Low temperature SNCR tests by injection of activated ammonia generated by DBD

Megumi Masui[1], Yukio Hayakawa[2], Akihiro Takeyama[2], Tomonori Miura[3], Shinji Kambara[2]

[1] Actree Co. Ltd., 375 Hakusan, Ishikawa, 924-0053, Japan.
[2] Gifu University, Graduate School of Engineering, 1-1 Yanagido, Gifu, 501-1193, Japan
[3] Sawafuji Electric Company, 3 Nittahayakawa-cho, Ota, Gunma, 370-0344, Japan.

Abstract— Removal of nitrogen oxides (deNOx) from flue gas emitted from stationary combustors is desirable for environmental pollution control and public health. SNCR systems utilize a conceptually simple process that involves injecting molecular ammonia into the furnace without using a catalyst. A novel NOx removal system by activated ammonia injection using an intermittent dielectric barrier discharge (DBD) has been developed for deNOx. Currently, application of the unique NOx removal system has been carried out for a small-scale incinerator. In this paper, characteristics of NOx removal were reported. When the activated ammonia generated by the DBD injected into the incinerator, about 80% DeNOx was attained.

Keywords—Dielectric barrier discharge, nitrogen oxide, DeNOx, ammonia, hydrogen.

I. INTRODUCTION

Removal of nitrogen oxides (deNOx) from flue gas emitted from stationary combustors is desirable for environmental pollution control and public health. In Japan, strict emission limits are in place for all stationary sources, including small-scale combustion plants such as waste incinerators. Although combustion modifications involving low-NOx burners and the two-stage combustion methods contribute to reducing NOx emissions, NOx treatment techniques are also usually required to meet the strict NOx emission limits. Selective catalytic reduction (SCR), an efficient treatment technology, has been used world-wide for NOx removal in large-scale combustors such as coal-fired power plants. However, a drawback of SCR systems in application to coal combustion of high sulfur coals is that they are particularly costly because frequent replacement of the catalyst is required owing to catalyst poisoning by sulfur dioxide.

Another possibility for NOx removal is to adopt selective non catalytic reduction (SNCR) techniques. SNCR systems utilize a conceptually simple process that involves injecting molecular ammonia into the furnace without using a catalyst. In SNCR systems, gas-phase reactions in an $NO/NH_3/O_2$ system occur at temperatures between 850 °C and 1175 °C, and the optimum reaction temperature is approximately 950 °C at which maximum NO removal of about 90 % is attained[1]. The temperature range in which NO removal takes place is termed as the temperature window. Most waste incinerators use a rotary kiln for combusting solid wastes. The distribution of the gas temperature in the kiln significantly varies because of the heterogeneous combustion of solid wastes; hence, it is difficult to remain within the SNCR temperature window. The kiln exit is the most suitable location for installing an ammonia injector, but the temperature at the kiln exit is between 700 °C and 800 °C, which is outside the temperature window. Therefore, it is essential for waste incinerators to shift the temperature window for incorporating lower temperatures.

To broaden and lower the narrow temperature window of the SNCR, a unique NOx removal system by activated ammonia injection using an intermittent dielectric barrier discharge (DBD) have been developed[2-5]. In this paper, field tests result were described, when the activated ammonia injection technique was adapted to a small-scale incinerator.

II. METHODOLOGY

A. The activated ammonia injection techniques

Figure 1 depicts a schematic diagram of the activated ammonia radical injection system using the pulsed DBD. The facility contains two gold furnaces with quartz tubes for controlling gas temperatures, the reaction chamber, the radical injector, the gas mixing and feed systems, and two gas analyzers (NOx/O_2 analyzer and N_2O analyzer). The quartz tubes installed in the pre- and post- heaters have a 46 mm inner diameter, and are 500 and 600 mm in length, respectively.

Ammonia gas diluted with nitrogen was used as the NO removal agent, which was fed into the DBD reactor at room temperature. Flow rates of NH_3 gas mixture and NH_3 concentrations were adjusted by MFCs and the gas blender. Activated ammonia generated by the DBD was introduced into the mixing chamber through a polytetrafluoroethylene pipe (length: 1.0 m; inner diameter: 4 mm) and streamed into the reaction quartz tube together the model flue gas. The gold furnace, which incorporated a two-zone heating control system, was used where it was necessary to obtain a uniform temperature distribution. The reaction temperature was varied from 500 °C to 850 °C.

The pulsed DBD, one-cycle sinusoidal (OCS: Sawafuji Electric Co.) output, was employed as the power source for generating the DBD plasma.

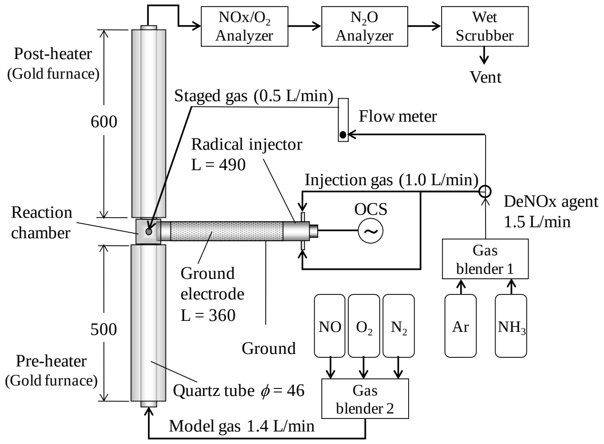

Fig.1 Schematic diagrams of experimental apparatus.

B. The small-scale incinerator

A small-scale test facility is shown in Figure 2. It is simple system, which consists of fuel feeder, combustor, heat exchanger, gas cooler, bag filter, induced draft fan, and stack. Flue gas flow rate was 4,000 m^{3}N/h, and NOx concentration was about 200 ppm on dry basis.

Activated ammonia was injected into the combustor at molar ratio (NH_3/NO) MR = 1.5. The gas temperature at injection point was 700−750 °C.

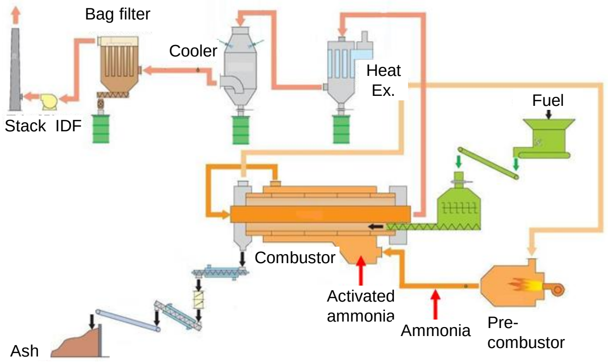

Fig.2 Schematic diagrams of the small-scale test facility.

III. RESULTS & DISCUSSION

Figure 3 shows test results for DeNOx by activated ammonia injection generated by the pulsed DBD. Activated ammonia was generated at applied voltage of 15 kV and repetition rate of 10 kHz using 100% NH_3 gas.

At first, molecular ammonia gas was injected into an exit pipe from a pre-combustor at MR = 0.75, which well known as the normal SNCR. In this condition, deNOx was 50% at gas temperature of 800 °C. When activated ammonia injected into the combustor, deNOx attained 80% at gas temperature of 730 °C, which was the same characteristics obtained by lab-scale experimental tests shown in Fig.1. It should be noted that SO_2 was also reduced by activated ammonia injection; however, the removal mechanisms of SO_2 are not elucidated.

IV. CONCLUSION

DeNOx characteristics of activated ammonia injection techniques using an intermittent dielectric barrier discharge (DBD) have investigated using a small-scale incinerator. Test results came up to expectations, about 80% DeNOx was attained when the activated ammonia generated by the DBD injected into the incinerator,

REFERENCES

[1] Lyon RK, Longwell JP. Selective non-catalytic reduction of NOx by NH3. In: Proceedings of NOx Control Technology. Seminar in San Francisco, CA USA. 1976:237–256.

[2] Nishida, M., Yukimura, K., Kambara S., Maruyama, T., Japan Journal Applied Physics, Vo1. 40, No. 2B Part I (2001) pp.1114-1117.

[3] K. Yamamoto, K. Yukimura, S. Kambara, H. Moritomi, T. Yamashita, T. Maruyama, “Effect of O2 on NO removal by ammonia radical injection using one-cycle sinusoidal power source”, Thin Solid Film, Vol. 457, pp. 39-43, 2004.

[4] Kambara, S., Kumano, Y., Moritomi, H., Nagao, I., Yamamoto, K., Yukimura, K., Maruyama, T., Japan Journal Applied Physics, Vol. 44, No. 3 Part I (2005) pp.1427-1430.

[5] Kambara, S., Kumano, Y., Yukimura, K., IEEE Transaction on Dielectrics and Electrical Insulation, Vol. 16, No. 3 (2009) pp.778-784.

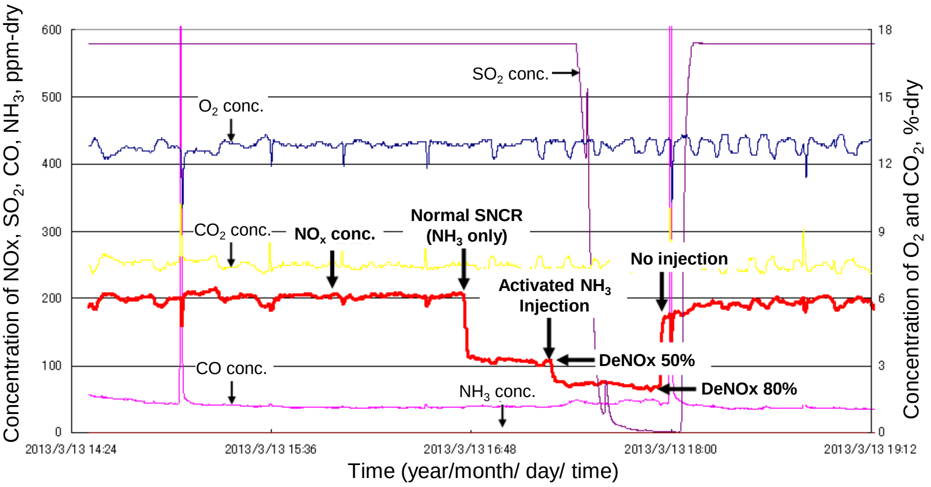

Fig.3 Test results for DeNOx by activated ammonia injection generated by the pulsed DBD.