

# RECENT TREND OF ASH MANAGEMENT FROM MSW INCINERATION FACILITIES IN JAPAN

**YASUJIRO WAKAMURA**  
Takuma Co., Ltd.,  
Osaka, Japan

**KUNIHIRO NAKAZATO**  
Itoh Takuma Resource Systems, Inc.,  
New York

## ABSTRACT

More than ten ash vitrification furnaces are being operated commercially in Japan in conjunction with MSW (Municipal Solid Waste) incinerators because of the scarcity of ash disposal sites.

Municipalities (City, town and village) are responsible on treatment and disposal of the MSW basically in their own territories, and it is one of their most important tasks to extend landfill life as long as possible.

Recently the fly ash has been classified as hazardous waste and disposal is no longer allowed unless it is treated by one of the four methods specified by the new law; they are 1) solidification by cement, 2) stabilization by chelate, 3) neutralization by chemicals, 4) vitrification.

In this paper, we will evaluate vitrification furnaces for residual ash from mass burn MSW facilities in Japan, which are under commercial operation, and also those which are contracted.

## OVERVIEW OF MSW ASH VITRIFICATION FURNACES IN JAPAN

Table 1 shows a listing of MSW ash vitrification furnaces being operated commercially and under construction in Japan.

The first demonstration unit of a MSW ash vitrification furnace, a surface melting furnace with capacity of 12T/D, was installed and tested in the manufacturer's research center in 1978. Followed by a testing period at the demonstrating unit, the first commercial furnace of 6.5T/8h was put in service in June 1981. This first unit was surface melting vitrification furnace with  $\text{E1}$  heavy oil burning. Since then, seven furnaces of this type have been oper-

ated with kerosine burning and three more units are under construction.

A 20 T/D rotating surface melting ash vitrification furnace was installed in the existing MSW incineration facility, tested and demonstrated in 1979. The first commercial furnace of 12.3T/D was started up in March, 1987, and so far one additional unit has been placed in operation and another is under construction.

An experimental electric arc vitrification furnace of 3.6T/D capacity was built and tested in 1978, and a demonstration unit of 25T/D was installed in the manufacturer's laboratories in 1985. The first commercial electric arc furnaces, 2 units 250T/D each were put in service in April, 1991.

A demonstration plasma furnace with a capacity of 24T/D was installed in an existing MSW facility in 1992, and was tested. The first commercial unit of 52T/D capacity was contracted to be built for start-up in March, 1994.

A coke bed furnace with a capacity of 10T/D has been tested in the research center of the manufacturer since January, 1990, and first two commercial units each of 15T/D capacity are scheduled to start up in March, 1995.

An internal combustion type ash melting furnace was tested at a MSW incineration facility in 1988, and two 15T/D furnaces were contracted for scheduled completion in 1995.

## Features and Tasks for Ash Vitrification Furnaces

**Surface Melting Vitrification Furnace.** As shown in Figure 1, fossil fuel burners are located through the roof of the furnace and the ash which is pushed onto a refractory-lined furnace floor receives radiation heat from the burner. The burner combustion gas is blown parallel

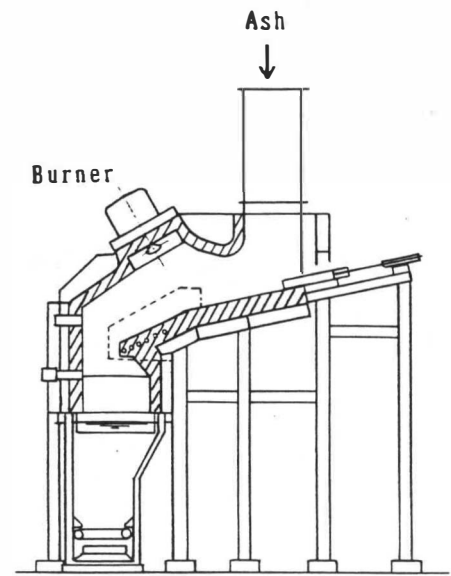
**TABLE 1 LIST OF ASH  
VITRIFICATION FURNACES IN JAPAN**

Municipalities	Capacity	Unit No.	Manufacturer	Startup Date	Type of furnace
Kashima Town	6.5T/8h	1	Takuma	06/1981	Surface melting
Saitama Tobu 2	14.4T/D	2	Takuma	03/1985	Surface melting
Saitama Tobu 1	15 T/D	2	Takuma	03/1986	Surface melting
Isahaya City	12.3T/D	1	Kubota	03/1987	Rotating surface
Anan City	4.8T/D	2	Takuma	03/1991	Surface melting
Sayama City 1	15 T/D	1	Kubota	03/1991	Rotating surface
Tokyo Ota	250 T/D	2	Daido	04/1991	Electric arc
Handa City	24 T/D	1	Ebara	03/1992	Plasma
Omiya City	75 T/D	1	Daido	03/1993	Electric arc
Matsuyama City	52 T/D	1	Ebara	03/1994	Plasma
Sakado City	9.6T/D	1	Takuma	07/1994	Surface melting
Shirane Town	7 T/16h	1	Kubota	10/1994	Rotating surface
Tokai City	15 T/D	2	Shinittetsu	03/1995	Coke bed
Saitama Tobu 3	80 T/D	2	Daido	09/1995	Electric arc
Kinuura City	15 T/D	2	I. H. I.	10/1995	Internal combus.
Sayama City 2	15 T/D	1	Takuma	03/1996	Surface melting

with the ash flow towards the outlet of the furnace so that the melting ash is kept at a fluid temperature for continuous discharge.

#### 1) Features

- Furnace temperate 1,200 ~ 1,300°C.
- Mechanically simple and robust; easy and reliable operation.
- No special skill is required for start up, shut down and maintenance.
- Accessible to the ash melting surface during operation.
- Water cooled furnace bottom for long term continuous operation.
- Larger quantity of exhaust gas compared to electric furnace.
- Higher fuel consumption than rotating surface melting furnaces.



**FIG. 1 SURFACE MELTING FURNACE**

- Separation of ferrous material from ash before charging melting hearth is required.
- Largest number of commercial units in continuous operation.

#### 2) Mass balance and volume reduction

When the residual ash is put into the furnace after two stages of magnetic separation, 92% of the ash (by weight) turns into slag, 4% into gas phase and 4% into dust. From the view point of volume reduction, a typical calculation shows that the volume of MSW decreases to 1/20 ~ 1/30 after being combusted, and the specific weight of the slag is increased two times that of the inlet ash, so that volume was reduced another 1/2 by using ash vitrification systems.

#### 3) Tasks of the surface melting furnace to be resolved

##### a) To reduce the fuel consumption

Although this system is a simple and reliable method for vitrifying ash continuously, the fuel consumption is relatively high compared to the rotating furnace. Reducing the fuel consumption by improving burner performance and minimizing the heat loss of the furnace is a most important task of this system.

##### b) To apply oxygen rich combustion air

One example of a commercially operated surface melting furnace directly connected with MSW incinerators has an oxygen rich combustion air system because space for ferrous material separators could not be found in front of the furnace. The PSA (Pressure Swing Absorption) oxygen generators are used for producing 95% oxygen, and 28% oxygen-containing combustion air for the burner of the furnace was made by mixing oxygen with normal air. The temperature of the furnace using oxygen rich combustion air is 100°C higher than that with normal air, and

as a result ferrous materials can be melted and better slag is obtained.

c) To control the alkalinity of the ash

Controlling the alkalinity of the ash by adding lime or other materials is effective to improve the fluidity of the molten ash.

### Rotating Surface Melting Vitrification Furnace

As shown in Figure 2, the ash is supplied from the outer shell to the rotating main furnace continuously and is formed into an inverted conical shape towards to the bottom outlet of the furnace. Burners installed at the top of the furnace which are adjustable upward or downward with top plate, heat the ash for melting.

A secondary furnace is located below the bottom of the main furnace, for reburning the residuals in the exhaust gas keeps up the temperature of the draining molten ash. Molten ash drops to the water quench tank and discharged by a slag conveyor.

1) Features

- Fuel consumption is quite low because of efficient heat transmissin to the conical shaped ash with high radiation effect from the surrounding refractories and low heat loss from the furnace.
- Plastics, shredded tires and other combustible wastes can be added to the ash as a supplemental fuel.
- Molten ash flows down to the bottom center of the furnace over the slope of ash forming natural angle by rotational effects. On the other hand, probability of unmelted ash dropping to the slag pit is higher compared to the stationary surface melting furnace.
- Same features as that of surface melting furnace exist in comparison to electric furnace.

2) Tasks of the rotating furnace

A stable continuous running shall be the most important task of this system since commercial units in operation with MSW do not have 24 hours continuous operation, and require daily or weekly shut down.

### Electric Arc Vitrification Furnace

Two 250 T/D and one 75 T/D electric arc furnaces for MSW ash are in operation commercially and two 80 T/D furnaces are under design. Ash is supplied from the top of the furnace after a dryer and ferrous metal separator and is melted by the heat of an electric arc generated by three electrodes. Molten ash overflows continuously along a refractory sluice with the help of an additional electrode located at the outlet (Figure 3).

1) Features

- Ferrous materials and ash are melted rapidly together by high temperature radiation heat of the electrodes

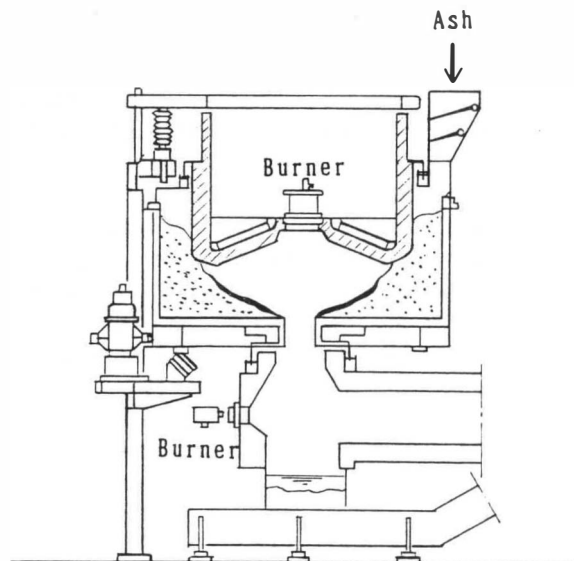


FIG. 2 ROTATING SURFACE MELTING FURNACE

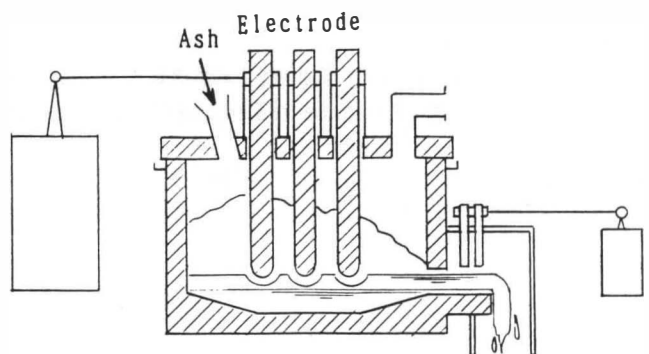


FIG. 3 ELECTRIC ARC FURNACE

(1,400°C).

- No additional outlet for molten metals is required.
- No alkalinity control is required because of high temperature electrodes.
- Ash is introduced from the top of furnace and spreads over the molten slag keeping heat loss low.
- The level of melting slag is constant because of overflow outlet system.
- An oxidizing atmosphere is maintained in the furnace because combustible gases are burned before going out, and as a result, explosion risk is kept to a minimum.
- No water-cooled parts are used, so the risk of a vapour explosion is minimized.
- Operators with special skill are required for operation of the furnace.

2) Tasks to achieve

- Improve the materials of sluice to extend its useful life.
- Reduce the consumption of electricity.
- Achieve the stable operation of the wet ash dryer.

## Plasma Arc Vitrification Furnace

As shown in Figure 4, the ash vitrification process is almost the same as in an electric arc furnace except for the use of plasma arc as a heat source. A plasma arc furnace can be designed smaller than an electric arc furnace because of its higher service temperature. There are two types of plasma furnace; one uses the transferring type plasma arc method which transfers an arc from electrode to the furnace bottom, and the other uses a non-transferring type plasma arc. To establish stable operation and long life of electrode, there are two different furnace operation methods. One is to maintain a reducing atmosphere inside the furnace to burn combustible gases in the five gas outlet duct, and the other is to maintain an oxidation atmosphere to burn combustible gases in the furnace. So far no commercial plasma arc furnace units for melting MSW ash are in operation.

### 1) Features

- As it keeps the high furnace temperature as high as  $1,500^{\circ}\text{C}$ , the molten material flows out more easily than with other systems.
- Less electrical noise and flicker is expected.
- Long life of electrode is expected especially with reducing atmosphere operation.
- Ash processing, life of refractories and other operational characteristics will be the same as with the electric arc furnace.

### 2) Tasks to achieve

It is most important for the plasma furnace operation to achieve the reducing atmosphere by keeping a positive pressure in the furnace and to burn combustible gases in the five gas duct in order to avoid the risk of an explosion. Experiences in long continuous operation are important to achieve stable operation, to investigate the life of electrode and refractories, and to identify other operational characteristics.

## Coke Bed Vitrification Furnace

As shown in Figure 5, ash, coke and limestone are fed from the top of the furnace center and more coke and limestone is added to the furnace girth to form a coke-filled layer for maintaining a five gas path through the furnace. A high temperature combustion air burns coke and ash while they move down from top to the bottom in the furnace. Ash is melted when passing through the high temperature coke bed and discharged continuously to the water quench tank.

Ferrous materials are melted and dropped in the water where it takes spherical shape. A high temperature five gas passes upward in the furnace, preheats materials and is burned in the secondary combustion chamber, and exhausted after passing through the combustion air preheater.

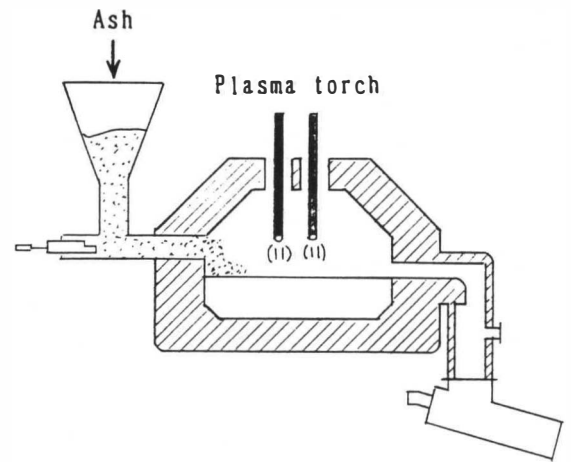


FIG. 4 PLASMA FURNACE

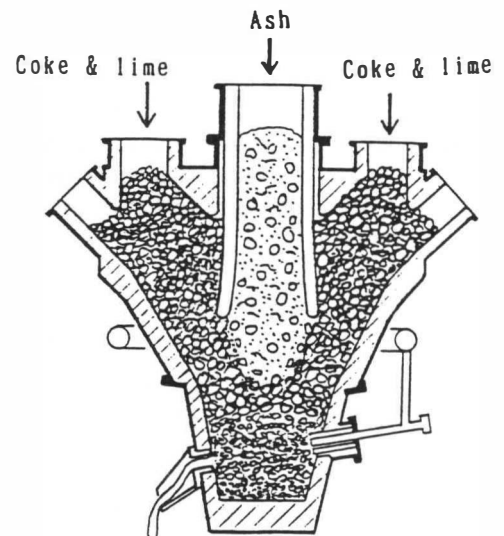


FIG. 5 COKE BED FURNACE

No commercial unit is in operation, therefore operational characteristics will be defined after long term experiences.

### 1) Features

- The slags is of excellent quality, one of best among ash vitrification furnaces. This is because of the high furnace temperature ( $1,700^{\circ}\text{C}$ ) and controlling of alkalinity by limestone.
- Higher exhaust gas volume compared with electric arc furnaces.
- Continuous operation will be achievable through the experiences of blast furnace which is similar to this furnace.
- Water cooled outlet sluice for melting ash will be able to last a long period.

### 2) Tasks to achieve

Unexpected troubles may happen and operational characteristics will be cleared only through long term commercial operation experiences.

### Internal Combustion Type Vitrification Furnace

As shown in Figure 6, this is a combined system with rotary type MSW combustor and ash melting furnace. MSW is not burned out in the rotary combustor and the remaining carbon becomes the heat source for melting ash with high temperature hot air. Electric heaters are installed in the bottom of the melting furnace as an additional heat source for melting ash. So far no commercial operated furnace exists.

#### 1) Features

- An ash melting furnace is connected directly to and in series with an MSW combustor.
- Remaining carbon, equivalent to 10 to 15 percent of the calorific value of MSW, is consumed as fuel for ash melting; as a result, fuel cost will be lower than surface melting furnace.
- Volume reduction rate will be the same as with the surface melting furnaces.

#### 2) Tasks to achieve

- Realization of a stable overall control system for both MSW combustor and ash melting furnace.
- Ferrous materials shall be easier to separate from MSW before charging into the combustor.
- Development of countermeasures to deposition of highly volatized heavy metals in the gas quenching chamber.
- Ways to minimize the carbon monoxide in the flue gas.

### INSTALLATION, OPERATION AND MAINTENANCE

For the most part, surface melting vitrification furnaces are suitable for unit capacities below 50 T/D of ash, and for MSW incineration facilities without power generators. Peripheral facilities for these furnaces are relatively simple compared with those of an electric furnace, and operation is also easier. On the other hand, flue gas treatment facilities are larger.

Electric vitrification furnaces for ash may be selected for MSW incineration facilities with power generators, which are relatively larger MSW processing facilities, and as a result the unit capacity of the furnace will be larger than 25T/D. Operators should have experience of electric furnace operation.

A coke bed vitrification furnace for ash can be designed for a wide range of capacity, from 10 T/D to 150 T/D, for MSW facilities with or without power generators. Peripheral equipment is required, just as with a fossil fuel com-

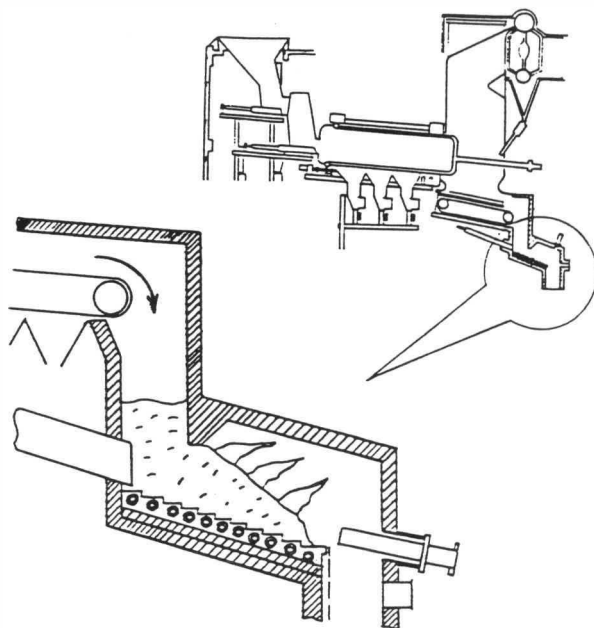


FIG. 6 INTERNAL COMBUSTION MELTING FURNACE

bustion vitrification furnace, coke and limestone storage and feeding facilities are also needed. Operators should have experience of blast furnace operation.

The design concept for a vitrification furnace density connected to a MSW rotary combustor is different than that of other vitrification systems which are independent from MSW incinerators. The flue gas treatment equipment and most other associated equipments are common for the MSW incinerator and the vitrification furnace so that installation cost is relatively lower compared to other systems.

Table 2 shows installation and O & M cost of various vitrification furnaces with the capacity of 50 T/D. As indicated in the table, installation cost of each furnace is almost at the same level except for the rotary combustor type furnace.

### PENDING TECHNOLOGICAL TOPICS

#### Preconditioning the Ash Before Melting

The ash should be dried and separated from ferrous materials before loading into the melting furnace. The preparation machinery consists of crushers, vibrating screens, magnetic separators, dryers, conveyors, ducts and ash distributors. Moisture in ash disturbs the stable ash melting effect, causing pressure rises in electric furnaces and increasing fuel consumption in furnaces using fossil fuels. The allowable maximum moisture content of ash melting is five percent regardless of the furnace type. Ferrous materials demand a high melting temperature and higher energy consumption, and reduce the quality of slag. Removing ferrous materials as much as possible is very im-

**TABLE 2 INSTALLATION AND O & M COST OF THE VITRIFICATION FURNACE (CAPACITY: 50 T/D PER DRY ASH TON)**

	Surface melting	Rotating surface	Electric arc	Plasma	Internal combus.
Installation \$/t	900.000	900.000	900.000	900.000	400.000
Operator No./t	0.18	0.28	0.32	0.24	
Fuel (l/t)	350	210	65	-	
Electricity KW/t	150	150	770	450	150
Water m <sup>3</sup> /t	2.5	1.2	4.5	0.5	
NH <sub>3</sub> kg/t	-	-	2.0	1.7	
Ca(OH) <sub>2</sub> kg/t	2	2.8	-	20	
Chelate kg/t	0.6	-	0.6	-	
NaOH l/t	-	60	2.1	-	
Cement kg/t	-	-	-	24	
Electrode kg/t	-	-	6.6	0.005	
Nitrogen kg/t	-	-	2.5	-	

portant for stable ash melting. It is also necessary to adjust the size distribution of ashes before feeding to the furnace. The size of ashes shall be 30 mm diameter maximum and preferably less than 10 mm diameter.

### Adjustment of Alkalinity

A high alkalinity ash shows high melting temperature and good fluidity; on the other hand, when adding materials of glass, sodium and potassium, the melting temperature of the ash decreases but fluidity of slag becomes worse. Selection of suitable additives is important for keeping good ash melting. The alkalinity of coke bed furnace can be made as high as 0.8 ~ 1.0 by mixing coke with limestone and the melting temperature comes to 1,500°C, the fluidity will be better, and good slags without sharp edges can be obtained.

### Service Life of Refractories

A characteristic of electric furnaces is that accumulated molten material is discharged by overflow from the outlet sluice, so the molten materials form separate layers according to their specific weight. Among materials, molten metals are heaviest and form a layer at the bottom of the furnace, and copper and lead in the metals penetrate the bottom refractories. Molten salts such as potassium chloride, calcium chloride and sodium chloride float on the molten slag and damage the surrounding refractories. The outlet sluice is damaged severely by overflowing molten materials and should be replaced every two to three weeks. The service life of refractories of electric furnaces depends upon the temperature of molten materials,

salt content, metal content, alkalinity of slag and operation time.

Fossil fuel burning furnaces receive ash and discharge molten materials continuously, so no layer of metal and salt is formed in the furnace. No outlet sluice is required, except for coke bed furnaces, and service life of refractories is much longer than that of electric furnaces.

### Highly Volatilized Materials in Flue Gas

Highly volatilized heavy materials such as cadmium, lead, zinc and others are volatilized at the furnace temperature and condensed in the ducting, gas quenching chamber and dust collector when a certain temperature is reached.

Salts are also flushed out and they stick and clog somewhere in the flue gas lines. These cause unscheduled shut downs of the system and disturb continuous operation. To minimize clogging, sudden dropping of flue gas temperature to around 250°C is quite effective by water injecting or introducing cooling air.

### Slag Utilization

Slag has been tested for utilization in road pavement, concrete gravels and tiles. It may be better to separate metals from the slag for utilizing the slag in a wider range of application. The strength of the slag is almost equal regardless of vitrification furnace systems, but is different according to the slag cooling methods; natural cooling (highest strength), air cooling (middle), and water cooling (lowest). So far commercially operated ash vitrification furnaces for MSW ash are using water cooling systems only because of their easy operation. Slag utilization testing has been carried on using mainly water cooled slag and little air cooled slag, and natural cooled slag is not tested.

### CONCLUSION

There are several other MSW ash vitrification furnace systems under development in addition to the six under commercialization as indicated in this paper. Even though these ash vitrification furnaces are commercialized, they have technological pendings to resolve and require continuous investigation to realize stable operation with minimum operation and maintenance cost.

The MSW ash vitrification furnaces are useful for extending service life of landfill sites, and the number of municipalities requiring vitrification furnace are increasing year by year in Japan. In view of economy, slag should be not only used for the landfill material but also be used for industrial products. Utilization of the vitrified slag will be the next target for investigation of the vitrification furnaces after the remaining technological pendings regarding the furnace operations are resolved.

## REFERENCES

H. Noda, "Residual ash vitrification equipment", Industrial pollution, vol. 16, 1980.

H. Iwasaki, "Residual ash film vitrification furnace", Living and Environment, April, 1988.

S. Inoue, "Vitrification furnace for MSW incinerator", 11th Sympo. on Kyoto Univ., 1989.

S. Takenaka, "Vitrification of MSW ash by plasma, No. 2 report", 12th Municipal Environmental Research Work", February 1991.

S. Inoue, "IHI Rotary combustor type vitrification furnace", Papers of 2nd Conference on the Society of Wastes Research", October 1991.

T. Kimura, "Vitrification of Fly Ash from MSW Incinerator", Research on Environmental Engineering", Vol. 6, No. 3.

Takuma Co., "Film Vitrification Furnace for Residual Ash", Environmental Technique, Papers Vol. 21, No. 4, 1992.

Ebara Infilco Co., "Residual Ash Vitrification by Plasma Torch", Environmental Technique, Papers Vol. 21, No. 4, 1992.

K. Kawamoto, "Vitrification of Fly Ash", Papers of 3rd Conference on the Society of Wastes Research", November 1992.

S. Kuwazuka, "Development of Vitrification Technique for MSW Residual Ash", Papers of 3rd Conference on the Society of Wastes Research, November 1992.

I. Kojima, "Trends and Tasks for Technologies for Residual Ash Vitrification", Journal of City and Wastes, Vol. 23, No. 5.