High Energy Efficiency Thermal WtE Plant for MSW Recycling

JFE High-Temperature Gasifying and Direct Melting Furnace

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EXECUTIVE SUMMARY

JFE High-Temperature Gasifying and Direct Melting Furnace System (hereinafter “JFE Gasifying & Melting System”) was developed to treat various types of wastes and to contribute to resource more materials for recycling. Since 2003, ten (10) JFE Gasifying & Melting plants (total 20 lines) have been in operation in Japan.
Starting from the basic explanations of the Japanese waste management and the reasons why gasification plants were introduced into the Japanese Waste to Energy (WtE) market, this report describes features of JFE Gasifying & Melting System, outline and operational results of the reference plant, such as highly efficient energy recovery under the conditions of steam parameters at 60 bar / 450 deg. C with re-circulation of exhaust gas.
Results of plant operation were satisfactory. That proves JFE Gasifying & Melting System is reliable in plant operation, flexible in wide range of wastes and efficient in power generation.
As the leading WtE plant supplier in Japan, JFE Engineering is making further efforts to contribute to resource recycling in this field.

INTRODUCTION

In Japan about 74 % out of 48.1 million tons of Municipal Solid Wastes (MSW) is being incinerated at 1,269 thermal WtE plants in 2008 (Refer to Fig.1).
Japanese municipal governments, i.e. cities, towns, and villages = approx. 1,750 in total,

are in principle required to treat wastes inside their territories according to the guideline of the Japanese government. They are not allowed to treat the wastes from other municipal governments without mutual agreements.

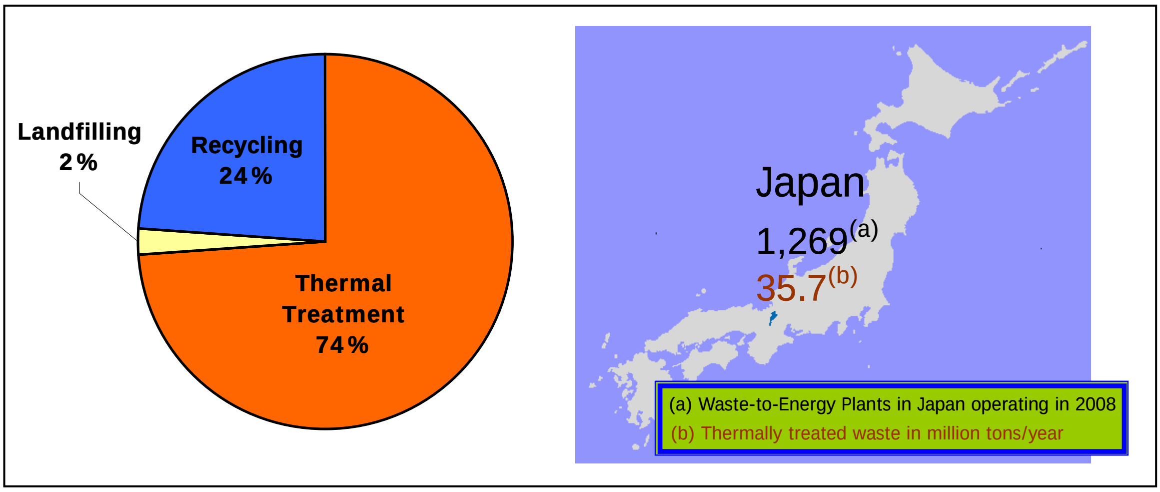

Fig.1 – MSW treatment: In Japan 35.7 mil tons of MSW is thermally treated in 1,269 WtE plants

In Japan therefore many thermal WtE plants had to be constructed in each municipal government, and as the result the average capacity of the plants, approx. 70,000 tons per year, is much smaller than that of Europe.

Until 1999 grate firing type incineration plants were the most popular in Japan. In January 2000, however, the new strict law named Act on Special Measures against Dioxins was enacted to reduce drastically the emission of dioxins from incineration plants.
As the countermeasure, the newly developed Gasifying and Melting Plants were introduced into the market to cope with the dioxins emission problem and the recycling of residues (bottom and fly ashes) from incineration plants because of limited landfill spaces.

In general the gasification process has advantages such as:
a) Drastic reduction in dioxins emission
b) Recycling of wastes to valuable slag and metals and
c) Reduction in the landfill space

JFE Gasifying & Melting System was developed by integrating JFE's own technology of iron blast furnace for steel making and of fluidized bed for incineration plants. JFE group owns JFE Steel for steel manufacturer and JFE Engineering for engineering and construction provider including the field of WtE plants. The advanced technologies of the two different fields were combined and integrated into the unique JFE Gasifying & Melting System.

This system realizes high performance specified below and is highly evaluated by its users.
a) Treatment of various kinds of wastes is possible such as refuse derived fuel (RDF),

sewage sludge, industrial wastes (IW), incineration residues, excavated wastes and/or asbestos in addition to MSW.

b) Non-combustibles in wastes can be reused as useful nontoxic slag.

c) Combustibles in wastes are converted into combustible gas.

d) Dioxins emission from the plants is minimized.

e) Highly efficient power generation, η_{el} = 27 %, is realized.

JFE has delivered 10 plants (20 lines) in total to the Japanese clients since the first one in 2003. The plants have been operated without any major troubles. The plant construction record of JFE Gasifying & Melting System is shown in Table 1.

Table 1 - Construction Record of JFE Gasifying & Melting Plant

	Name	Capacity	Input waste	Completion
①	Kakamigahara Plant	2.7 t/h, 3 Lines (192 t/d)	MSW	Mar. 2003
②	Amagi Plant	2.5 t/h, 2 Lines (120 t/d)	MSW	Mar. 2003
③	Hidaka Plant	0.8 t/h, 2 Lines (38 t/d)	MSW	Feb. 2003
④	Morioka-Shiwa Plant	3.3 t/h, 2 Lines (160 t/d)	MSW, Excavated Waste	Mar. 2003
⑤	Saiki Plant	2.3 t/h, 2 Lines (110 t/d)	MSW, Excavated Waste, Sludge	Mar. 2003
⑥	Fukuyama Plant	13.1 t/h, 1Line (314 t/d)	RDF from MSW	Feb. 2004
⑦	Kasama Plant	3.1 t/h, 2 Lines (145 t/d)	MSW, IW, Incineration residues	Mar. 2006
⑧	Aki Plant	1.7 t/h, 2 Lines (80 t/d)	MSW, Excavated Waste	Mar. 2006
⑨	Hamada Plant	2.0 t/h, 2 Lines (98 t/d)	MSW	Nov. 2006
⑩	Chikushino Plant	5.2 t/h, 2 Lines (250 t/d)	MSW	Mar. 2008

PROCESS DESCRIPTION

Features of Gasifying and Melting System

Fig.2 describes the structural drawing of the JFE Gasifying and Melting Furnace.

Comparing to the other gasifying and melting systems, JFE's system is one of the most compact systems. This is due to the simple structure that processes gasification and melting in a single furnace. Combustibles in wastes will be gasified by the high temperature of the furnace. Non-combustibles in wastes will be melted and turned into slag and metals for reuse.

Wastes are fed into the furnace with coke (approx. 5 % of wastes) and limestone (approx. 3 % of wastes) from top of the furnace. Coke plays a role as fire grates that keeps flow path for gas and slag. Also it works as the heat source and prevents cool-down of slag.

Limestone is to be put into the furnace together with coke to form fluid slag that can be easily discharged from the furnace bottom.

Since inside of the furnace is kept in reduction atmosphere, hazardous heavy metals are vaporized to the gaseous phase and molten ash is converted to safe slag. The molten ash from furnace bottom is quenched in a water-granulation conveyor to form granulated slag and metals.

JFE gasifying and melting furnace can be divided into the three zones as follows:

Zone 1 : For high temperature combustion and melting

Zone 2 : For drying, pyrolysis and gasifying

Zone 3 : For gas treatment in high temperature reducing atmosphere

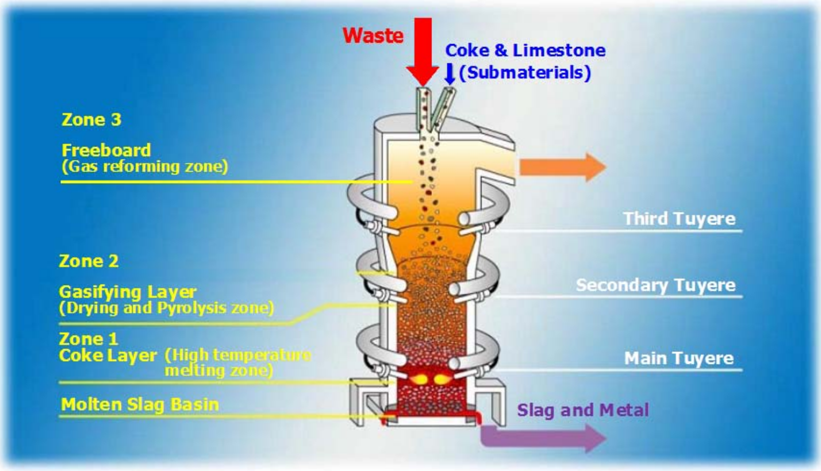

Fig. 2 - Structural drawing of Gasifying and melting furnace

Zone 1 is filled with coke, and the coke and fixed carbon in wastes are burned with oxygen-rich air (approx. 35 %) sent through the main tuyere at the lower part of the furnace. Air is introduced into the furnace through the main, secondary and third tuyeres located along the furnace wall. Oxygen-rich air for the main tuyere is supplied with a blower at the specific flow rate after the premixing of air collected from the nearby furnace area and the oxygen produced with the oxygen generator. The zone temperature exceeds 2,000 deg. C. At this high temperature, non-combustibles in waste are melted, and then discharged through a slag outlet at the furnace bottom while keeping a molten state approx. 1,600 deg. C. Generated CO_2 is reduced to CO by a Solution Loss Reaction, and CO flows into the upper Zone 2 as gas of approx. 1,000 deg. C.

In Zone 2, the gas produced at the lower part is partially burned and kept approx. 700 deg. C with air sent through the secondary tuyere while maintaining a fluidized state of wastes, coke and limestone, which are charged from the top of the furnace. By this heat, wastes are preheated and thermally decomposed.

In Zone 3, part of produced gas is burned in a high temperature reducing atmosphere above 850 deg. C by air sent through the third tuyere. Residence time of two seconds or longer enhances pyrolysis of tar and restrains dioxins generation. This process improves the quality of produced gas.

The combustible gas discharged from the furnace is introduced into the secondary combustion chamber before the boiler. Then, the combustible gas is combusted completely in this chamber. Combustion air is supplied with an air blower located near the waste pit. To minimize odor spread outside the plant, the air in the waste pit is used as combustion air. Automatic Combustion Control (ACC) regulates the combustion airflow rate automatically.

Flue-gas recirculation fan recirculates partial flue-gas (low oxygen content) to the combustion chamber to keep the temperature of combustion chamber stable and ensure high efficiency of combustion.

Steam from the boiler is fed into the steam header via super heaters. All the steam is supplied to steam turbines and steam extractions from turbines are carried out to improve the power generation efficiency.

Moreover, the working load for the operator to discharge slag and metals is decreased by adoption of JFE's original molten slag continuous discharging system.

Outline of Reference Plant "Fukuyama Recycle Power"

JFE completed "Fukuyama Recycle Power Plant" in Hiroshima Prefecture, Japan in March 2004 as the largest gasification and melting plant in the world.

The plant receives pelletized RDF from the seven RDF production plants in nine cities and villages in Hiroshima.

In Japan, MSW is, in principle, treated in each city, town, or village. Each municipal government has to invest to a WtE plant individually, or a couple of neighboring municipal governments jointly build a plant in case volume of MSW from one municipality is insufficient.

The plant is quite unique because of the reason that the nine cities and villages located and scattered in different areas produce palletized RDF in their seven plants, and the RDF is efficiently transported to the plant for power generation. This broad area treatment concept for efficient power generation was realized under the initiative by Hiroshima Prefecture.

The outline and operational results of the plant for 6-year operation are reported hereunder. Process flow, Outline and Photo of the Plant are shown in Fig.3, Table 2 and Fig.4 respectively.

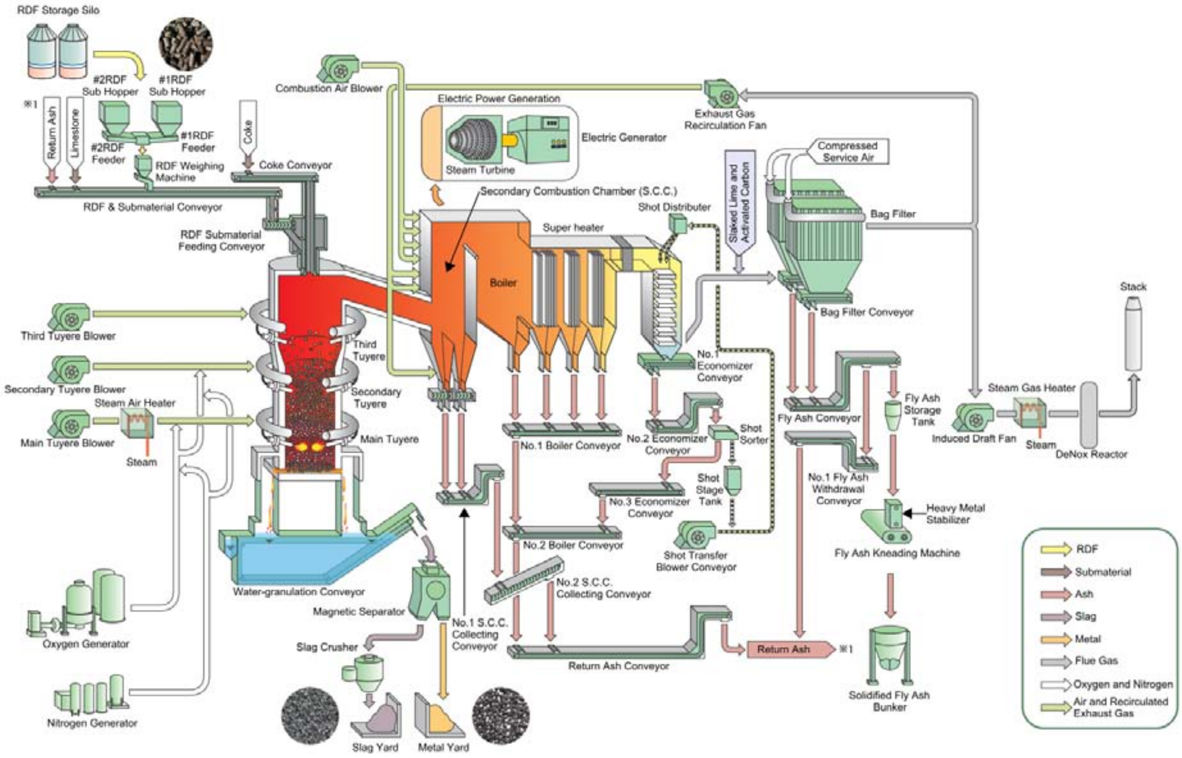

Fig. 3 - Process Flow of Fukuyama Recycle Power

Table 2 - Plant Outline

Capacity	13 t/h (314 t/day), 1 Line
Feedstock	Pelletized RDF from MSW
Furnace type	JFE High-temperature gasifying and direct melting Furnace (Vertical shaft furnace)
Energy recovery system	Boiler 90.8 t/h, 450 deg.C / 60 bar Steam turbine generator 20 MW
Flue-gas treatment	Dry type: slaked lime & activated carbon injection, Bag filter, DeNOx reactor
Slag treatment	Water-granulation conveyor, Magnetic separator, Slag crusher

Fig. 4 - Photo of Fukuyama Recycle Power

Results of Plant Operation of Fukuyama Recycle Power

Characteristics of RDF

Even though some fluctuation was observed, the average characteristics of RDF in the fiscal year 2009 were nearly equal to the planned ones (Refer to Table 3).

Table 3 - Characteristics of RDF

	Designed RDF	Result of analysis (Fiscal year 2009)
Lower calorific value (kJ/kg)	18,200	17,520 to 19,280
Water (wt %)	8.0	3.6 to 5.5
Combustible fraction (wt %)	81.4	80.5 to 85.1
Ashes (wt %)	10.6	10.6 to 14.6

State of Operation

Material Balance

The plant has been operated without any major troubles for over 6 years. Table 4 shows the material balance of slag and metals, and also shows their ratio against the annual RDF throughput, 70,753 ton, treated in 2009. The slag discharged from in the plant is reused as the backfilling material for road construction. All the metals produced are also recycled.

Table 4 - Material Balance

	Weight (t/y)	Ratio (wt%)
Total RDF Throughput	70,753	100
Slag	7,012	9.9
Metal	439	0.6

Electricity Balance and High Electrical Efficiency

Table 5 shows the electricity balance in 2009.

Table 5 - Electricity power balance

Item	Electric Power (MWh/y)
Generated	104,245
Consumed	20,407
Sold	86,387
Purchased	2,549

The demand of electric power for plant operation is covered with the electricity produced at the generator, and most of the remaining electric power is exported to the grid for sale.

The plant is designed to input high calorific RDF of 18 MJ/kg into the furnace and operates at the steam parameters of 60 bar, 450 deg. C, resulting in electrical efficiency close to 27 %. The electrical efficiency represents the typical electrical efficiency in normal load operation during a specific period of 6 June to 30 June 2009.

The electrical efficiency (η_{el}) is defined as below:

$$\eta_{el}\,(\%) = \frac{P \times 3{,}600 \times 100}{((W \times LHV,w) + (C \times LHV,c)) \times 1{,}000\ (kg/t)} = 26.98$$

P	:	Power generated	10,998.6	(MWh)
W	:	Waste input (RDF)	7,418.0	(ton)
LHV, w	:	Lower calorific value of RDF	17.8	(MJ/kg)
C	:	Coke input	502.0	(ton)
LHV, c	:	Lower calorific value of coke	29.3	(MJ/kg)

The increase in the temperature and pressure of the superheater tubes may cause severe corrosion. However, the plant has been being operated with no serious damage or no replacement of the superheater tubes for over 6 years. Moreover, flue-gas has been recirculated to increase the overall plant efficiency and to keep the temperature of combustion chamber stable through achievement of increased combustion efficiency.

Environmental Standard

Emission

Table 6 shows the regulation values (self-restricted) of flue-gas emission and the analysis values of emission from the plant. All the values analyzed are within the regulation values.

Table 6 - Results of Emission Analysis

Emission	Regulation Value	Analysis Value
Dust (mg/m^3N)	＜11.1	1.1
SOx (mg/m^3N)	＜63.44	3.1
NOx (mg/m^3N)	＜114.0	84.3
HCl (mg/m^3N)	＜88.9	44.4
CO (mg/m^3N)	＜41.63	4.1
Dioxins (ng-TEQ/m^3N)	＜0.06	0.000059

(dry gas at 11% O_2)

Slag

Table 7 shows the regulation values of leaching amounts of toxic substances according to the environmental quality standards for soil specified in Notification No.46 (Ministry of the Environment (JPN)) and its measurement results. All the measured leaching amounts of toxic substances are lower than the regulation values. All the slag produced from the plant is reused as the backfilling material for road construction.

Table 7 - Result of Slag Measurement

	Leaching Amount (mg/L)	
	Regulation	Measured
Cd	<0.01	<0.001
Pb	<0.01	<0.005
Cr^{6+}	<0.05	<0.02
As	<0.01	<0.005
T-Hg	<0.0005	<0.0005
Se	<0.01	<0.002
F	<0.8	<0.08
B	<1.0	<0.01

As shown above, the results of plant operation of Fukuyama Recycle Power in 2009 was satisfactory.

Discussions on Differences in Objectives for WtE Plants between Europe and Japan

Plant Availability (Power Generation in Europe and Waste Treatment in Japan)

In Europe, mainly private companies own and operate WtE plants under the sponsorship of local municipal governments. They give top priority to power and heat generation through the plant operation, and aim to earn as much income as possible. Therefore higher availability of plants is most important for their purpose.

In Japan, on the other hand, local municipal governments in principle own and operate WtE plants. This is because they are obliged to treat wastes in their own territories under the Japanese laws. They give top priority to waste treatment, not power generation. Not to suspend their plant operation, they try to avoid any overload to their plants, schedule enough maintenance and repair considering 30 years plant operation.

As a result, in Japan the working days of plants are in general from 250 to 280 days per year, and the plant operation is suspended for the remaining three months or so for maintenance. In Europe, on the other hand, the plant availability for more than 8,000 hours (333 days) per year is required.

From a technical point of view, it is possible to increase the availability to 8,000 working hours or more per year even in Japan. However, no operational data in Japan show more than 8,000 working hours per year due to the reason mentioned above.

In future, however, they may change their policy and make efforts to achieve higher availability in Japan referring to the high availability in Europe and income from power generation.

Utilization of Bottom Ash

In Europe, bottom ash, the residue from Grate firing WtE plants, is traditionally utilized as construction or landfill material. In Japan, on the other hand, there exists the governmental guideline that the ash from WtE plants, in principle, should be melted. It is because hazardous heavy metals contained in the ash may be dissoluble in water.

Bottom ash was sometimes dumped at landfill sites, but such sites are recently quite limited in Japan. The recent trend in Japan is therefore to melt the ash for safety and to utilize it as valuable by-product.

From the viewpoint of environmental risk management on utilization of ash, the melting technology may be effective as a countermeasure. Additionally, should a new law or regulation on utilization of ash be enacted in Europe, the melting technology will be truly meaning technology for the society.

CONCLUSION

The JFE Gasifying & Melting System has special features as follows:

a) Reliability: Since 2003, 10 JFE Gasifying & Melting plants (total 20 Lines) are in operation in Japan without any major trouble.
b) Flexibility: Recycling of wastes to valuable slag and metals and treatment of various kinds of wastes are possible.
c) Efficiency: Highly efficient power generation, η_{el} = 27 %, is realized.

JFE Engineering is making further efforts to contribute to resource recycling in this field achieving lower environmental load, running cost and higher operational efficiency.

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