Stoker Type Incinerator Utilizing Counter Flow Combustion

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Abstract:

JFE Engineering has developed the advanced stoker-type incineration system utilizing counter flow combustion based on "JFE Hyper 21 Stoker system", which has been proven its superiority by long term accomplishment. In this system, high temperature air counter flow is used to stabilize waste combustion. This system was developed to meet varied requirement and function such as high efficiency of power generation and minimization of environmental pollution. In this paper, the combustion stability demonstrated by the first facility with this forefront technology is reported. In particular, the combustion with both low NOx and low CO emission is confirmed.

1. Introduction

In recent waste incinerators, a response to various issues, including increased electric power generation, reduction of environmental loads, reduction of operating costs, etc., has been strongly required. Achieving stable low excess air ratio combustion is indispensable for meeting these requirements, as it contributes to reduction of environmental loads by reducing discharged gases, reduction of chemical costs by reducing pollution, and improved efficiency in power generation by improving heat recovery efficiency. However, combustion under a lower excess air ratio condition easily becomes unstable due to the diverse and nonuniform wastes. To realize stable combustion even under lower excess air ratios, JFE Engineering developed the JFE Hyper 21 Stoker system by applying High-temperature Air Combustion Technology (HiCOT)[1)] and has accumulated an extensive record of installations of this system as a next-generation stoker furnace since 2009. This paper introduces a new stoker type incinerator utilizing counter flow combustion (hereinafter, new system), which was developed by improving the JFE Hyper 21 Stoker System (hereinafter, conventional system) and successfully achieved a further improvement in stable combustion performance.

2. Explanation of System

2.1 Features of System

Before introducing the new system, this section will first introduce the features of the conventional system. The distinctive feature of the conventional system is that high temperature mixed-gas air is injected into the furnace from the furnace walls (**Fig. 1**). This element technology causes the high temperature mixed-gas air injected from the right and left walls to collide with the pyrolysis gas from the waste layer and form a stationary stable plane combustion region above the waste layer. Combustion efficiency is improved by heat radiation from this region to the waste layer, enabling stable combustion under a lower excess air ratio condition,

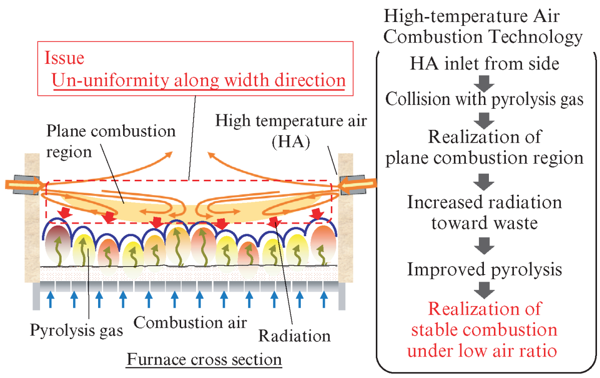

Fig. 1 Schematic configuration of High—temperature Air Combustion Technology (HiCOT) in conventional equipment

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which is normally prone to unstable combustion, thereby simultaneously suppressing CO and NOx generation. However, if the scale of waste treatment is increased, it is necessary to expand the furnace width, and as a result, the collision between the pyrolysis gas and high temperature mixed-gas air will be weakened in the center of the furnace. Therefore, in large-scale incinerators, as represented by overseas projects, securing uniformity in width direction was a challenge.

To overcome this problem, the new system utilizing counter flow combustion, which is a further evolution of the high temperature mixed-gas air technology described above, was applied to a waste incinerator for the first time in the world with the aims of further improving combustion stability and reducing NOx, while also improving applicability to large-scale incinerators. **Figure 2** shows the concept of this combustion configuration in the new system.

In the new system, a more uniform plane combustion region is formed in the furnace width direction and combustion stability is improved by causing a counter flow-type collision between the pyrolysis gas from the waste layer and the high temperature mixed-gas air by injecting the high temperature mixed-gas air from the furnace roof, resulting in a simultaneous reduction of CO and NOx. NOx is reduced by the following mechanism by forming a uniform combustion region and achieving two-step combustion by optimizing the gas supplied from the furnace roof (**Fig. 3**, **Fig. 4**).

(1) By appropriately controlling the injection rate and oxygen concentration of the high temperature mixed-gas air from the incinerator roof, a primary combustion field with a reducing atmosphere is formed in the upstream part of the incinerator (Fig. 3, central part of furnace), while a combustion field with an oxidizing atmosphere is formed in the downstream section of the furnace.

(2) This configuration materializes two-step combustion, as the nitrogen compounds such as ammonia, cyanogen, etc., which form in the first-step combustion field with the reducing atmosphere, act as reductants for NOx in the second-step oxidizing combustion field.

(3) Recirculated exhaust gas is supplied from the incinerator roof around the downstream part of the incinerator, and the in-furnace denitrification effect during two-step combustion is improved by the increased turbulence and mixing of the exhaust gas in this area (Fig. 4).

As an additional feature of this technology, because the high temperature mixed-gas air injection zone is located in the incinerator roof, the new system has improved expansion capability in the furnace width direction, enabling application to a wide range of furnace widths, from compact incinerators to large-scale

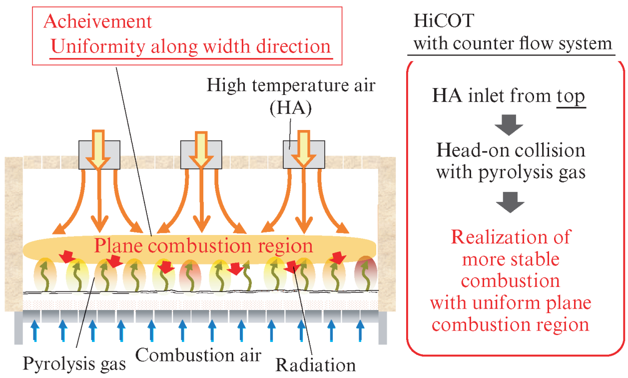


Fig. 2 Schematic configuration of HiCOT with counter flow system

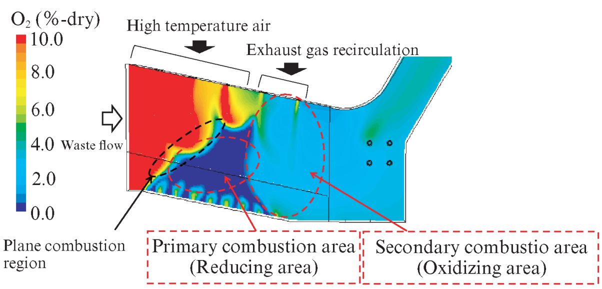


Fig. 3 O_2 concentration distribution

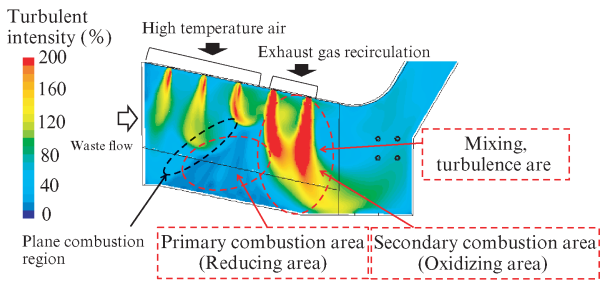


Fig. 4 Turbulence intensity distribution

plants.

2.2 History of Development

The history of the development of the new system is summarized below.

1999: Start of basic research on high temperature mixed-gas air combustion technology with a demonstration test plant (12 t/d)

2002: Start of operation of an actual-scale test furnace (105 t/d) in which the high temperature mixed-gas air combustion technology was applied

2009: Completion of No. 1 Hyper 21 Stoker plant (conventional system) (117.5 t/d), followed by construction of a large number of actual plants

2012: Start of basic research on new system of "Counter flow combustion" as a further evolution of the high temperature mixed-gas air combustion technology with a demonstration test plant (3 t/d)

2016: Completion of No. 1 counter flow combustion plant (60 t/d)

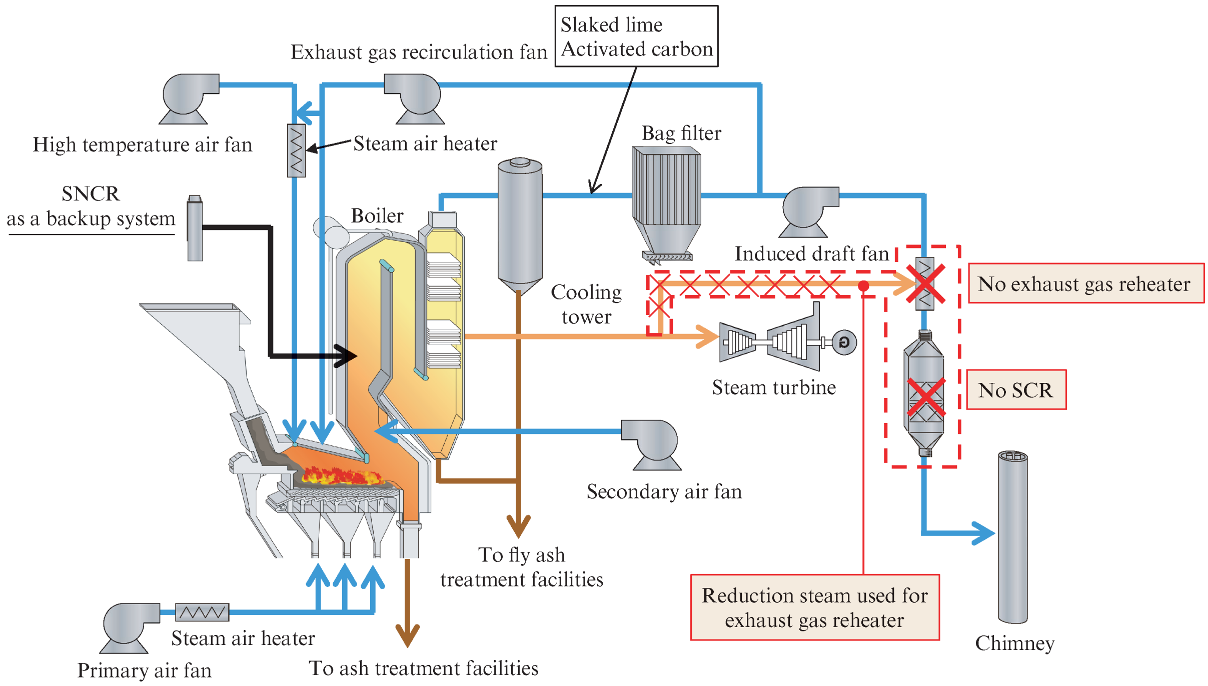
2020: Completion of No. 2 counter flow combustion plant (55 t/d)

2021: Completion of No. 3 counter flow combustion plant (60 t/d)

2022: Completion of No. 4 counter flow combustion plant (100 t/d)

2.3 Equipment Overview and Material Flow at Actual Plant

Figure 5 shows the equipment overview and material flow at the first commercial plant (60 t/d) in which the counter flow system was installed. For injection of high temperature mixed-gas air from the furnace roof, which is an element technology of the counter flow combustion system, exhaust gas which has been dedusted by the bag filter is recirculated to the incinerator by the exhaust gas recirculation fan. The flow of this exhaust gas branches into two systems. In one system, oxygen is adjusted to the specified O_2 concentration by mixing with air supplied by the high temperature air fan, and the exhaust gas is then heated by the steam air preheater and injected into the incinerator roof as high temperature mixed-gas air. In the other system, the exhaust gas is independently injected into the incinerator roof as recirculated exhaust gas. Conventionally,



Furnace type		Continuous stoker type furnace (HiCOT with counter flow system)
Capacity	(t/d)	60 x 2
Exhaust gas cooling system		Natural circulation boiler 3.0 MPa, 300 degree Cooling tower
Exhaust gas treatment system		SNCR BF with slaked lime and activated carbon
Power generation system		Steam turbine 2.8 MPa, 295 degree 1 550 kW

Fig. 5 Schematic flow of the first plant with counter flow system

steam had been used to raise the temperature of the low temperature exhaust gas in a SCR (selective catalytic reduction) process, which is used as a denitrification unit in many waste incineration facilities. Because the SCR was eliminated in the new plant, steam is not needed for this purpose, and this surplus steam can be used to increase power generation. However, an ammonia mist-type selective non-catalytic reduction (SNCR) unit was installed at the outlet of the incinerator as a backup system.

2.4 Performance of Equipment

Table 1 shows the outline of the equipment and operating conditions of a conventional JFE Hyper 21 Stoker System and the new system utilizing counter flow combustion at the same scale. In the conventional system, the CO concentration is 3 ppm and the NOx concentration is 53 ppm before denitrification. In contrast, the plant equipment which commercialized the new counter flow system achieves a CO concentration of 1 ppm and a NOx concentration of 41 ppm without denitrification, thus achieving simultaneous suppression of both CO and NOx. It should also be noted that the amount of electric power sold was increased by 17% by utilizing the surplus steam available due to elimination of the SCR denitrification process, and a large reduction of ▲99% in denitrification chemical consumption has also be realized by operation without using the back-up non-catalytic denitrification system.

2.5 Future Potential

According to the statistics of the Ministry of the Environment, there were 1 141 waste incineration facilities in Japan as of the end of fiscal year 2015, of which only 348 had electric power generation equipment. As one factor in this low generating equipment installation rate in spite of rising social demand for increased waste power generation, approximately 1/2 of the waste incineration facilities in Japan are small-scale plants with a capacity of less than 100 t/d. Considering the low generating efficiency of small plants, there would be little benefit in retrofitting those plants with power generating equipment. However, with the new system introduced here, a large increase in power generation can be expected due to the elimination of the SCR denitrification system and exhaust gas reheater. Because a 17% increase in electric power selling is expected in comparison with facilities with SCR, retrofitting with power generating equipment has substantial economic benefit, even for small-scale facilities, and is expected to contribute to an increase in the number of waste incineration facilities equipped with generating equipment.

Since the non-catalytic denitrification system (SNCR), which was normal equipment in conventional plants without SCR (used in regions with comparatively high regulatory values for NOx) can also be used as a backup system in the new system, a large reduction in chemical consumption is foreseen. In addition, the decrease in the number of units of equipment by elimi-

Table 1 Performance comparison between JFE Hyper 21 Stoker System and Counter Flow System

Furnace type			Continuous Stoker type furnace (HiCOT)		Continuous Stoker type furnace (HiCOT with counter flow system)
Capacity		(t/d)	70×2		60×2
Air ratio			1.3		1.3
High temperature air flow rate		(kNm^3/h)	1.2		0.9
Exhaust gas recirculation flow rate		(kNm^3/h)	2.6		1.7
NOx concentration		(ppm)	53 (before denitration)	−22% ➡	41 (without denitration)
CO concentration		(ppm)	3		1
Exhaust gas flow rate		(kNm^3/h)	16.5		15.4
Electricity	Generation	(%)	100	+8% ➡	108(1
	Consumption	(%)	53		53(1
	Selling	(%)	47	+17% ➡	55(1
Used amout of NH_3 for denitration		(Nm^3)	9 400 per year of NH_3 gas (SCR) 8 050 per year eqiates to 60 t/d capacity	−99% ➡	40 per half year of NH_3 gas (SNCR) as a backup system
Exhaust gas treatment device			BF with slaked lime and activated carbon exhaust gas reheater SCR		BF with slaked lime and activated carbon SNCR

(1) When power generation with JFE Hyper 21 Stoker system is regarded as 100%

nation of the SCR and exhaust gas reheater can also be expected to reduce the life cycle cost and make it possible to use a more compact plant layout. On the other hand, the easy upscaling of the new counter flow system is also an important feature from the viewpoint of incinerator design. Although upscaling of stoker type incinerators generally requires an increase in the furnace width, with the new system, a modular design in the furnace width direction is possible, in which the module size is determined by the pitch of the injection nozzles used to supply high temperature mixed-gas air from the incinerator roof. This will enable easy upscaling of stoker incinerators.

As described above, the new system will not only become a mainstay technology of JFE Engineering, but is also expected to make an important contribution to the waste treatment industry of the future.

3. Conclusion

The roles required in waste incinerators are becoming increasingly advanced and diverse every year. In response to this trend, JFE Engineering applied counter flow combustion technology to a waste incinerator for the first time in the world. This technology, called the "stoker type incinerator utilizing counter flow combustion," is based on the JFE Hyper 21 Stoker System (conventional system), which is backed by a high level of completion based on actual results extending over many years. The results of the performance verified with the No. 1 unit of the new system may be summarized as follows.

(1) In terms of simultaneous suppression of CO and NOx, a comparison of the performance of plants of the same scale confirmed that the new technology has performance equal or superior to that of the conventional technology.

(2) At the No. 1 plant, electric power selling were increased by 17% by utilizing the surplus steam resulting from elimination of the catalytic denitrification system (SCR), and consumption of denitrification chemicals was also greatly reduced by ▲99% because it is normally possible to operate the plant without using the back-up non-catalytic denitrification system.

(3) The features of the new system also include high expansion capability in the furnace width direction and applicability to a wide range of furnaces, from small-scale units to large-scale incineration plants.

References

1) The research and development project on advanced high-temperature air combustion technology. NEDO Report. 2001, p. 235–295.