermoselect process eliminates the need for land-fill disposal, users can avoid the costs associated with constr-ucting, managing, and maintaining landfills.

## 3. Results of Waste Treatment at Chiba Plant

### 3.1 Demonstration of Municipal Solid Waste Treatment

In the demonstration test, approximately 15000 t of municipal solid waste (MSW) from Chiba City were treated at the Chiba Recycling Center. The character-istics of this MSW are shown in Table 1. An example of the properties of the synthesis gas obtained by treating the MSW is shown in Table 2. The concentration of dioxins in the fuel gas was  $0.000\ 39\ ng-TEQ/Nm^3$  ( $0.000\ 09\ ng-TEQ/Nm^3$ ,  $O_2: 12\%$  conversion value\*6), or less than 1/1 000 of the  $0.1\ ng-TEQ/Nm^3$  standard set by Japan's Ministry of the Environment.\*7)

Slag quality satisfied the leaching standard in Guide-line for Recycling of Melted Solids of Municipal Waste. In the demonstration with MSW from Chiba City, the main metal component was Fe. However, since the average Cu content was as high as 17.5%, it was recovered as source for Cu

smelting. S was recovered as source for  $H_2SO_4$ , and metal hydroxides were used as source for Zn smelting as they had a high Zn content. Total release of dioxins was  $0.000\ 69\ \mu g-TEQ/t-waste$ , which is far below the target value of  $5\ \mu g-TEQ/t-waste$  (Table 3). Considering the fact that the content of diox-ins in the charged waste is currently assumed to be around  $10\ \mu g-TEQ/t-waste$ , the Thermoselect process clearly proved its performance in decomposition of diox-ins.

### 3.2 Industrial Waste Treatment/Fuel Production Business

Treatment of industrial waste on a consignment basis began in Apr. 2000. In Apr. 2001, the Chiba Recy-ling Center also entered the plastic recy-cling business (licensed for plastic gasification) under the Containers and Packaging Recycling Law. As of Mar. 2005, a cumu-lative total of more than 270 000 t had been received.

The plant mainly treats civil and architecture industry waste. Categories of industrial waste include waste plastics, sludge, wood chips, waste paper, and others, as shown in Fig. 2, which also shows the amounts and compo-sition of wastes received. It may be noted that the waste which is classi-fied here as waste plastics (according to indus-trial waste control manifests) also contains a consider-able amount of waste from other categories.

An example of the analysis of received waste is shown in Table 4 (example of average composition of waste in pit, Sept.–Nov. 2001). Wastes A–D are exam-ples of analysis for each lot of received waste, while waste D is an example of packaging waste plastics. Because the heating value, ash content, and other char-acteristics of this waste fluctuate widely by lot in com-parison with MSW, it is also more important to stabi-lize waste quality by waste mixing control in this case. The plant therefore adjusts waste receiving, maintains a stock yard, and performs operation with special attention to mixing in the pit.

The average properties of the waste in the pit after mixing include a lower heating value (LHV) of 13.7 MJ/kg, and ash content of 9.8%, Cl content of 1.15%, and S content of 0.64% (waste standard).\*8) Thus, in compa-ri-son with MSW, LHV is large and the ash, Cl, and S contents are high (compared with MSW received from Chiba City during demonstration). Based on the large amount of metal hydroxides recovered, this indus-trial waste also has a high content of heavy metals.

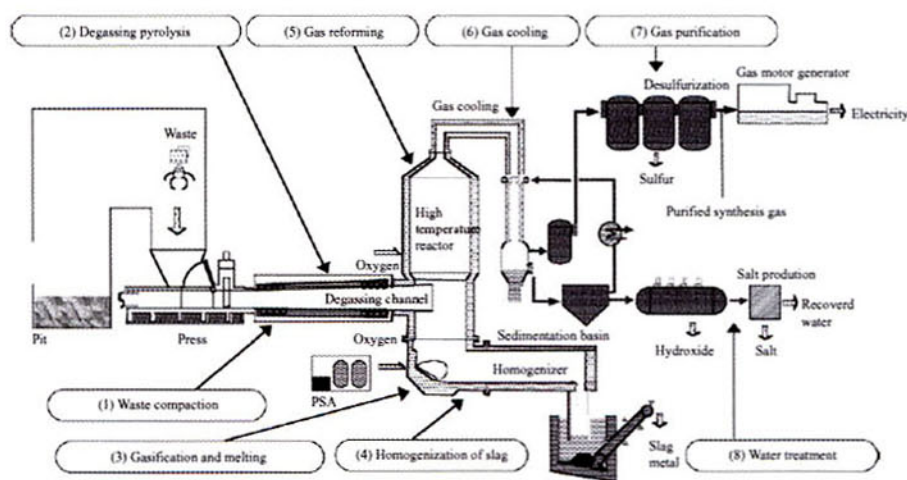


Fig. 1 Thermoselect process



Table 6 shows an example of the characteristics of the synthesis gas obtained by treating industrial waste. Table 5 shows the distribution and total amount of dioxins. Total emission of dioxins was 0.000 30  $\mu\text{g-TEQ/t-waste}$ , which is virtually the same level as in the demonstration with MSW.

Table 1 Characteristics of municipal solid waste (MSW)

3 components		
Moisture content	(%)	47.7
Ash content	(%)	6.7
Volatile matter	(%)	45.6
Measured lower heat value	(MJ/kg)	8.5

Table 2 Characteristics of synthesis gas

Component		Concentration
H <sub>2</sub>	(%)	30.7
CO	(%)	32.5
CO <sub>2</sub>	(%)	33.8
N <sub>2</sub>	(%)	2.3
Dioxins	(ng-TEQ/m <sup>3</sup> )	0.000 39
Dioxins (O <sub>2</sub> :12% conversion value)	(ng-TEQ/m <sup>3</sup> )	0.000 09

Table 3 Total dioxins emitted at the Chiba Recycling Center (MSW)

By-product	Dioxins content	Recovered quantity	Dioxins output ( $\mu\text{g-TEQ/t-waste}$ )
Synthesis gas	0.000 39 ng-TEQ/Nm <sup>3</sup>	722 Nm <sup>3</sup> /t-waste	0.000 28
Slag	0.000 7 ng-TEQ/kg-dry	65 kg/t-waste	0.000 04
Sulfur	0.35 ng-TEQ/kg-dry	0.52 kg/t-waste	0.000 18
Metal hydroxide	0.29 ng-TEQ/kg-dry	0.63 kg/t-waste	0.000 18
Recovered water	0.000 01 ng-TEQ/l	680 l/t-waste	0.000 01
Total dioxins emitted			0.000 69

Table 4 Characteristics of industrial waste

Industrial waste	LHV* (MJ/kg)	3 Components			Cl (%-wet)	S (%-wet)
		Moisture content (%)	Ash content (%)	Volatile matter (%)		
A	16.1	22.2	15.4	61.9	1.29	0.97
B	5.5	26.8	42.7	30.5	1.11	1.66
C	18.2	46.3	2.0	51.7	0.15	0.17
D	38.3	1.3	1.8	96.9	0.01	—
Average	13.7	44.4	9.8	45.8	1.15	0.64
MSW**	8.5	47.7	6.7	45.6	0.19	0.04

\* Lower heating value, \*\* Demonstration

Slag quality satisfies leaching standards. Slag quality control includes on-line size adjustment and magnetic classification. Quality confirmation tests with recycling contractors have been completed for respective applications, and Thermoselect slag is now being used as fine aggregate for interlocking blocks, etc.\*9)

### 3.3 Use of Purified Synthesis Gas

Since 1987, JFE Steel's East Japan Works (Chiba District) has operated a gas turbine combined-cycle power plant<sup>10)</sup> using byproduct gases generated in the steel works (Blast furnace gas, coke oven gas, etc.; LHV: 4.6 MJ/Nm<sup>3</sup>). Therefore, the purified synthesis gas recovered by the Thermoselect process is transferred to the works, where it supplies part of the fuel for the combined-cycle power plant. Figure 3 shows the energy flow at Chiba District of East Japan Works, including the purified synthesis gas from the Chiba Recycling Center.

In cases where a Thermoselect process plant is sited at a steel works or similar energy-consuming facility, it is possible to use the purified

Table 5 Total dioxins emitted at the Chiba Recycling Center (Industrial waste)

By-product	Dioxins content	Recovered quantity	Output of dioxin ( $\mu\text{g-TEQ/t-waste}$ )
Synthesis gas	0.000 30 ng-TEQ/Nm <sup>3</sup>	826 Nm <sup>3</sup> /t-waste	0.000 248
Slag	0.000 49 ng-TEQ/kg-dry	109 kg/t-waste	0.000 053
Metal	0.000 13 ng-TEQ/kg-dry	24.1 kg/t-waste	0.000 003
Sulfur	0.002 2 ng-TEQ/kg-dry	2.23 kg/t-waste	0.000 005
Metal hydroxide	0.000 68 ng-TEQ/kg-dry	2.29 kg/t-waste	0.000 002
Recovered water	0.000 06 ng-TEQ/l	899 l/t-waste	0.000 000
Total dioxins emitted			0.000 31

Table 6 Characteristics of synthesis gas

Component	Concentration
H <sub>2</sub>	(%) 32.4
CO	(%) 43.1
CO <sub>2</sub>	(%) 18.8
LHV	(MJ/Nm <sup>3</sup> ) 8.9

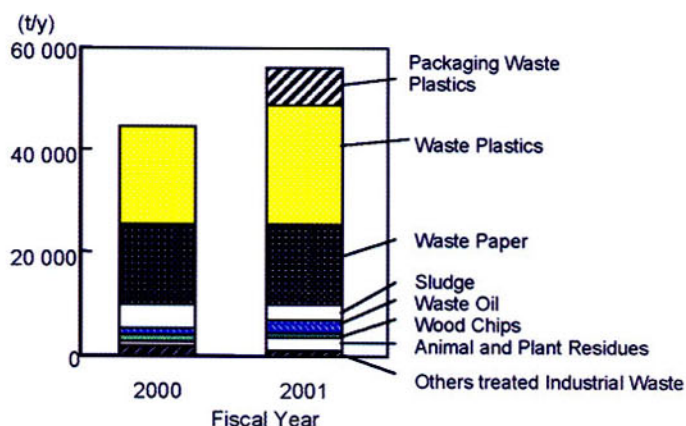


Fig. 2 Composition of Waste

synthesis gas in the works. However, under general siting conditions, highly efficient power generation on a comparatively small scale is required in order to utilize the purified synthesis gas recovered by waste treatment. Conceivable generating methods for such small-scale waste treatment operations include gas engine power generation and fuel cells, as these methods offer high generating efficiency with small-scale equipment.

To demonstrate the effectiveness of the Thermoselect process in this type of power generation, a 1.5 MW gas engine generator was installed at the site of the Chiba Recycling Center for demonstration. The appearance of the generator is shown in Photo 2; its main specifications are shown in Table 7. A demonstration test of gas engine power generation was performed using part of the fuel gas supplied to the steel works. Since the properties of the gas generated by the Thermoselect process tend to fluctuate, depending on waste properties, the gas engine generating system includes a control system which maintains a constant output based on external signals by changing the air ratio in response to the change in heating value of the fuel gas. Constant generating operation was possible in spite of fluctuations in the heating value of the fuel gas. The energy balance in gas engine generation at 100% load is shown in Fig. 4. The generating efficiency of the gas engine generator itself was 37% at rated load, and combined efficiency was 72%. Figure 5 shows generating efficiencies under various partial load conditions. In comparison with 37% efficiency at 100% load, 33% efficiency was maintained at 50% load, which was a decrease of only 4% from rated (100%) load.



Table 8 shows an example of the measured values of toxic substances in the gas engine exhaust gas by  $O_2$ : 12% conversion, which confirm that the dioxin content of the gas engine exhaust gas is low. Exhaust gas  $NO_x$  is also low, even without denitrification.11)

At present, a highly efficient (50–60%) fuel cell is being developed. Thus, in the future, it will be possible to achieve even higher equipment efficiency by applying the Thermoselect process

#### 4. Summary

The Thermoselect process described in this paper offers numerous advantages as a waste treatment system. In particular, it can cope effectively with a diverse range of wastes in fuel gas recovery, it has demonstrated outstanding dioxins decomposition performance, and it is capable of direct reduction of nonferrous metals such as Zn at the site. JFE Groups is confident that this technology can contribute to realizing a recycling-based society without final landfill disposal sites.

At present, orders have been received for the following Thermoselect process waste treatment facilities, which are now under start up operation stage or construction.

- (1) Mizushima Eco-Works Corp. (Okayama Pref.)  
Treatment capacity: 555 t/d - (scheduled startup: 2005)
- (2) Kenoukennan Regional Environmental Association (Nagasaki Pref.)  
Treatment capacity: 300 t/d - (scheduled startup: 2005)
- (3) Cyuoukouiki Environmental Facility Association (Tokushima Pref.)  
Treatment capacity: 120 t/d - (scheduled startup: 2005)
- (4) Yorii ORIX Eco Services Corp. (Saitama Pref.)  
Treatment capacity: 450 t/d - (scheduled startup: 2006)

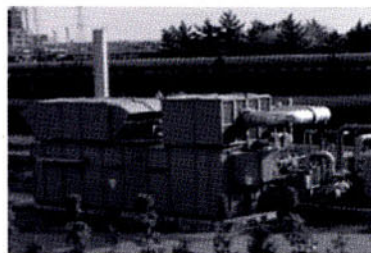


Photo 2 Gas motor generator

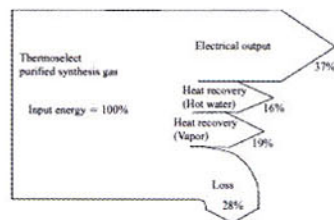


Fig. 4 Energy balance at 100% load

Table 7 Specifications of gas motor generator

Type	Lean-burn engine
Electrical output (kW)	1 507
Cylinders	20
Bore/Stroke (mm)	190/220
Rotation (rpm)	1 500
Maker	Jenbacher

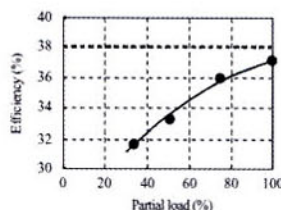


Fig. 5 Electrical efficiency in partial load

Table 8 Emission of gas-engine

DXNs (ng-TEQ/Nm <sup>3</sup> )	0.000 007 2
Dust (mg/Nm <sup>3</sup> )	0.2
NOx (ppm)	14
HCl (mg/Nm <sup>3</sup> )	< 5

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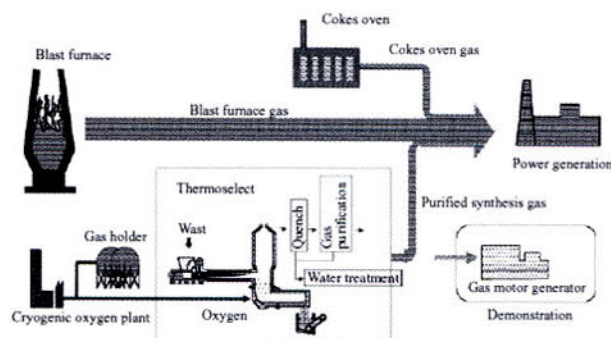
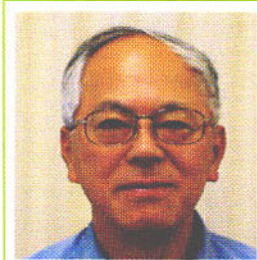


Fig. 3 Energy flow at Chiba District of East Japan Works



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