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Contents

About the Cover
The central control room of the Minatojima Clean Center, operated by the Environment Bureau of Kobe City. See *Special Feature* for details.

Waste-to-Energy Power Generation:

Cutting-edge Technology Drives the Minatojima Clean Center (Kobe City's 11th Clean Center, Operated by Kobe City's Environment Bureau)

Waste incineration facilities no longer exist simply to burn waste; now they serve as energy stations, turning waste products into sources of renewable energy. Such an evolution has been propelled by various innovations, including the Kawasaki Advanced Stoker System, which achieves efficient incineration and power generation, as well as a reduced environmental burden.

Delivering to the public as many benefits of energy stations as possible

When the Minatojima Clean Center in Kobe City became visible in its entirety, everybody thought that it was a plant producing electronics parts or precision machinery. The design of the white building's façade is a lattice pattern created by the outer walls and inner skeletal structures, and looks like a posh laptop in landscape orientation — a design suitably named "Techno-display." Greenery surrounds the building and there are two parks adjacent to it. Realization that it is a waste incineration plant only occurs when waste collection vehicles are seen entering and leaving.

The Center, located on the southeast side of Kobe's man-made island called Port Island, began full operations on April 1, 2017. For this project, Kawasaki was awarded both a contract for building the waste treatment plant and a 20-year maintenance contract, which went into effect as soon as operations began.

The Center is comprised of three 200-ton furnaces (treating a total of 600 tons of waste per day); a facility capable of crushing 20 tons of wood waste in five hours; a recycling station where 40 tons of collected glass containers, cans, and PET bottles can be reloaded onto other transport vehicles in five hours' time; and other related facilities.

Heat generated from burning waste is used to produce steam that rotates turbines, generating up to 15,200 kW of electricity. The Center's power generation efficiency stands at 20.8%, which is in the industry's top tier in Japan for waste-to-energy power plants, and is significantly higher than the national average of 12.8%. The Center itself consumes around 1,000 kW, so the excess power generated is sold to energy companies. The volume of this excess electricity is sufficient to power 50,000 average homes. However, the Center is also equipped with a gas turbine power generation facility, to be used in the event of disaster.

Akihisa Hiroishi
Senior Staff Officer, Project Engineering Section
Environmental Plant Department
Environmental Plant Engineering Division
Plant & Infrastructure Company

The dumping of the waste into the pit. About 200-300 waste collection vehicles per day bring the waste to the Center.

Kawasaki's project manager, Akihisa Hiroishi comments, "Kawasaki built the Minatojima Clean Center based on three principles. First, the facility shall contribute to local communities and be open to the public. Secondly, it shall be eco-friendly, safe, and reliable. And thirdly, it shall achieve high economic efficiency and the capacity to treat waste in a stable and continuous manner."

The Techno-display and adjacent parks were planned to make it a community-oriented, "open" facility. Its structural design, allowing highly-educational social studies field trips, also exemplifies Kawasaki's pursuit of openness. The introduction of cutting-edge furnaces and an exhaust gas treatment system should also lead to a sense among local residents that the plant is secure and reliable. Reinforcement of building structures, measures to extend structural longevity, highly efficient power generation, and auto-controlled incineration are all contributing to good economic efficiency. Maintenance costs over the next 20 years are estimated at 1.5 billion yen less than other waste-to-energy plants of a similar size.

"'Stability' is the word that epitomizes our approach: burning waste steadily, producing heat and steam steadily, and generating power steadily. On top of that, the Center's environmental footprint is small. Many benefits will be provided to the public," says Hiroishi. Supporting sophisticated waste-to-energy power generation is the Kawasaki Advanced Stoker System — a true embodiment of Kawasaki's comprehensive technological capabilities.

Achieving complete combustion with the minimal amount of air

The Kawasaki Advanced Stoker System was developed based on four foundational concepts: 1. Achieve complete combustion with a small amount of air (low air ratio to complete combustion), 2. Improve heat recovery rate, 3. Achieve cleaner incineration ash and exhaust gas, and 4. Perform our operations with stability.

Let's look at the waste incineration process. Waste accumulated in the pit is fed into the feeding area and enters into a stoker-type parallel-flow furnace. After drying, incinerating, and after-burning processes, the waste is turned into ash in three hours. Concurrently, a boiler turns the thermal energy resulting from waste incineration into high-temperature, high-pressure steam, which rotates a power-generating turbine. Exhaust gas is purified in a bag filter and by low-temperature denitration catalyst equipment.

The stoker-type parallel-flow furnace is the core of this system. A stoker-type incinerator, which is the most popular type today, takes its name from the "stoker" — a mechanical system which feeds coal into the furnace of a steam boiler. In a waste-to-energy plant, waste is constantly fed into the furnace.

Most of the stoker-type incinerators burn waste in their central area, and the heat and exhaust gas are led upward. A parallel-flow furnace, however, operates differently and is equipped with a step-grate stoker furnace in which a partition is installed in the ceiling parallel to the movement of the waste, forcing the flue gas to invert and to mix turbulently with air. Also, part of the exhaust gas passed through the bag filter is returned to the furnace, to reduce the volume of secondary air required and achieve low-air, high-temperature combustion.

Commenting on the incinerator's structure, Atsushi Hashimoto, who is in charge of the development and design of this type of incinerator, says, "It was designed to address the challenge of burning waste stably and completely, with the smallest amount of air. It is easy to burn waste by increasing the volume of injected air, but that results in increased exhaust gas and energy loss."

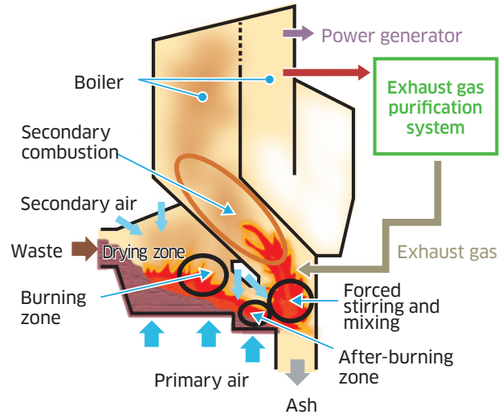
Hashimoto adds, "Because a parallel-flow incinerator is designed in such a way that flue gas flows parallel to the flow of the waste, it achieves complete combustion of gas which previously remained unburned in the ash. By forcibly mixing air and exhaust gas in the area where the flue gas is inverted toward the secondary combustion, the temperature is kept high, completely burning the unburned gas. As a result, the generation of dioxin and the emission of carbon monoxide are both reduced, so smaller exhaust gas treatment equipment can be utilized."

Atsushi Hashimoto
Senior Staff Officer, Equipment Design Section
Environmental Plant Department
Environment Plant Engineering Division
Plant & Infrastructure Company

Another innovation used for the incinerator is a method for minimizing combustion fluctuation. Stoker-type incinerator technology was first developed in Europe and later introduced to Japan, but waste in Japan had a much higher level of moisture which made it harder to burn. Japanese engineers therefore strove to upgrade the technology to achieve stable combustion of moist waste. The parallel-flow furnace is one of the resulting inventions, but Kawasaki has gone further, developing the Smart-ACC (Automatic Combustion Control), an automatic combustion control system whereby combustion and steam generation are controlled simultaneously by artificial intelligence.

This system has been introduced in the Minatojima Clean Center. The Smart-ACC automatically judges the state of combustion and the level of steam generation in a comprehensive manner, and determines how much waste should be fed into the furnace under what conditions, as well as how much air and exhaust gas are needed, and automatically controls the incineration operation itself. Hashimoto comments, "The Smart-ACC is the epitome of waste incineration expertise."

Conceptual diagram of a parallel-flow incinerator



Waste is collected in the pit. Giant "claws" hanging from the crane mix and feed the waste into the furnace from the feeding area. The waste enters the furnace through a square opening at the back.

Inside the furnace. The waste is burned, starting from the back and moving to the front. The brick-like objects on the floor are grates. Pipes filled with cool water run through these grates to prolong their lives. Some grates move back and forth to send the waste forward.

A high-pressure, high-temperature boiler provides the foundation for stable power generation.

The waste fed into the furnace is burned at 850 - 1,050℃.

An eco-friendly system that incinerates safely and completely

Stable incineration at high temperatures provides a variety of benefits. The heat recovery rate is improved and therefore power generation efficiency is increased. A high-pressure, high-temperature boiler (4 MPa, 400°C) is used to rotate the turbine.

"Quality steam" can be obtained from stable incineration, as the steam being generated is also stabilized. If "quality steam" is generated consistently, the electricity generated by the turbine stabilizes, too. When selling excess power to energy companies, this capacity to stably supply "quality electricity" is a big plus, because that is what power companies seek the most from suppliers.

Prolonged life of structural components also enhances the benefits of a stably-operating incinerator. For example, boiler pipes, which experience high temperatures, require special features. Hashimoto explains, "To prevent corrosion, Kawasaki performs a unique 'weld overlay' for the pipes of the superheater, utilizing a metal with extremely high corrosion resistance." Normally, such pipes must be replaced every 10 years, but these weld-overlay pipes last for more than 30 years. Since the average life of an incineration plant is 30 years, these pipes rarely need to be replaced. The reason why maintenance costs at the Center are 1.5 billion yen lower than at similar plants is because the Kawasaki Advanced Stoker System is designed to be a complete ecosystem.

Kazuhiko Ichie
Manager
Western Region Sales Section
Environmental Plant Sales Department
Marketing & Sales Division
Plant & Infrastructure Company

The central control room of the Minatojima Clean Center, operated by the Environment Bureau of Kobe City.

Comprehensive technological expertise that converts incineration plants into profit centers

Kobe City began operating its first waste incineration plant in 1963, one of the earliest in Japan. The Minatojima Clean Center is the city's 11th such construction project, and, as this history suggests, the city is well-experienced in waste incineration, and has sufficient knowledge for evaluating relevant technologies.

Kazuhiko Ichie, who is a manager of Kawasaki's sales in this region, comments, "Waste incineration plants are beginning to play a pivotal role in the formation of community energy networks, and today, large municipalities are trying to be suppliers of stable sources of electricity by running multiple incineration facilities. To accommodate such a trend, plant business operators must have the acumen for making proposals that address highly specific challenges."

Kawasaki delivered its first waste incineration plant in 1964, to Ichinomiya City in Aichi Prefecture, Japan. However, it was not until the company received an order in 1980 from the city of Kyoto to build a waste-to-energy plant with a 4,000 kW output (the Toubu Clean Center), that it began intentionally pursuing the concept of incineration plant systems serving as energy producers. Its endeavors culminated in the 1996 completion of the Nanyo Incineration Plant in Nagoya City, with an incineration capacity of 1,500 tons of waste per day and power generation of 27,000 kW—one of the largest facilities of this kind in Japan.

Ichie says, "Thanks to its extensive experience in building various plants, Kawasaki is able to present benefits of waste-to-energy plants, including improved power generation and a smaller environmental footprint, in a comprehensive manner. With the recycling and reusing of resources becoming so popular, the overall volume of waste has decreased, and this is precisely why municipalities are avid advocates of converting these plants into profit centers, rather than cost centers. Addressing these needs is extremely meaningful in terms of societal benefits."

Expectations for waste incineration facilities to act as energy centers will only intensify in the future, and Kawasaki must be poised to respond to those demands with the comprehensive technological expertise which culminated in its Advanced Stoker System.

From the Project Team

By Hideaki Murata

Senior Manager, Environmental Plant Engineering Division,
Plant & Infrastructure Company
Kawasaki Heavy Industries, Ltd.

Addressing a Global Agenda using Japan's Advanced Technologies

Since the beginning of the 1960s, when rapid economic growth was beginning to take place in Japan, waste incineration facilities have grown in number and have needed replacing about every 30 years. The combined incineration capacity of the facilities constructed in Japan on an annual basis is about 4,000 tons, and most of those are for renewal projects for facilities built in the early 1990s. Environmental issues promoted the "waste-to-energy" concept, which has become the standard today. For new construction of waste incinerators, technological solutions for achieving both stable incineration and high economic efficiency are proving effective in reducing the financial burden on municipalities.

Since its first delivery in 1964, Kawasaki has constructed 178 waste incineration plants in Japan and overseas, of which 78 are currently in operation in Japan. Since the 1980s, the company has been striving to establish incineration facilities as energy stations, resulting in the development of parallel-flow furnaces, structural components with longer lives, and other proprietary technologies for which Kawasaki has won high acclaim. Kawasaki's track record, particularly for the construction of large furnaces and large-scale incineration facilities with large power generation systems, is overwhelmingly higher than that of its competitors. Because they are large-scale, a good balance of safety, stability, and economic efficiency was immensely important, and Kawasaki tackled the challenge with its comprehensive technological expertise.

It is said that waste "treatment" usually takes the form of landfills in the beginning, and it is not until the gross domestic product (GDP) exceeds 5,000 US$ per capita that countries can afford to pay for waste treatment, and start building waste incineration plants. China, Malaysia, and Singapore are currently at this stage, soon to be followed by Thailand and Indonesia.

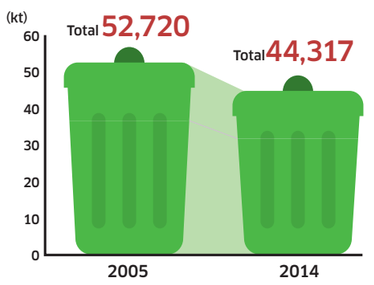
Kawasaki formed a joint venture with a Chinese company, and has already received orders for 10 stoker-type waste-to-energy facilities. In China, the ash remaining after gasification of waste is used as cement material—a system called the CONCH Kawasaki Kiln (CKK) System. We are committed to pro-actively addressing global environmental challenges, by applying the superior technology of waste incineration in Japan. I believe that this is an extremely meaningful business that leads to resolving issues which are considered to be a global agenda.

Looking Forward to Tomorrow

Kawasaki's Involvement in Waste issues in Japan

The heightened eco-consciousness of the public has encouraged a reduction in volume of waste generation and the promotion of recycling and reusing, as well as the development of eco-friendly products. Owing to such developments, the volume of waste generation in Japan is decreasing, which has resulted in a decline in the number of waste incineration facilities. On the other hand, the remaining facilities are increasing in size and more are accompanied by power generation systems. As a result, total power generation output has been increasing and so has power generation efficiency. Against such a backdrop, Kawasaki has been delivering waste incineration facilities capable of burning more than 300 tons of waste per day. Total volume of waste treated by the 78 facilities Kawasaki has built (including some that are still under construction) will reach 18,400 tons and power generation capacity will be around 500 MW.

◎ Total volume of municipal waste in Japan



◎ Total gross power generation capacity (MW) and power generation efficiency (%) of waste incineration facilities in Japan