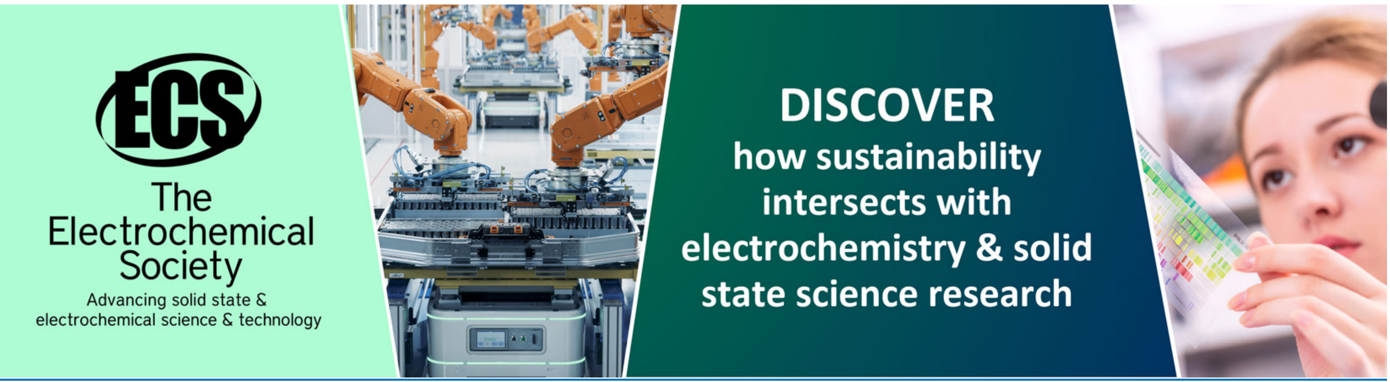
IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

Discussion on Boiler Efficiency Correction Method with Low Temperature Economizer–Air Heater System

To cite this article: Liu Ke *et al* 2017 *IOP Conf. Ser.: Earth Environ. Sci.* **63** 012002



IOP Conf. Series: Earth and Environmental Science **63** (2017) 012002 doi:10.1088/1755-1315/63/1/012002

Discussion on Boiler Efficiency Correction Method with Low Temperature Economizer–Air Heater System

Liu Ke[1], Yang Xing-sen[1], Hou Fan-jun[2] and Hu Zhi-hong[1]

[1] State Grid Shandong Electric Power Research Institute, Jinan 250003, China
[2] Zhong Shi Yi Tong Group, Jinan 250003, China

luliuke@163.com

Abstract. This paper pointed out that it is wrong to take the outlet flue gas temperature of low temperature economizer as exhaust gas temperature in boiler efficiency calculation based on GB10184-1988. What's more, this paper proposed a new correction method, which decomposed low temperature economizer-air heater system into two hypothetical parts of air preheater and pre condensed water heater and take the outlet equivalent gas temperature of air preheater as exhaust gas temperature in boiler efficiency calculation. This method makes the boiler efficiency calculation more concise, with no air heater correction. It has a positive reference value to deal with this kind of problem correctly.

1. Introduction

The heat loss due to exhaust gas lays direct impacts on the efficiency of the boiler. In the premise of corrosion in low temperature being under control, the lower the exhaust gas temperature is the better. In most of the circumstances, reformation of the utilization of flue-gas heat is not capable of reducing the temperature of the exhaust gas in boiler efficiency calculation; however, it is effective for improving the economy of the machine unit [1-5]. For example, heating condensate water is a common way to utilize residual heat [6].

Along with the development in ultra-low emission and energy conservation reconstruction work in China, a new technical reconstruction scheme has been gradually popularized, namely the modification of the low-temperature economizer`s joint heater [7-8], in which, a low temperature economizer is added in the chimney intake of the original deduster to coordinate with the modification of the electrical deduster and realize low temperature dedusting, as well as achieve the dust emission target at the electrical dedusting outlet; a heater is designed to heat up the air at the preheater inlet through the low temperature economizer-heated condensate water. The system can not only satisfy the low temperature dedusting demand, but also heat the condensate water and exhaust air; meanwhile, it has also realized the utilization of residual heat at the rear section, which could demonstrate significant economic benefits. However, such technical scheme has also brought certain interferences towards the boiler efficiency calculation; some errors may occur in terms of exhaust gas temperature determination, inlet air temperature rectification and the like. Thus, the article carries out studies corresponding to these problems by exploring and discussing methods for boiler efficiency rectification during system operation.

2. System introduction and boiler efficiency calculation boundary

2.1. System introduction

Figure 1 is Low Temperature Economizer–Air Heater System. Condensate water from the low-pressure feed water heater enters into the low temperature economizer; after being heated, the water enters into the heater in order to heat up the air; then, it returns to the low-pressure feed water heater at the subordinate level. After being heated by the heater, air temperature at the preheater inlet will be increased, and the flue-gas temperature at the preheater outlet will also be increased accordingly; however, after passing through the low temperature economizer, the flue-gas temperature could drop to 90~100℃. It is subject to a common error to consider the foregoing as the exhaust gas temperature in boiler efficiency calculation.

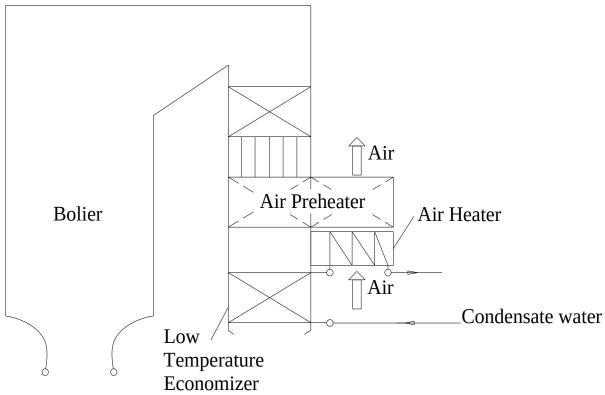


Figure 1. Low temperature economizer–air heater system.

2.2. Error Cause Analysis

Boiler efficiency calculation boundary specified in GB10184-1988 standard is shown in Figure 2, according to which, the calculation boundary shall be divided as from the preheater outlet to the deduster; heater that uses external heat has also been ruled out from the calculation boundary. Nevertheless, the low temperature economizer is located behind the preheater and before the deduster; as for whether it can be merged into the calculation boundary, it requires the analysis from the aspect of System Energy Conservation by considering the coverage of the calculation boundary as a system, in which, energy input into the system is equivalent to effectively-used heat plus the system heat loss. Assuming that the low temperature economizer`s joint heater is merged into the system and the heat absorbed by the low temperature economizer is referred to as Q_{dd}, heat absorbed by cold air in the heater is referred to as Q_{nf}; the heat of air in the low-pressure feed water heater reduced by the existence of the low temperature economizer is referred to as Q_{pj}, and Q_{dd}=Q_{nf}+Q_{pj}; then system heat loss has reduced by Q_{dd} through comparison to the previous value, yet the heat input into the system only increases by Q_{nf}. Although Q_{pj} is returned to the system together with water, total heat brought to the water has not been increased accordingly; Q_{pj} has merely exhausted partial air in the low-pressure feed water heater, based on which, wrong conclusion is made about the occurrence of non-conservation of system energy. It indicates that, the previous assumption of merging the low temperature economizer`s joint heater into the system is incorrect. So, the calculation boundary is still at the preheater outlet, namely the exhaust gas temperature is still the flue-gas temperature at the preheater outlet instead of at the lower temperature economizer outlet.

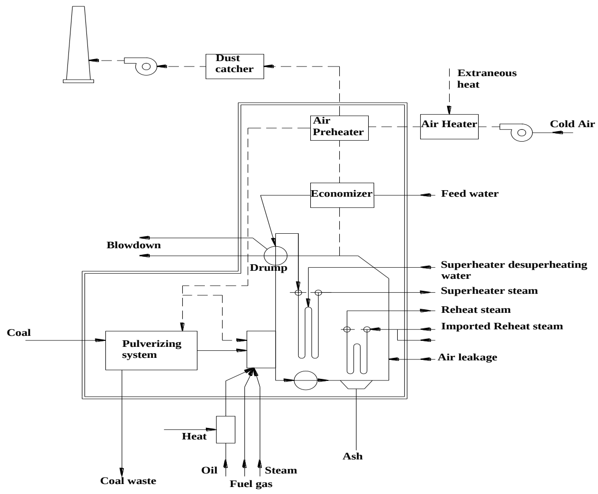


Figure 2. Thermal balance system of boiler unit.

3. Calculation of boiler efficiency

3.1. Calculation Thought

Based on the above analysis, while the low temperature economizer - air heating system is functioning, according to respective GB10184-1988 standard, the boiler efficiency calculation shall consider the flue-gas temperature at the preheater outlet as the actual exhaust gas temperature, and the heat absorbed by the heater as the external heat source to be added in the feeding heat of the boiler. In the case of no heater under normal circumstances, it is only necessary to convert the exhaust gas temperature in accordance with equation (1) so that it can guarantee the inlet air temperature. At this moment, it is required as a must to take into consideration the influences of the heater on the exhaust gas temperature. According to Part 7.2.1.2 in the GB10184-1988 standard, when it is equipped with a heater and put into operation, calculations and rectifications corresponding to three different circumstances shall be performed, analysis of which is relatively complex.

$$\theta_{\mathrm{py}}^{\mathrm{b}} = \frac{t_0^{\mathrm{b}}\left(\theta'_{\mathrm{ky}}-\theta_{\mathrm{py}}\right)+t'_{\mathrm{ky}}\left(\theta_{\mathrm{py}}-t_0\right)}{\left(\theta'_{\mathrm{ky}}-t_0\right)} \tag{1}$$

Where,

$\theta_{\mathrm{py}}^{\mathrm{b}}$——exhaust gas temperature while conversion to the guaranteed inlet air temperature, ℃；

$\mathrm{t}_0^{\mathrm{b}}$ ——guaranteed inlet air temperature, ℃；

t_0 ——Measured temperature, ℃；

θ'_{ky}——Measured gas temperature at air preheater inlet, ℃；

θ_{py}——Measured exhaust gas temperature, ℃.

As the rectification method for a heater is obscure and difficult to use, in the following section of the article, we would discuss about a boiler efficiency calculating method that doesn`t require the rectification of exhaust gas temperature in accordance with the heater.

Based on the above analysis, we discover that, there are two ultimate flow directions for flue-gas heat absorbed by the low temperature economizer; one part would be used to heat up cold air, whereas the other part would remain in the condensate water, with the former part serving as a pre-positive preheater. Thus, according to the flow direction of heat, the low temperature economizer`s heater can be decomposed into two sections, the virtual pre-positive preheater and the condensate water heater. Reduced heat of the flue-gas in the pre-positive preheater is equivalent to the increased heat of the cold air entering into the boundary. Therefore, the pre-positive preheater can be merged into the calculation boundary. The condensate water heater also absorbs partial flue-gas heat, but the feed water enthalpy entering into the boiler has not increased accordingly, which shall not be merged into the calculation boundary. The re-divided calculation boundary is shown in Figure 3. After the pre-positive preheater being merged into the calculation boundary, exhaust gas temperature of the boiler shall be equivalent to the flue-gas temperature at the pre-positive preheater outlet. Due to the fact that the pre-positive preheater doesn`t exist for real, we refer to the flue-gas temperature at the outlet as converted exhaust gas temperature. By considering the converted exhaust gas temperature as the real temperature, boiler efficiency during the operation with a low temperature economizer - heater can be acquired.

3.2. Calculation of converted exhaust gas temperature
Based on the flow direction of heat, the low temperature economizer's joint heater system can be decomposed into the pre-positive air preheater and the condensate water heater, and flue-gas temperatures and heat at various positions have been shown in Figure 4.

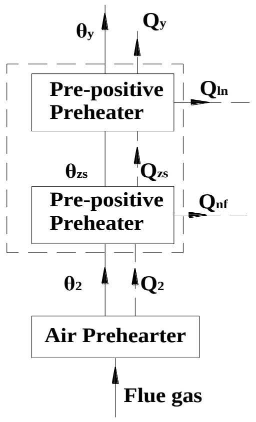


Figure 3. Schematic diagram of energy carried by flue gasθ2-exhaust gas temperatureat air preheater outlet; Q2- heat of flue gas at the outlet of air preheater; θzs-gas temperature at virtual pre-positive preheater; Qzs- heat of flue gas at virtual pre-positive preheater; Qnf-Heat absorption of air in air heater; θy-gas temperature at low temperature economizer outlet; Qy- heat of flue gas at the outlet of air preheater; Qln-Heat absorption of condensate water after heating cold air;

$$Q_{zs} = Q_2 - Q_{nf} \tag{2}$$

$$Q_{nf} = D_{ln}(h''_{ln} - h'_{ln}) \tag{3}$$

Where,

D_{ln}-Condensate water flow rate in air heater, kg/h;

h_{ln}''-Enthalpy of Condensate water at air heater outside, kJ/kg;

h_{ln}'- Enthalpy of Condensate water at air heater outside, kJ/kg;

Through equation (3), heat output of condensate water in the heater can be calculated. Assuming the heat exchange efficiency is 100%, then heat is reduced by Q_{nf} as being taken away by flue-gas in the hypothetical pre-positive preheater. According to equation (2), heat Q_{zs} taken away by flue-gas at the pre-positive preheater outlet can be calculated, based on which, the converted exhaust gas temperature θ_{zs} at the pre-positive preheater outlet can be calculated through iteration. The process of iteration is shown in Fig.4. It is required to firstly assume the flue-gas temperature at the pre-positive preheater outlet is θ'_{py}, based on which, the exhaust gas heat loss Q'_2 can be calculated. In case of the difference between it and the heat Q_{zs} taken away by flue-gas at the pre-positive preheater outlet being no more than 0.05%, the assumption holds; otherwise, the value of θ'_{py} shall be re-assumed and re-calculated, until the difference is no more than 0.05%.

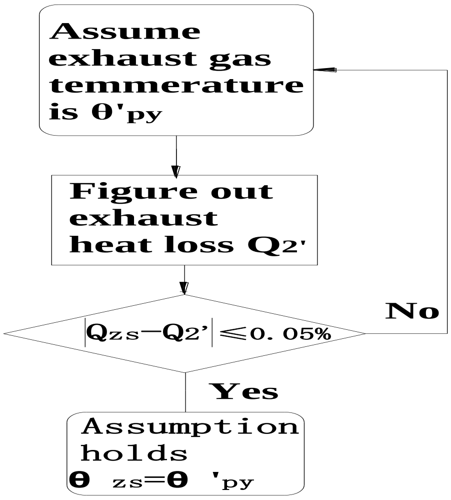


Figure 4. Flow chart of iterative calculation of converted exhaust gas temperature

4. Conclusion

While the modification of the low temperature economizer`s joint heater bringing environmental-protection and economic benefits to the thermal power unit, it also has some certain interferences with the boiler efficiency calculation.

By referring to the relevant provisions in respective GB10184-1988 standard on calculation boundary, and starting from the aspect of Energy Conservation, the article analyses corresponding error causes in boiler efficiency calculation on the basis of considering the flue-gas temperature at the low temperature economizer outlet as the exhaust gas temperature; it also points out according to the calculation methods specified in GB10184-1988 standard that, boiler efficiency calculation shall regard the flue-gas temperature at the preheater outlet as the exhaust gas temperature, with the heat from heater as the external heat and being added into the feed heat of the boiler. When rectifying the exhaust gas temperature, the influences of the heater should be considered.

In addition, by analysing the energy flow direction in the low temperature economizer - heating system, the article decomposes the system into two parts of the hypothetical pre-positive preheater and the condensate water heater while merging the previous one into the boiler efficiency calculation boundary, so as to replace the actual exhaust gas temperature with the converted waste temperature at the pre-positive preheater outlet in order to calculate the boiler efficiency. By applying this method, it is capable of avoiding the complex rectification to the heater during boiler efficiency calculation; instead, it is only necessary to rectify the (converted) exhaust gas temperature to the extent that it guarantees the feed air temperature, so that the boiler efficiency calculation can be carried out in a more concise manner.

5. References

[1] Kitto J B 1996 *Presented at Missouri valley electricassociation engineering conference*， Kansas City
[2] Guo Jianglong, Zhang Shufang and Song Zhiping 2004 *J Proceedings of the CSEE 24(3) 210-215*
[3] Jiang Feng and Wang Peihong 2008 *J Turbine Technology* 50(4) 261-264
[4] Zhang Weibin, Zhang Chunfa and Wu Zhong 2008 *J Turbine Technology* 50(4) 259-260.
[5] Lu Wanpeng, Sun Fengzhong and Shi Yuetao 2011 *J Proceedings of the CSEE* 31(11) 6-10.
[6] Huang Xinyuan, Sun Fengzhong and Shi Yuetao 2008 *J Thermal Power Generation* 37(3)56-58 .
[7] Zhao Zhijun, Feng Weizhong and Zhang Ling 2009 *J Journal of Power Engineering* 29(11)994-997.
[8] Lin Wanchao 1994 Theory of energy conservation for thermodynamic system in coal-fired power plant *Xi' an Jiaotong University Press* pp 224-239 .