Control System Design of Microwave Load Water-Cooling for Spacecraft Thermal Vacuum Test

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Abstract: The microwave energy released by satellite transponder in the vacuum heat test needs to be converted into heat energy and dissipated through the water-cooling system. To dissipate this heat energy, a microwave load water-cooling system is designed, which realizes the automatic operation and remote monitoring of the water pump and refrigeration unit through Siemens S7-300 and IFIX 5.0 configuration software.

1. Introduction
Vacuum thermal test is one of the important tests in the space environment simulation test of spacecraft. It can expose the material and process defects of spacecraft in the vacuum environment and thermal environment, eliminate the early failure, and greatly improve the reliability of spacecraft in orbit [1]. The satellite transponder needs to simulate the actual in-orbit working state during the test, which will release microwave energy in the space environment simulator. Due to the tightness of the container, the energy released directly will reflect back and forth in the container, which will affect the safety of the test. Therefore, it is necessary to configure the corresponding load to convert the microwave energy into heat energy and then dissipate through the cooling circulation device. The cooling circulation device works partly in a vacuum and low temperature environment, and partly in a normal temperature and pressure environment. The circulation pipeline must pass through the metal wall of the closed container and be reliably connected with the satellite microwave load. At the same time, the cooling circulation device needs to adapt to the requirements of continuous test operation and work steadily for a long time [2].

2. Design scheme of microwave load circulating water
The microwave load cooling-water system mainly consists of several parts, such as refrigerator, heat exchanger, water pump, water tank, valve, pipeline, sensor and electric control system, as shown in figure 1. The refrigerator and water pump are the key equipment of the system.
2.1 Refrigerator and heat exchanger
In the tests, the heating power is about 32 KW load, considering the thermal efficiency in factors, such as selection of merlot ko air-cooled box machine, model for LSQ20ADE (15), the water temperature is 20 ℃, the temperature 15 ℃, the refrigerating capacity of 69.6 KW. Each refrigerator is equipped with two compressor heads, which can avoid the damage of the independent head, and improve the operation stability and efficiency of the equipment. At the same time, the heat exchanger was installed indoors to avoid water freezing caused by the equipment shutdown in winter.

2.2 the water pump
In the test, the cooling medium needs to flow through the load on the star. In order to prevent the impurities in the cooling medium damage the load, distilled water is adopted as the circulation cooling medium. The water pump, pipeline and water tank are all made of stainless steel. The internal circulation pump adopts 2 vertical MVI3202 vertical stainless steel pumps, one for use and one for standby, and the rotary training starts to heat up the water in the water tank and the refrigerator in the heat exchanger. The microwave load pump adopts 2 horizontal MHI803 stainless steel pumps, which are activated by one device and one device. The pump also meets the demands of head, power and performance curve.

2.3 water tank
The purpose of the water tank is to store cold water, which ACTS as a buffer to prevent the refrigerating unit from starting frequently. When the system stops running, most of the water in the pipe will return to the water tank for storage.

2.4 sensor and valve
All kinds of sensors and valves in the microwave load water-cooling system are used to ensure the normal operation of the system and the smooth operation of daily maintenance.

2.4.1 water flow switch
The water flow switch is used to determine whether there is enough water flow through the heat exchanger after the operation of the pump and control the start and stop of the compressor according to the water flow. The pressure difference flow switch can control the flow accurately by detecting the inlet and outlet water pressure difference of both ends of the heat exchanger and comparing with the pre-set flow value of the refrigerator.

Figure 1. Schematic diagram of the water-cooling system for microwave load
2.4.2 water tank sensor
There are two temperature sensors in the water tank. The temperature measured by the temperature sensor of the water tank can be used to determine whether the refrigeration unit should be opened. 1 liquid level sensor to measure the water height. If the water level is above the upper limit, an alarm will be sent to you.

2.4.3 pipeline sensor
Pressure sensor, temperature sensor and flow sensor are installed on the supply pipe of main road and branches. Pressure sensor and temperature sensor are installed on the return pipe. These sensors can measure water supply pressure, water supply temperature, water supply flow, water return pressure and water return temperature. Based on these measurements, it can be judged whether the system is working normally or not.

2.4.4 valve
Microwave load cooling-water system is also equipped with one-way valve, globe valve, bypass valve and other valves. The outlet of each pump is equipped with a check valve to prevent sudden stop of the pump, the force of water hammer hitting the pump and the backflow of water in the pipeline, and the impeller reverse damage the pump. One globe valve is installed at both ends of the pump. When the pump, filter and one-way valve need maintenance, the valves can be closed at both ends and the connection with the pipeline can be cut off. A bypass valve is installed on the return pipe to connect the supply and return water pipes short. The opening of the bypass valve is adjusted to adjust the water supply pressure and flow at the end.

2.5 electronic control system
The electronic control system mainly consists of Siemens s7-300 plc and corresponding modules, field control cabinet, monitoring computer, IFIX5.0 series configuration software, switch, UPS and 2 frequency converters. It includes two parts: internal circulation control and microwave load cycle control.

The inner loop control logic is shown in figure 2. Set the temperature and lower limit of the water tank through the parameter setting interface, start the automatic running program of internal circulation, run the water pump of internal circulation, and judge the running status of the water pump through the water flow switch. There are two temperature sensors in the water tank, and one of them is selected as the reference temperature. PLC sends out control signals through judgment, calculation and processing to realize the automatic control of the refrigeration unit.
The control logic of microwave load cycle is shown in figure 3. Through the parameter setting interface, the system flow and pressure parameters are set and the automatic operation program is started. The flow and pressure sensors in the system transmit the data collected to PLC, which sends out the control signal after judgment, calculation and processing to realize the automatic control of the microwave load pump.

### 3. Monitoring System

#### 3.1 Communication between PLC and IFIX

PLC and IFIX communication IFIX communicate with lower computer PLC through Ethernet, which has the advantages of high reliability, fast communication rate and large transmission amount, and can guarantee the high efficiency and stability of the monitoring room and programmable controller when transmitting mass data. In IFIX5.0, add MBE driver, set the driver on the network, select TCP/IP
protocol, add communication Channel under the driver, select Device under the Channel, add data block under the Device, and set the variable address in the data block to be consistent with the data block address in PLC\textsuperscript{[3]}. 

### 3.2 compilation of monitoring interface

In order to realize remote monitoring of the system, the upper computer uses IFIX5.0 series configuration software to create monitoring images. This configuration software runs under the Windows system, which is a combination of security, universality and ease of use. The database adopts Microsoft SQL 2008 for data processing and archiving, and supports WEB functions, which can be viewed by staff at any time. The operation structure of the upper computer is shown in figure 4\textsuperscript{[4]}. 

![Figure 4. Computer structure](image)

The whole system is divided into monitoring screen, data monitoring screen, real-time curve screen, alarm recording screen, operation recording screen, data report screen, etc\textsuperscript{[5]}. The monitoring screen is divided into two parts: the navigation bar and the process monitoring. The navigation bar is mainly used to switch other functional pictures. The monitoring screen is the real-time monitoring of the operation of internal circulation and microwave load circulation equipment. At the same time, in order to ensure the safe operation of the system, different account permission levels were set, and different accounts had different operating permissions after logging into the system.

### 4. conclusion

The microwave load cooling-water system for spacecraft vacuum thermal test has realized automatic operation and remote monitoring through the use of PLC and IFIX configuration software, which has a high safety, reliability and energy-saving performance in regulating operation and greatly reduces the labor intensity of the staff. Several spacecraft vacuum thermal tests have been successfully completed.

### References

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