Research and Analysis of Energy Conservation for organic heat medium heater

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Abstract: Organic heat medium heater is defined as boiler of B grade, C grade and D grade as per heat load and is inspected by local government. Organic heat medium heater is widely used in finery factory and chemical plant, and a large amount of energy is consumed by heater. Increasing efficiency is important for energy conservation and saving operation cost. Method of saving energy is discussed and method how to operate safely and effectively is also discussed.

1. Introduction
Organic heat medium heaters are widely used in petrochemical industry. Even in the process, multiple organic heat medium heater operate in parallel, which is an important energy-consuming unit in factories. Generally, the thermal efficiency is used to measure the heater energy effective utilization. The parameter is an important index for evaluating fuel consumption, i.e. economy, design level and operation level. Organic heat medium heater belongs to the scope of government supervision, and there are strict assessment requirements for energy consumption. For organic heat medium heater that burns gas loads greater than 1.4MW, it is required that the exhaust temperature should be less than 170 ℃ and the efficiency should be greater than 90% [1]. If the fuel is natural gas, the efficiency requirement is 92%. Improving thermal efficiency not only meets the environmental needs of energy saving and emission reduction, but also can effectively reduce the operating costs of users and improve the operation economy of organic heat medium heater.

2. Theoretical Basis
There are two methods for calculating and measuring thermal efficiency: positive balance method and negative balance method, which are usually calculated and measured by negative balance method.

The Formula for Calculating the Thermal Efficiency of negative balance method [2]:

\[ \eta = 100 - q_1 - q_2 - q_3 - q_4 \]

- \( q_1 \): Heat loss of exhaust flue gas, %
- \( q_2 \): Heat Loss from Chemical Incomplete Combustion, %
- \( q_3 \): Heat Loss from Mechanical Incomplete Combustion, %
$q_4$ – Dissipation heat Loss, %

For oil and gas burns, $q_2 + q_3 = 0$. Heat efficiency can be improved by reducing heat loss of exhaust flue gas and dissipation heat loss. Energy saving and emission reduction can start from these two aspects.

3. Energy Saving Measures

According to the conclusion drawn from the calculation formula of the negative balance, the energy saving measures of organic heat medium heater are also carried out from two aspects: reducing the heat loss of exhaust flue gas and reducing heat dissipation loss.

3.1 Energy saving is achieved by reducing heat loss of exhaust flue gas

There are two ways to reduce the heat loss of exhaust flue gas: first, to reduce the temperature of exhaust flue gas; second, to reduce the quantity of exhaust flue gas. There are several ways to reduce the exhaust temperature.

3.1.1 Air preheater can be used to reduce the exhaust temperature

The combustion air of the organic heat medium heater and the high-temperature flue gas at the outlet of the heater take part in the burning after heat exchange, and the flue gas temperature after heat exchange is lowered to the required temperature and discharged. This is the most common heat recovery method. The commonly used air preheaters are tubular type, heat pipe type air preheater and plate type air preheater. Theoretically speaking, the exhaust flue gas temperature can be reduced to tens of degrees. However, in practice, infinite reduction of exhaust flue gas temperature will lead to low temperature water dew point and acid dew point corrosion of equipment, and high combustion air temperature will lead to increase emission of nitrogen oxides. Therefore, it is not advisable to reduce the exhaust temperature indefinitely. Generally, the range of exhaust flue gas temperature is 110 ~ 170°C, and bypass is needed for combustion air to adjust the exhaust flue gas temperature according to the sulfur content of fuel during operation. In recent years, enameled tubes or ND steel have been widely used in the cold end of tubular air preheaters in order to solve dew point corrosion in low temperature section of equipment.

3.1.2 The exhaust flue gas temperature can be reduced by using a flue gas waste heat boiler or a hot oil heat exchanger

The high-temperature flue gas at the outlet of the heater exchanges heat with steam or low-temperature hot oil, and the flue gas is discharged after the temperature is lowered to the design temperature. If the flue gas can not reach the designed flue gas temperature after the waste heat boiler or the hot oil heat exchanger, a air preheater can be added to further reduce the flue gas temperature.

3.1.3 Clean heat exchanger tubes

Because of the serious fouling of heat exchanger tubes for a long time, the fouling of heat exchanger tubes should be cleaned up during the maintenance period to ensure the efficiency of heat exchange.

Generally speaking, under the same excess air, the thermal efficiency will decrease by about 1% [3] for every increase of the exhaust flue gas temperature of the heater by 15-20°C. This is an empirical estimation. The relationship between the exhaust temperature and the thermal efficiency needs to be determined by calculation. Taking a 2.5 million Kcal/h organic heat medium heater which has been operated in a project as an example, the excess air coefficient is 1.15 at this time. From the data collected in Table 2, it can be seen that the heat loss of exhaust flue gas increases by 0.6%~0.7% for every 13-14°C increase of flue gas.
Table 1. Fuel Gas Composition

| Composition | V% |
|-------------|----|
| N2          | 1.19 |
| CO2         | 0.62 |
| CH4         | 94.34 |
| C2H6        | 3.00 |
| C3H8        | 0.85 |

Table 2. Comparing table of calculation results of exhaust temperature and heat loss

| exhaust temperature °C | 137 | 146 | 160 | 174.5 | 187 | 200 |
|-------------------------|-----|-----|-----|-------|-----|-----|
| Heat Loss of Exhaust Flue gas | 5.73 | 6.12% | 6.79% | 7.49% | 8.09% | 8.72% |

Because the design calculation usually has a margin, and the field operation conditions often deviate from the design value. The following two tables are the summary tables of fuel conditions and energy efficiency test results measured in site.

Table 3. Fuel gas Composition in Site

| Composition | V% |
|-------------|----|
| N2          | 1.717 |
| CO2         | 0.547 |
| CH4         | 93.151 |
| C2H6        | 3.591 |
| C3H8        | 0.634 |
| Unsaturated hydrocarbons | 0.36 |

Table 4. Summary of Energy Efficiency Test Results

| Operation Load | 250MMKcal/h |
|----------------|-------------|
| Excess air     | 1.14        |
| Exhaust Temperature | 137°C      |
| Heat Loss of exhaust flue gas | 5.56%      |
| Dissipation Loss | 2%          |
| Efficiency     | 92.44%      |

Reducing the quantity of flue gas can also reduce the heat loss of exhausted flue gas. The direct way to reduce flue gas quantity is to reduce excess air, that is, to reduce excess air as much as possible under the condition of ensuring full combustion of fuel. This not only can achieve the purpose of energy saving, but also can effectively prevent the formation of nitrogen oxides. In other words, in order to achieve the same thermal efficiency, if the flue gas quantity is small, the exhaust temperature can be increased appropriately; if the excess air can not be effectively controlled and the flue gas quantity is increased, then the high thermal efficiency can only reduce the exhaust temperature, and the low exhaust temperature will cause the corrosion of the equipment. The control of excess air reflects the operation level of operators. Experienced on-site operators will adjust the air distribution
according to the on-site residual oxygen analyzer. Some organic heat medium heater are designed with high-level automatic control system, which can automatically adjust the air distribution. Therefore, effective control of excess air is conducive to reducing the heat loss of exhaust flue gas. Table 5 is a comparison of energy efficiency test results of 1000 million Kcal/h organic heat medium heater running on site.

Table 5. Comparison of Energy Efficiency Test Results

| Operation Heat Load | 750 MMKcal/h | 750 MMKcal/h |
|---------------------|-------------|-------------|
| Excess air          | 1.15        | 1.71        |
| Exhaust Temperature | 148 ºC      | 110.5 ºC    |
| Heat Loss of Exhaust Flue Gas | 6.01%       | 6.02%       |
| Dissipation Heat Loss | 2%         | 2%          |
| Efficiency         | 91.99%      | 91.98%      |

From the comparison data, it can be seen that reducing the excess air can make the equipment run economically and safely. Therefore, site operators should also improve their own operation level, adjust excess air according to the site operation data, and improve the thermal efficiency of the equipment.

3.2 Energy saving by reducing heat loss
Organic heat medium heater generally reduces heat loss by setting thermal insulation layer. Generally, the calculation of insulation layer thickness must satisfy the requirements of no wind and ambient temperature of 27 ºC. The outer wall of radiation section, convection section and flue gas duct should not exceed 80 ºC, and the outer surface temperature of bottom should not exceed 90 ºC [4]. Usually, the heat loss of fuel based on low calorific value ranges from 1.5% to 3%. The heat loss of dissipation is mainly caused by the convection heat transfer between the outer wall and the environment. The wind speed and temperature of the environment have a certain influence on the heat dissipation. When the wind speed is high, the convective heat transfer coefficient increases, but the temperature difference of heat transfer also decreases, so the total heat dissipation does not change much. Generally, the efficiency of newly built heaters is calculated according to the loss of heat dissipation of 2%. If the old heaters is reconstructed, air leakage and damaged insulation layer need to be repaired to reduce heat loss. The thermal insulation material should adopt the material with lower thermal conductivity as far as possible. If the material with lower thermal conductivity can not meet the requirement of heat temperature, composite lining material can be chosen to reduce the thermal conductivity of the material as far as possible.

4. Economic Analysis
The higher the thermal efficiency of the organic heat medium heater is, the more energy-saving it will be and the lower the operating cost will be. Moreover, the larger the load, the higher the thermal efficiency of the heater will bring more considerable benefits. For example, an organic heat medium heater with a design load of 10 million Kcal/h consumes natural gas with a design efficiency of 91%. The annual consumption of natural gas is 10720986Nm3, calculated by an annual operation of 8000 hours. If energy-saving renovation is carried out, the efficiency will be increased to 92%, and the annual consumption of natural gas will be 10604454 Nm3. The annual saving of natural gas is 116532 Nm3, and the price of natural gas is calculated at 4 yuan/Nm3, so the annual saving of operation cost is about 466000 yuan.
5. Conclusion
Reducing the exhaust temperature can improve the thermal efficiency. But the sulfur content in the fuel restricts the exhaust temperature. In order to ensure the safe and long-term operation of the equipment, the exhaust flue gas temperature must be reasonably calculated according to the sulfur content of the fuel to prevent acid dew point corrosion. In addition to considering dew point corrosion, too much sulfide is not allowed to be discharged into the atmosphere, so the fuel is best desulfurized.

Using advanced automatic control system control excess air and improve thermal efficiency. It is also very important to improve the operation level of site operators.

During the overhaul of the equipment, the dirt should be removed as far as possible and the damaged insulation should be repaired in time.

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