State-of-the-art Stoker-type Waste Incinerator Begins Commercial Operation

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In waste treatment, the priorities include achieving stable reduction of waste volume and lowering the environmental impact. Mitsubishi Heavy Industries Environmental & Chemical Engineering Co., Ltd. (MHIEC) has developed a new stoker-type waste incinerator by improving and sophisticating the conventional one under the concept of realizing stable volume reduction of waste with wide-ranging properties and contributing to lowering the environmental load. In January 2021, our first delivery of the new unit was made to Xiaogan City, Hubei Province, China. It has started commercial operation. This report summarizes this improved stoker-type waste incinerator and presents how it has been operated thus far.

1. Background for development

Figure 1 is a flow diagram of the major treatment processes at Waste-to-Energy (WtE) plants (with a stoker-type incinerator). A stoker is a device used for combustion, and consists of movable grates (which have a grid-like structure and are used to agitate and convey waste). The stoker-type waste incinerator operates by waste being thrown in by a waste crane onto a stoker and then burned at high temperature. In MHIEC's conventional stoker (**Figure 2**), each grate was installed in such a way as to form an upslope against the direction of waste conveyance. The merits of this grate installation method include achieving better agitation of waste and securing the residence time necessary for complete combustion within a compact area. Having been developed by improving the conventional unit while making use of these advantages, our new stoker offers the features of stable treatment of waste with high water content (as often in the case of overseas waste) and the scalability for large treatment capacities. These features have made it possible for the new stoker to be utilized not only in Japan but also across the world.

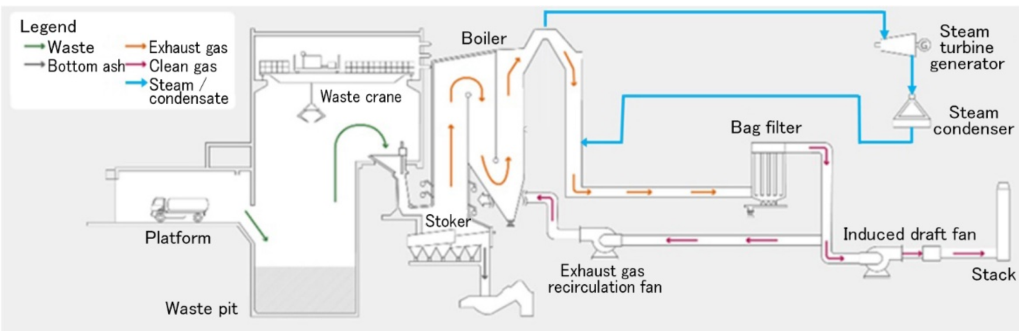

Figure 1 General flow diagram of the major treatment processes at WtE plants

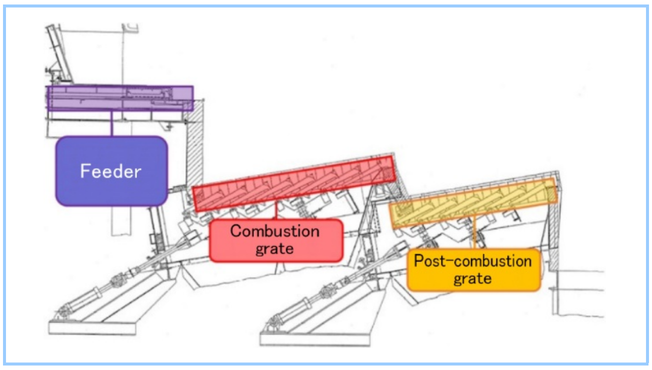

Figure 2　A diagram of MHIEC's conventional stoker

2. Features of the improved stoker

2.1 Structure of the improved stoker

Figure 3 is a diagram of our improved stoker. It has a V-shaped structure formed by a downslope grate for accelerating the waste drying process, and an upslope grate with the above-mentioned advantages.

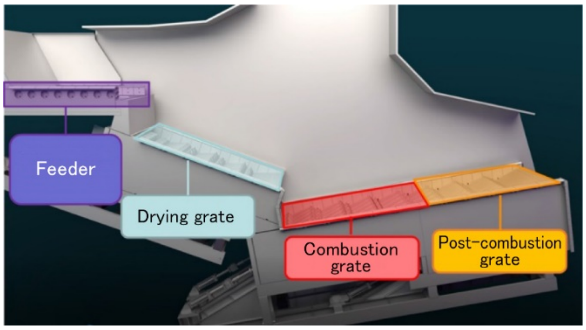

Figure 3　A diagram of our improved stoker

2.2 High efficiency combustion enabled by the optimal stoker structure and incinerator shape

The merits of adopting a downslope for the drying process are:

- Able to smoothly convey waste toward the combustion area.
- Easier to receive radiant heat from the flame, which is necessary for drying waste.

The merits of adopting an upslope for the combustion and post-combustion processes are:

- Able to secure the residence time necessary for complete combustion within a compact area.
- Able to efficiently agitate waste by pushing upward with the grate.
- Easier to receive radiant heat from the flame in the post-combustion area.

By optimizing the stoker structure and incinerator shape, our improved stoker has been designed in such a way that the surface of the grates in all the processes of drying, combustion and post-combustion is directed at the center of the flame. Therefore, it is most characterized by efficient reception of radiant heat during the combustion of waste (**Figure 4**).

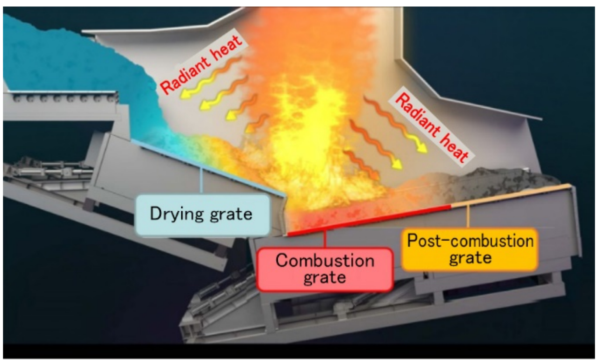

Figure 4　An image of receiving radiant heat with the improved stoker structure and incinerator shape

2.3 Downsizing of stoker

Because of the addition of the downslope grate, the length of our improved stoker is increased approximately by a factor of 1.5 compared with the conventional one. As shown in **Figure 5**, however, since a stoker is installed in a space beneath the boiler, this increase in the length causes almost no impact on the combined installation area of the boiler and stoker. On the other hand, if the width of the stoker can be reduced, that of the boiler can also be reduced because their structures are integrated. The weight and volume of waste are decreased after it is carried on the downslope grate with the accelerated drying effect, which lowers the carrying load of the upslope grate. As a result, the stoker can have a smaller width than the conventional one, thus realizing the downsizing. When compared with the conventional unit, our improved stoker is greater in length but smaller in width, and the grate area is nearly 0.8 times smaller. Because the incinerator chamber containing the stoker and boiler, whose occupancy rate in the WtE plant is high, can be downsized, the improvement in the freedom of facility layout for a small site is expected.

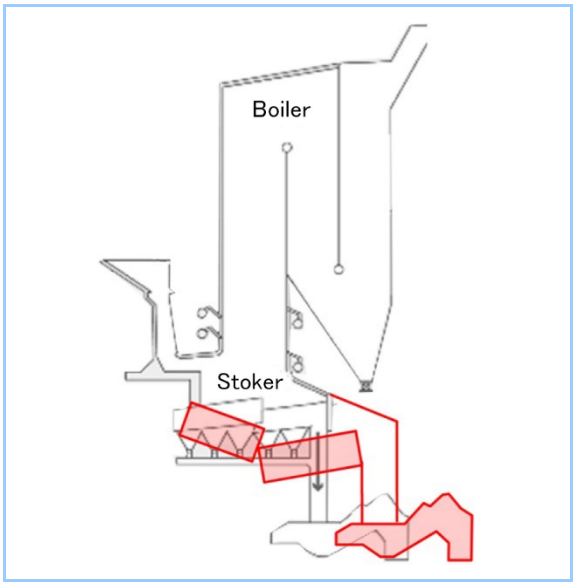

Figure 5 Cross-sectional image of the facility layout with our improved stoker
As the stoker is installed in a space beneath the boiler, its increased length has almost no impact on the building.

2.4 Use of modular structure

Our improved stoker is flexible in terms of meeting the required throughput. Specifically, the feeder, drying grate, and combustion/post-combustion grate are provided in separate modules. Depending on the required throughput, the width of the stoker can be adjusted by increasing or decreasing the number of modules to be aligned. The merits of this modular structure include substantial reduction of on-site installation processes because of the assembly being carried out by attaching each module (**Figure 6**).

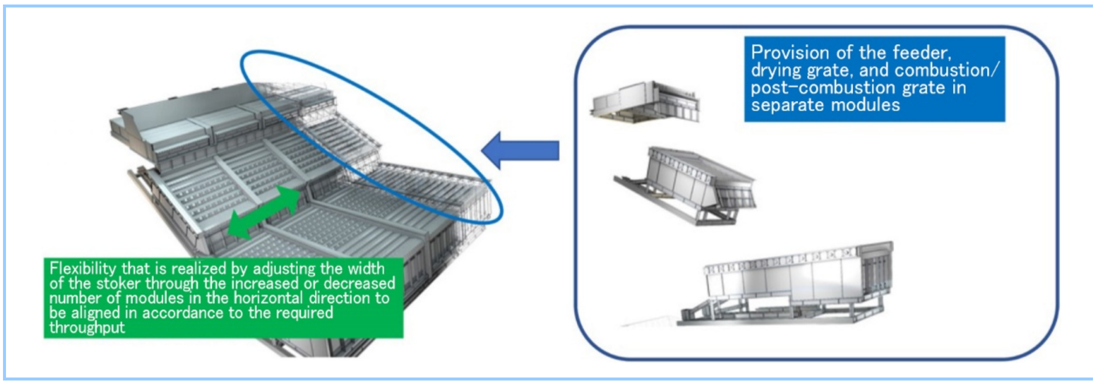

Figure 6 Flexibility in meeting the required throughput with the modular structure

3. Plant summary

The plant summary is given in **Table 1**, and its location is shown in **Figure 7**. The plant is the first WtE plant in Xiaogan City, Hubei Province, China. It has two incinerators, each with a nominal capacity of 750 tons per day or tpd (1,500 tpd in total) and is equipped with a 35,000-kW condensing extraction turbine. Since its start of commercial operation, the plant has supported people's lives as one of the important environmental infrastructures in the city. As indicated by the plan to build the facilities such as a sludge treatment facility in the neighborhood, this area including this first WtE plant is envisioned as the future center of venous industry. In this project, MHIEC is entrusted with the "provision of the stoker and the boiler basic plan".

Table 1 Plant summary

Completion of construction	February 2021
Type of incinerator	Full continuous-type incinerator (stoker)
Nominal capacity	1,500 tpd (750 tpd × two units) *Required capacity: 900 tpd per unit
Gas cooling system	Waste heat boiler system (6.4 MPa, 450°C)
Power generation system	Condensing extraction- turbine (35,000 kW)
MHIEC's scope of work range	Stoker provision + Boiler basic plan

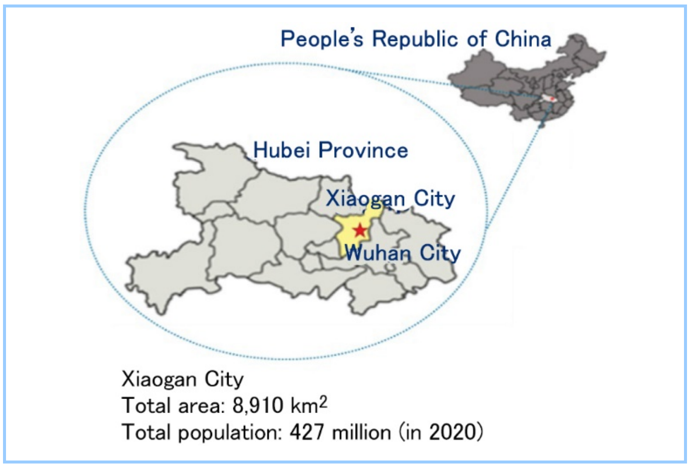

Figure 7 Plant location

4. Operating conditions

4.1 Treatment capacity and loss on ignition

Figure 8 shows the amount of waste treated during the test operation and the loss on ignition of bottom ash (wet ash). Because the requirements specified an incinerator that is operable continuously for 24 hours a day at 120% load, we designed a stoker-type incinerator with an incineration capacity of 900 tpd, although its nominal capacity was 750 tpd. As shown in Figure 8, the loss on ignition(*) values averaged 1.6% for about three months including the days of treatment exceeding the incinerator's design capacity of 900 tpd. This indicates stable continuous operation of the incinerator and sufficient fulfilment of the guaranteed value of loss on ignition (which is less than 5% in this project). Low loss on ignition values mean a low amount of decaying organic matter that causes soil pollution or water contamination at landfill sites, which can help to reduce the environmental impact.

During the test operation, the lower heating value (LHV) of waste ranged from 6-7 MJ/kg with the minimum value of about 5 MJ/kg. This indicates that the waste is relatively difficult to be burned, as it has a higher water content and a lower LHV than the typical LHV range of 8-10 MJ/kg in Japan.

*Loss on ignition: represents the weight ratio of the unburnt content in the dried bottom ash

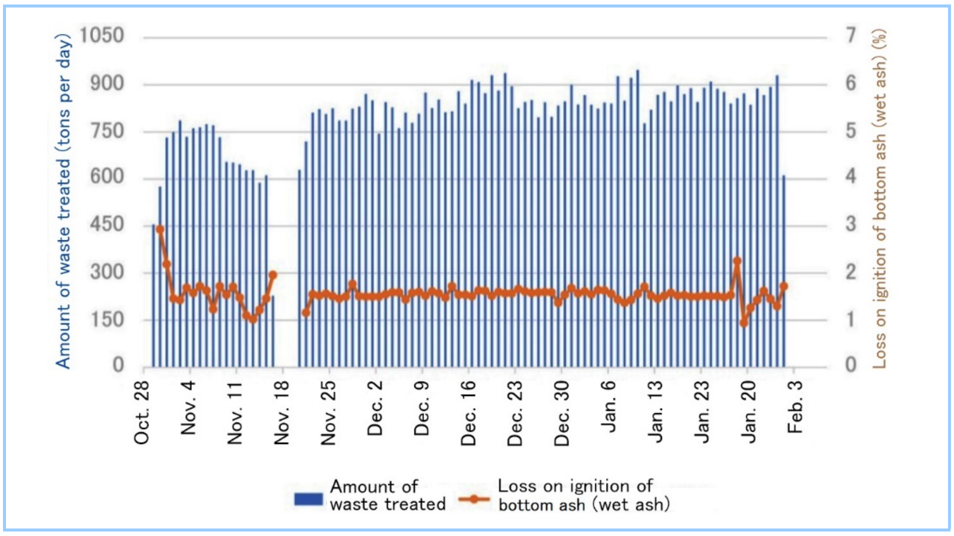

Figure 8 Amount of waste treated and loss on ignition (Incinerator No. 1)

4.2 Handling of low LHV waste (co-firing with the excavated waste)

In this plant, the waste excavated from the neighboring landfill site is co-fired; on some days, it accounted for more than 30% of all the waste brought for incineration. The excavated waste has been fermented to some extent, and is muddy with high water content and low LHV. Even when co-fired with the excavated waste (**Figures 9** and **10**), the loss on ignition values remained low as shown in Figure 8. The incinerator's capability of handling the waste with wide-ranging properties has thus been confirmed.

Figure 9 Excavation at the landfill site

Figure 10 Excavated waste (in the waste pit)

4.3 Stability of exhaust-gas values

The stability of combustion can be indicated by the carbon monoxide (CO) concentration in exhaust gas. **Table 2** shows the CO concentration for the five days when on average 900 tpd or more of waste was treated. In this project, the guaranteed value of the daily average CO concentration is 50 mg/m^{3}N (i.e., 43 ppm). The daily average during the actual operation was 1-3 ppm, with no CO-concentration peaks exceeding 100 ppm. Stable combustion has thus been confirmed.

Table 2 CO concentration in exhaust gas

Date	Amount of waste treated	CO concentration	
		24-hour average	Number of >100 ppm
Dec. 19	909 tpd	1.78 ppm	0
Dec. 20	873 tpd	2.10 ppm	0
Dec. 21	930 tpd	1.89 ppm	0
Dec. 22	881 tpd	2.28 ppm	0
Dec. 23	937 tpd	1.83 ppm	0

4.4 Conveyance of large incombustible waste

In the countries with a less strict waste-sorting system than Japan, large incombustible waste such as bicycles and large truck tires can be delivered together with household waste. In order to realize the worldwide application of our improved stoker, it is important for such waste to be discharged without disrupting the operation of the incinerator, enabling waste treatment to be continued in a stable manner. There was an incident during the test operation; a stainless wastewater screen installed in the waste pit (with dimensions of width 1.2 m × length 1.2 m × height 0.3 m, **Figure 11**) was detached and was, by mistake, thrown in the incinerator together with other waste. However, the wastewater screen was discharged without getting stuck on the upslope of the combustion/post-combustion grate. During the test operation, at least two wastewater screens were thrown in the incinerator. Both were discharged without getting stuck, thus demonstrating the capability of operating the incinerator continuously.

Figure 11 Stainless wastewater screen

4.5 Number of operating days

Since its start of commercial operation in January 2021, the plant has been in operation as per the customer's incinerator operation plan. **Table 3** shows the number of operating days for the past 1 year. During this period, the operation was stopped when the operation of the incinerator needed to be adjusted in accordance with the amount of waste received. The stability of the equipment was thus confirmed to be sufficient. During this past 1 year, 125 days of continuous operation was achieved, which well exceeds 90 days of continuous operation required generally in Japan.

Table 3 Number of operating days

	Number of operating days	Availability rate
Incinerator No. 1	282 out of 365	77%
Incinerator No. 2	316 out of 365	87%

5. Future development

Having confirmed that our improved stoker can achieve stable complete combustion of low LHV waste or overseas waste containing quantities of large incombustible waste, we will accelerate the promotion of its overseas sale as well as promote the application in Japan plants by making use of the advantages of the downsized stoker such as greater freedom of facility layout. In Japan, low excess air combustion with exhaust gas recirculation (EGR) is the mainstream of high-efficiency waste power generation. According to the computational fluid dynamics (CFD) analysis, our improved stoker can achieve a low-excess-air and low-NOx combustion when combined with EGR. The application in the actual unit can be done smoothly.

In the test operation, the on-site computer was connected to our computer at the main office through the virtual private network, which allowed us to remote-monitor the operating conditions of the incinerator and collect the operational data. Therefore, we will explore the possibility of linking with MHIEC's AI-based remote monitoring and operational support system called MaiDAS®.