Design and implementation of infrared lamp automatic screening system

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Abstract. To improve the efficiency of infrared lamp screening during the vacuum thermal environment test, an automatic screening system for infrared lamps is designed in this paper. The paper first introduces the main indicators required for the infrared lamp screening system and the main components of the system. The detailed design of each part of the system was completed on the basis of investigating the relevant detection methods according to the needs of use. Specifically, it includes mobile device design, circuit design, and software design. According to the design scheme, the machining of each part was completed and the main body of the instrument was assembled. Using the assembled system to complete the automatic test of infrared lamp screening, the test results meet the needs. In addition, the system has a high degree of automation, which greatly improves the work efficiency.

1. Introduction
The vacuum thermal test of a spacecraft is a crucial and indispensable ground test for a spacecraft. Its purpose is to verify the correctness of the thermal design and to evaluate the performance of the spacecraft and its components in a low-temperature vacuum environment. How to efficiently and accurately complete the simulation and control of external heat flow is one of the key technologies of thermal testing. Infrared lamps have the advantages of fast response speed, small shielding factor for spacecraft, flexible installation, good versatility, non-contact heating, etc. Therefore, infrared lamp arrays composed of infrared lamps have been widely used in spacecraft thermal test external heat flow simulation devices. The reliability of the use of infrared lamps is directly related to the success or failure of the test, so the reliability of the infrared lamps itself is receiving more and more attention.

During the routine testing, inspection and test of the infrared lamp, there are failures such as lamp leakage, filament breakage, loose ceramic columns, lamp tube cracks and blackening, and lamp tube burst. Therefore, the selected infrared lamps need to be screened before use. The methods currently used are mainly visual recognition and manual use of a multimeter to measure the cold and hot resistance values of infrared lamps. Generally, about 100 infrared lamps are used in the infrared lamp array. With the current screening method, the work efficiency is low and the occupation time is long, so it is extremely necessary to develop an automatic infrared lamp screening system.

2. System structure and test principle
2.1. Infrared lamp test index and test principle
Infrared light screening is performed on the basis of visual inspection. The main function of infrared lamp screening is to select infrared lamps with more similar cold and hot resistance values and more
consistent electric-to-heat radiation conversion efficiency in qualified appearance rulers, and assemble them into infrared lamp array. Therefore, according to the characteristics of the spacecraft vacuum thermal environment test, the main indicators of infrared lamps can be summarized.

- Cold resistance: Screening current 0.2A, excluding infrared lamps with excessive cold resistance bias;
- Thermal resistance: The screening current is usually 3.5A. Sort the screened infrared lamps according to the thermal resistance, and cut and select them according to the number of infrared lamps required by the infrared array. The resistance deviation of the infrared lamps used in the same array is usually required to be within ± 2%.
- Infrared lamp surface heat flow screening: The screening current is usually 3.5A. The system uses a silicon photocell for the infrared light radiation power test. During the test, the silicon photocell is placed on a flat surface under the infrared lamp to receive light energy from the lamp. The screening current is usually 3.5A. The system uses a silicon photocell for the infrared light radiation power test. During the test, the silicon photocell is placed on a flat surface under the infrared lamp to receive light energy from the lamp.

2.2. System Components
In accordance with the testing requirements of infrared lamp screening, the design of an automatic infrared lamp screening system was completed. Specifically, it includes a mobile mechanical device, a resistance test unit, a radiation power test unit, a data acquisition storage unit, and display control module. The mobile fixed mechanical device is used to fix the unit under test and the mobile radiation power test unit; The display control module is used to control the mobile device and display, process, and store test data.

3. Detailed system design

3.1. Mobile device design
The mechanical structure of the infrared lamp automatic screening system is shown in Figure 2. It mainly consists of four parts: instrument support, test lamp holder, lamp holder moving mechanism, and test moving mechanism.
Figure 2. Mobile device.

The instrument support is used to support the overall structure of the infrared light screening tester, and the overall design is square. The test lamp holder is made with a card slot according to the shape of the infrared lamp. 10 infrared lamps can be quickly tiled in the test lamp holder. The ear pieces are stuck in the card holder slot so that the infrared lamp will not move.

The lamp holder moving mechanism is equipped with a servo motor to enable the infrared lamp holder to be moved out of the instrument holder for infrared lamp replacement work. After the infrared lamp is replaced, the lamp holder moving mechanism is used to move the infrared lamp holder into the instrument.

The test moving mechanism is equipped with a stepper motor, which can translate the test unit on the instrument holder directly above each infrared lamp to test the infrared lamp. Install two servos on the test moving mechanism, and control the lifting and falling of the servo contacts through the electronic control system. The servo contact drops to the ear of the infrared lamp, and the infrared lamp under test will fix it with a constant force. At this time, the servo contact starts to power up and starts the infrared lamp test. The test mobile mechanism is equipped with three silicon photocells, which are arranged directly above the infrared lamp according to the three-point center point of the infrared lamp. It is used to test the illumination voltage of the infrared lamp and compare the uniformity of the infrared lamp illumination.

In addition, a cooling fan is installed at the lower part of the instrument holder to timely conduct the heat of the infrared lamp, thereby reducing the temperature rise of the silicon photocells cell and avoiding the influence of the temperature drift of the silicon photocells cell on the light voltage test.

3.2. Circuit design

In accordance with the testing requirements of infrared lamp screening, the design of an automatic infrared lamp screening system was completed. Specifically, it includes a mobile mechanical device, a resistance test unit, a radiation power test unit, a data acquisition storage unit, and display control module. The mobile fixed mechanical device is used to fix the unit under test and the mobile radiation power test unit; The display control module is used to control the mobile device and display, process, and store test data.

The circuit design part of the infrared lamp automatic screening system is mainly composed of a main control circuit, a test circuit, a liquid crystal display circuit, a constant current power supply, and a motor drive circuit. The main functions of the main control circuit are the mechanical control of the instrument, data storage and reading, power communication, etc. The test circuit controls the Agilent 5750 program-controlled power supply to power on the infrared lamp through the LAN port of the communication module. Read the voltage and current data during the test. The test period is 0.5s. At the same time, the test circuit also tests the voltage values of the three Silicon Photocell with a test cycle of 1ms. The test circuit sends the test data to the main control circuit. The data storage unit of the
instrument is a 24G SSD solid state hard disk. The storage contents include the measured lamp name, voltage, current, resistance, light-sensitive voltage, and time. After completing the system circuit design, use Altium Designer software to design the PCB printed board. The PCB of this circuit is shown in the figure 3.

![Figure 3. PCB circuit diagram.](image)

3.3. Software design
The software design of the infrared lamp screening tester is developed based on the WIN7 SP1 platform using Visual Basic language. The basic software flow is shown in Figure 4.

After starting the program, first to choose to create a new test project or open an existing unfinished test project. If you are creating a new test project, you need to create a test name, enter the number of lamps, enter the current and voltage value of the test thermal resistance, and select a stable interpretation method for the thermal resistance test. In addition, you can set the power-on time or select the voltage difference to judge the stability of the thermal resistance test. If you choose to set the power-on time mode, that is, when you test the thermal resistance, perform the power-on test according to the power-on time. When the thermal resistance test of one infrared lamp is completed, switch to the next infrared lamp. Record the test data of the last collection cycle as the data of the lamp. If the selected voltage difference is selected as the stability criterion, after the stable voltage criterion is reached during the test, the measurement is continued for ten cycles, and after confirming that the ten cycles meet the stable voltage criterion, the test is completed. The measurement value of the tenth cycle is used as the report value of all test lamp data.
4. System integration and testing

According to the above scheme, the overall effect of the system after processing is shown in Figure 5.

The infrared light screening test instrument calculates the resistance value by reading the voltage and current of the Agilent 5750 program-controlled power supply. The silicon photocells on the
infrared lamp screening tester are only used as a qualitative test for the illumination uniformity of the infrared lamps. The voltage values of the three silicon photocells tested at the same time are compared to determine the uniformity of the light. The test results are shown in Figure 6. According to the test results, the infrared lamps are screened and the test data are sorted, and the infrared lamps with uniform uniformity are selected from them, thereby providing an important guarantee for the smooth running of the test.

5. Summary
According to the importance of infrared lamp screening in the vacuum thermal test of spacecraft, this paper clarifies the performance indicators concerned in the infrared lamp screening process, and proposes a test method for infrared lamp screening. According to the requirements of performance indicators, the design of the infrared lamp screening tester was completed. The system works stably and reliably, with a high degree of automation, saving time and labor costs. It provides a reliable verification method for the screening of infrared lamps, further improves the reliability of infrared lamps, and reduces the risk of infrared lamp failure affecting the test results and test progress during the test.

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