

The Inspection Technology for the Maximum Surface Temperature Test of Coal Mine Explosion-Proof Electrical Equipment

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Abstract. Based on the analysis of the domestic energy structure, this paper introduces the functions and main categories of coal mine explosion-proof electrical equipment, describes the technical requirements, test conditions, test methods, and result judgment of the maximum surface temperature test for coal mine explosion-proof electrical equipment, designs a maximum surface temperature test system for coal mine explosion-proof electrical equipment, and conducts a maximum surface temperature test on the explosion-proof electromagnetic starter for coal mines, achieving the inspection of the maximum surface temperature test for coal mine explosion-proof electrical equipment.

Keywords: Mining, limited rotation angle, actuator, inspection.

1. Introduction

A major characteristic of fossil energy in China is its irrational structure, with the energy structure being “short of oil, lacking gas, and relatively rich in coal,” which determines the dominant position of coal in the energy consumption structure. In terms of the total amount of fossil energy resources, coal accounts for 94%, while oil and gas only account for 6%. Utilizing new energy sources such as wind energy, solar energy, and biomass energy to replace fossil energy is the premise and foundation for achieving the “dual carbon” goal. However, the production of new energy sources is currently unstable and faces various constraints such as the development of large-scale energy storage and peak shaving technologies. Based on the basic national conditions of “relying on coal”, strengthening the development of green and low-carbon technologies is an important requirement for us to achieve the “dual carbon” goal in the future.

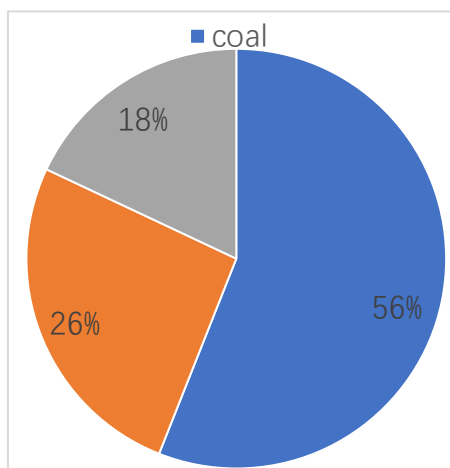


Figure 1. Proportion of China's energy consumption in 2021

2. Coal mine explosion-proof electrical equipment

Coal mine explosion-proof electrical equipment refers to electrical equipment used in the underground power distribution system, mining system, transportation system, safety protection system, and rescue system in coal mines. Coal mine explosion-proof electrical equipment mainly includes mine explosion-proof high-voltage distribution devices (as shown in Figure 2), mine explosion-proof low-voltage feeder switches, mine explosion-proof control boxes, mine explosion-proof electromagnetic starters (as shown in Figure 3), and other products. Coal mine explosion-proof electrical equipment plays a dual role in controlling and protecting safety in underground production. It is suitable for use in explosive environments containing gas, dust, and other hazardous substances and is classified as Class I explosion-proof equipment. The thick and heavy explosion-proof housing of coal mine explosion-proof electrical equipment prevents internal explosion flames from spreading to the external environment and ensures that the equipment is not affected by external explosions. However, the thick and tight structure is not conducive to heat dissipation, which leads to the temperature of explosion-proof electrical equipment being much higher than that of similar electrical equipment on the ground.



Figure 2. Mine explosion-proof high-voltage distribution device



Figure 3. Mine explosion-proof electromagnetic starter

3. Maximum surface temperature test

3.1. Test requirements

The maximum surface temperature test is the main test item of the type test for coal mine explosion-proof electrical equipment, and it is also a test condition for assessing the impact resistance

of the non-metallic housing, heat and cold resistance of introduced devices, and thermal stability of transparent components. Excessive maximum surface temperature can lead to decreased mechanical strength, structural damage, reduced insulation capacity, and can easily cause short circuits between phases, equipment damage resulting in electrical fires, and even trigger gas explosions, coal dust explosions, and other safety production accidents. The long-term full-load and overload operation of transformers at the Er Tang Coal Mine in Nanning City has led to an increase in temperature, accelerated aging of cables, generation of electrical arcs, and resulted in a fire causing 30 deaths. The maximum surface temperature of coal mine explosion-proof electrical equipment should not exceed the requirements specified in Table 1.

Table 1. Requirements for Maximum Surface Temperature of Explosion-proof Electrical Apparatus in Coal Mine

Operating environment	Maximum surface temperature (K)
When the explosion-proof electrical surface may accumulate coal dust	150
When the explosion-proof electrical surface will not accumulate coal dust (such as inside a dust-proof enclosure)	450

3.2. Test conditions

The maximum surface temperature of coal mine explosion-proof electrical equipment should be between 90% and 110% of the rated voltage, and the test should be conducted under the most unfavorable conditions when the equipment reaches its highest surface temperature. For products such as starters and feeders where the input voltage does not directly affect the temperature rise of the coal mine explosion-proof electrical equipment, the test current can be increased to 110% of the rated current. If the rated value of the coal mine explosion-proof electrical equipment is a range (e.g., 100V-250V or 240V±24V), the test should be conducted under the most severe rated conditions. If the most severe conditions for the maximum surface temperature test of the coal mine explosion-proof electrical equipment cannot be determined, the test should be conducted at 90% of the lowest voltage within this range and at 110% of the highest voltage.

3.3. Test method

The maximum surface temperature test of coal mine explosion-proof electrical equipment uses a thermal imager to identify the point of highest surface temperature, and then uses a temperature detector (preferably using the method of thermocouples, which complies with the relevant provisions of GB/T 2903-2015) to measure the highest surface temperature in the test environment. During the measurement of the maximum surface temperature of the coal mine explosion-proof electrical equipment, the hot end of the thermocouple is fixed to the measurement point of the equipment using methods such as silver soldering, soldering, adhesive bonding, or drilling, and the two thermocouple wires are twisted together while being placed as far as possible outside the influence of strong alternating magnetic fields. The temperature measurement of the maximum surface temperature test of the coal mine explosion-proof electrical equipment should only be performed using a thermometer if the following conditions are met: the measured part has a sufficiently large contact area and can be in close contact, and the temperature of the measured part will not change significantly due to the presence of the thermometer. A mercury thermometer should not be used for the maximum surface temperature test of coal mine explosion-proof electrical equipment to avoid errors caused by alternating magnetic fields. For coal mine explosion-proof electrical equipment with a high temperature rise, a high-temperature thermocouple should be used for measurement, and methods such as soldering or adhesive bonding to fix the hot end are not applicable.

3.4. Result determination

If the temperature variation measured at two intervals 1 hour apart during the maximum surface temperature test of coal mine explosion-proof electrical equipment does not exceed 2 K, it is considered that the test has reached a stable state, and the data obtained at this time represents the highest surface temperature in the test environment. Since the highest surface temperature is the temperature under the most unfavorable conditions, it is necessary to convert the data obtained in the test environment. The conversion method is as follows:

$$T = T_s - T_h + T_c \quad (1)$$

Where T is the temperature under the most unfavorable conditions in degrees Celsius ($^{\circ}\text{C}$), T_s is the highest surface temperature in the test environment in degrees Celsius ($^{\circ}\text{C}$), T_h is the ambient temperature in degrees Celsius ($^{\circ}\text{C}$), and T_c is a constant, usually taken as +40.

4. Test system design

The high surface temperature test system for coal mine explosion-proof electrical equipment is mainly composed of distribution switches, protection switches, voltage regulators, high-current generation devices, signal input units, power supply units, storage units, environmental temperature detection modules, temperature detection modules, parameter detection modules, and control and data acquisition systems. The distribution switches, protection switches, voltage regulators, and high-current generation devices form the main circuit test current line for the high surface temperature test of coal mine explosion-proof electrical equipment. The distribution and protection switches are used for the connection, disconnection, and fault protection of the test circuit for the high surface temperature test of coal mine explosion-proof electrical equipment. The voltage regulator is used to adjust the rise and fall of the test current for the high surface temperature test of coal mine explosion-proof electrical equipment. The high-current generation device is used to convert electrical energy from the grid into the test current for the high surface temperature test of coal mine explosion-proof electrical equipment. The signal input unit converts input signals from experimenters into control commands. The environmental temperature detection module and temperature detection module are used to collect environmental and equipment temperature signals. The control and data acquisition system is used to send control commands and action signals, as well as to collect variable information such as system temperature, current, and time. The structural schematic diagram of the high surface temperature test system for coal mine explosion-proof electrical equipment is shown in Figure 4.

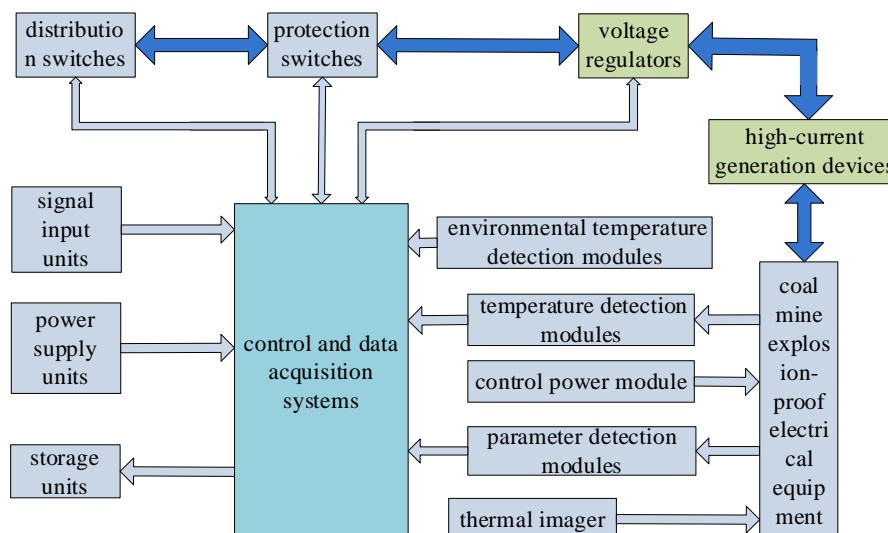


Figure 4. The structural schematic diagram of the high surface temperature test system for coal mine explosion-proof electrical equipment

The coal mine explosion-proof electromagnetic starter is selected as the typical equipment for conducting the high surface temperature test. The rated working voltage and current of the coal mine explosion-proof electromagnetic starter are 1140V and 200A, respectively. The test current for the high surface temperature test is 220A, and the highest surface temperature is found using a thermal imager and tested using a thermocouple. The highest surface temperature of the coal mine explosion-proof electromagnetic starter is 76.2°C.

5. Conclusion

The high surface temperature test is a major test item in the type test of coal mine explosion-proof electrical equipment. Based on the analysis of the requirements for the high surface temperature test of coal mine explosion-proof electrical equipment, a high surface temperature test system for coal mine explosion-proof electrical equipment was designed based on the high-current generation device, and the high surface temperature test of the coal mine explosion-proof electromagnetic starter was completed, improving the quality and safety of coal mine explosion-proof electrical equipment.

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