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The Potential and Approach of Flue Gas Waste Heat Utilization of Natural Gas for Space Heating

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Abstract

After the combustion of natural gas, the flue gas contains large amounts of water vapor. The latent heat of the water vapor in the flue gas account for 10%-11% of the lower heating value of natural gas, that is, if the condensing heat of the flue gas were recovered, the energy efficiency could be improved greatly. In order to improve the efficiency of the space heating system by natural gas, the potential of waste heat of the flue gas were analyzed, and the problems of the conventional space heating system were proposed. A new approach was proposed, which could decrease the temperature of the flue gas, and recover the waste heat of the flue gas simultaneously. The flue gas outlet temperature could be reduced to below 25ºC. The different processes were proposed for gas boiler, distributed energy system, and natural gas cogeneration systems. The energy saving analysis and economic evaluation were investigated. A remarkable economic advantage can be achieved in this technology. The payback year is within 4 years. It provides the important reference for reasonable application of the technique.

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Keywords: District heating waste heat of the flue gas, Gas boiler, Distributed energy system, Cogeneration

1. Introduction

With the increase of heating demand, the problem of environmental pollution is enhanced by space heating. The use of clean energy, natural gas has become an important measure to solve the problem of environmental pollution.

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At the same time, the resource of natural gas is limited, how to use the limited resource and play the biggest role of clean energy has become an important issue.

After the combustion of natural gas, the flue gas contains large amounts of water vapor. The latent heat of the water vapor in the flue gas account for 10%-11% of the lower heating value of natural gas, that is, if the condensing heat of the flue gas were recovered, the energy efficiency could be improved greatly[1]. At present, the exit flue gas temperature of the household gas-water heater is 110ºC~160ºC,and the exit flue gas temperature of the gas boiler is about 90ºC~130ºC,and the exit flue gas temperature of the natural gas power generation plant (gas power plant, thermal power plant or the combined cooling heating and power system) is about 90ºC~150ºC.At such temperatures, the water vapor in the flue gas does not condense, and the latent heat cannot be reclaimed, which leads to a considerable heat loss. The flue gas temperature is lower, the recoverable heat is greater. Since the 1970s, condensing boilers have been developed and have found wide applications in Europe and North America [2-6]. Dann [7] concluded that the potentially high operating efficiencies offered by condensing boilers can be achieved in practice, and the condensing boiler will provide substantial savings in running costs when compared to the more conventional boiler. Searle [8] and Pickup [9] showed that many parameters of design and installation would influence the performance of condensing boilers. Various schemes for recover the latent heat in flue gas have been put forward [10, 11]. The study of the design and efficiency analysis have been done in condensing heat exchangers and system [12-14].The waste heat recovery can be used for household hot water, for heating the return water of district heating system, for regeneration the dehumidification system solution, preheating air, preheating gas etc. In the heating system, the return temperature is the key factor to affect the use of waste heat recovery. The investigation [15] showed that when the return temperature is between 40.8 and 53.3, the efficiency improvement would be 2.12%~5.76% in the use of the condenser heat exchanger. It is feasible to use the return water of a heating system as the cooling medium of the condensing heat exchanger because the return temperature varies with the ambient temperature and is lower than the dew point of the flue gas in some periods of a heating season. In China, the return temperature of the heating system is always above 50 ºC, so the flue gas temperature could not be reduced to below 50, therefore the condensing heat of the flue gas can not be fully recovered. There are two methods to solve the problem: one is to keep the return temperature not changed, and to use a heat pump to produce a low temperature environment, extracting heat from the flue gas, another is to take some technical measures to reduce the return temperature in the heating network, and use the low temperature return water as the cooling medium of the condensing heat exchanger directly to recover the waste heat of the flue gas. For gas boiler or gas engine, method one is applicable, and for combined cycle system, method one and two are all applicable, but the waste heat recovery and utilization degree is different.

In this paper, the potential of the waste heat recovery was analyzed quantitatively. A new approach was proposed, which could decrease the temperature of the flue gas, and recover the waste heat of the flue gas simultaneously. The outlet temperature of the flue gas could be reduced to below 25ºC. The different processes were proposed for gas boiler, distributed energy system, and natural gas cogeneration systems. The energy saving analysis and economic evaluation were investigated. A remarkable economic advantage can be achieved in this technology. The recovered year is within 4 years. It provides the important reference for reasonable application of the technique.

2. The potential of the waste heat in the flue gas

We all know that the excess air coefficient α could be used to describe the combustion process of ideal and actual combustion process.

$$\alpha = \frac{V_{act}}{V_0} \tag{1}$$

Where V_{act} is the actual supply air quality to burn 1 cubic meters of natural gas, and V_0 is the theoretical air quality required 1 cubic meters of natural gas for full combustion.

Corresponding to the different excess air coefficients, recoverable heat in flue gas is different, in general, the higher the excess air coefficient, the greater the recoverable heat. The excess air coefficient of gas boiler is about