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# Sludge Incineration Technology with Power Generation and Optimum Air Injection System: "OdySSEA"

## 1. Introduction

In the sewage field, reduction of greenhouse gases ($N_2O$, $CO_2$) and air pollutants (NOx) has become a major issue[1]. In particular, reduction of $N_2O$ generated by sludge incinerators is urgently needed because greenhouse effect of $N_2O$ is 298 times greater than that of $CO_2$. Therefore, JFE Engineering developed "Sludge Incineration Technology with Power Generation and Optimum Air Injection System" as a FY 2017–2018 B-DASH Project (Breakthrough by Dynamic Approach in Sewage High Technology Project) of Japan's Ministry of Land, Infrastructure, Transport and Tourism (MLIT) in joint work with the Japan Sewage Works Agency and Kawasaki City, and commercialized this technology as the JFE Sludge Incineration System with Power Generation (OdySSEA).

This paper presents an overview of the two core technologies of OdySSEA, i) High-efficiency Power Generation Technology and ii) Optimum Air Injection System, together with the results of a demonstration test.

## 2. Overview of "OdySSEA" Technologies

### 2.1 Incineration System for Introduction of "OdySSEA" Technologies

The flow chart of the facility where the OdySSEA technologies were introduced is shown in **Fig. 1**. The main equipment of the technology i) is the boiler, steam turbine and condenser, while the main equipment of ii) is the ducts and nozzles used to branch off the fluidization air and inject it into the freeboard zone of the incinerator. Installation of the additional equipment is comparatively simple, not only in newly constructed plants but also in existing facilities, as the equipment for i) can be installed by changing the duct connections and installing the boiler in the exhaust gas line, and that for ii) can be installed by revamping the fluidization air duct[2].

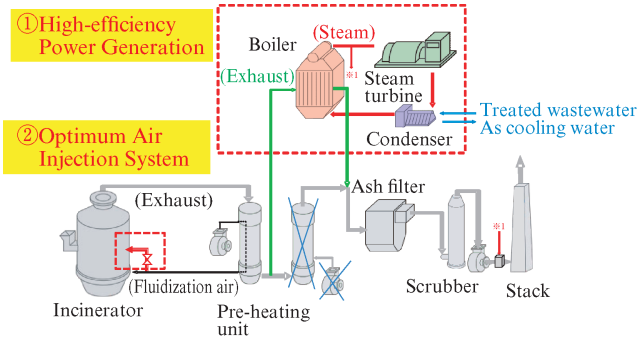


Fig. 1 Flow chart of "OdySSEA"

### 2.2 High-efficiency Power Generation Technology

Conventionally, it was difficult to introduce a steam turbine with high power generation efficiency at incinerators where the incineration amount of dehydrated cake was less than about 200 wet-t/d because little unutilized waste heat could be obtained.

The "OdySSEA" system enables high-efficiency power generation with as little as 60 to 200 wet-t/d of dehydrated cake by introducing a newly-developed small condensing-type steam turbine (**Fig. 2**) and a water-cooled type of condenser which utilizes with abundant sewage treatment water[2]. Because the electric power consumption of the incineration system can be reduced by using power generated by "OdySSEA," an indirect reduction of $CO_2$ emissions can also be expected.

### 2.3 Optimum Air Injection System

The $N_2O$ emission reduction technology of "OdySSEA" is based on the mechanism of branching off part of the fluidization air and efficiently injecting it into the secondary combustion of exhaust gas process (freeboard zone) (**Fig. 3**) in the upper part of the incinera-

Fig. 2 Interior view of small condensate steam turbine

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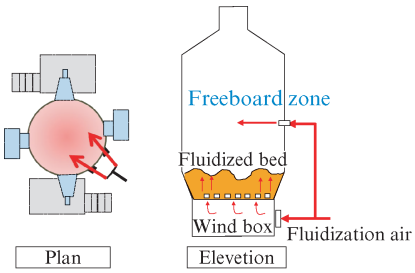


Fig. 3 Schematic diagram of Optimum Air Injection System

Table 1 Specification of incineration facility where demonstration equipment was installed

| Item | Specification |
|---|---|
| Type of sludge | Mixed raw sludge |
| Type of furnance | Bubble fluidized bed incinerator |
| Incineration | About 150 wet-t/day |
| Combustion temperature | 850°C |

tor. When fluidization air is injected into the freeboard zone, the injection nozzles are generally arranged in the furnace circumferential direction. The key feature of the “OdySSEA” technology is that the effects of this system are achieved by injection of the air into the furnace from one direction. This equipment can be installed in the limited space (approximately 2.5×2.0 m) near the furnace, the cost of the additional equipment is low, and installation is easy because as interference with the incidental equipment of the existing incinerator is slight.

## 3. Results of Demonstration Test

### 3.1 Overview of Demonstration System

The demonstration system was installed at one of the four lines of the Iriezaki Sludge Treatment Center in Kawasaki City. **Table 1** shows the specification of the facility where the system was installed [2–4].

### 3.2 Results of High-efficiency Power Generation Technology

**Table 2** shows the results of the high-efficiency power generation technology at the rated incineration amount (approximately 150 wet-t/d). The table also shows the operating results for the dehydrated cake with a low moisture content in spring, summer and autumn.

Although the heat input to the incinerator varied due to seasonal changes in sludge properties such as the moisture content (73% to 76%), the amount of power generated by the “OdySSEA” system corresponded to those changes, demonstrating that stable

Table 2 Demonstration test results of high-efficiency power generation technologies in each season

| Season | SPR | | SMR | | AUT | | WTR |
|---|---|---|---|---|---|---|---|
| Feed sludge condetions | ① | ② | ① | ② | ① | ② | ① |
| Incineration (wet-t/day) | 150 | 138 | 150 | 136 | 151 | 140 | 154 |
| Moisture content (%) | 74.7 | 71.6 | 72.9 | 72.2 | 75.6 | 73.1 | 75.0 |
| Heat input (GJ/h) | 14.9 | 17.8 | 16.6 | 18.8 | 14.8 | 15.8 | 15.4 |
| Generarion output (kW) | 420 | **690** | **605** | **730** | 448 | **683** | 385※ |
| Power consumption (kW) | 529 | 559 | 552 | 563 | 567 | 569 | 560 |

(Bolded, underlined part is power independent)
①: Rated value ②: Low moisture content
※ In winter, the incinerator could not be operated stably, and energy was required to raise the temperature inside the furnace, resulting in low power generation.

Table 3 Results of using Optimum Air Injection System

| | | | Optimum Air Injection System | | Reduction rate (%) |
|---|---|---|---|---|---|
| | | | Stop | Operation | |
| $N_2O$ | Concentration | ppm-12 %$O_2$ | 88 | 41 | 53 |
| | Emission factor | kg-$N_2O$/wet-t | 0.494 | 0.232 | |
| NOx | Concentration | ppm-12 %$O_2$ | 52 | 13 | 75 |

power generation operation is possible. Moreover, since the electric power output of the plant exceeded the total power consumed by the incineration system and the power generating equipment regardless of the season, complete electric energy self-sufficiency was confirmed in operation with dehydrated cake with a low moisture content (71% to 73%)[3]. Complete electric energy self-sufficiency technology like this is the first such technology in the industry at a scale of 150 wet-t/d of incineration of dehydrated cake.

### 3.3 Effect of Optimum Air Injection System

**Table 3** shows the measured results of the $N_2O$ and NOx emission concentration at the stack outlet. The emission concentrations were measured when the optimum air injection system was operated during rated operation of the incinerator, and when the injection system was stopped.

It was found that operation of the optimum air injection system simultaneously reduced the $N_2O$ emission factor and the NOx emission concentration by more than 50%[4].

## 4. Effect of Introduction of “OdySSEA” Technology as Global Warming Countermeasure

Based on the results of the demonstration operation described above, a trial calculation of the energy con-

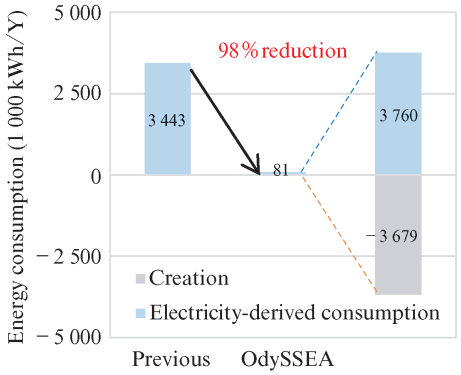


Fig. 4 Reduction in energy consumption

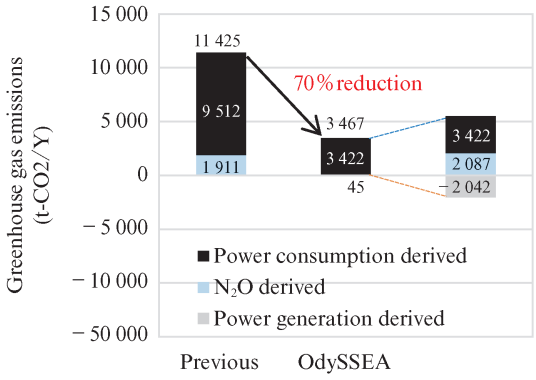


Fig. 5 Reduction in greenhouse gas emissions

sumption reduction effect and the greenhouse gas emission reduction effect assuming introduction of the demonstration technology was carried out. The results of the trial calculation energy consumption and GHG emissions under substantially the same conditions as in Table 1 are shown in **Fig. 4** and **Fig. 5**, respectively.

The results of the trial calculation confirmed that a reduction of 98% in energy consumption and a reduction of 70% in GHG emissions are possible by introduction of this technology.

## 5. Conclusion

This paper has presented an overview of the two core technologies of the JFE Sewage Sludge Incineration System with Power Generation (OdySSEA), that is, i) High-efficiency Power Generation Technology and ii) Optimum Air Injection System, together with the results of a demonstration test.

In addition to newly-constructed sludge incineration plants, this technology can also contribute to global warming countermeasures at existing incineration facilities, where retrofitting was difficult, while also responding to the diverse needs of local governments which can introduce this system.

In October 2021, JFE Engineering received an order for the “Iriezaki General Sludge Center sewage sludge treatment system renewal and expansion project” from the Waterworks Bureau, City of Kawasaki. The introduction of the “OdySSEA” technology in this project is expected to contribute to a further reduction in greenhouse gases.

## References

1) Ministry of the Environment and Ministry of Land, Infrastructure, Transport and Tourism. “Manual for Global Warming Countermeasures in Sewerage -Guidelines for Greenhouse Gas Emission Reduction in the Sewerage Sector-. 2017
2) Hashimoto, H.; et al. Demonstration Study of Power Generation Type Sludge Incineration Technology in Consideration of Greenhouse Gas Reduction. Proceedings of The 55th Japan Annual Technical Conference on Sewage. 2018, p. 524–527.
3) Hashimoto, H.; et al. Demonstration of High-Efficiency Power Generation Technology in Power Generation-Type Sludge Incineration Technology Considering Greenhouse Gas Reduction. Proceedings of The 56th Japan Annual Technical Conference on Sewage. 2019, p. 587–589.
4) Akiyama, H.; et al. Demonstration of Automatic Control Technology for Local Agitation and Air Blowing in Power Generation Sludge Incineration Technology. Proceedings of The 57th Japan Annual Technical Conference on Sewage. 2020, p. 514–516.

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