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RESEARCH ARTICLE

TEST AND ANALYSIS OF ENERGY SAVING EFFECT OF THERMAL INSULATION SYSTEM OF 600 MW SUBCRITICAL THERMAL POWER UNIT

***XU Peng, TIAN Jianxin and FAN Ruixin**

College of textile and light industry, Inner Mongolia University of Technology; Hohhot 010050, The Inner Mongolia Autonomous Region, China

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ABSTRACT

In recent years, the rapid economic development of China increasing power plant energy consumption, thermal equipment and pipelines as an important part of the plant, has a very large energy saving potential. To further improve the thermal power plant and power plant energy efficiency, should be systematically analysis of heat loss. In this paper, many representative sites are selected according to the operating conditions of the 600MW unit in Tuoketuo Power Plant. Based on field test and calculation analysis of the heat loss on the insulation layer, the energy saving effect of the unit insulation system is analyzed. Tests show that there are different degrees of excessive heat dissipation in boiler body, boiler down comer and drum.

INTRODUCTION

Thermal power generation has been a major energy consumer in China. Practice over the years tells us that thermal insulation project is an indispensable and important part of energy saving because of its characteristics of "wide application, easy realization in technology, little investment in capital and quick economic results". It is understood that the heat loss caused by poor insulation of equipment and pipes in some thermal power plants in China is huge. Taking the imported 300WM unit as an example, the main steam temperature is reduced by 1 C, the heat consumption rate of steam turbine is increased by 0.28%, the reheat steam temperature is reduced by 1 C, and the heat consumption rate is increased by 0.2%. The most direct manifestation of poor thermal insulation is that the external surface temperature of thermal insulation structure exceeds the standard. In addition, thermal insulation in thermal power plants also plays a role in maintaining production capacity and ensuring personal safety. Based on describing the development and application of thermal insulation materials at the present stage, this paper evaluates and analyses the thermal insulation and energy-saving effect of 600 MW typical units in Toketo Power Plant by testing and calculating the thermal insulation system of main thermal equipment and pipes.

Thermal Insulation Principle of Thermal Insulation Material: Normally, materials with thermal conductivity less than $0.174W/(m^2 \cdot K)$ and significant impedance to heat flow are considered as thermal insulation materials. Thermal insulation materials generally have the functions of light weight, loose, heat preservation, cold insulation, heat insulation, sound absorption and noise elimination. The first criterion for evaluating thermal insulation materials is thermal conductivity. The smaller the thermal conductivity, the better the thermal insulation performance of materials. Thermal insulation materials can generally be divided into several types according to their state, such as fibrous, micro-porous, bubbly, etc. According to their chemical properties, they can be divided into inorganic non-metal, organic polymer materials and metal materials, etc. However, regardless of which form, the principle of thermal insulation is the same: the material itself has a small thermal conductivity, and there are many small and basically non-convective air gaps in the material, because of the empty space. The thermal conductivity of gas is very small [$0.0257\ W/(m^2 \cdot K)$] at room temperature and pressure, which makes the thermal insulation material have low thermal conductivity. The thermal conductivity of thermal insulation materials is not a fixed value, it will change with the change of temperature, and the thermal conductivity of different thermal insulation materials varies with the change of temperature.

Application of Thermal Insulation Material in Thermal Equipment and Pipeline Insulation of Power Plant: In recent years, in the thermal equipment and pipeline insulation of large thermal power plants, there are several widely used insulation materials: aluminum silicate fiber, rock mineral wool, glass wool, micro-porous calcium silicate, etc.

****Corresponding author:*** **XU Peng,**
College of textile and light industry, Inner Mongolia University of Technology; Hohhot 010050, The Inner Mongolia Autonomous Region, China

Table 1. Performance List of Thermal Insulation Materials in Common Power Plants (1)

Aluminum silicate fibers		**Rock wool**	
Volume-weight（kg/m^3）	130	Volume-weight（kg/m^3）	120
Thermal conductivity W/(m^2·K)	≤0.093(average temperature 973K)	Thermal conductivity W/(m^2·K)	0.047～0.052（Normal atmospheric temperature）
Average diameter of fibers (μm)	≤6	Average diameter of fibers (μm)	≤7
Slag ball content %	＜12（The particle size of slag pellets is larger than 0.25mm）	Slag ball content (%)	＜12（The particle size of slag pellets is larger than 0.25mm）
Alumina content (%)	≥50	Moisture content (%)	＜1.5
Maximum operating temperature (℃)	1000	Maximum operating temperature (℃)	350
Centrifugal glass wool		**Microporous calcium silicate**	
Volume-weight（kg/m^3）	38-50	Volume-weight（kg/m^3）	220
Thermal conductivity W/(m^2·K)	0.037(average temperature 343K)	Thermal conductivity W/(m^2·K)	0.062(average temperature 343K)
Average diameter of fibers (μm)	6	Minimum compressive strength (MPa)	0.50
Slag ball content (%)	0	Minimum flexural strength (MPa)	0.30
Moisture content (%)	0.2	Maximum linear contraction rate %	2.0
Maximum operating temperature (℃)	350	Maximum operating temperature (℃)	600
		Maximum water content of mass(%)	7.5

Table 2. Measuring working conditions

Working condition number	Test position	Types of insulation materials
Working condition 1	5# Unit Boiler Body	Aluminum silicate
Working condition 2	5#Unit steam Turbine Body	Aluminum silicate
Working condition 3	5#Unit boiler bituminous-air-coal pipeline	Rock wool
Working condition 4	5#Unit boiler side water supply pipeline	Rock wool
Working condition 5	5#Unit boiler down comer	Rock wool
Working condition 6	5#Unit steam pocket	Aluminum silicate
Working condition 7	5#Unit main Steam Pipeline	Aluminum silicate
Working condition 8	5#Unit thermal reheat steam pipe	Aluminum silicate
Working condition 9	5#Unit cold reheat steam pipe	Aluminum silicate
Working condition 10	5#Unit high pressure water supply Pipeline	Aluminum silicate
Working condition 11	5#Unit high pressure heater (steam)	Aluminum silicate
Working condition 12	5# Unit low pressure heater	Aluminum silicate
Working condition 13	5#Unit hot air pipe for grinding inlet	Rock wool
Working condition 14	5# Unit deaerator	Rock wool
Working condition 15	3#Unit side Wall of Boiler Body 7 Floor	Aluminum silicate
Working condition 16	3#Unit side Wall of Boiler Body 8 Floor	Aluminum silicate
Working condition 17	3#Unit boiler top	Aluminum silicate
Working condition 18	3#Unit steam pocket	Aluminum silicate

Aluminum silicate fiber insulation materials are commonly used in the form of aluminum silicate sheet, aluminum silicate blanket, aluminum silicate tube and shell, aluminum silicate braided rope, etc. Aluminum silicate insulation materials have a wide range of applications, its maximum use temperature is generally considered to be 1000℃, which can be applied to the insulation of equipment and pipelines with higher temperature. This material belongs to soft material, and its price is relatively low, so it has advantages in application. Rock wool insulation materials are commonly used in the form of rock wool board, rock wool felt, rock wool tube and shell. The highest temperature of rock wool insulation materials is 350 C, which is mainly used in thermal power plants for the insulation of low-temperature equipment and pipelines. Rock wool thermal insulation materials are cheap and have excellent thermal insulation performance. The shortcoming is that they pollute the environment and affect people's health, especially the production and construction personnel. Glass wool is a new kind of energy-saving and heat preservation material with high efficiency both at home and abroad in recent ten years. It is commonly used in glass wool board, glass wool felt, glass wool tube and other forms. At present, it is generally used for heat preservation of equipment and pipes whose temperature is not higher than 350 C. Microporous calcium silicate insulation materials are commonly used in the form of calcium silicate plate and calcium silicate tile, which are mainly suitable for thermal equipment and pipelines with medium temperature greater than 350 C. In recent years, the use of microporous calcium silicate has shown a significant downward trend. In addition, insulation materials that may be seen in thermal insulation of general power plants and pipes include foam asbestos, expanded perlite, silicate and expanded vermiculite. These materials are seldom applied in thermal insulation construction of most power plants at present. Usually, the surface of insulation layer is usually coated or metal. Metal cladding includes anti-rust aluminium alloy cladding and galvanized iron sheet cladding (color steel plate).

Performance comparison of several common thermal insulation materials: The performance lists of several thermal insulation materials commonly used in power plants are compared (Table 1). Through comparison, we can draw the following conclusions: when choosing insulation material, we should first consider using temperature. When the medium temperature or the surface temperature of equipment is higher than 350℃, we should choose micro-porous calcium silicate or aluminum silicate fiber as insulation material. The former belongs to hard material with high strength and structure is not easy to be destroyed, but the construction is more complex, the latter belongs to soft material with strong construction flexibility. It is easy to use, but its strength is small, and it is easy to destroy. In material price, the price of micro-porous calcium silicate is much higher than that of aluminum silicate fiber. Glass wool, rock wool or other materials can be selected when the medium temperature or the surface temperature of

Table 3. Calculation results of heat loss (1)

Calculation item	Unit	Calculation results										
		Working condition 1	Working condition 2	Working condition 3	Working condition 4	Working condition 5	Working condition 6 East side	Working condition 6 West side	Working condition 7	Working condition 8	Working condition 9	Working condition 10
External surface temperature of thermal insulation layer (T_w)	K	417.15	314.85	313.25	324.95	367.45	401.55	375.65	365.75	349.05	328.35	302.65
Ambient temperature (T_f)	K	314.35	304.55	306.65	302.45	308.95	318.45	315.56	323.65	303.75	313.45	300.35
Difference between Surface Temperature and Environmental Temperature (ΔT)	K	102.80	10.30	6.6	22.50	58.50	83.10	60.10	42.10	45.30	14.90	2.30
Average Surface Temperature and Environmental Temperature (T)	K	365.75	309.70	309.95	313.70	338.20	360.00	345.60	344.70	326.40	320.90	301.50
Surface heat transfer coefficient (α)	$W/m^2 \cdot K$	16.97	10.49	9.75	10.55	12.35	13.58	12.43	11.53	11.69	10.17	9.54
Heat flux density (q)	W/m^2	1744.10	108.06	64.35	237.26	722.18	1128.08	746.74	485.20	529.33	151.46	21.93

Table 4. Calculation results of heat loss (2)

Calculation item	Unit	Calculation results								
		Working condition 11	Working condition 12	Working condition 13	Working condition 14	Working condition 15	Working condition 16	Working condition 17	Working condition 18 East side	Working condition 18 West side
External surface temperature of thermal insulation layer (T_w)	K	320.85	312.95	301.55	328.05	397.15	377.15	335.75	407.15	361.55
Ambient temperature (T_f)	K	307.55	303.35	301.15	310.65	334.85	312.35	310.95	317.75	311.75
Difference between Surface Temperature and Environmental Temperature (ΔT)	K	13.30	9.60	0.40	17.40	63.3	64.8	24.8	89.4	49.8
Average Surface Temperature and Environmental Temperature (T)	K	314.20	308.15	301.35	319.35	366.00	344.75	323.35	362.45	336.65
Surface heat transfer coefficient (α)	$W/m^2 \cdot K$	10.09	9.90	9.44	10.29	14.201	14.306	11.506	16.028	13.256
Heat flux density (q)	W/m^2	134.13	95.04	3.78	179.05	898.923	927.03	285.35	1432.90	660.15

Table 5. Maximum allowable heat loss (heat dissipation density) of external surface of thermal insulation structure

Medium temperature (℃)	50	100	150	200	250	300	350	400	450	500	550	600	650
Perennial operating conditions(W/m^2)	58	93	116	140	163	186	209	227	244	262	279	296	314
Seasonal operating conditions(W/m^2)	116	163	203	244	279	308	-	-	-	-	-	-	-

equipment is equal to or less than 350℃. Glass wool has great advantages in terms of heat preservation performance, construction and transportation convenience, and its price is higher than that of rock wool, especially centrifugal high temperature glass wool. The price is much lower than that of rock wool. Measurement and analysis of surface temperature of main thermal equipment and pipeline insulation layer in toketo power plant.

Research object

This experiment takes the 600 MW sub-critical thermal power generating unit of Inner Mongolia Datang International Toketo Power Generation Co., Ltd. (hereinafter referred to as Toketo Power Plant) as the object of investigation, investigates and tests the thermal insulation and heat dissipation status of the main thermal equipment of 5# units and part of the thermal equipment of 3# units, and tests the heat dissipation data. Based on comprehensive investigation, the steam turbine, furnace top, drum and main unit are investigated. Thermal test and heat loss survey were carried out on high temperature thermodynamic equipment such as steam pipeline and reheat steam pipeline hot section to find out the overall heat loss and main heat loss parts of the unit.

Test basis

(1) GB/T 8174-2008 "Testing and Evaluation of Insulation Effect of Equipment and Pipeline"
(2) GB/T 18021-2000" Field Measurement of Heat Loss on Insulation Layer Surface of Equipment and Pipeline "
(3) CJ/T140-2001" Heat Loss Testing and Thermal Insulation Effect Evaluation Method for Heat-supply Pipeline Insulation Structure "
(4) GB/T 4272-2008" General Principles of Insulation Technology for Equipment and Pipeline "
(5) DL / T 936-2005" Guidelines for Fire Resistance and Insulation Maintenance of Thermal Equipment in Thermal Power Plants "
(6) GB/T8174-2008" Testing and Evaluation of Insulation Effect of Equipment and Pipeline "

Table 6. Statistical Table of Excessive Heat Loss of Unit 5 in Toketo Power Plant

Working condition number	Over-standard position of heat dissipation	Measured heat flux (W/m^2)	Maximum heat flux allowed by national standards (W/m^2)	above the normal rate (%)
1	5# Unit Boiler Body	1744.10	314	455.45
4	5#Unit boiler side water supply pipeline	237.26	186	27.56
5	5#Unit boiler down comer	722.18	186	288.27
6	5#Unit steam pocket	1128.08（East）	186	506.50
		746.74（West）		301.47
7	5#Unit main Steam Pipeline	485.20	279	73.91
8	5#Unit thermal reheat steam pipe	529.33	279	89.72

Test working conditions: The working condition items and test contents of this test are shown in Table 3. The main test contents are the outer surface temperature and environment temperature of insulation layer.

Test data and calculation results: The surface temperature and corresponding heat loss calculation data of insulation layer under different working conditions tested in this experiment are shown in Tables 4 and 5.

Standard Value of Heat Loss on External Surface of Thermal Insulation Structure: Chinese GB/T8174-2008 "Test and Evaluation of Insulation Effect of Equipment and Pipeline" and DL/T 936-2005 "Guidelines for Insulation and Insulation Maintenance of Thermal Equipment in Thermal Power Plant" have definite scope of heat loss on the outer surface of main thermal equipment and pipeline insulation structure under different operating conditions of power plant. Detailed requirements are shown in Table 6.

Conclusion

According to the temperature measurement data and scattering loss calculation results of the outer surface temperature of the insulation layer under different working conditions of Unit 5 in Toketo Power Plant, the scattering loss at present exceeds the maximum allowable scattering loss value specified in GB/T8174-2008 "Test and Evaluation of Insulation Effect of Equipment and Pipeline" under the corresponding medium temperature, as shown in Table 7. According to the data in the table, the main places where the overtemperature is serious are the boiler body, the boiler descending tube and the steam drum. The heat loss is 2-5 times higher than the national standard. The proportion of the main steam pipeline and the heat reheat steam pipeline exceeding the corresponding national standard is also between 70% and 90%, and the overtemperature phenomenon is more serious. According to the temperature measurement data and scattering loss calculation results of the outer surface temperature of the insulation layer of the boiler body of Unit 3 in Toketo Power Plant, the scattering loss of the outer surface of the insulation layer of the seven and eight layers of the boiler body is 898.923 W/m^2 and 927.03 W/m^2, respectively. The scattering loss exceeds the national standard GB/T8174-2008 "Test and Evaluation of Insulation Effect of Equipment and Pipeline" under the corresponding medium temperature. The maximum allowable scattering loss is fixed. In addition, the scattering loss of the drum is larger, which also exceeds the corresponding heat dissipation loss.

REFERENCES

Deziani M., Rahmani K., Roudaki S. J. M., et al. 2017. Feasibility study for reduce water evaporative loss in a power plant cooling tower by using air to Air heat exchanger with auxiliary *Fan[J]. Desalination*, 406:119-124.

Yuh-Ming Ferng, Shau-Shei Ma. 1996. Investigation of System Responses of the Maanshan Nuclear Power Plant to the Loss of Residual Heat Removal During Midloop Operation Using a RELAP5/MOD3 *Simulation [J]. Nuclear Technology*, 116(2):160-172.

Ouagued M., Khellaf A., Loukarfi L. 2013. Estimation of the temperature, heat gain and heat loss by solar parabolic trough collector under Algerian climate using different thermal oils *[J]. Energy Conversion & Management*, 75(5):191-201.

Wu J Q., Zhu DF., Wang H. et al., 2013. Exergetic Analysis of a Solar Thermal Power Plant *[J]. Advanced Materials Research,* 724-725:156-162.

Li, Po, Zhang, Cheng Wei. 2014. The Analysis between Two Different Methods of Power Plant Boiler Thermal Efficiency *[J]. Applied Mechanics & Materials*, 536-537:1578-1582.

Acır A., Bilginsoy A K., Coşkun H. 1986. Investigation of varying dead state temperatures on energy and exergy efficiencies in thermal power plant *[J]. Journal of the Energy Institute*, 85(1):14.

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