Environmental Business Contributing to the Resource Recycling Society*


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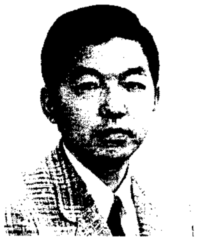
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Synopsis:

Environmental business by Kawasaki Steel, whose technical base has been developed through construction and operation of steel works, offers many kinds of environmental systems, such as Kawasaki Steel Thermoselect System, Plasma Arc Ash Melting Plant, Refuse Derived Fuel Plant, Water Treatment Plant, and so on. The aim of environmental business is to contribute to the coming resource recycling society by applying developed technology, and to contribute to the local community around the steel works by supplying the service which the steel works can offer by utilizing their facilities and/or technology.

1 Introduction

Kawasaki Steel has carried out environmental business as part of activities in the field of energy and water supply within the Engineering Div., on the basis of its own technologies developed in the long history of the construction and operation of steel works, such as high-temperature melting treatment and inorganic waste water treatment. In 1998, the company established the Environmental Div. in order to promote resource recycling. The company's oldest environmental business involves water treatment facilities. On the basis of its construction and operation of environmental protection facilities at steel works, the company first received orders in the 1990s for effluent treatment systems appurtenant to overseas steel works on a full turnkey basis and has since achieved significant results with water treatment facilities for industries other than the steel industry. Since the 1990s, the company has been developing products in the field of sewerage treatment.

Since around 1990 the company has been developing refuse-derived fuel (RDF) plants for making fuel with excellent storability, transportability and combustibility from combustible refuse without incineration. At present, 13 RDF plants of the company's method are operating in Japan accounting for about 50% of the nation's total.

In 1994 the company received an order for mechanical stoker type batch refuse incinerators. After that, however, the company determined that it should work to bring technologies for environmental protection, including measures against dioxins, and technologies for bringing resource recycling to the commercial stage. Thus, it decided to introduce its Kawasaki Steel Thermoselect gasification and melting system and constructed a demonstration plant of 300 t/d scale at Chiba Works in 1999.

Anticipating shortages of final disposal sites in the future, in 1986 the company started fundamental experiments on ash melting plants. After that, joint research with Chiba City, Tokyo Electric Power Co., Inc. and Kawasaki Heavy Industries, Ltd. was carried out, fundamental techniques were established, and the development of ash melting was completed. Techniques for stable operation of commercial plants have been established.

This report describes the history of development and future prospects of these products.

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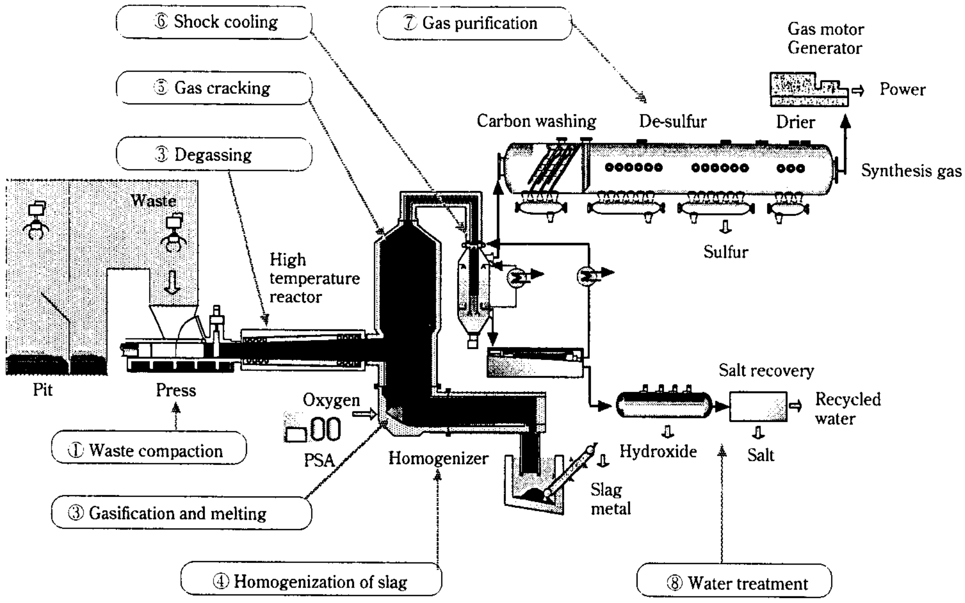


Fig. 1 Kawasaki Steel Thermoselect process

2 Waste Disposal Plant Business

2.1 Kawasaki Steel Thermoselect System and Incineration Facilities

2.1.1 Background of introduction of next-generation waste resource recycling plant

The company entered the market of municipal refuse incineration facilities relatively recently. Its first order was for the mechanical stoker type batch incinerators (two furnaces that operate for 8 h/d and each has a treatment capacity of 17 t/8 h) constructed in August 1994 in the Amakusa District of Kumamoto Pref.[1].

After that, the company decided to bring technologies for environmental protection, including measures against dioxins, and technologies for resource recycling to the commercial stage. In 1997, the company decided to obtain the licence of state-of-the-art waste gasification and melting technology that had been developed by Thermoselect of Switzerland[2]. This Thermoselect System was developed to vastly reduce the adverse effect of waste disposal on the environment, and to recycle all by-products including generated gases. In a demonstration plant that was brought into operation in Italy in 1992 (treatment capacity 100 t/d), the company attained a dioxin emission concentration of 0.001 ng-TEQ/m^3_N, an achievement that was highly acclaimed by the German Technical Inspection Society in 1994. In Karlsruhe, Germany, the No. 2 plant (3 furnaces each with a treatment capacity of 240 t/d) started operation in March, 1999.

Kawasaki Steel immediately constructed the first plant in Japan (two furnaces each with a treatment capacity of 150 t/d) at Chiba Works in a short construction period of 15 months. Using municipal waste generated in Chiba City, the company has demonstrated since September 1999 that consistent treatment is possible.

An outline of the features of the Kawasaki Steel Thermoselect System[3–5] is given below.

2.1.2 Features of the Kawasaki Steel Thermoselect System

The process flow diagram of the Kawasaki Steel Thermoselect System is shown in **Fig. 1**. The features of this system are summarized as follows.

(1) Suppression of the Formation of Dioxins

In the conventional incineration systems, waste is burned and dioxins contained in effluent gas are removed after the recovery of waste heat. In contrast, in the Kawasaki Steel Thermoselect System, the gas generated by pyrolysis and melting is kept at high temperatures of not less than 1 200°C, cracked and then rapidly cooled to 70°C to minimize the formation of dioxins and to recover the gas as a fuel. During the treatment, useful by-products such as metal hydroxides can be recovered without the formation of fly ash, which is hard-to-treat waste. The dioxin concentration after rapid cooling is much lower than 0.1 ng-TEQ/m^3_N, which is the new guideline set by the Ministry of Health and Welfare, and is not more than 1/100 of the regulatory standard for effluent gas after gas power generation[6,7].

Furthermore, the total emission load of dioxins from this plant can be controlled to levels of not more than 0.01 μg-TEQ/t-refuse.

(2) Complete Resource Recycling from Waste

In this system, waste is converted to purified synthetic gas, slag, metal, metal hydroxide, sulfur, mixed salts and recycled water, and almost complete

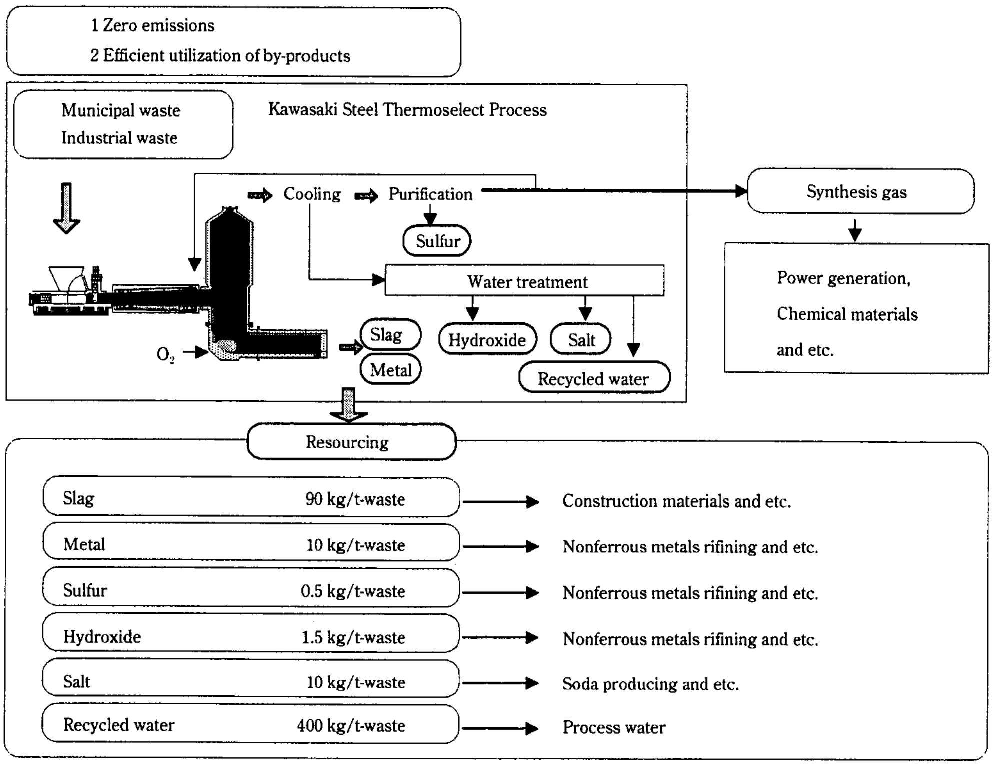


Fig. 2 Resourcing of clean by-products

resource recycling is achieved (**Fig. 2**). Slag can be used as construction materials such as road bed material, metals and metal hydroxides as the raw materials for nonferrous metal refining, and sulfur and mixed salts as chemical materials. Further, recycled water is used for cooling in the plant.

(3) Clean Gas Recovery by Gas Cracking

In this system, the gasification and high-temperature cracking of waste converts the energy of waste into a very clean, recoverable combustible gas equivalent to natural gas (gas reformation)[8]. This synthetic gas, which is mainly composed of H_2 and CO, can be used not only as a fuel for high-efficiency gas power generation and other industrial uses, but also as a chemical raw material for the synthesis of methyl alcohol, acetic acid, ammonia, etc. When this synthetic gas is used as a fuel, toxic substances such as HCl and SO_X are almost non-existent in the combustion exhaust gas and the formation of NO_X can also be suppressed. For this reason, a large stack becomes unnecessary. When the synthetic gas is used as a fuel for power generation, an optimum method of power generation suited to the scale of equipment, site conditions, etc. can be selected based on generation using a gas engine, a fuel cells, etc. Generation using fuel cells, is particularly attractive, since NO_X is scarcely formed and the environmental impact can be minimized.

(4) Space Savings and Cost Minimization

The plant is compact and the construction space can be reduced to about 70% in comparison with the conventional incineration-plus-ash-melting system, because the degassing channel and the high-temperature reactor are a one-piece design, a large stack is unnecessary, and the volume of generated gas to be treated is not more than 1/6 of the exhaust gas volume of an ordinary incinerator.

2.1.3 Outline of process

The process of the Kawasaki Steel Thermoselect System comprises the following steps:

(1) Press and Degassing Channel

(a) Waste Compression (for Solid Waste)

First, waste is compacted to about 1/5 of the initial volume by means of a press. As a result, the distribution of moisture in the waste is made uniform and air is removed. Therefore, the degassing efficiency improves.

(b) Drying and Pyrolysis

Next, the compacted waste is dried and degassed in the degassing channel, which is an indirect heating furnace. Subsequently, it is further pyrolized by the radiation heat from the high-temperature reactor, etc.

(2) High-Temperature Reactor and Homogenizer

(c) Gasification and Melting

The gas generated in the degassing channel flows into the high-temperature reactor and pyrolytic substances are pushed out by the charge of new compacted waste and accumulate in the lower portion of the high-temperature reactor. When O_2 is blown into the lower portion of the high-temperature reactor, the temperature in the lower portion rises to about 2 000°C maximum in the central portion due to the reaction of C in the pyrolytic substances with O_2, and the metals and inorganic components in the waste melt.

(d) Homogenization of Slag

The melt flows from the high-temperature reactor into the homogenizer kept at about 1 600°C and trace amounts of C, etc., are gasified. The molten substances are pushed out, continuously flow through the homogenizer down into the slag granulating system, where they are recovered and the metals are separated from slag by magnetic separation.

(e) Gas Cracking

The gas generated in the lower portion of the high-temperature reactor and the pyrolytic gas generated in the degassing channel join and remain for not less than 2 s at about 1 200°C in the cracking section of the high-temperature reactor.

(3) Gas Purification

(f) Rapid Gas Cooling (Shock Cooling, Acid Washing and Alkali Washing)

The crude synthetic gas cracked in the high-temperature reactor is rapidly water-cooled by the rapid cooler from about 1 200°C to about 70°C to prevent the resynthesis of dioxins by de Novo synthesis. After that, heavy metals and acid gas are removed by acid washing and alkali washing.

(g) Gas Purification (Dedusting, Desulfurization and Dehumidification)

Next, the gas is dedusted, desulfurized, washed and dried to produce a clean purified synthetic gas.

(4) Water Treatment

(h) Water Treatment and Salt Recovery

The H_2O gas generated up to the gas cracking step condenses in the gas rapid cooling and purification steps and all the heavy metals and salts that are contained in exhaust gas as fly ash in the conventional incineration system move into the washing water. For this reason, fly ash is not formed and the water contains metals such as Fe, Zn, Pb, Na and K. However, the metals are recovered as useful substances such as hydroxides and mixed salts by the water treatment and salt recovery facilities, and water that can be reused as the process water for cooling is obtained.

2.1.4 Results at the Chiba plant

(1) Results of Treatment

In the plant having a treatment capacity of 300 t/d constructed at Chiba Works, about 15 000 t of municipal waste have been subjected to gasification and melting treatment since September 1999. The results of an analysis of the recovered purified synthesis gas are shown in **Table 1**.

Table 1 Characteristic of synthesis gas (at Chiba Plant)

			After gas purification
Component	CO	(%)	32.5
	H_2	(%)	30.7
	CO_2	(%)	33.8
	N_2	(%)	2.3
Pollutant	Dust	(mg/m^3)	69
	H_2S	(mg/m^3)	3.4
	HCl	(mg/m^3)	5.3
	$PCDD_S/PCDF_S$	(ng-TEQ/m^3)	0.000 39
$PCDD_S/PCDF_S(O_2$: 12%)		(ng-TEQ/m^3)	0.000 09

Table 2 Leaching test of slag (at Chiba Plant)

	Achievements (mg/ℓ)	Soil standard (mg/ℓ)
Cd	<0.01	≦0.01
Pb	<0.01	≦0.01
Cr (VI)	<0.05	≦0.05
As	<0.01	≦0.01
T-Hg	<0.000 5	≦0.000 5
Se	<0.01	≦0.01

The pyrolysis, rapid cooling, etc., in the gas cracking section, resulted in a dioxin concentration in the purified synthetic gas of 0.000 09 ng-TEQ/m^3 (O_2: 12% conversion)

(2) Properties of By-Products

As shown in **Table 2**, the quality of slag meets the leaching standard contained in the "Guidelines for the Recycling of Melted and Solidified By-Products from Municipal Waste[9]" set by the Ministry of Health and Welfare. The principal metal component is iron but there are also high concentrations of copper. Therefore, it is possible to use this copper as a raw material for nonferrous metal refining. In the demonstration project using combustible waste from Chiba City, the copper content in metals exceeded 10%. Metal hydroxides contain not less than 30–40% Zn on a dry basis and can be effectively used as a material for nonferrous metal refining. The total emission of dioxins in the by-products in the Chiba plant is about 0.001 μg-TEQ. This value is much lower than 5 μg-TEQ/t-waste[10], which is estimated to be achievable with conventional incineration technology (**Table 3**).

2.1.5 Future prospects for the Kawasaki Steel Thermoselect System

Through the use of the plant equipped with two furnaces each with a treatment capacity of 150 t/d constructed at Chiba Works, continuous operations of not less than 90 d and operations for a total of not less than 130 d were completed in a fiscal year 1999 with cooper-

Table 3 Emission of DXNs (at Chiba Plant)

By-products	$PCDD_S/PCDF_S$ (TEQ)	Total emission per 1 t-waste
Synthesis gas	0.000 39 ng-TEQ/m^3	0.000 69 μg-TEQ/t-waste
Slag	0.000 70 ng-TEQ/kg	
Metal hydroxide	0.29 ng-TEQ/kg	
Sulfur	0.35 ng-TEQ/kg	
Salt water	0.000 01 ng-TEQ/ℓ	

ation from Chiba Pref. and Chiba City for the demonstration prescribed in the "Guidelines for Waste Disposal Performance." This was the first demonstration in Japan of municipal waste disposal using gasification and melting equipment of an actual plant (150 t/d · furnace).

At this plant location in Chiba Works, the company intends to start in fiscal 2000 refuse-derived fuel gas producing business, which involves producing a fuel gas from consigned industrial waste and utilizing the gas as a fuel for power generation at Chiba Works and elsewhere (the company has already acquired the Minister's authorization based on the stipulations under Clause 1, Article 8 of the Special Law for Promoting the Utilization of New Energy).

2.2 Refuse-Derived Fuel (RDF) Plant

2.2.1 Background of the introduction of RDF plants

The waste disposal facilities in Japan have so far been constructed and improved under a disposal system mainly based on incineration and landfilling. However, the emission of dioxins, etc. associated with incineration has become a health problem, making it difficult to construct such waste disposal facilities. On the other hand, there has been a growing interest in resource recycling and recovery of unutilized energy and citizens are working to promote environmental protection and resource recycling in society.

Against this social backdrop, Kawasaki Steel, in collaboration with Recycling Management Japan, Inc. (RMJ), has been working since around 1990 to promote the widespread use of RDF plants using combustible refuse to make fuel having excellent storability, transportability and combustibility. In 1993, RDF plants were recognized as facilities to be subsidized by the national government and in April 1996 the Nanto Recycling Center was brought into full-scale as the first facility to be subsidized by the Ministry of Health and Welfare.

RDF plants have since received attention as refuse disposal facilities that can replace incineration facilities. In 1997, the regulations governing the formation of dioxins were strengthend, with a result that small and medium municipalities where the promotion of regional waste disposal[11] is difficult have shown an increasingly acute interest in RDF plants.

2.2.2 Features and installation status of RDF plants

(1) Features of RDF Plants

RDF processes are classified into the Kawasaki Steel (RMJ) system and the J-Catrel system. The J-Catrel system was developed for refuse of low moisture content, as in Europe, whereas the Kawasaki Steel system is a domestic technology developed for refuse of high moisture content. The main differences between the two systems are the sequence of drying and pelletizing steps and the drying method[12]. **Table 4** gives a comparison of the features of the two systems, and **Fig. 3** shows the process of the Kawasaki Steel RDF plant. The features of the Kawasaki Steel system are described below.

(a) Drying System Suitable for Refuse of High or Highly Variable Moisture Content

In contrast to the indirect heating method by the

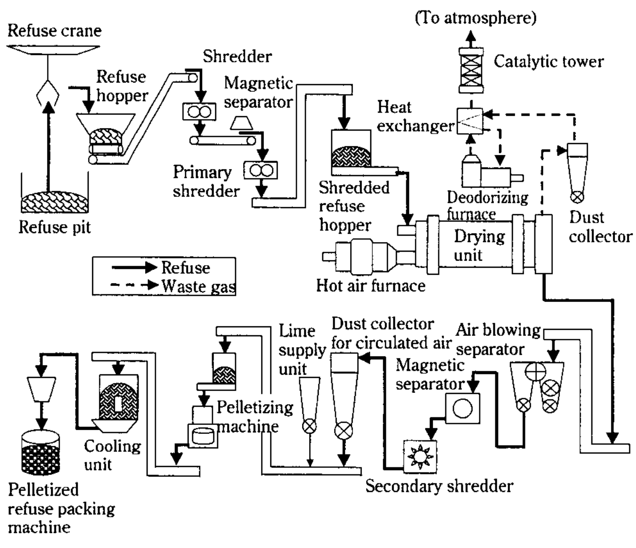


Fig. 3 Kawasaki Steel RDF process

Table 4 Comparison of Kawasaki Steel system with J-Catrel system

	Kawasaki Steel system	J-Catrel system
Plant process	Primary shredding and separation → Drying → Secondary shredding and separation → Pelletizing	Shredding and separation → Chemical reaction and steam drying → Pelletizing → Drying
Method of drying	Direct drying by hot air	Chemical reaction heat of quicklime + Indirect steam drying + Ventilating by hot air

heat of reaction by the addition of quick lime (5 wt% relative to the weight of refuge) and steam in the J-Catrel system, in the Kawasaki Steel system refuse is hearted directly by hot air (kerosene is used as the fuel) through the use of a rotary drum type dryer that also stirs the refuse. Therefore, the drying time is short and this system is suited to refuse of high moisture content. Furthermore, automatic control is performed to constantly maintain the moisture content on the delivery side of the dryer within a specific range even when there are variations in the moisture content of refuse on the entry side of the drier.

(b) Manufacturing of High-Quality RDF

In terms of quality, RDF is required to have strength high enough to avoid breakage during handling and transportation and also to provide consistent combustibility. The Kawasaki Steel system uses a stone mill type compression-extrusion pelletizing machine in which refuse is pelletized by being ground by multiple rollers that rotate and revolve on a porous die suitable for strongly compacting refuse. Before pelletizing, additives are added for sterilization and to suppress the generation of chlorine compound gas during combustion.

(c) Plants of High Reliability, Maintainability and Safety

As will be described later, the Kawasaki Steel system has the best track record of all RDF system. The occurrence of equipment troubles is suppressed by stabilizing refuse transfer equipment, improving the separation accuracy of unsuitable substances, and other measures. Maintainability has been improved by the adoption of a unit replacement method for the cutters of the shredder.

(2) Installation Status of RDF Plants

In Japan, 27 RDF plants are in operation and 3 other plants are under construction[13]. Almost all the plants are small-scale facilities with a treatment capacity of 6 to 40 t/d. Recently, however, construction has started on plants with a treatment capacity of the 200 t/d class aimed at RDF power generation. Thirteen of these RDF plants are Kawasaki Steel RDF plants, including one under construction. Thus the Kawasaki Steel system is the most popular for RDF plants. The Locations of the Kawasaki Steel RDF plants are shown in **Fig. 4**.

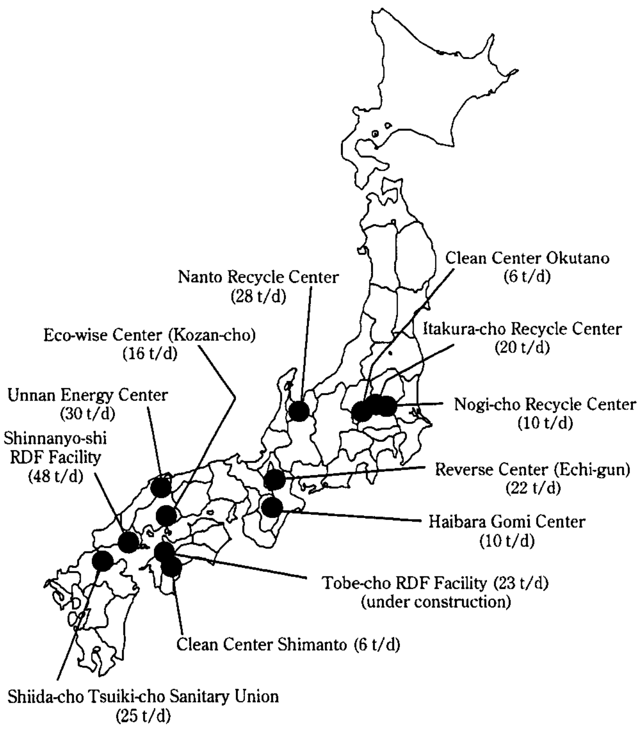


Fig. 4 Sales records of Kawasaki Steel RDF plant

2.2.3 Future prospects for RDF technology

As society becomes more concerned about environmental protection and resource recycling, the RDF technology has been recognized as a new refuse disposal technology that replaces small- and medium-scale incinerators, and the number of RDF plants has been increasing. To promote more widespread use, however, manufactured RDF must be utilized. Uses of RDF so far reported include heat sources for public facilities of surrounding communities (air conditioning systems, heated swimming pools, etc.) and auxiliary fuels in private enterprises such as cement plants (all cases being small- and medium-scale RDF plants). However, in all such cases, the uses of RDF are limited due to problems such as locations of RDF-using facilities, stable RDF supply and disposal of combustion ash. Recently, the large-scale use of RDF power generation has been vigorously promoted in Mie and Fukuoka Pref.[14]. However, there are many problems such as cost efficiency and cooperation from neighboring municipalities, so it seems that it will take time to bring large-scale RDF plants into widespread use.

Against this background, Kawasaki Steel has moved with the research and development of an "RDM (refuse-derived material) carbonization system". In the Kawasaki Steel RDM carbonization system, RDF is heated and carbonized at 300–900°C in the absence of O_2 or in a low-oxygen atmosphere using an oscillating type carbonization furnace. The resulting carbide is called "River Eco Coal." River Eco Coal is used in the pulverized-coal injection (PCI) for blast furnaces and is mixed with raw materials for sintering. A demonstration plant with an RDF treatment capacity of 10 t/d was brought into operation in April 2000 at the Mizushima Works and test runs are being carried out. It is expected that the RDM carbonization system will come into widespread use at home and abroad as one of the extensions of RDF technology.

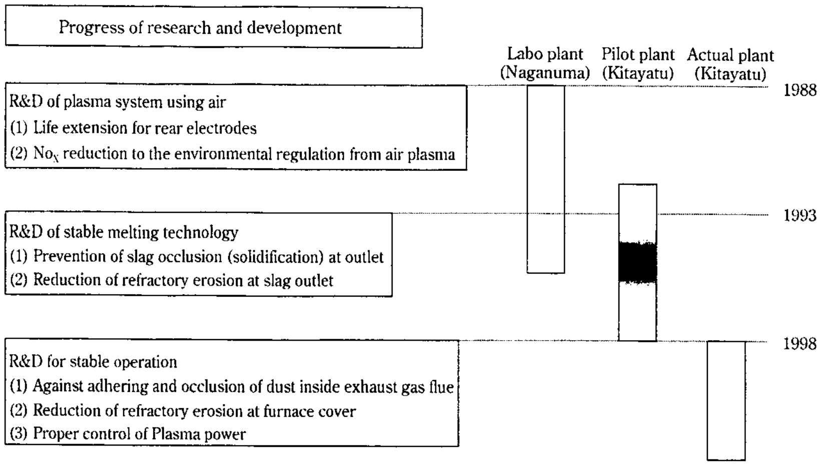


Fig. 5 Progress of research and development of ash melting process

2.3 Plasma Melting Process

2.3.1 Progress of research and development

The company started to develop an ash melting process in 1986, when the shortage of final disposal sites for municipal waste ash started to become a social issue. At that time, fuel-type melting mainly by volume reduction, such as burner melting, was widely used to cope with the shortage of disposal sites. Predictions that the public would start to demand a reduction of environmental load with the coming dioxins and global warming problems and the trend toward resource recycling in society, the company selected a plasma melting process that enables high temperatures to be easily obtained and the atmosphere to be freely adjusted as a method for melting ash at high temperatures, thereby making ash harmless and recyclable. The progress of the research and development of the ash melting process is shown in **Fig. 5**.

The development of ash melting is broadly divided into solutions to problems in pilot plant tests, demonstration tests and continuous operations using an actual plant.

In 1987, a pilot plant equipped with a 200 kW plasma generator (treatment capacity 1.2 t/d) was constructed and fundamental tests were conducted for five years[15]. In these tests, material balance and heat balance, which provide the basic data for this melting process, were made clear and it was ascertained that the volume is reduced by 1/3 and that slag is formed with stable leaching properties. Furthermore, it was found that the plasma torch structure has a great effect on the life of plasma torch electrodes, which poses a problem in actual operation, and the life was substantially extended, from 20 h to 2 000 h.

In 1993, a demonstration plant equipped with a 1 000 kW plasma generator (treatment capacity 1 000 kg/d) was constructed on the premises of the Kitayatsu Waste Incineration Plant in Chiba City. In demonstration tests, continuous long-term operations were carried out, and the furnace profile was optimized and deslagging runners were improved in order to ensure consistent melting and deslagging[16]. In addition to a 30 d continuous operation test, slag production for field tests for slag recycling, an incineration fly ash mixing and melting test[17], etc., the demonstration plant was operated to respond to requests for melting tests from municipalities, and it was ascertained that the demonstration plant has sufficient durability to be used commercially. After that, the demonstration plant was partially modified in 1998 and is now operating on a 24 h basis at the Kitayatsu Plasma Melting Center.

2.3.2 Features of the plasma melting process

In the plasma melting process for waste, pyrolytic toxic substances such as dioxins are made harmless by melting waste using a high-temperature heat source of plasma (tens of thousands of degrees centigrade). At the same time, waste is recycled by making incineration ash harmless as stable slag that does not leach heavy metals and by reducing the volume of incineration ash.

Figure 6 shows the schematic flow of the plasma melting process in the Kitayatsu Waste Incineration Plant that has been in continuous operation as a commercial plant. This process has the following three features.

(1) Because heavy metals vaporize in a high-temperature melting plasma, the amount of heavy metals in slag decreases. Furthermore, because a plasma jet stirs the high-temperature molten pool and completely melts the heavy metal, the metal is enclosed in the slag in a stable manner. For this reason, the amount of metal leached from the slag meets the standards for leaching in soil (e.g. Pb $<$ 0.01 wt ppm and Cd $<$ 0.01 wt ppm).

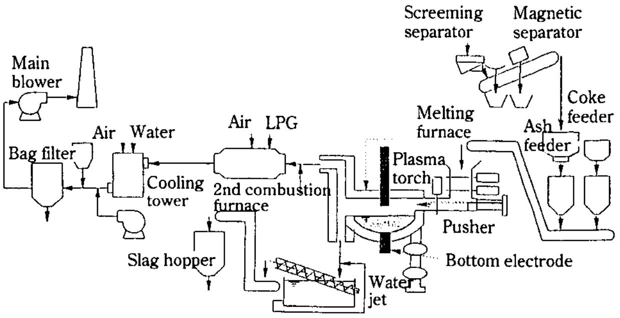


Fig. 6 Schematic flow diagram showing ash melting process

(2) The formation of a high-temperature atmosphere decomposes toxic chemical substances such as dioxins and decomposition rates of not less than 99% have been confirmed[18]. (Nontoxicity)

(3) A metallic plasma torch that uses air of high general versatility has been adopted as the heat source and the life of the torch electrode has been substantially extended, thereby making maintenance easy[19]. (General versatility)

Making the most of these features, the company has also vigorously investigated the individual melting of the fly ash from stoker incinerators that contains large amount of toxic substances such as dioxins and has high melting temperatures due to the lime derived from the exhaust gas treatment of incineration facilities. As a result, in 1998 the plasma melting process was adopted as Japan's first process for individual melting of fly ash from stoker incinerators in the soot and dust melting equipment of the Kyoto City Northeastern Waste Incineration Plant (tentative name). The company is pursuing research and development to resolve concerns about the melting of fly ash with high chlorine and lime content while incorporating the obtained knowledge in the design.

2.3.3 Future prospects

For the past several years, refuse incineration has been reviewed and gasifying and melting processes in which incineration ash is not formed have been developed. However, a long period is required to replace processes and it seems that the demand for ash melting will continue into the future. Using the waste disposal processes developed specifically as environmental technology and the high-temperature melting process of high reliability developed and further refined for many years

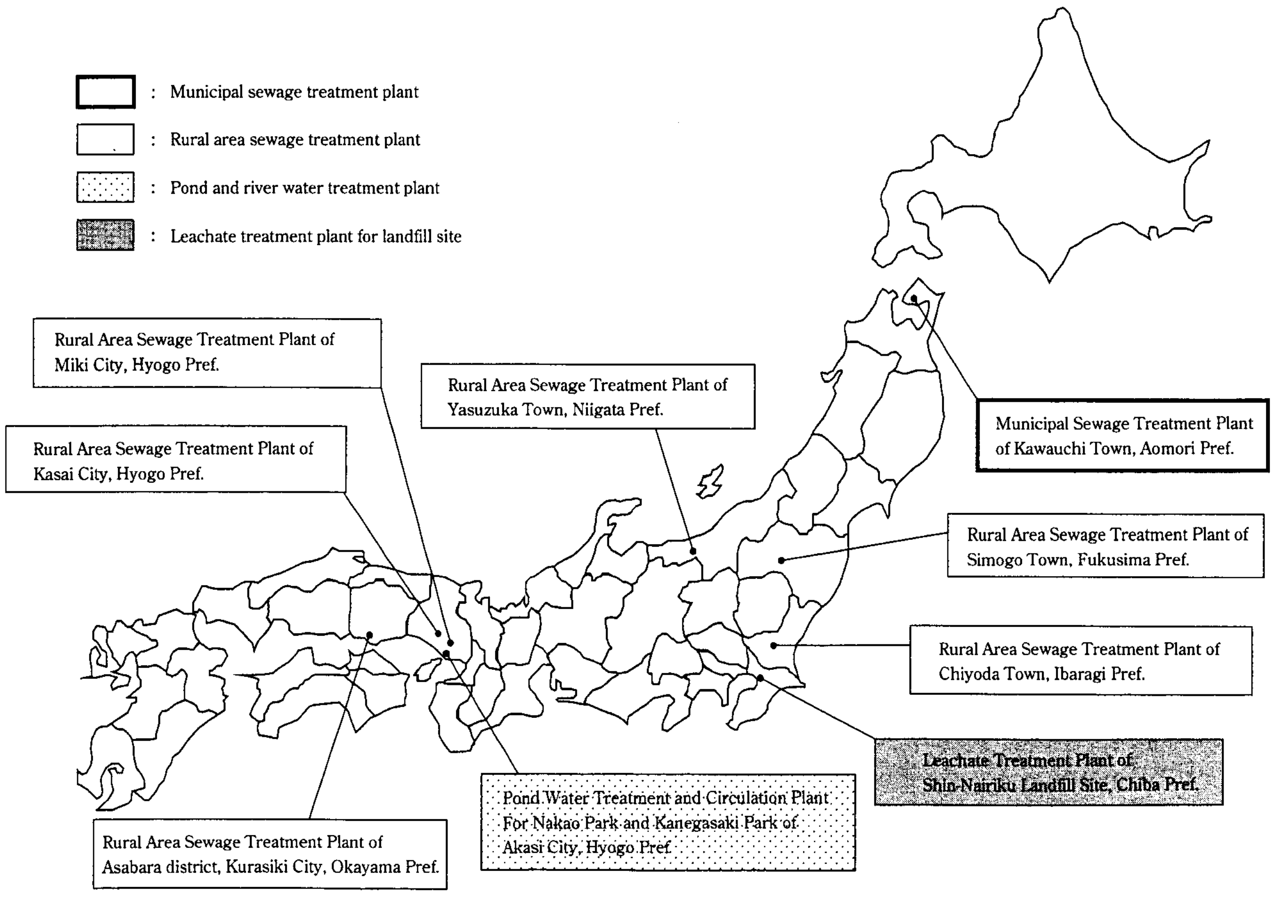


Fig. 7 Recent main sales records of water treatment plant in Japan

Table 5 Description of various water treatment facilities

Classification	Client/Authority	General description, market status	Sales of Kawasaki Steel
Rural area sewage treatment plant	Ministry of Agriculture	Smaller size of sewage treatment plant for rural area Mostly less than a capacity of 1 000 m^3/d	Applied process is mainly contact aeration method or batch process aeration method Many sales records at Niigata, Hyogo, Ibaragi, Fukushima and Okayama Pref.
Municipal and integrated sewerage plant	Ministry of Construction	Main facilities are pumping station and sewage treatment plant. Capacity is over hundreds thousand m^3/d for larger size, and several thousand m^3/d for smaller size. Renovation or extension for advanced treatment process to remove N and P have been planned and constructed recently in many pants of larger city area.	Screen and sand scraper facility for pumping station (many plants in Kurasiki city, Chiba city and others) Oxidation ditch method plant in Aomori Pref. (1999), popular process for smaller sewage treatment plant Advanced nitrification and denitrification process technology, using comprehensive bacteria fixing (called "Pegasus"), was introduced. Dipped membrane activated sludge treatment process was developed.
Pond and river water treatment plant	Ministry of Construction, Agriculture, Environment etc.	Environmental improvement of water quality for pond and city river	Upflow bio-filtration process using floating media (called "River Float") was developed and applied to pond water treatment of Akashi City
Leachate treatment plant of landfill site	Ministry of Health and Welfare	Leachate treatment of landfill site has been focused in recently. It is small water volume but contains many pollutants so that the treatment is one of the most difficult fields. Dioxins is also required now to be removed in leachate treatment.	Construction and operation of leachate treatment plant for; Sea area land reclamation at Okayama Pref. Landfill site at Chiba Pref.
Water wastewater treatment plant of overseas countries	Private company	Many firms of steel and other industries have been constructed in southeast Asia in 1980s and 1990s, but it is decreacing after 1997.	Water and wastewater treatment plants have been constructed mainly for steel industries in Taiwan and Philippines.

in the steel industory, the company intends to apply the plasma melting process to the individual melting treatment of fly ash from high-tech stoker incinerators, and the melting treatment of polluted soil, miscellaneous solid waste from nuclear power stations, etc.

3 Water Treatment Engineering Business

3.1 History of Water Treatment Engineering

In the steel industry, various kinds of water are used in large quantities, including industrial water, purified water, clean water, and softened water. More than 95% of this water is circulated and recycled and the remainder is purified in water treatment facilities in accordance with effluent standards and then discharged. In the water treatment facilities, almost all treatment processes presently in use are applied, including physico-chemical treatment processes, such as coagulation, sedimentation, pressure floatation, filtration, adsorption, ion exchange, oxidation, reduction, neutralization, dehydration and cooling, and biological treatment processes, such as the activated sludge process and catalytic oxidation process.

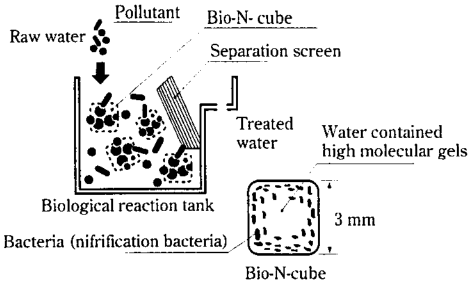
In order to make use of the technologies developed in the construction, operation and maintenance of these water treatment facilities, the company entered the water treatment engineering business in the late 1970s. In the 1980s, the company received orders for water treatment plants to be constructed with steel works abroad on a full turnkey basis and provided assistance with construction, guidance in operation, etc. Since then, Kawasaki Steel has also received orders abroad for water treatment plants other than those for steel works, such as water purification plants, and has gradually developed engineering technologies and gained experience as a plant maker.

In the 1990s, the company participated in many water treatment projects abroad, especially in Taiwan and the Philippines, such as steel mill water treatment, industrial effluent treatment for semiconductors, automobiles, and sewage treatment. It has been highly evaluated in Southeast Asia as a water treatment engineering company and plant maker that is competitive in terms of quality, price, operation and guidance, among categories.

During the same decade, the company received orders for various types of water treatment facilities and constructed them. The company's recent main water treatment plants constructed in Japan are shown in **Fig. 7**.

3.2 Kawasaki Steel Commitments in Various Water Treatment Fields

Table 5 shows an outline of facilities in each field of water treatment and the company's commitments. Overall, requirements for the quality of treated water have



Specific sort and volume of bacteria can be seeded and grow inside Bio-N-cube.

Fig. 8 Principle of advanced nitrification and denitrification method using comprehensive bacteria fixation

been increasingly stringent. For this reason, in addition to the conventional physico-chemical treatment processes, such as coagulation, sedimentation and filtration, and biological treatment processes, such as the activated sludge process, the development of various treatment processes has been pursued including, those based on the use of carriers of living organisms, membranes, ozone and ultraviolet rays.

As future new water treatment technologies, the company is working to apply nitrification and denitrification method using comprehensive bacteria fixation in a system called Pegasus (for which the company has been awarded a license by Japan Sewage Works Agency and Hitachi Plant Engineering & Construction Co., Ltd.,) and the membrane separation activated-sludge method[20–22] (developed by the company).

In the nitrification and denitrification method using comprehensive bacteria fixation, the nitrification time is shortened to less than half that of the conventional method by putting polyethyleneglycol gels 3 to 5 mm in side, which are called Bio-N-Cubes (developed in collaboration with Hitachi Plant Engineering & Construction Co., Ltd.), as nitrifying bacteria into the nitrification tank of the circulation type nitrification and denitrification method generally applied advanced sewage treatment (denitrification) (**Fig. 8**). In the conventional method, the addition of nitrogen treatment to an existing plant requires a substantial increase in the site area such as installation of an additional nitrification tank. Under this new method, in contast to the conventional method, it has become possible to perform advanced treatment by merely partially modifying the biological reaction tank of an existing plant, without having to increase in the treatment area.

In the membrane separation activated-sludge method, precision filtering membranes (membrane pore diameter: about 0.1 μm) are immersed in the biological reaction tank of the activated-sludge process, and treated water coming directly from the biological treatment tank is separated from sludge via the membranes. In this method, a sedimentation tank behind the biological treatment tank is unnecessary and the biological treatment tank itself can hold bacteria at high concentrations. Therefore, only 60–70% of the equipment needed with the conventional method is required for the new method. Furthermore, because various types of bacteria can be held at high concentrations, various pollutants can be decomposed, and the treated water passing through 0.1 μm membranes is much clearer than the treated water from a sedimentation tank. Therefore, it is possible to reuse treated sewage water[20–22]. This process was approved for general performance appraisal of septic tanks by The Building Center of Japan. It can be applied not only to sewage treatment, but also to plant waste water treatment and the treatment of the effluent from sanitation truck washing.

For the purification of pond and river water, the company developed a water treatment process of biological membrane filtration type using a floating filtering medium (brand name: River Float) and acquired technical certification in 1992 from the Public Works Research Center as a river water purification system. In this process, a filtering medium of expandable polypropylene is put in a filtering tank and filtration and biological treatment by microbes adhering to the surface of the filtering medium are simultaneously performed while the water is passing through the filtering medium in upward countercurrents. Simple and compact equipment is used in this process. Because washing is also easy, operation and maintenance are easy, making this process suitable for the clarification of a large volume of pond and river water containing medium levels of organic substances and suspended solids (SS)[23]. The company applied this process to the water treatment of park ponds in Akashi City and the water treatment of streams flowing into golf courses in the Philippines.

3.3 Future Prospects

Today, water treatment problems are being posed by various pollutants, including organic substances by the biological oxygen demand (BOD) and chemical oxygen demand (COD), as well as nutrient salts such as nitrogen and phosphorus, difficult-to-decompose organic compounds such as dioxins and endocrine disrupters, and microbes, bacteria and viruses such as cryptostorisium. For this reason, increasingly complicated and sophisticated treatment facilities and operations will be required in the future. The company, which has already possessed sufficient experience with the construction and operation of water treatment facilities in various fields, is developing further advanced water treatment processes for both Japan and abroad to benefit the grobal environment.

4 Concluding Remarks

The aim of the company's environmental engineering business is to contribute to resource recycling by making use of the environmental technologies developed on the basis of the technologies developed at steel works. Furthermore, the company considers it important to provide services to surrounding districts by making full use of the infrastructure and equipment of steel works. As a general planner of environmental engineering business including industrial waste disposal, Kawasaki Steel Group intends to work contribute to the coming resource recycling society.

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