Development of Super Clean Recycle Generation System

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Abstract

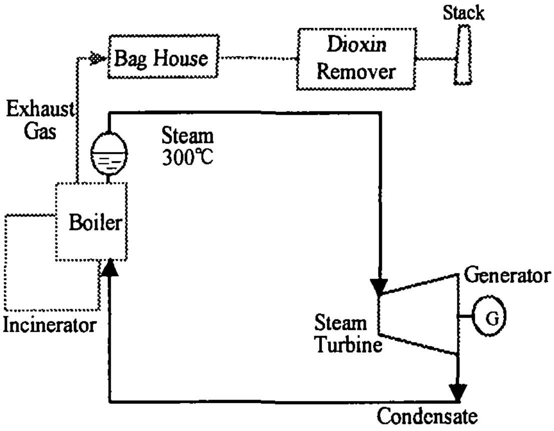
We proposed a new waste-to-energy incineration system, or " SCRG (Super Clean Recycle Generation)" system. This system is based on a fuel reformer/combustor which reburns incinerator exhaust gas at high temperature (more than 850℃), in order to decompose dioxins and NOx. In addition, this system enhances 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 could decompose dioxins as expected.

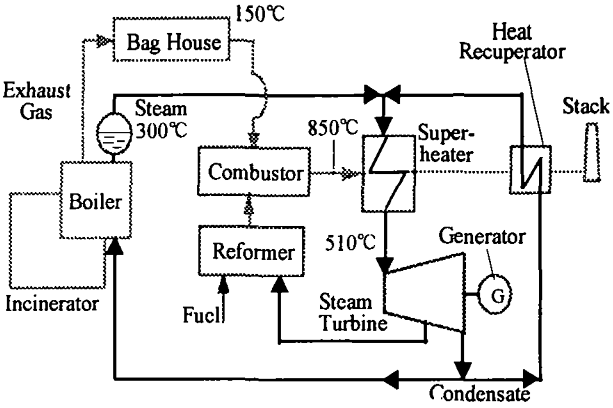
Introduction

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

Fig. 1 compares a conventional system and our "SCRG (Super Clean Recycle Generation)" system. The



(a) Conventional system



(b) SCRG system

Fig.1 Comparison between conventional and SCRG systems

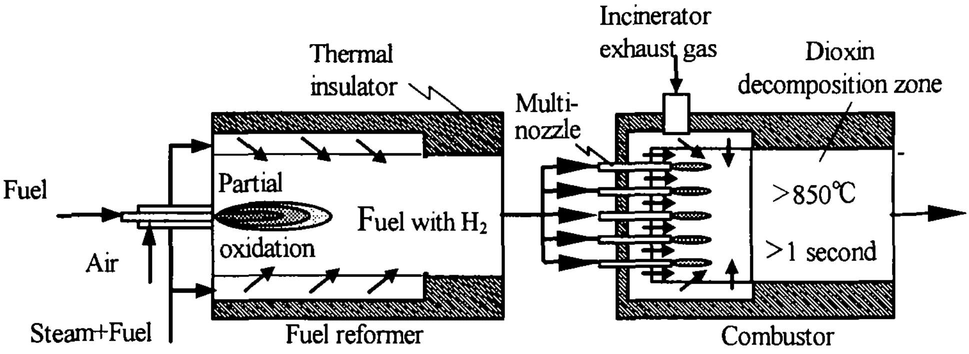


Fig. 2 Scheme of fuel reformer/combustor

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 cleanness and high power output (high efficiency).

Fig. 2 shows a fuel reformer/combustor. The reformer is an indispensable component of the system. And 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 the stable and lean burning for the incinerator exhaust gas which decomposes the dioxins stably. Concerning the reformer/combustor, we adopted heavy oil other than LNG for the fuel despite a problem of deterioration of reforming catalyst due to a

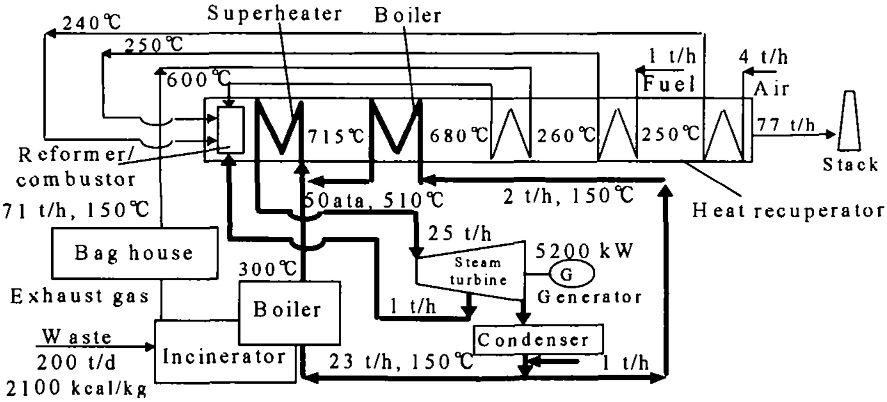


Fig. 3 Heat mass balance in SCRG system

contaminant in 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.

Heat mass balance of the system is shown in Fig. 3. In order to investigate the feasibility of the total system, we checked the heat mass balance. The calculation conditions were as follows. (1) Waste disposal: 200 t/d. (2) Waste low heat value: 2100 kcal/kg. (3) Exhaust gas temperature at the bag house outlet: 150 ℃. (4) Exhaust gas temperature after reheating: 600 ℃. (4) Steam carbon ratio: 2. Consequently, the heat mass balance indicated that the system was feasible.

Subsequently, in order to verify purifying performance of the system, we carried out experiments using an experimental model with a reformer/combustor. And the experimental results were obtained by injecting dilute dioxins solution into the combustor.

Experimental Methods

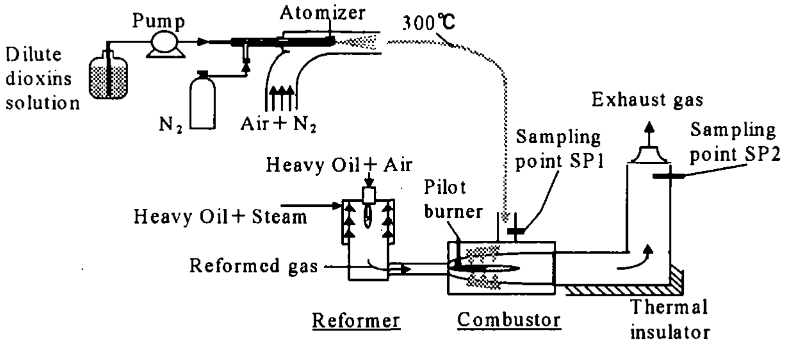


Fig. 4 Experimental model

In order to evaluate the decomposition performance for dioxins, we used the experiment model shown in Fig. 4. 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 experiments, 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

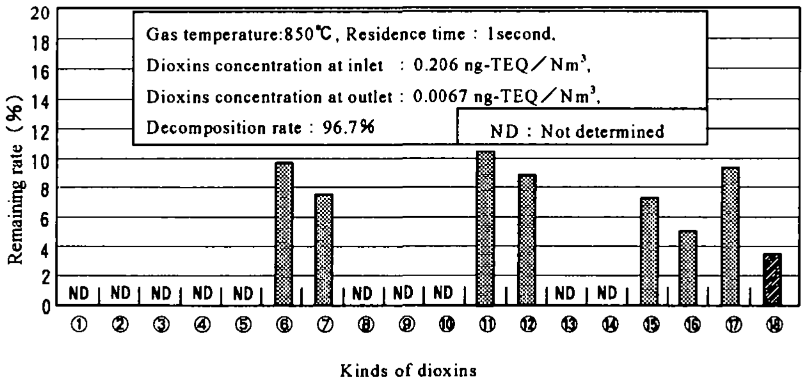


Fig. 5 Dioxins decomposition data

consideration the experimental results of Duval and Rubey1), we kept the combustor and the downstream passage temperature at more than 850 ℃, and used a high temperature for more than 1 second by selecting the optimal burning condition to break down the dioxins completely. Incidentally, the simulated exhaust gas passage to the combustor was kept at more than 300 ℃ to prevent the dioxins from sticking to the passage wall.

Results and Discussion

Fig. 5 shows one of the experimental results in the dioxins decomposition experiments. 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 experiment revealed the following points.

(a) The reformer/combustor decomposed the dioxins totally from 0.206 ng-TEQ/Nm^3 at the inlet to 0.0067 ng-TEQ/Nm^3 at the outlet. The total decomposition rate was 96.7%.

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

Then, we were convinced by the decomposition data that the reformer/combustor functioned so well as to destroy the dioxins by forming a high temperature zone and the system concept was verified. Concerning the dioxins which remained (⑥, ⑦, ⑪, ⑫, ⑮, ⑯, 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 "Super Clean Recycle Generation" system in which the 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 experiments were at a basic level, we confirmed that the reformer/combustor could break down the dioxins from 0.206ng-TEQ/Nm^3 to 0.0067ng/TEQ/Nm^3. The experiment results of the reformer/combustor verified its effectiveness as a gas purifier and indicated that the system was feasible.

At present, we are applying the reformer/combustor to an industrial waste disposal facility in order to demonstrate and collect design data. We expect to make these data public late this year.

Acknowledgments

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

Literature

(1)D. S. Duval and W. A. Rubey, Laboratory evaluation of high-temperature destruction of polychlorinated biphenyls and related compounds, EPA-600/2-77-288, p21, December ('77)