Status and Control Technologies of Dioxin (DXN) Emission in Municipal Solid Waste (MSW) Incineration in Japan

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3. Examples of Retrofitting of MSW Incineration Facilities in Japan
### Table. Percentage of MSW Combusted and Number of MSW Incineration Facilities in Different Countries, 2000

<table>
<thead>
<tr>
<th>Region</th>
<th>Country</th>
<th>Percentage</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia</td>
<td>Japan</td>
<td>77 %</td>
<td>1,715</td>
</tr>
<tr>
<td>Europe</td>
<td>Switzerland (not in the EU)</td>
<td>80 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Luxembourg</td>
<td>80 %</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Denmark</td>
<td>65 %</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Sweden</td>
<td>60 %</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Belgium</td>
<td>60 %</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>France</td>
<td>40 %</td>
<td>210</td>
</tr>
<tr>
<td></td>
<td>The Netherlands</td>
<td>40 %</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Germany</td>
<td>25 %</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>Norway (not in the EU)</td>
<td>25 %</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Italy</td>
<td>17 %</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>UK</td>
<td>6 %</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Spain</td>
<td>6 %</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Portugal</td>
<td>0 %</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Ireland</td>
<td>0 %</td>
<td>0</td>
</tr>
<tr>
<td>North America</td>
<td>US</td>
<td>15 %</td>
<td>approx. 150</td>
</tr>
<tr>
<td></td>
<td>Canada</td>
<td>6 %</td>
<td>approx. 20</td>
</tr>
<tr>
<td>Other Countries</td>
<td></td>
<td>5 %</td>
<td></td>
</tr>
<tr>
<td>World Average</td>
<td></td>
<td>&lt; 5 %</td>
<td></td>
</tr>
</tbody>
</table>

(G.Bertolini, 2003; the European IPPC Bureau, 2004)
Fig. Histogram of Operation Starting Year of MSW Incineration Facilities in Japan (The National Survey in 2003)
Fig. Histogram of Operation Starting Year of MSW Incineration Facilities in Japan (The National Survey in 2003)

Total 182,717 t/d
Table. Emission Standards for Waste Incineration Facilities According to the Law for Special Measures Against Dioxins in Japan

<table>
<thead>
<tr>
<th>Treatment Capacity of Combustion Furnace</th>
<th>Emission Standard for Facilities to be newly Constructed</th>
<th>Emission Standard for Existing Facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Up to Nov. 30, 2002</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 t/h or more</td>
<td>0.1 ng-TEQ/m³ [N]</td>
<td>80 ng-TEQ/m³ [N]</td>
</tr>
<tr>
<td>2 to 4 t/h</td>
<td>1 ng-TEQ/m³ [N]</td>
<td></td>
</tr>
<tr>
<td>Less than 2 t/h</td>
<td>5 ng-TEQ/m³ [N]</td>
<td></td>
</tr>
</tbody>
</table>

- **Effluent Standard**: 10 pg-TEQ/L
- **Concentration Standard for Incineration Residues**: 3,000 pg-TEQ/g
- **Emission Factor**: 5μg-TEQ/t-waste

* This value was set in the DXN Guidelines.
The Issue of the DXN Guidelines (Jan. 23, 1997)

Fig. Trend of the Annual Emission of DXN from Waste Incineration Facilities in Japan

The Completion of the Moratorium in the Guidelines (Nov. 30, 2002)
Fig. Histogram of DXN Concentration in MSW Incineration Facilities (2003)
Fig. Type of MSW Thermal Treatment Processes (2003)

- **Incineration**: 2,239
- **Gasification and Syngas Production**
- **Gasification and Melting**: 112
- **The Others**: 11

(*1 Not Facilities)
(*2 A Combustible Synthesis Gas)
Fig. Operation Type of MSW Incinerators (2003)
Fabric or Bag Filters (FF/BF)

Electrostatic Precipitators (ESP/EP)

Multi-Cyclones (MC)

The Others

Not Installed

Fig. Type of Dust and Particle Collector Equipment MSW Incinerators (2003)
Fig. Scatter Plot of DXN vs. Treatment Capacity of MSW Incinerators
(Data of ND are plotted at 0.000001ng-TEQ/m³[N] expediently.)
Fig. Scatter Plot of DXN vs. Treatment Capacity of MSW Incinerators
(Data of ND are plotted at 0.000001ng-TEQ/m³[N] expediently.)
Fig. Histogram of DXN Concentration in Industrial Waste Incineration Facilities (2003)
Fig. DXN Concentration in **Industrial Waste** Incineration Facilities (Waste Plastics, Waste Oil) (2003)
Sludge
594 Facilities

The Others
1,152 Facilities

DXN
Average 0.64 ng-TEQ/m³[N]
Median 0.04 ng-TEQ/m³[N]

Fig. DXN Concentration in Industrial Waste Incineration Facilities (Sludge, The Others) (2003)
Cleanup and Removal of Disused Incineration Facilities Contaminated by DXN

REMAINING PROBLEM

- Disused Municipal Waste Incineration Facilities: Approx. 500 Facilities
- Disused Industrial Waste Incineration Facilities: Approx. 3,800 Facilities

(Dec. 1, 2003)
### Table. Trend of Number of Operating and Disused *Industrial Waste* Incineration Facilities

<table>
<thead>
<tr>
<th>Date</th>
<th>Operation</th>
<th>(Work)</th>
<th>(Pause)</th>
<th>Disuse</th>
<th>New Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec. 1, 1997</td>
<td>5,757</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Dec. 1, 1998</td>
<td>4,493</td>
<td>(3,840)</td>
<td>(653)</td>
<td>1,393</td>
<td>129</td>
</tr>
<tr>
<td>Dec. 1, 1999</td>
<td>4,487</td>
<td>(3,942)</td>
<td>(545)</td>
<td>282</td>
<td>101</td>
</tr>
<tr>
<td>Dec. 1, 2000</td>
<td>4,259</td>
<td>(3,705)</td>
<td>(554)</td>
<td>246</td>
<td>49</td>
</tr>
<tr>
<td>Dec. 1, 2001</td>
<td>3,942</td>
<td>(3,421)</td>
<td>(521)</td>
<td>311</td>
<td>24</td>
</tr>
<tr>
<td>Dec. 1, 2002</td>
<td>2,578</td>
<td>(1,534)</td>
<td>(1,044)</td>
<td>1,387</td>
<td>50</td>
</tr>
<tr>
<td>Dec. 1, 2003</td>
<td>2,356</td>
<td>(1,833)</td>
<td>(523)</td>
<td>253</td>
<td>48</td>
</tr>
<tr>
<td>Total</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>3,872</td>
<td>401</td>
</tr>
</tbody>
</table>
2. Control Technologies in MSW
Thermal Treatment

2.1. Thermal Treatment Process
Stoker Incineration
Kawasaki-Sun-type Reciprocating Stoker

**Intermediate Flow Type Incinerator**
- Adaptation to wide range of the calorific value of the waste.

**Parallel Flow Type Incinerator**
- Adaptation to higher calorific value of the waste compared to intermediate Flow Type Incinerator.

- Forced mixing of gas and air minimizes the formation of carbon monoxide.

**Incorporation process**
- Uniform supply of air via the Kawasaki-Sun-type stoker.

- Primary air

- Drying

- Incineration

- Post-combustion

**Turbulence of combustion gas**
- Large

**Retention time at high temperature**
- Long

**Relationship between O2 and CO Concentrations in Flue Gas**

The appropriate amount of air is drawn in so that the gas has an optimal balance of between 7% and 9% O2 concentration after the primary and secondary air intakes. Supplying air in this manner, combined with an incinerator shape that optimizes mixing, ensures complete incineration, eliminating the incidence of CO and other unburned gases. The absence of these catalysts prevents the formation of soot.
A Concept of the Kawasaki-advanced Stoker

Flue Gas Re-circulation

Boiler Condition
6MPa×450℃

SCR
(approx. 170℃)

Parallel Flow Type

Water Cooling of Grates

Water Cooling of Refractory Panel

Hydration of Bottom Ash

180 ℃
Annex 1.

Development and Commercial Applications of Parallel Flow Type Incinerator for Municipal Solid Waste

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Abstract: At the request of “formation of a recycling-based society,” for municipal solid waste incineration facilities, reduction of environmental load (suppression of emission of dioxins and other harmful substances) and high-ratio recovery of energy and resources are requested. For the former request, it is essential to suppress generation in the combustion process, and it is the essential point how the perfect combustion should be achieved. Kawasaki Heavy Industries, Ltd. has developed a parallel flow type incinerator to achieve more sophisticated combustion than a conventional intermediate flow type incinerator. The parallel flow type incinerator has a special shape of gas flow system classified as a “parallel flow type” (that is, combustion gas flows in the same direction as that of the refuse transported on a stoker). The incinerator was applied to a commercial plant and further development was carried forward, and it has been able to be confirmed that the incinerator provides the properties that enable low air-ratio combustion and low-NOx operation advantageously. The low air-ratio combustion contributes to reduction of combustion gas emission and retention of high temperature, as well as improvement of combustion gas waste heat recovery ratio (the latter report). This paper reports the characteristics, performance, development process, and actual operation results of our “parallel flow type incinerator.”

Keywords: parallel flow type incinerator, suppression of dioxins emission, low air-ratio combustion, low-NOx operation, intermediate flow type incinerator

1. INTRODUCTION

To achieve perfect combustion in municipal solid waste incinerators, it is necessary to secure “Combustion’s 3Ts” (Temperature: high-combustion temperature; Time: sufficient residence time in the high-temperature zone; and Turbulence: satisfactory mixing of unburned gas with air). Kawasaki Heavy Industries possesses the technology of intermediate flow type incinerators with excellent agitation and mixing of combustion gas flows and has constructed a large number of facilities. And for the tightened dioxins controlled values in recent years, the Company has succeeded in achieving the satisfactory results by making various improvements in structural improvement and combustion method. However, to achieve still more perfect combustion as a still higher target, the Company thought it necessary to radically review the incinerator construction, and undertook the development of a parallel flow type incinerator with an intention to increase the combustion gas residence time in the high-temperature zone around 1993. The actual incinerator No. 1 (300 t/d x 2 units) was completed in 2001 and the results later discussed were obtained.

2. CONSTRUCTION OF THE PARALLEL FLOW TYPE INCINERATOR

Fig. 1 shows the construction of the parallel flow type incinerator. With respect to the furnace shape, an intermediate partition wall is installed at the center of the upper part of the furnace (i.e. primary combustion chamber), and the combustion gas outlet (i.e. secondary combustion chamber inlet) is located above the burnout stage. Above the burnout stage, a combustion space (hereinafter called the “space above the drying stage”) partitioned by the furnace ceiling and the intermediate partition wall is provided, and secondary air is charged mainly into this space. By this furnace shape, combustion gas passes under the intermediate partition wall in the same direction as that of the refuse. The furnace wall surface is of a water-cooled wall construction by extending the boiler water pipe right above. The portion susceptible to friction with refuse is covered with refractory brick, and the portion other than that is lined with castable refractory to prevent corrosion. In the secondary combustion chamber, consideration is given to retention of high temperature, too.

The combustion system shown in Fig. 1 is a rocking stoker (three-stage type comprising drying, combustion, and burnout stages) that is our prime product.
Advanced Thermal Treatment of MSW

Advanced Stoker Systems

- Gasification and Melting Systems
  - Shaft Furnace Type
  - Rotary Kiln Type
  - Fluidised Bed Type
  - Stoker Type

Gasification and Syngas Production Systems

- Shaft Furnace Type
- Rotary Kiln Type
Gasification and Melting System

Kawasaki Shaft Furnace Gasification and Melting System
Gasification and Melting System

Fluidized Bed Gasification and Melting System
2. Control Technologies in MSW
Thermal Treatment

2.2. Flue Gas Treatment Process
Flue Gas Treatment Process

Three processes to reduce dioxin levels:

1. **Inhibitor formation**: disposal of dioxin formation, and the exhaust gas is sprayed with slaked lime and activated carbon. These substances react with HCl, SOx, and Hg, and can be collected by the filtration-type dust catcher.

2. **Spray Gas Cooler**: Rapid cooling of the gas prevents the recombination of dioxins, and the exhaust gas is sprayed with slaked lime and activated carbon. These substances react with HCl, SOx, and Hg, and can be collected by the filtration-type dust catcher.

3. **Dust Filter**: The fly ash in the flue gas, as well as the SOx and HCl that has reacted with and been absorbed by such substances as slaked lime, is eliminated when they attach to the cylindrical filtration cloth.

**Wet Scrubber**: Chlorides and sulfuric oxides, as well as mercury, are removed from the exhaust gases by mixing the gases with hot air in the gas reheater, where plumes can be prevented.

**Activated Carbon Absorption Tower**: Activated carbon charged from the upper part moves down, and is discharged with maximum absorption rate of dioxin, etc. Activated carbon moves down by rotating roll feeder at the bottom part of packed bed, and discharged periodically. This device is composed of a plural packed bed for simplifying its structure.

**Selective Catalytic Reactor (SCR)**: In the reactor, ammonia gas is blown into the flue gas, which includes nitrogen oxide. A catalyst removes the nitrogen oxide, turning it into nonpolluting nitrogen and water. It also decomposes and removes dioxine.
B Spray Gas Cooler

Rapidly cooling the gas prevents the recombination of dioxins, and the exhaust gas is sprayed with slaked lime and activated carbon. These substances react with HCl, SOx and Hg, and can be collected by the Filtration-type dust catcher.
Bag Filter  The fly ash in flue gas, as well as the SOx and HCl that has reacted with and been absorbed by such substances as slaked lime, are eliminated when they attach to the cylindrical filtration cloth.
**D Wet Scrubber**

Chloride and sulfuric oxides, as well as mercury, are removed from exhaust gases. By mixing the gases with hot air in the gas reheater, white plumes can be prevented.
Activated Carbon Absorption Tower
Activated carbon charged from the upper part moves down, and is discharged with maximum absorption rate of dioxins, etc.
Activated carbon moves down by rotating roll feeder at the bottom part of packed bed, and discharged periodically. And this device is composed of a plural packed bed for simplifying its structure.

- Principle of moving bed device

- Activated carbon
- Toxic gas
- Separate Plate
- Moving bed
- Clean gas
- Separate plate
- Cutting up
- Roll feeder
Selective Catalytic Reactor (SCR)

In the reactor, ammonia gas is blown into the flue gas, which includes nitrogen oxide. A catalyst removes the nitrogen oxide, turning it into nonpolluting nitrogen and water. It also decomposes and removes dioxins.

How a catalyst works

Flue gas

Denitration catalyst
### Recent Dioxin Data

<table>
<thead>
<tr>
<th>Incinerating Capacity</th>
<th>Flow</th>
<th>Dioxin Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 t/ 24 h × 3 :</td>
<td>Furnace → Boiler → FF → WS → <strong>SCR</strong> → Stack :</td>
<td>ND - 0.07 ng-TEQm³[N]</td>
</tr>
<tr>
<td>40 t/ 24 h × 2 :</td>
<td>Furnace → Water Spray → <strong>FF</strong> → <strong>ACR</strong> → Stack :</td>
<td>↑ <strong>Activated Carbon</strong>&lt;br&gt;0.0008 - 0.04 ng-TEQm³[N]</td>
</tr>
<tr>
<td>10 t/ 8 h × 2 :</td>
<td>Furnace → Water Spray → FF + FF → Stack :</td>
<td>↑ (<strong>↑</strong> <strong>Activated Carbon</strong>&lt;br&gt;ND - 0.0002 ng-TEQm³[N]</td>
</tr>
</tbody>
</table>

ACR : Activated Carbon Reactor/Reduction  
SCR : Selective Catalytic Reactor/Reduction
Other Techniques for Flue Gas Treatment

1. Double Filtrations (1st FF + 2nd FF) and Utilization of Additives : A

2. Utilization of Na Compounds (ex. NaHCO₃) Instead of Ca Compounds : A

3. Ceramic Filters or Cyclones at Temperatures of approx. 800 ℃ : P

4. Electron Beam (EB) : P

5. Electro Dynamic Venturi (EDV) : P

(A : Actual Equipment ; P : Pilot Equipment )
### Table. Gas Sampling Equipment for DXN Monitoring in the EU

<table>
<thead>
<tr>
<th>Maker</th>
<th>Method</th>
<th>Characteristic</th>
<th>Sampling Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Becker Messtechnik GmbH (Germany)</td>
<td>• AMESA Adsorption</td>
<td>• Sampling Equipment (See Fig.1)</td>
<td>6 h – 4 weeks</td>
</tr>
<tr>
<td>Dioxin Monitoring System (Austria)</td>
<td>• DMS Adsorption</td>
<td>• Sampling Equipment (See Fig.2)</td>
<td>6 h – 4 weeks</td>
</tr>
</tbody>
</table>

* Adsorption Method for Sampling of Dioxins and Furans

---

**Fig.1 AMESA**

**Fig.2 DMS**
Table. Gas Monitors in Japan for Dioxin Surrogate Compounds

<table>
<thead>
<tr>
<th>Maker</th>
<th>Method</th>
<th>Compound</th>
<th>Detection Limit</th>
<th>Detection Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hitachi, Ltd.</td>
<td>•CP-2000 APCI ionization → ITMS</td>
<td>T₃CPh</td>
<td>500 ng/m³</td>
<td>20 s</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PCB</td>
<td>10,000 ng/m³</td>
<td>15 min</td>
</tr>
<tr>
<td>NKK - ToaDKK, Ltd.</td>
<td>•GDX-2000 Adsorption → ECD</td>
<td>CBz</td>
<td>80 ng/m³</td>
<td>15 – 60 min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CPh</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mitsubishi Heavy Industry, Ltd.</td>
<td>UV ionization → TOFMS (*Adsorption)</td>
<td>CBz</td>
<td>80 ng/m³</td>
<td>20 s</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P₅CDF</td>
<td>0.05 ng/m³ *</td>
<td>2 – 6 h</td>
</tr>
<tr>
<td></td>
<td>Laser Ionization → TOFMS</td>
<td>PCB</td>
<td>10,000 ng/m³</td>
<td>1 min</td>
</tr>
</tbody>
</table>
2. Control Technologies in MSW Thermal Treatment

2.3. Treatment of Incineration Residues
Fly Ash Treatment Equipment for Dechlorination of DXN

**Dioxin Thermal Decomposition System**

- Electrical heating zone
- Fly ash entrance
- Heating drum
- Cooling water outlet
- Cooling drum
- Fly ash discharge

**Extent of Decomposition**

To disassociate dioxins, ash is heated at 350°C to 400°C for between 30 and 60 minutes in an oxygen-starved environment. Next, the ash is quenched to a temperature of 140°C or less. This causes the dioxins within the fly ash to disassociate without resolidifying.
### Ash Melting System

**Plasma-type**
- Torch raising/lowering maintenance system
- Operating gas
- Access panel

**Oil Burner-type**
- Ash hopper
- Drying gas outlet
- Ash feeder

### Improving the Quality of Formed Slag and using as a Resource

<table>
<thead>
<tr>
<th>Slag</th>
<th>Magnetic separation process</th>
<th>Crushing processing</th>
<th>Hot water processing (Improved)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Splintered and smooth</td>
<td>Removal of magnetic substances</td>
<td>Depending on the application, adjust the size of granules, or reduce to splintered and angled slag</td>
<td>Submerge slag surface in OH group to create jagged surface</td>
</tr>
<tr>
<td>surface</td>
<td>Prevention of coloring from rust</td>
<td>Minimize volumetric reduction, change toward corrected CBR</td>
<td>Improve hydrophilic andropic properties of slag surface</td>
</tr>
<tr>
<td>Non-processed slag (water-granulated)</td>
<td>Crushing processed slag</td>
<td>Improved slag (hot water processing)</td>
<td></td>
</tr>
</tbody>
</table>

May be used in place of natural sand in concrete aggregates, thereby improving concrete strength, and in asphalt aggregates to increase Marshall stability, through hot water processing.
Other Countermeasures for DXN Abatement in MSW Treatment

- Wide-area Treatment System in Waste Management
- Non-combustion Treatment (ex. Bio-treatment)
An Idea of Wide-area-treatment System by RDF (Refuse-derived Fuel) in MSW Management
Transforming Waste into Fuel

Refuse-derived Fuel (RDF) Production Plant
Fluidized Bed Incineration

Fluidized Bed Incinerator

Internal Circulation Fluidized Bed-type Boiler
Annex 2.

3rd i-CIPEC, October 21-23, 2004, Hangzhou, China

Development and Commercial Applications of an Internal Circulation Fluidized Bed-type Boiler

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Abstract: This paper reports on the characteristics, performance, development process, component technologies, and practical operation results of an internal circulation fluidized bed-type boiler.

We have developed an internal circulation fluidized bed-type boiler, in abbreviation ICBB, which is specially designed for RDF combustion and power generation. This boiler can be operated in favorable steam conditions (8.14 MPa@50°C) and thus the boiler-power generation system is anticipated to achieve 30% and more power-generation efficiency, which is far higher than that of conventional systems.

The low efficiency of waste-burning power generation plants is attributed to the low temperature and pressure of boilers. The reason is that the steam temperature of boilers is held below 320°C in order to prevent the corrosion of heat exchanger tubes by HCl gas in the combustion gas.

We have tried to develop a more efficient RDF incinerator with waste heat boiler based on a bubbling type fluidized-bed combustion system. Our first commercial plant has a combustion capacity of 315 ton/h of RDF per day. The plant has achieved a steam temperature of 300°C and a gross efficiency of 30% by incorporating an internal circulation fluidized bed-type boiler.

Keywords: refuse-derived-fuel, high power-generation efficiency, internal circulation fluidized bed-type boiler

1. INTRODUCTION

In order to avoid the corrosion by corrosive gas such as hydrogen chloride gas generated by waste burning, steam temperature has been below 400°C or less. Consequently, power generation efficiency was about 20%.

We have developed an internal circulation fluidized bed-type boiler specially designed for RDF combustion and efficient power generation. It could operate on steam conditions (8.14 MPa@50°C) advantageous to power generation, and it enabled 30% or more power generation efficiency.

This paper reports the feature and actual operation result of a RDF efficient power generation plant.

2. AN INTERNAL CIRCULATION FLUIDIZED BED-TYPE BOILER

2.1 Structure of an internal circulation fluidized bed-type boiler

Fig. 1 shows the schematic configuration of the fluidized bed. The fluidized bed is functionally separated into two portions with partition walls. One is a combustion cell in the center and the other is outer heat recovering cells.

By keeping the fluidizing air velocity in the heat recovering cell smaller than that of the combustion cell, the high-temperature fluidizing medium circulates from the top of the partition wall to the heat recovering cells. In the heat recovering cells, the fluidized medium is cooled down at the heat exchanger tube mounted in the bed and thus heat is recovered. The cooled low-temperature fluidizing medium circulates from the bottom of the partition wall to the combustion cell, and is diffused and mixed with the high-temperature fluidizing medium in the combustion cell, whereby the fluidized medium forms a steady circulation flow, and hence the combustion cell bed temperature is controlled at a specified level.

The fluidized bed has large heat capacity so that RDF fed into the combustion cell, where violent fluidizing motion takes place, is burned immediately within the combustion cell. Most of HCl gas generated during RDF-burning goes through the combustion cell to the secondary combustion zone. Accordingly, HCl gas concentration in the recovering cells is low enough to prevent the heat exchanger tubes from the corrosion. The ICBB can thus operate in favorable steam conditions.

Fig. 2 shows the structure of an internal circulation fluidized bed-type boiler.
The Overview of the Commercial RDF Power Plant (The City of Omuta)
Gasifying Waste (Bio-treatment of Garbage, Grass, and Trees)
Organic Waste Gasification System
The Overview of the Pilot Plant (Kyoto City)
The Overview of the Fermentation Vessel (Kyoto City)
3. Examples of Retrofitting of MSW Incineration Facilities in Japan
Fig. The Sectional Outline of the Plant A before Retrofitting (200 t/d × 3)
Fig. The Sectional Outline of the Plant A after Retrofitting (200 t/d x 3)
Table. DXN Data before and after Retrofitting of the Plant A (200 t/d x 3)

<table>
<thead>
<tr>
<th></th>
<th>Before Retrofitting</th>
<th></th>
<th>After Retrofitting</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Concentration</td>
<td>Emission Factor</td>
<td>Concentration</td>
<td>Emission Factor</td>
</tr>
<tr>
<td></td>
<td>(μg-TEQ/t-waste)</td>
<td>(μg-TEQ/t-waste)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flue Gas</td>
<td>1.5 ng-TEQ/m³</td>
<td>9.5</td>
<td>0.00034 ng-TEQ/m³</td>
<td>0.0022</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>12 ng/g</td>
<td>200</td>
<td>0.020 ng/g*</td>
<td>0.74</td>
</tr>
<tr>
<td>Bottom Ash</td>
<td>0.022 ng/g</td>
<td>2.4</td>
<td>0.014 ng/g</td>
<td>1.5</td>
</tr>
<tr>
<td>Total</td>
<td>–</td>
<td>210</td>
<td>–</td>
<td>2.3</td>
</tr>
</tbody>
</table>

* Fly ash treatment equipment for dechlorination of DXN was installed.
Fig. The Sectional Outline of the Plant B before Retrofitting (200 t/d × 3)
Fig. The Sectional Outline of the Plant B after Retrofitting (200 t/d × 3)
Table. DXN Data at the Outlet of SCR after Retrofitting of the Plant B (200 t/d × 3)

- Furnace #1: 0.0014 ng-TEQ/m³[N]
- Furnace #2: 0.00039 ng-TEQ/m³[N]
- Furnace #3: 0.00065, 0.00029 ng-TEQ/m³[N]
  - (Before Retrofitting: 0.78 - 2.7 ng-TEQ/m³[N])
<table>
<thead>
<tr>
<th>Facility</th>
<th>Plant A</th>
<th>Plant B</th>
<th>Plant C</th>
<th>Plant D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>200 t/d x 3</td>
<td>200 t/d x 3</td>
<td>300 t/d x 2</td>
<td>80 t/d x 3</td>
</tr>
<tr>
<td>Retrofitting of Firing System</td>
<td>1,320</td>
<td>500</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>ESP → Spray Gas Cooler + FF</td>
<td>3,350</td>
<td>1,430</td>
<td>2,950</td>
<td>1,395</td>
</tr>
<tr>
<td>Injection Unit of Activated Carbon</td>
<td>410</td>
<td>40</td>
<td>—</td>
<td>75</td>
</tr>
<tr>
<td>SGH + S_2CR</td>
<td>1,160</td>
<td>1,690</td>
<td>1,410</td>
<td>—</td>
</tr>
<tr>
<td>Fly Ash De-chlorination Equipment</td>
<td>1,100</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Total</td>
<td>7,340</td>
<td>3,660</td>
<td>4,360</td>
<td>1,470</td>
</tr>
</tbody>
</table>

- *1 Fabric Filter with dosage of Slaked Lime
- *2 Steam Gas Heater
- *3 Selective Catalytic Reactor/Reduction
1. Reduction target of DXN emission in Japan was achieved.

2. The problem of cleanup and removal of disused incineration facilities is remaining.

3. Advanced thermal treatment of MSW is in operation in Japan.

4. Abatement techniques of DXN in flue gas are adopted as actual equipment or pilot equipment.

5. Retrofitting costs of MSW incineration facilities varied site by site.
Thank you for your kind attention.

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