Design and Verification of Valve Fire-Resistant Experimental Device

Yingjun Xiang * a, Jilin Li b
National Quality Supervision and Inspection Center of Petroleum Mechanical Products, Jiangsu 224700, China

* Corresponding author email: 563957088@qq.com, b jhsycjb@163.com

Abstract. The valve plays the role of a switch in the production process of the petrochemical industry, but there are often fire and explosion accidents in actual working conditions. The fire resistance of the valve is the ability of the valve to maintain normal operation in high temperature flames. It is a measure of the safety performance of the valve. Important indicators. This article mainly describes in detail the principle, equipment structure and design schemes of the fire resistance test device. The test of the valve fire test device was successfully carried out. The tests show that the performance parameters of the test device, such as temperature and pressure, meet the relevant requirements of the standard API 607 and API 6FB. Using high-precision sensors and advanced data collectors, it can simultaneously collect data such as pressure, temperature, and leakage. The fire resistance test of the valve was successfully completed, and the problems existing in the test were improved, and the direction of future optimization was proposed.

Keywords: Valve; Fire Test Device Design; Automatic Acquisition System.

1. Introduction
By reviewing the literature, we can know the current research progress of fire-resistant valves. For example, China's Hefei General Research Institute, Shanghai, Shenzhen Special Equipment Research Institute and large valve manufacturers have more research on refractory valves. There are also some literatures on the study of fire-resistant test tools, but they are mainly implemented in laboratories. Production enterprises also have some detection devices, but the degree of automation is low. However, it is urgent to connect the fire-resistant valve and the end in the chemical industry. For this reason, it is necessary to research and design the fire resistance of the fire-resistant valve and the end [1, 2].

At present, domestic and international fire test standards use two pressure system sources, one using a pump as the pressure source (Figure 1), and the other using compressed air as the pressure source (Figure 2). Because of the gas as a pressure source, there is a huge safety hazard in the fire test under high pressure. Therefore, the mainstream valve test devices on the market use pumps as the pressure source [3,4].
2. Experimental system design

This subject research is based on the current basic situation of the application of fire test equipment, and synthesizes its advantages and disadvantages. According to the actual needs of the market for the fire resistance performance of the valve and end connection, a comprehensive, systematic and in-depth study of the fire test equipment is made to break the past automation In the case of a low degree, a device with a high degree of automation is designed.[5][6]

According to the research goals and the technical route of the problem solving, we can carry out research, which can be divided into the main parts of theoretical research, device design, and test analysis. The main research contents of this topic are:

2.1. Hardware Design.

The hardware design mainly includes the design of pressure system, combustion system and mechanical device. Based on the previous research and the collected data and specifications, combined with the specific situation of the subject, the system design, component design, and data arrangement are organized, and the structural design principle diagram and structure diagram are written.
Valve fire test items include high pressure test, low pressure test and operation test. Pressure and temperature have different requirements at different test stages. Therefore, the design of the valve combustion chamber, ignition system, mechanical device, and control hardware is a prerequisite for meeting these requirements, and it is also the focus of the normal operation of this test device.

2.2. Software Design.
It is mainly a test software system. Fire resistance test of the test piece, how to carry out visual operation is also an important subject, the login system of the test system, the test operating system is a digital record of the fire test.

2.3. Integrated Implementation and Test Analysis.
After the design of the hardware and software systems is completed, the various components are systematically connected, and the fire test data acquisition and control system hardware platform is completed. All the hardware systems are reasonably arranged to form a test control cabinet to achieve the integration of the detection system. In order to verify its functionality, a verification test is required to carry out the assembly of the test device, field commissioning and test tests, including preparations before the test, commissioning tests, and fire resistance test tests of the actual test pieces.

3. Overall design of the test device system
The overall design of this test device mainly includes the design of 6 aspects including pressure system, combustion device, machinery and control device, software system, and foundation map.

The pressure system mainly includes three parts: water storage tank, hydraulic pressure booster system and control system; The combustion device mainly includes a combustion chamber, an ignition combustion flame retardant device, and a gas oxygen pipeline; Machinery and control device mainly include four parts: test rail car, cooling pipe, bending moment system and control cabinet; The software system mainly has four parts: login interface, information input interface, test operation interface and data statistics interface; The foundation map mainly designs the water and electricity for the entire test device. Detailed block diagram of the overall test device system.

![Figure 3. Overall block diagram of the test device system](image)

According to the valve test device system schematic diagram, we can know that the entire refractory system includes five parts: pressure system, combustion chamber, ignition system, fuel and air delivery system, mechanical device and control device, and cooling system. The design of each part must take into consideration the research objectives and research content of this topic. It can carry out the integrated test of the valve and end connection, solve the problems of low automation and poor safety of the previous valve fire test device, and also solve Need for end-to-end fire resistance test equipment.
We designed the components of the valve and end connection integrated fire test device. The schematic layout of the specific design system is shown in Figures 4 and 5.

![Figure 4. Front view of test system](image1)

![Figure 5. Top view of the system](image2)

3.1. Mechanical and control device design of valve fire test device
The mechanical device of the valve fire test device is mainly used for the transportation and combustion support of the valve. Therefore, a test rail car for the support and transportation of the valve test piece needs to be designed. During the combustion process, the gas phase change of the test water pressure will occur. Designed for use in cooling water sections of pressurized water sources.

3.2. Software System Design of Valve Fire Test Device
According to the valve fire resistance test standard API607 data collection requirements for pressure and temperature during the test, all data collection needs to be recorded every 30 seconds, so 30 seconds is used as a collection cycle. The main flow of the fire test of this device is shown in Figure 7.
4. Fire resistance test of fire-resistant ball valve

In order to verify the actual function of the designed valve test device, the test object used in this verification test is a fire-resistant ball valve Q347N-1500LB-8", and the test standard is API 6FA-1999" Code for Valve Fire Test ".

The refractory ball valve is a high-pressure large-caliber valve, so the cavity and weight of the valve are relatively large. The structure diagram is shown in Fig 8. The rail car needs to enter the combustion chamber after the valve is assembled outside the combustion chamber. The valve installation must be safe and reliable. After the valve is installed, the system is tested for pressure.

4.1. Test results

From the recorded data of 30 minutes, the flame temperature and the temperature of the thermocouple during the fire reached the standard requirements within 5 minutes, and the internal and external leakage of the valve during the fire also reached the standard requirements.

4.2. Analysis of temperature conditions

According to the requirements of the standard, the temperature of the thermocouple in the fire zone reaches 750 °C within 2 minutes after ignition, and the temperature value during the 30-minute combustion is not less than 700 °C. It can be seen from the 30-minute fire test value that the data can be
recorded once every 30 seconds, and the system can record the pressure and temperature sensor values in detail.

4.3. Stress analysis
From the recorded situation of valve pressure data, there is no significant drop in pressure, all within the range required by the standard, which indicates that the pressure system has a good pressure holding condition. This point has been tested at room temperature before the test. The reason for the small pressure drop during the refractory process is that the first reason is that the internal leakage of the valve in this test is relatively small, but the large internal water pressure in the valve cavity is high, and timely pressure compensation is performed.

4.4. Leak analysis
The leakage of this test device is calculated based on the measurement of the internal leakage water received by the cooling system. The internal leakage of the valve is recorded by measuring the liquid collected after cooling. Although the internal leakage of the valve obtained through calculation meets the standard requirements. However, the loss of high-pressure steam during the test was not calculated, which needs to be further studied in the future.

5. Conclusions
This topic mainly developed a set of automatic recording test system for the fire resistance test of industrial valves. The test method is based on API SPEC 6FA "Valve Fire Test Specification" and API 607 Fire resistance test "and other standards, carried out test device design, test verification work, the specific work and conclusions completed in the paper are as follows:

(1) Summarized and analyzed the technical standard requirements for the performance test of the refractory valve, the design principle of the test device and the application value of the subject research.

(2) According to the design requirements of the fire resistance valve performance test system, the overall mechanism of the test system is determined, and the components of the valve performance test system are designed, mainly the pressure system, combustion device, mechanical device, control device, software application, etc.

(3) According to the design goals of the fire resistance valve performance test system, the hardware part of the control system is selected and designed to complete the selection of the temperature sensor and pressure sensor.

References
[1] ISO 10497-2004: Testing of Valve-Fire type-testing requirements [S]
[2] API 607-2010: Fire resistance test for 1/4 turn valve and non-metal seat valve [S]
[3] API SPEC 6FA-1999: Valve fire test specification [S]
[4] API SPEC 6FD-2008: Non-return valve fire test specification [S]
[5] GB/T26479-2011: Resiliently sealed partial rotary valve [S]
[6] GB/T26482-2011: Non-return valve fire test specification [S]
[7] TSG D7002 -2006: Type test rules for pressure pipeline components[S]