PWMI Newsletter

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Plastic Waste Management Institute
JAPAN

At the Frontline of Plastic Recycling

Latest Trends in Recycling Technologies for Plastic Waste Contained in Post-use Home Appliances and Household Trash in Japan

New Recovery Technology for Brominated Flame Retardants

It's been about two and a half years since Japan's Appliance Recycling Law first went into effect. This law targets four types of home electric appliances (air conditioners, televisions, refrigerators, and washing machines), and for the one-year period from April 2002 to March 2003, a total of 10,150,000 units were collected. This number represents an increase of about 11.9% over the previous year's pickup of about 8,500,000 units and an average recycling rate of 68.5% for these four types of appliances.

Also of importance to recycling is the fact that brominated flame retardants are contained in the plastic used for home electric appliances, in shredder residue from automobiles, and in printed circuit boards used throughout information technology (IT). The Plastic Waste Management Institute (PWMI) has headed a successful effort in establishing the world's first completely closed recycling technology for brominated flame retardants. This work was consigned by the Chugoku Bureau of Economy, Trade and Industry (Hiroshima City) and performed by a team consisting of one university (The University of Tokyo), one research institution, and six companies including Sumitomo Metals Industries, Ltd., Ube Industries, Ltd., and Tosoh Corporation.

At the same time, a variety of trash-processing methods for use by local governments are now attracting attention. One of these is a system that generates electricity not only by incinerating household trash that includes plastics but also by completely processing its toxic gases for reuse as a heat source. Another system generates electricity by using the heat produced by gasification and melting, and thermal recycling and material recycling use the slag and metals generated by gasification and melting as auxiliary materials in public works projects.

This report describes these latest trends in recycling technologies.

I Progress in Home Appliance Recycling Technologies

1. FY2002 Average Recycling Rate for the Four Designated Appliances Reaches 68.5%

● Home appliance recycling rate increases steadily

The target recycling rates established by law (where "recycling rate" means the weight ratio of extracted resources to collected appliances) are 60% or greater for air conditioners, 55% or greater for televisions, 50% or greater for refrigerators, and 50% or greater for washing machines. The recycling rates achieved in the one-year period from April 2002 to March 2003 were 78%, 75%, 61%, and 60%, respectively, resulting in an average recycling rate of 68.5%, a two-point increase over the previous fiscal year.

There are currently 40 plants throughout Japan recycling these four types of home appliances.

● Collected units increase by about 1.6 million units in FY2002

There are 380 designated pickup centers throughout Japan for air conditioners, televisions, refrigerators, and washing machines. The total number of units picked up in FY2002 is as follows (FY2002 runs from April 2002 to March 2003).

2. New Technology for Recovering Brominated Flame Retardants from Plastic Waste Established

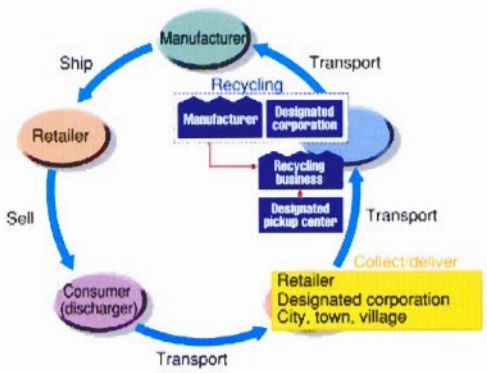
Plastics containing brominated flame retardants are found in post-use home electric appliances and automobile components. These brominated flame retardants have traditionally presented a problem when processing such plastic material.

In response to this problem, a PWMI-led project has established the world's first technology for recovering brominated flame retardants using gasification and melting plants without generating dioxins in the process and for recycling them as electrical energy and chemical materials (completely closed recycling technology).

Consigned by the Chugoku Bureau of Economy, Trade and Industry (Hiroshima City), this R&D work was performed by a team consisting of one university, 1 research institution, and six companies. These are the School of Engineering at The University of Tokyo, National Institute of Advanced Industrial Science and Technology (AIST), Sumitomo Metals Industries, Ltd., Ube Industries, Ltd., Tosoh Corporation, Naka Metal Co., Ltd., Kyoei Steel Ltd. (Yamaguchi Office), and Kaneka Techno Research Co., Ltd.

A demonstration test for this technical development was performed by a partial-oxidization type of high-temperature gasification and melting technology developed by Sumitomo Metals. Three types of samples were used in the test: television back covers, general plastic from the four designated appliances, and automobile shredder residue (ASR).

The demonstration test employed a zero-emission process consisting of three main elements. The first is a high-temperature gasification and melting furnace that performs gasification at 1200°C and melting at 1500°C simultaneously. The second is a quenching column that cools generated gases almost instantly dropping them from a high-temperature state of 1000°C to 200°C or less (to prevent the generation of bromine-based dioxins). The third is bromine recovery equipment that separates and recovers bromine from fly ash (for reuse as a chemical material). The test achieved a decomposed-gas/cooled-gas efficiency of 71% (which is expected to rise to at least 90% in a working furnace) and a dioxin concentration less than 1/10 that stipulated by emission regulations thereby demonstrating the possibility of a high bromine-recovery rate. There are plans to deploy this process commercially some time



Mechanism of appliance recycling

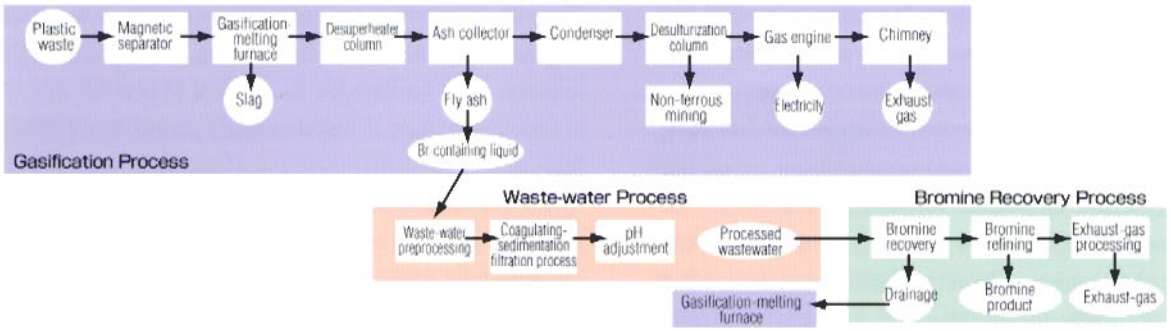
	Unit	Air Conditioners		Televisions		Refrigerators		Washing machines	
		2001.4 ~ 2002.3	2002.4 ~ 2003.3	2001.4 ~ 2002.3	2002.4 ~ 2003.3	2001.4 ~ 2002.3	2002.4 ~ 2003.3	2001.4 ~ 2002.3	2002.4 ~ 2003.3
Number of units picked up at designated collection centers	1000	1,334	1,636	3,083	3,520	2,191	2,565	1,930	2,426
Number of units processed for recycling	1000	1,301	1,624	2,981	3,515	2,143	2,556	1,882	2,409
Recycling rate	%	78	78	73	75	59	61	56	60

Number of collected units for the four designated appliances

between spring and autumn 2004.

This demonstration test included a life cycle assessment (LCA) that demonstrated the superiority of the process in suppressing the generation of carbon dioxide and in other LCA considerations. On the basis of this result, the recycling of personal computers is scheduled to begin in October 2003 supplementing the recycling of home appliances began in April 2001. Much attention is also being paid to automobile recycling technologies in accordance with the recently passed Automobile Recycling Law.

As described above, Japan is making great strides toward systematizing the zero-emission recycling of all plastics in society.



Process flow of bromine recovery

3. Case Study

Sorting post-use air conditioners, televisions, refrigerators, and washing machines into different materials on separate dedicated lines

—Matsushita Eco Technology Center (METEC)—

● Using on-site recycling information in new product development

METEC is an appliance recycling facility established and fully owned by Matsushita Electric Industrial Co., Ltd. It began operation in April 2001 with the role of making post-use electric home appliances into new products, researching and developing recycling technologies, and testing and demonstrating those technologies.

A matter of interest here is that the head of Matsushita Electric Industrial's R&D department resides at METEC. This enables him to collect various types of information at the recycling facility itself as an aid to researching new product development and structural design from a recycling perspective.

● Aiming for the recycling of 1-million units

The most outstanding feature of METEC's recycling system is that air conditioners, televisions, refrigerators, and washing machines (either Matsushita's products or those of other companies) flow along separate dedicated lines to sort out the materials which characterize each of these four types of home appliances. Having only one type of product flow on one line is far more efficient than having different types of products flow on a single line.

In addition, METEC is continuously enhancing the system to achieve higher levels of efficiency and to meet higher targets for the total number of units processed by all four lines. The total number of units recycled in FY2002 was about 640,000, an increase of 14.3% over the 560,000 units processed in FY2001.

Progress is also being made in technology development with the aim of achieving zero waste products in the future.

● "From products to products" through recycling technologies

Based on the concept of "from products to products," METEC is working to develop diversified material recycling technologies.

The Appliance Recycling Law defines "recycled" as the sorting of home appliances into various materials and processing those materials into a sellable state as recycled materials. For METEC, however, it is not simply a matter of recovering recyclable materials. The company feels that an important objective of developing recycling technologies is to utilize recycled materials in new home appliances.

Overall view of the Matsushita Eco Technology Center

II Recovering and Recycling Electrical Energy, Slag, and Metals from Household Trash

In Japan, the annual amount of discharged household trash containing plastics (excluding PET bottles) is currently running at about 50 million tons. Thermal recycling of this trash by using it as fuel for creating high-temperature steam and generating electricity is increasing throughout the country.

The Ministry of Economy, Trade and Industry (METI) and one of its affiliated organizations called the New Energy and Industrial Technology Development Organization (NEDO) are promoting a variety of new energy technologies. These include solar and wind power generation, incineration of waste with power generation, and incineration of waste with heat utilization facility. The use of heat through the processing of solid waste is taking on an especially important role in view of the New Energy Law that emphasizes reduction of environmental load.

The use of combined recycling systems based on the gasification and melting of household trash is also spreading. These systems recover slag and metals as recycled materials and generate electricity using exhaust heat.

The following provides a status report on recycling plants in Japan with a focus on how the above types of thermal recycling are progressing in local governments throughout the country.

1. Active Use of Thermal Energy through Incineration of Household Trash

● Steam-based power generation using the heat from incinerating household trash containing plastics

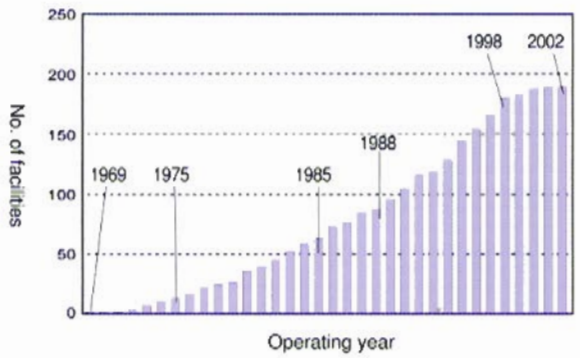
Up to recently, the thermal energy generated by incinerating plastic-containing trash discharged from households has generally been used for local hot-water supplies, heating needs, warm-water pools, and the like. This, of course, is a true recycling system as it recovers and reuses heat. This idea is being taken even further, however, in a nationwide movement to convert this heat to electric power, a resource indispensable to modern life.

While this movement to use household trash for generating power is supported by the New Energy Law (enacted in 1997 under the official title of "Law Concerning Special Measures for Promotion of New Energy Use, etc."), it must be kept in mind that the expression "household trash" covers many kinds of trash in actuality. Of these, household trash that contains plastics is coming to be used as a useful resource by thermal recycling systems that are beginning to penetrate society.

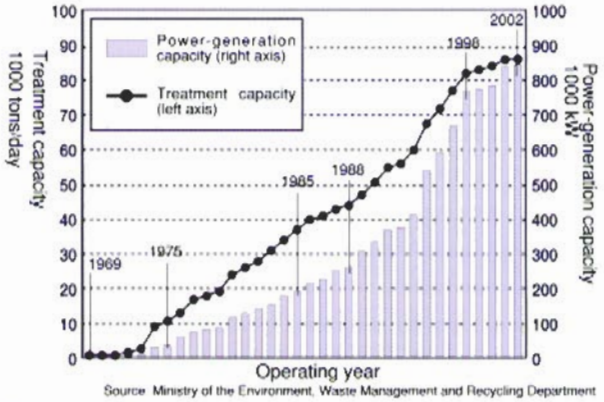
● Trash-based power generation reaches about 860,000 kW nationwide

Although the amount of household trash for processing depends on power-plant scale, we can say that from 150 to 200 tons per day at the least would be required as a general index. Consequently, to enable operation of a power plant by the processing of household trash, local governments are increasingly joining forces to manage household trash to this end.

At present, there are about 1,900 facilities for processing household trash in Japan, and about 190 of these incorporate a power plant. The total amount of power generated by these 190 plants is currently about 860,000 kW. In contrast, the 2010 target set by new energy policies in Japan for total power generated by



Change in number of trash-incineration power generation facilities



Source: Ministry of the Environment, Waste Management and Recycling Department

Change in trash-treatment capacity and power-generation capacity

trash (including household and industrial trash) is 4,170,000 kW, and efforts are now underway to meet this target.

The current situation is such that 70-75% of the total amount of discharged trash (more than 50-million tons) is simply incinerated at processing facilities. The idea behind trash-incineration power generation is that using trash in place of some fossil fuels to generate power should reduce the emission of carbon dioxide (a greenhouse-effect gas).

At the same time, incineration of household trash generates toxic gases presenting a problem to society. This problem has come to be solved, however, by several excellent processing technologies.

2. Case Studies

(1) Takahama Clean Center

Creating steam for generating power using household trash as fuel and recovering and recycling residual materials

The Takahama Clean Center (which incorporates a recycling center for PET bottles, beverage cans, glass bottles, and paper-based products) was completed in November 1988 by health and sanitation associations of Takasaki City and four other towns and villages in Gunma prefecture. It went into actual operation the following month. This facility, which was built to replace previous worn-down processing facilities, processes an average of 120,000 tons of trash annually. Also constructed on the same premises is a power station (Takahama Power Station) that combines a gas turbine and a steam turbine using the steam from the incinerator's boiler. This power station, which came on line in 1996, is operated by the Gunma Prefecture Business Bureau.

● Materials not suitable for material recycling are used as fuel for generating electricity

In this region, household trash (burnable trash) is collected without separating different types of plastic (soft plastic such as plastic bags and trays and hard plastic such as plastic buckets and sinks). The annual average ratio of plastic in household trash is about 25.1% for soft plastic and about 15.1% for hard plastic. These types of burnable trash are used as fuel for generating power.

Among unburnable trash that is collected, glass and ceramic ware, small metallic products, small electric appliances, and steel and aluminum cans are recovered and recycled as resources.

Oversize trash is also collected. In this case, burnable material (such as plastics and wooden goods) are separated and crushed and then recovered as thermal energy in incinerators. Plastics that remain after recovering metals from small electric appliances are also used as fuel.

The associated recycling center hands over PET bottles, beverage cans (steel and aluminum), glass bottles (cullet or returnable bottles), and paper-based products to specialized processors as recycled materials for a fee.

The same center is also looking to process and reuse incinerator ash, which is currently buried in landfills, in melting furnaces. This approach is being adopted as the capacity of landfills decreases year by year.

● Plastic used as a fuel for generating power from the start

In Japan, there are still many cases where plastic waste discharged from households is treated as unburnable and processed as landfill. In contrast, the Takahama Clean Center considered from the very beginning that household plastic waste is burnable and is a material that could be used as fuel for creating steam to generate electricity. This idea was way ahead of its time.

● Plan supported by national policies

The plan to construct a power station (Takahama Power Station) to use household trash containing plastics as fuel as part of the Takahama Clean Center conformed to METI's "Promotion of Energy Communities in Harmony with the Environment." Through joint research conducted with NEDO and with an eye to the possibility of selling electricity to power companies, the plan moved forward quickly. The fact that national policies were calling for the use of household trash as a form of "new energy" helped this plan in no small way.

In this way, Japan's first gas-turbine-combined power generation system using steam from the trash incinerator's boiler and natural gas was completed in 1996.

● Approved power capacity of 25,000 kW

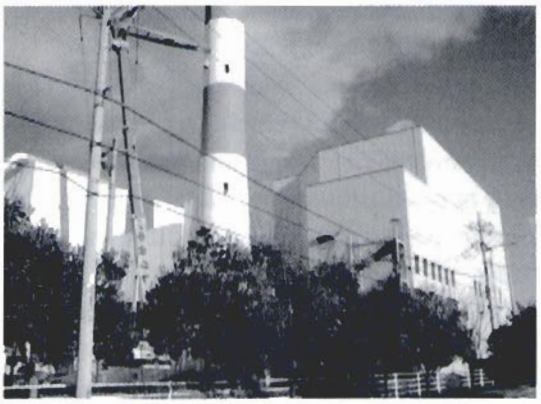
The Takahama Power Station pays the Takahama Clean Center for a continuous supply of steam at 255°C and generates power by operating a steam turbine by itself or in combination with a gas turbine. Maximum power capacity is 25,000 kW for combined operation. In addition, power generation by the steam turbine under combined operation uses 28 tons/hour of 255°C

steam from the Takahama Clean Center and about 20 tons/hour of post-use steam recirculated within the plant. Minimizing energy loss in this way is a major feature of this plant.

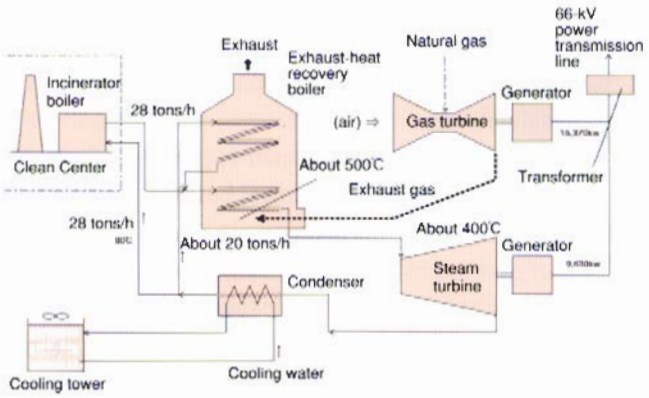
● **Power generation efficiency of 34%**

The fuel used for the gas turbine is natural gas supplied at a maximum rate of 5,000 m3/hour. The advantage of using natural gas as fuel is that exhaust gases are clean with minimal CO2 emission per unit energy resulting in an extremely small load on the environment. Combined operation, moreover, achieves a power generation efficiency of 34%, the highest in the country. This also contributes to easing the load on the environment.

This new "household trash recycling" technique that supports the generation of electricity by creating steam from plastic-containing household trash and that provides a source of income for the plant operator is expected to receive more attention in the years to come.



Overall view of the Takahama Clean Center (structure on the right is the power station)



Flow of gas-turbine-combined trash-incineration power generation

(2) Gasification and melting furnaces

Focus on gasification and melting furnaces in household trash processing

—Extending the life of landfill sites—

In recent years, a movement advocating the recycling of melted trash materials in addition to reducing the volume of household trash has become quite active.

Though the melting systems differ, the following introduces two examples of local governments promoting thermal recycling through the adoption of a gasification and melting method.

● **Melting ash at temperatures from 1300°C to 1800°C**

Gasification and melting furnaces come in various types. These include shaft furnaces (applying steel-manufacturing technology), kiln furnaces (using a rotating-drum system; same in principle as a carbon-burning kiln), and fluidized-bed furnaces (creating a fluid layer within a gasification furnace by floating sand in the air and heating that sand at temperatures from 500-600°C to gasify trash).

Gasification and melting is a technology that thermally decomposes and gasifies household trash containing plastics within a furnace. The resulting gas is burned at high temperatures to thermally decompose dioxins and reduce their amount to a value less than the nationally regulated standard. The ash content is melted at high temperatures from 1300°C to 1800°C. In addition, non-melted metals left at the bottom of the gasification furnace are removed and inorganic materials left at the bottom of the melting furnace are recovered as slag. In a shaft furnace, slag (sand-shaped molten residue) and metals are separated before recovery.

● **Material recycling by recovering slag and metals**

Slag and metals recovered in the above way are then recycled. Slag is often recycled as blocks of secondary concrete products and as auxiliary materials such as roadbed and asphalt for civil works and construction. The metals are often recycled as raw materials for steel manufacturing, as reducing agents for metal smelting, and as counterweights for heavy construction machinery. The use of slag and metals in this way constitutes a form of material recycling

The heat expelled from the melting furnace can also be used to create high-temperature, high-pressure steam from a boiler. This steam can then be used in turn to generate power, a part of which can be used within the plant and the remainder for sale to power companies.

● **Aging of incinerators raises interest in gasification and melting plants**

Local governments in Japan have been using

incineration as a means of dealing with household trash. Many of their incinerators are aging, however, and limits are being reached in terms of trash processing and facility maintenance. For these reasons, much attention has come to be focused on gasification and melting furnaces using new technologies.

Another factor generating this interest is the maximum number of years that a landfill site can be used, a major issue for local governments. Current social needs such as easing environmental load and recycling trash also create a need for new approaches.

If the amount of landfill can be reduced to 1/10 its current rate by the use of gasification and melting furnaces, it should be possible to extend the life of landfill sites by 10 times. In addition, melting ash to slag while raising the efficiency of trash processing should ease the load on the environment at landfill sites and neighboring areas. Using plastics suitable for material recycling for that purpose makes sense, and using plastics unsuitable for material recycling for thermal recycling can be said to be an appropriate response to the needs of the times.

① Sakata City

From "purchasing" to "no purchasing" of electricity by introducing gasification and melting equipment with power generator

● Introducing fluidized-bed gasification and melting furnaces to extend the life of landfill sites by 30 years

The Waste Treatment Facility in Sakata City was constructed by the Sakata Area Refuse Disposal Union representing one city and six towns. After 15 years, however, maintenance and management expenses rose as facilities aged, and the need for a waste recycling system arose. To deal with these issues and to meet stricter regulations regarding dioxins in accordance with the Waste Management and Public Cleansing Law and the Air Pollution Control Law, the Refuse Disposal Union decided to adopt fluidized-bed gasification and melting furnaces.

This facility incorporates extensive measures to save resources and energy. For example, it adopts a closed system that breaks down dioxins through high-temperature combustion and prevents drain water from escaping to the outside, recycles material by converting ash to slag, supplies electricity and hot water through power-generation facilities using excess heat, and incorporates snow-melting facilities. Construction of Unit No. 1 of a fluidized-bed gasification and melting furnace with power generator as a treatment facility for municipal solid waste was initiated in 1999 and completed in 2002. The work was performed as a government-subsidized operation.

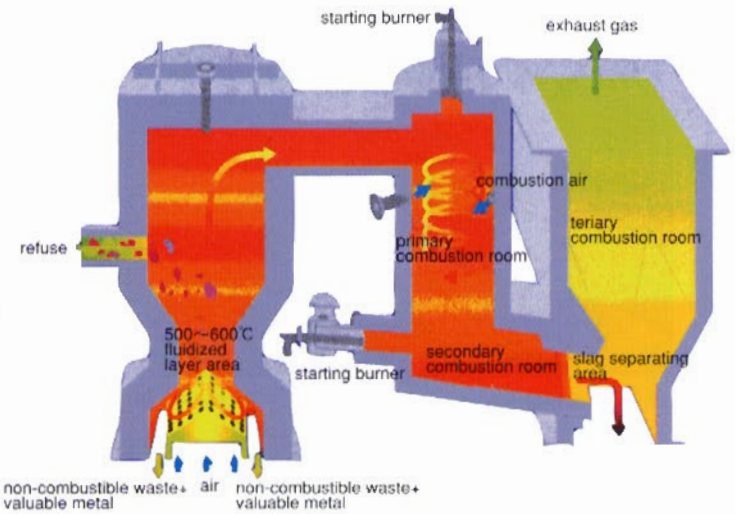
The deployment of this furnace extended the life of landfill sites currently in use by 30 years.

● "No purchasing of electricity" has great effect

Power generated using exhaust heat is supplied to the raw-sewage treatment facility, administration buildings, waste treatment facility, and other facilities on the premises. During the daytime, the power requirements of these facilities are nearly covered by the capacity of the power generator attached to the furnace. Although surplus power at nighttime may be sold off, the main purpose of generating power from exhaust heat as established in the planning stage has been to meet in-house needs.

In this way, the "no purchasing of electricity" has a far greater economical effect than the sale of electricity since reduction of such purchases has social advantages in terms of saving energy.

Sakata Area Waste Treatment Facility



Fluidized-bed gasification and melting furnace (source: Ebara Corporation)

Main Equipment of the Sakata Area Refuse Disposal Union

Completed: March 2002

Type: Fluidized-bed gasification and melting furnace

Capacity: 98 tons/day — 2 furnaces

Heat recovery: Steam turbine generator and steam usage system

Power capacity: 1,990 kW maximum output

● Making molten slag into useful materials

About 2000 tons of slag can be obtained by melting ash for every 50,000 tons of trash treated. This slag is being used as a material in street gutters and as roadbed material in Sakata City.

② Akita City

Aiming to become a resource-recycling city

The Total Environment Center of Akita City features a shaft-type gasification and melting furnace that went into operation one and a half years ago. It also includes one stoker furnace, a recycling plaza for intermediate treatment of cans, bottles, PET bottles, dry batteries, etc., bulky-waste pulverizing equipment, and a landfill site.

Akita City performed a study on what kind of furnace could contribute to the formation of a resource-recycling city, could recycle slag by melting ash as a government-subsidized operation, had a proven track record, and could extend the life of landfill sites. On the basis of this study, the city decided on a shaft-type gasification and melting furnace (a vertical-type high-temperature gasification and melting furnace).

Another reason for choosing a thermal recycling system was that a gasification and melting furnace would mean the introduction of a new sorting method that would enable almost all plastics discharged from households (excluding PET bottles) to be treated as household (burnable) trash. This, in turn, would reduce total costs from collection to waste treatment without adding a burden to sorting.

The case of white plastic trays discharged as household trash, city residents were asked to continue their use of existing reclamation channels at convenience stores and grocery stores for material recycling of this form of plastic.

Akita Total Environment Center

Main Equipment of the Total Environment Center of Akita City

〈Melting Facility〉	〈Incinerator〉
Completed: March 2002	September 1983
Type: Shaft-type gasification and melting furnace	Continuous-combustion stoker furnace
Capacity: 200 tons/day — 2 furnaces	200 tons/day — 1 furnace
Heat recovery: Waste-heat boiler	Waste-heat boiler
Power capacity: Steam-turbine generator rated at 8,500 kW	Steam-turbine generator rated at 1,000 kW

● FY2002 sales of electricity come to 160 million yen

Maximum output power when operating two melting furnaces is 8,500 kW, which usually covers all power requirements within the facility. Surplus power is sold off and power is purchased whenever in-house power is insufficient. Nevertheless, total revenue on power sales for FY2002 came to 160 million yen.

Shaft-type gasification and melting furnace
(source: Nippon Steel Corporation)

Web site: http://www.pwmi.or.jp

Plastic Waste Management Institute
Fukide Bldg. 4F, 4-1-13 Toranomon Minato-ku, Tokyo 105-0001 Japan
Tel: 81-3-3437-2251, Fax: 81-3-3437-5270