Development of Super Clean Recycle Generation System

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Abstract

We have proposed a new waste-to-energy incineration system, or "SCRG (Super Clean Recycle Generation)" system. This system is based on a fuel reformer/combustor which reburns incinerator exhaust gas at high temperature (more than 850℃), in order to decompose dioxins and NOx. In addition, this system enhances power generation efficiency by recovering heat from the high temperature exhaust gas due to the reformer/combustor reburning.

We used a basic experimental model to confirm that the reformer/combustor can decompose dioxins as expected.

Introduction

We have been focusing on waste-to-energy incineration, in particular, making it more efficient and more eco-friendly for environmental protection and energy savings. We have proposed a new system concept to decompose dioxins while increasing generating power[1].

Fig. 1 compares a conventional system and our "SCRG (Super Clean Recycle Generation)" system. The conventional system consists of two subsystems: (1) the exhaust gas subsystem and (2) the steam subsystem. The former subsystem consists of a bag house (dust remover) and a dioxin remover, while the latter subsystem has a steam turbine and a generator. The two subsystems are independent of each other except in the incinerator boiler. In this respect, our system is different from the conventional. Moreover, the following items are added to the SCRG system: (1) a reformer, (2) a combustor, (3) a superheater and (4) a heat recuperator. In this way, our system reburns the exhaust gas in the combustor downstream from the bag house in order to break down and change the exhaust gas dioxins into harmless substances, that is, water and carbon dioxide. Due to its high temperature (> 850℃) because of reburning heat, the combustor outlet gas can be used not only to heat saturated steam from 300℃ to 510℃ through the superheater, but also to generate more steam from water through the heat recuperator. As a result, this system is expected to be able to attain both high cleanliness and high power output (high efficiency).

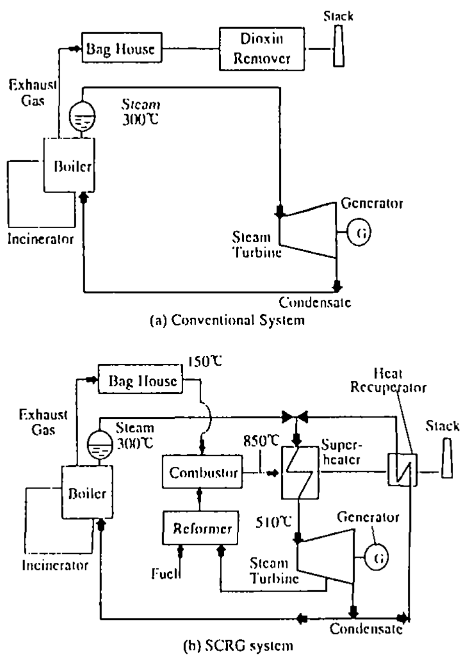

Fig. 1 Comparison between conventional and SCRG systems

Fig. 2 shows a fuel reformer/combustor. The reformer is an indispensable component of the system. It converts fuel into fuel gas including hydrogen according to the following hydrothermal reaction.

$$C_mH_n+O_2+H_2O \rightarrow C_xH_y+CO+CO_2+H_2$$

The hydrogen in the fuel gas promotes stable and lean burning for the incinerator exhaust gas which decomposes the dioxins stably. With regard to the reformer/combustor, we adopted heavy oil rather than LNG for the fuel despite a problem of deterioration of reforming catalyst due to a contaminant in the heavy oil. We solved that problem by oxidizing the heavy oil partially with no catalyst to get an operation cost reduction from the lower fuel cost.

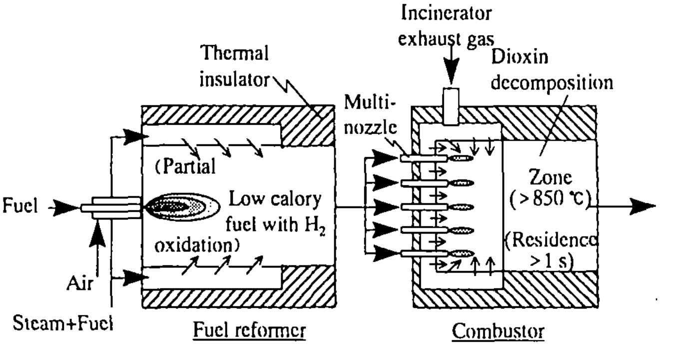

Fig.2 Schematic of fuel reformer/combustor

Experimental Methods

In order to evaluate the decomposition performance for dioxins, we used the experimental model shown in Fig. 3. It consists of a reformer/combustor and an injector of dilute dioxins solution. The reformer, which is connected in series to the combustor, feeds the reformed fuel gas to the combustor. The fuel gas is converted from heavy oil and steam. Air to the combustor is thinned with nitrogen to 10-12% O_2 so as to simulate the incineration exhaust gas. In the dioxins decomposition experiment,

we measured dioxin concentrations by injecting the dilute dioxins solution into the simulated exhaust gas, and compared the concentration at the outlet (SP2) with that at the inlet (SP1). Taking into the consideration the experimental results of Duval and Rubey[2], we kept the combustor and the downstream passage temperature at more than 850℃, and used a high temperature for more than 2 second, selected for the optimal burning condition, to break down the dioxins completely. In addition, the simulated exhaust gas passage to the combustor was kept at more than 350℃ to prevent the dioxins from sticking to the passage wall.

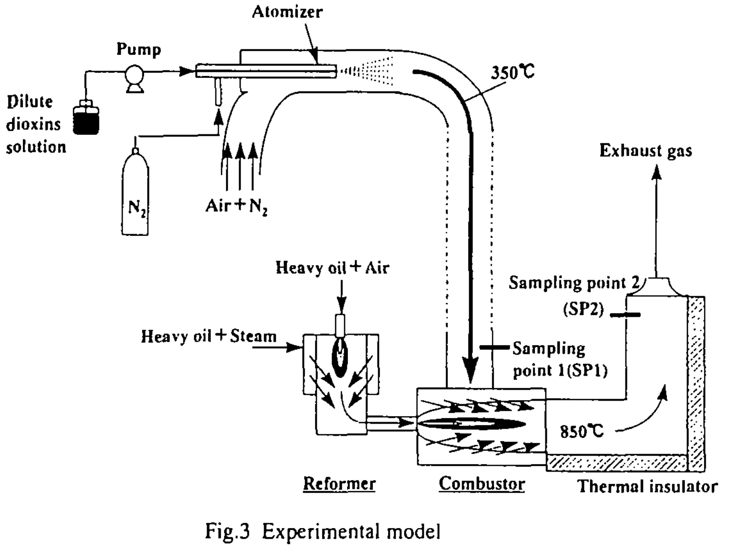

Fig.3 Experimental model

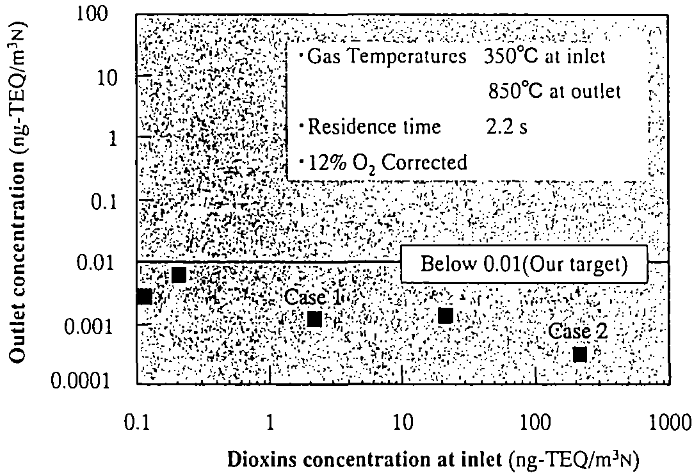

Fig.4 Dioxins decomposition experiment results
(detail of Cases 1 and 2 : see Figs. 5 and 6)

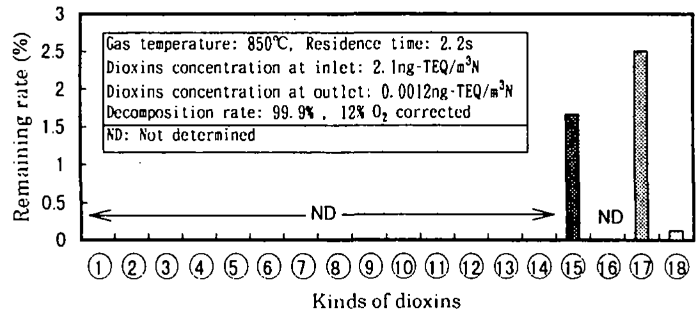

Fig.5 Dioxins decomposition data of case 1

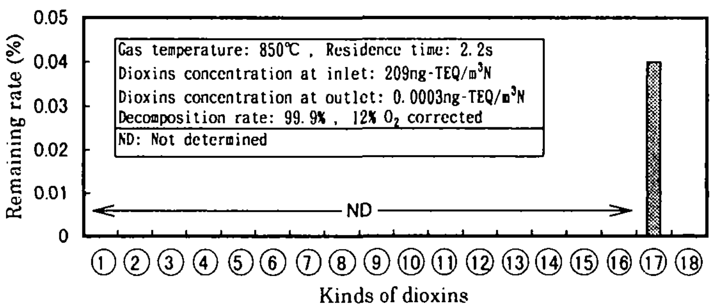

Fig.6 Dioxins decomposition data of case 2

Results and Discussion

Fig. 4 shows the experimental results in the dioxins decomposition experiment. The objective of this experiment was to grasp the relation between inlet and outlet dioxin concentrations. In this experiment, we changed the inlet dioxin concentration from 0.1ng-TEQ/m^3N to 209 ng-TEQ/m^3N. Representing of all the cases, case 1 and case 2 in Fig.4 are shown respectively in Figs.5 and 6, to detail the dioxins decomposition data. The bars indicate the remaining rate of respective toxic dioxins, which are classified in Table 1. The rightmost bar indicates total equivalent remaining rate. The concentrations are expressed at 12% O_2.

The following points were seen in the study.

(a) The reformer/combustor decomposed the dioxins completely ; concentration dropped from 209 ng-TEQ/m^3 N at the inlet to 0.0003ng-TEQ/m^3 N at the outlet. The total decomposition rate was 99.9%.

(b) All kinds of dioxins were reduced, and more than half the toxic dioxins were brought below the determination level.

Then, we were convinced from the decomposition data that the reformer/combustor functioned very well, destroying the dioxins by forming a high temperature zone and our system concept was verified. Concerning the dioxins which remained (Table 1, ⑮ and ⑰), they were considered to require a little more time or temperature to be destroyed.

Table 1 Kinds of dioxins

① 2,3,7,8-TetraCDD
② 1,2,3,7,8-PentaCDD
③ 1,2,3,4,7,8-HexaCDD
④ 1,2,3,6,7,8-HexaCDD
⑤ 1,2,3,7,8,9-HexaCDD
⑥ 1,2,3,4,6,7,8-HeptaCDD
⑦ OctaCDD
⑧ 2,3,7,8-TetraCDF
⑨ 1,2,3,7,8-PentaCDF
⑩ 2,3,4,7,8-PentaCDF
⑪ 1,2,3,4,7,8-HexaCDF
⑫ 1,2,3,6,7,8-HexaCDF
⑬ 1,2,3,7,8,9-HexaCDF
⑭ 2,3,4,6,7,8-HexaCDF
⑮ 1,2,3,4,6,7,8-HeptaCDF
⑯ 1,2,3,4,7,8,9-HeptaCDF
⑰ OctaCDF
⑱ Total(PCDDs+PCDFs)

Conclusion

This paper described the "Super Clean Recycle Generation" system in which waste incinerator exhaust gas, though difficult to burn due to its low O_2 concentration, is reburned to destroy dioxins. The system has a reformer/combustor which produces fuel gas including hydrogen, which promotes stable burning of the incinerator exhaust gas despite its low combustibility. Though the present experiment was at a basic level, we confirmed that the reformer/combustor could break down the dioxins, reducing their concentrations from 209ng-TEQ/m^3N to 0.0003ng-TEQ/m^3N. The experiment results of the reformer/combustor verified its effectiveness as a gas purifier and indicated that the system was feasible.

Currently, we are applying the reformer/combustor to a public waste disposal facility in order to collect design data and demonstrate its applicability.

Acknowledgments

We thank our colleagues for discussions and advice on the super clean system concept.

Literature

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(2)D. S. Duval and W. A. Rubey, Laboratory Evaluation of High-temperature Destruction of Polychlorinated Biphenyls and Related Compounds, EPA-600/2-77-288, p.21, December (1977)