Report on Delivery and Operational Condition of Large-scale Grate-type (Stoker-type) Incinerator in Nanchang City, Jiangxi, China

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Abstract
Ebara’s grate-type waste incinerators with a treatment capacity of 1200 t/d were delivered to Nanchang city, Jiangxi, China, and their performance test was completed in August 2015. In the past, Ebara Environmental Plant Co., Ltd., and Ebara Qingdao Co., Ltd., delivered incinerators to five facilities in China: fluidized-bed incinerators to two facilities and grate-type incinerators to three. Among them, two grate-type incinerators have been reported in the Ebara Engineering Review. This time, we delivered incinerators to the sixth facility, with the biggest capacity per unit among all grate-type incinerators delivered by Ebara, including those under construction or commissioning.

This paper describes the engineering refinement and improvements for upscaling and the NOx control effect of a flue-gas recirculation system, along with the operation status so far and performance test results.

Keywords: China, Waste, Incinerator, Stoker, Calorific value, Combustion, Environmental, HPCC, Qingdao, Nanchang

1. Introduction
On August 3, 2015, The Ebara group delivered grate-type incinerators to a Waste-to-Energy Plant in Nanchang City, Jiangxi Province, China, and conducted a performance test and turned over them.

This is the first Waste-to-Energy Plant in Nanchang. Based on our experience, we performed an appropriate design considering to the China-specific waste characteristics − high moisture and ash content − and adopted refinement and improvements on the design of the scale-up of the incinerator.

The plant was constructed by Nanchang Biomax Green Energy Limited a special purpose company (SPC) established by Beijing Capital Group Co., Ltd. which undertook the project from Nanchang government. The scope of Ebara’s contribution to the projects includes the basic design of the incineration system and supply of main equipment of the incinerators, auxiliary equipment, an automatic combustion control system (ACC), and other instruments (Figure 1).

2. Overview of Nanchang
Nanchang City, the capital of Jiangxi Province, China, is the center of politics, economy and culture as well as strategic point of Jiangxi traffic. Poyang Lake, the
largest freshwater lake in China, located in the northeast of the city. The city has an area of 7402 km$^2$ with a population of approximately 5.2 million. Nanchang has a monsoon-influenced humid subtropical climate with the annual average temperature of 16.8 °C. It is rainy season from April to June and approximately 80% of the annual precipitation falls during this period.

Nanchang is well known as a historical and cultural city built about 2200 years ago during the Han dynasty, and it is the largest industrial city in Jiangxi Province now.

**Figure 2** shows the location of Nanchang in China.

### 3. Overview and characteristics of the plant

**Table 1** shows the lower calorific values and composition of the waste in Nanchang.

Followings are the specifications of the main equipment of the plant. Items (2) to (5) are procured by the client.

(1) **Incinerator**

Type: EBARA HPCC (High-Pressure Combustion Control) grate-type incinerator

Capacity: 1200 t/d (600 t/24 h × 2 units)

(2) **Boiler**

Type: Natural-circulation water tube boiler with superheaters

Capacity: 53.2 t/h (Max. 58.5 t/h) × 2 units

Steam condition: 400 °C × 4.0 MPaG (at the exit of the superheater)

(3) **Steam turbine generator**

Type: Steam turbine (condensing type) + generator

Rated power: 12 MW × 2 units

(4) **Flue-gas treatment facility**

Flue-gas treatment system:

- Semi-dry type system (slaked-lime slurry spraying)
- + dry type system (slaked-lime injection) + activated carbon injection + bag filter

(5) **Stack**

Type: External wall - Reinforced concrete structure

Internal cylinder - Steel

Height: 80 m

(6) **Emission values [flue gas from stack]**

Inside [ ] are the values converted to the standard oxygen concentration used in Japan$^\text{1}$.

Dust: Less than 80 mg/m$^3$ (NTP) (O$_2$ 11% equiv.)

[Less than 72 mg/m$^3$ (NTP) (O$_2$ 12% equiv.)]

Sulfuroxide: Less than 260 mg/m$^3$ (NTP) (O$_2$ 11% equiv.)

[Less than 81.9 ppm (O$_2$ 12% equiv.)]

Nitrogen oxide: Less than 400 mg/m$^3$ (NTP) (O$_2$ 11% equiv.)

[Less than 175.4 ppm (O$_2$ 12% equiv.)]

Hydrogenchloride: Less than 75 mg/m$^3$ (NTP) (O$_2$ 11% equiv.)

[Less than 41.4 ppm (O$_2$ 12% equiv.)]

Carbonmonoxide: Less than 150 mg/m$^3$ (NTP) (O$_2$ 11% equiv.)

[Less than 108 ppm (O$_2$ 12% equiv.)]

Dioxins: Less than 0.1 ng-TEQ/m$^3$ (O$_2$ 11% equiv.)

[Less than 0.09 ng-TEQ/m$^3$ (O$_2$ 12% equiv.)]

(*1: The emission values are indicated for reference purposes only and not guarantee values)

**Figure 3** shows the process flow in the plant.

Collected Municipal waste is stored in the waste bunker and dried by moisture separation and high temperature produced by fermentation. This increases the calorific value of the waste. Then, the waste is fed to the waste hopper by waste crane. Then, the waste is transferred...
to the incinerator by waste feeder, and incinerated at a high temperature of 850 °C or higher. The generated heat is recovered in the boiler and flue gas temperature is cooled to 195 °C and then flue gas is entered to the semi-dry reactor where gas is neutralized by spraying slaked-lime slurry and cooled down to 155 °C. Then, the gas is mixed with slaked lime and activated carbon injected into the flue to neutralize acidic gas and absorb heavy metals and dioxins.

By-products of flue gas cleaning and some amount of fly ash containing heavy metal compounds and dioxins absorbed to activated carbon are filtrated in the bag filter. Cleaned flue gas is discharged to the atmosphere through the stack.

Ash from the incineration furnace is cooled in the bottom ash discharger and transferred by vibrating conveyor to the ash bunker for temporary storage. Then, the ash is loaded onto an ash truck by ash crane and transported to outside of the plant.

Fly ash collected through the bag filter is fed by a conveyor to an ash silo for temporary storage. Then, it is kneaded in a fly ash treatment system and carried out on truck to a landfill site.

4. Overview of the project

4.1 Scope of supply and performance warranty

In China, different from Japan, construction of Waste to Energy Plants is often is undertaken by the SPC itself which secures the project. Consequently, we are responsible for the basic design (including a part of detailed design) of the incineration system, delivering main equipment (grates, hydraulic drive unit, burners, ACC system, and waste hopper level sensor), and dispatching supervisors.

The following is guaranteed items and values:

1. Annual total operation hours: 8000 hours or longer
2. Operating load (incineration amount) range: 60 to 110% (Within 2 hours/day for 110% load)
3. Furnace outlet temperature: 850 °C or higher, for 2 seconds or longer
4. Ash ignition loss: 3% or less
5. Boiler efficiency: 80% or higher
6. Grate replacement ratio:
   - Less than 1% for 8000 hours in operation
   - Less than 2% for 16000 hours in operation
   - Less than 2.5% for 24000 hours in operation
   - Less than 3% for 32000 hours in operation

4.2 Construction schedule

We formally contracted with the SPC on the Waste-to-Energy plant in Nanchang City on January 25, 2013, and started engineering. After the successful progress of the engineering, construction, equipment installation, and test-run phases, a performance test was completed on
August 3, 2015. Table 2 shows a detailed construction schedule.

We started to install our equipment in November 2013, and completed the installation in November 2014. Figures 4 and 5 show the grates and waste feeder installed in the plant, respectively.

During the period from November to the end of December 2014, we made no-load test runs of all equipment and started load test runs with waste actually treated in January 2015. We implemented a 72 + 24 hour test (China-specific test conducted at thermal power stations by operating equipment with the rated capacity for continuous 72 + 24 hours) at the end of January 2015 and completed all performance tests on August 3, 2015.

5. Characteristics of the plant

The incinerators of this plant are the first ones with a capacity of 600 tons per day and per unit. For successful upscaling, we made some improvements to the prior design.

5.1 Adoption of 4-row grate incinerator

Our large stoker type incinerator, in accordance with the processing amount, adopt the structure combining multiple units in the width direction, and are provided thermal expansion absorption mechanism for a joint between each unit.

The individual grate unit and the mechanism for absorbing thermal expansion at the joints of the units is designed based upon our long experience so that they can easily accept scale-up of incinerator.
The basic structure of each row is the same as the incinerators previously delivered in China; along the traveling direction of waste, the grate is divided into the following parts: a drying grate, combustion grates I and II, and post-combustion grate. Each grate can be independently driven, and the number of movements per unit time to be set individually.

To address the low-calorific-value waste in China, we increased the length of the entire grate compared with that for the plants in Japan, and provided steps at the exit of the drying grate and the entrance of the post-combustion grate to loosen waste and facilitate incinerating it.

Combustion air is supplied through the under-furnace chutes located at the bottom of the grate and the quantity of airflow is adjustable on a chute-by-chute basis. By adjusting the number of movements of each grate and the quantity of combustion air for each chute according to the nature and amount of waste, it is possible to realize stable combustion handling a variety of waste types.

The 4-row-grate incinerator is composed of 4 rows of units arranged along the width direction, and width dimension is wider than the prior incinerators. Therefore we strengthened the structure of each section to prevent from bending.

In addition, a large, wide grate-type incinerator may cause inhomogeneous combustion in the width direction within the furnace. To prevent this, we installed in the width direction several cameras for monitoring the inside of the furnace to enable the combustion air to be adjusted on a row-by-row basis according to the combustion conditions in each rows.

As a result, during the several months period of the load test run, we verified that the incinerators operated stably without problem associated with the mechanical functions of the grate-type incinerators. The combustion condition inside the furnace was also excellent; a homogeneous combustion completion point was maintained on the 4-row grate with a width of approximately 10 m. It was also verified that the temperature at the exit of the furnace was constantly at an optimally high level, i.e., between 900 and 1000 °C, and the retention time of high-temperature gas sufficiently satisfied the design requirements.

Also the incinerators for this plant has high capacity to overload operation, and achieved an average treatment rate of 670 t/d (112% load) and a maximum treatment rate of 733 t/d (122% load) against the rated treatment rate of 600 t/d (in China, overload operation is not legally restricted and therefore continuous overload operation is allowed provided that equipment safety is ensured).

As a result, we successfully verified the effectiveness of the approach of upscaling by combining multiple units in the width direction, revealing that the same approach can be used for further upscaling.

Figure 7 shows the actual combustion state inside of the incineration furnaces.

5.2 Upsizing of bottom ash discharger

For this plant, we developed a high-capacity bottom ash discharger. To increase the pusher area of the
discharger, we used a large-diameter cylinder, achieving a 45% increase in discharge amount. The operation of the discharger has been very stable without a problem. The ash at the exit of discharger contains approximately 22% water, revealing that the discharger exhibits excellent dehydration performance. Figure 8 shows the bottom ash discharger installed in the plant.

5.3 Adoption of a grate-bearing cooling structure
Since the waste in China contains more water and exhibits lower calorific values than the waste in Japan, we adopted an air preheater with a large heat transfer area to increase the primary combustion air temperature to 240 °C. On the other hand, large incinerators with multiple rows also have multiple under-furnace chutes in the width direction, which easily cause heat storage between the chutes.

For these reasons, the conventional large incinerators designed for the Chinese market are likely to have high temperature around the under-furnace chutes and the grate-bearing, which requires a bearing lubricating grease resistant to high temperatures.

For this plant, to prevent the grate bearing temperature from rising, we adopted a bearing cooling structure. This structure prevents the bearing temperature from rising by installing a jacket between the bearing and under-furnace chutes to let in cooling air so that the heat of the hot air inside the chutes will not be directly transferred to the bearing.

We also designed to blow cooling air into the area between the under-furnace chutes of each row to lower the temperature around the chutes.

As a result, the bearing temperature has been successfully lowered by 40 to 50 °C compared to the incinerator without a bearing cooling structure.

The temperature around the chutes has also dropped, resulting in substantial improvement to the working environment. In addition, the lowered bearing temperature has enabled grease with a low heat resistance temperature to be used, resulting in reduced operation costs.

Table 3 compares the measured bearing temperatures between the equipment in Nanchang that uses the bearing cooling structure and equipment in Weihai that does not use this structure.

### Table 3 Measured temperatures of grate bearings

<table>
<thead>
<tr>
<th>Position</th>
<th>Combustion grate I</th>
<th>Combustion grate II</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEIHAI without bearing cooling</td>
<td>162</td>
<td>152</td>
</tr>
<tr>
<td>NANCHANG with bearing cooling</td>
<td>111</td>
<td>109.5</td>
</tr>
<tr>
<td>Temperature difference</td>
<td>51</td>
<td>42.5</td>
</tr>
</tbody>
</table>

5.4 Flue-gas recirculation for NOx reduction
To achieve higher energy efficiency and to reduce NOx based on low air ratio combustion, we have been actively adopting flue-gas recirculation systems in plants in China as well, based on the technology established in Japan.

In the plants in Nanchang, when a flue-gas recirculation system is not used, the average concentration of NOx generated is 330 mg/m³ (NTP) (O₂: 11% equiv.) [Approximately 145 ppm (O₂: 12% equiv.)]. When the flue-gas recirculation system is used, the concentration of NOx generated is approximately 173 mg/m³ (NTP) (O₂: equiv.) [approximately 76 ppm (O₂: equiv.)], indicating that the flue-gas recirculation system effectively helps reduce NOx. Figure 9 shows the data.
about operation when the flue-gas recirculation system is used.

6. Operation condition and performance test results

6.1 Operating condition

During the load test runs, waste put into the waste bunker was stored for five to seven days to increase its calorific value before it is fed into a furnace.

The lower calorific values (analysis values for the performance test) of the waste fed into the incinerator furnace were between 6100 and 6600 kJ/kg, which were close to the design waste of 6270 kJ/kg. The waste was composed of an approx. 28% ash content, approx. 50% water content, and approx. 22% combustible content by weight.

Figure 10 shows the temperatures at the exit of the incineration furnace and evaporation amounts. The temperatures at the exit of the furnace were between 950 and 1050 °C.

6.2 Performance test results

In the performance test, we measured the volume of waste treatment, ash ignition loss, retention time of flue gas of higher than 850 °C, boiler efficiency, steam temperature and pressure, and steam evaporation amount. All measured values satisfied the guaranteed values.

Table 4 shows the performance test results.

Although it does not contain the results of the flue gas from stacks because its emission values are out of our guarantee, the customer additionally measured them to reveal that all measured values passed the criteria.

6.3 110% load operation

Waste-to-Energy plants in China often request incinerators to be able to operate with a load exceeding the rated load (specified calorific value). This plant also requests two hours of operation with 110% load per day.

During the one-month period of the load test run, the incinerators were operated with a load 110% or more of the rated treatment capacity of 600 t/d (i.e., 660 t/d) on more than half of the month, with a maximum treatment capacity of 733 t/d (122% load).

Figure 11 shows the actually treated waste amount during the one-month period of the load test run.

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### Table 4: Results of performance test (100% load)

<table>
<thead>
<tr>
<th>Test item</th>
<th>Unit</th>
<th>Guaranteed performance</th>
<th>No.1 furnace</th>
<th>No.2 furnace</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of waste treatment</td>
<td>t/d</td>
<td>660.0</td>
<td>665</td>
<td>605</td>
<td>Qualified</td>
</tr>
<tr>
<td>Boiler total efficiency</td>
<td>%</td>
<td>≧80.00</td>
<td>80.25</td>
<td>82.6</td>
<td>Qualified</td>
</tr>
<tr>
<td>Steam flow</td>
<td>t/h</td>
<td>53.2</td>
<td>54</td>
<td>54.13</td>
<td>Qualified</td>
</tr>
<tr>
<td>Steam temperature</td>
<td>°C</td>
<td>400</td>
<td>398.9</td>
<td>398.9</td>
<td>Qualified</td>
</tr>
<tr>
<td>Steam pressure</td>
<td>MPa</td>
<td>(4.00, –0.3)</td>
<td>4.00</td>
<td>3.90</td>
<td>Qualified</td>
</tr>
<tr>
<td>Ash ignition loss</td>
<td>%</td>
<td>≦3.00</td>
<td>3.92</td>
<td>3.95</td>
<td>Qualified</td>
</tr>
<tr>
<td>Retention time of flue gas of 850 °C or higher</td>
<td>s</td>
<td>2.0</td>
<td>4.8</td>
<td>5.3</td>
<td>Qualified</td>
</tr>
</tbody>
</table>
| Lower calorific value of waste | kJ/kg | 6270.0 | 6132 | 6605 | ～

*Excluded from the qualification judgment because the performance of this test item is not guaranteed.*
7. Conclusion

With a performance test completed in August 2015, the plant has been successfully operating.

This is the first plant to which we delivered large grate-type incinerators with a capacity of 600 t/d per unit. However, our incinerators adapted to the waste in China and achieved stable operation that satisfied the each guaranteed values. We also obtain some information for further upscaling.

In recent years, environmental awareness has been raised in China as well, upgrading the technology required for Waste-to-Energy plants. We are committed to responding to requests from the Chinese market by achieving technological improvements based on our experience.

We has been consistently receiving orders for incinerators from the Chinese market. Another several plants based on our incinerators are to be completed in China. So far, we have published in the Ebara Engineering Review the cases in which we delivered large grate-type incinerators to plants in China, including this one. We will continue to report such cases in this journal.

Finally, we should like to express our grateful thanks to all the people who cooperated to this project.

References

