HIGH PRESSURE HEATER

Operation and Maintenance Instruction Manual

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1. Equipment Overview

1.1 Equipment Purpose and Principle

The high-pressure feedwater heater (referred to as "high heater") is an important piece of equipment in the regenerative system of thermal power plants. It utilizes steam extraction from the turbine to heat the boiler feedwater, raising it to the required feedwater temperature, thereby improving the thermal efficiency of the power plant and ensuring the unit's output. The high heater operates under the highest pressure within the power plant and will be subjected to sudden changes in pressure and temperature due to variations in unit load, feedwater pump failures, bypass switching, etc., which can damage the high heater. Therefore, in addition to ensuring quality during design, manufacture, and installation, the operation, monitoring, and maintenance of the high heater should be strengthened, along with the training of operators to ensure long-term safe operation and good condition of the high-pressure heater.

The operation and maintenance of this unit's high heater, in addition to this manual, should also comply with relevant regulations and be tailored to actual conditions to meet the power plant's safety, economic, and full-load requirements.

1.2 Structural Characteristics

High-pressure heaters generally adopt a three-section heat exchange structure (specific to the steam turbine thermal balance diagram).

1.2.1Superheated Steam Cooling Section

Since the steam supplied to the high heater generally has a high degree of superheat, when heat exchange occurs between superheated steam and feedwater, the feedwater is heated to a temperature equal to or above the saturation temperature of the steam, thus improving the heat transfer efficiency. The superheated steam cooling section is enclosed with shell plates, tubes, and thermal shielding plates, with internal partitions to ensure that the steam flows through the heat transfer surface at a certain speed and direction for good heat transfer effects while avoiding direct contact of the superheated steam with the tube sheet and shell to reduce thermal stress and ensure that the steam retains sufficient superheat to leave this section in a dry state, preventing wet steam from eroding the tubes. This section is located at the outlet of the high heater's feedwater.

1.2.2 Condensation Section

The saturated steam with a certain degree of superheat from the superheated steam cooling section exchanges heat with the feedwater in this section, which typically has the largest heat transfer area. The steam condensation section heats the feedwater using the latent heat released during steam condensation, with the steam flowing in from both sides of the entire condensing tube bundle. Non-condensable gases are discharged through the exhaust pipe located at the center of the tube bundle, which is set along the entire condensation section to ensure the timely and effective removal of non-condensable gases from the high heater, preventing a reduction in heat transfer efficiency.

1.2.3 Drain Cooling Section

The drain cooling section continues to cool the condensate from the condensation section by releasing heat to heat the feedwater, reducing the temperature of the condensate below the saturation temperature to further improve the unit's thermal efficiency. The drain cooling section is also completely sealed with shell plates, baffles, and partitions around the heating tube bundle.

The heater with a drain cooling section must maintain a specified liquid level to prevent steam from leaking into the drain cooling section, which could cause two-phase flow and erode the tubes, while ensuring the drain end pressure difference meets design requirements.

1.3 Equipment Parameters

For details, see the "Technical Characteristics Table" in the accompanying drawings.

1.4 Equipment Outline Drawing

For details, see the accompanying drawings.

2. Equipment Description

2.1 Structural Layout Description

The high heater adopts a fully welded structure with tube sheets and U-tubes, incorporating three sections: the superheated steam cooling section, steam condensation section, and drain cooling section (as determined by the steam turbine thermal balance diagram).

In addition, each high heater is equipped with a water level regulation and alarm system; refer to the relevant drawings for details about the water level regulation and alarm system.

The main components of the high heater include: shell, water chamber, tube sheets, heat exchange tubes, support plates, anti-erosion plates, supports, and accessories.

2.1.1 Shell

The shell is a fully welded structure (smaller, lower pressure equipment may use flange connections). The shell undergoes post-weld heat treatment and non-destructive testing according to technical conditions, with pipe connections either welded or flanged, as detailed in the drawings.

When the high heater shell needs to be disassembled, it should be cut along the cutting line indicated in the attached assembly drawing.

2.1.2 Water Chamber

The water chamber of the high heater consists of a tube box (some equipment does not have a water chamber tube box) and end caps. The structure of the water chamber includes hemispherical and large opening self-sealing structures. The hemispherical water chamber is equipped with an oval manhole for maintenance convenience. The oval manhole features a self-sealing design, utilizing a stainless steel graphite winding gasket with a reinforcing ring. The water chamber has a closed partition to prevent short-circuiting of the feedwater within the high heater's water chamber. An anti-erosion device is installed on the feedwater inlet side.

2.1.3 Tube Sheet

The component connected to the water chamber serves as the tube sheet.

2.1.4 Tubes

The high heater uses U-tubes as heat exchange tubes, made from carbon steel or stainless steel.

The tubes in the high heater are connected to the tube sheet using a welded and expanded joint structure.

2.1.5 Tube Support Plates

A certain number of support plates are arranged along the entire length of the heat exchange tubes, allowing the steam flow to scrub the tubes vertically to improve heat transfer efficiency, enhance the overall rigidity of the tube bundle, prevent vibration, and ensure that the tubes can freely expand when heated.

Support plates are fixed in place with tension rods and positioning tubes.

2.1.6 Anti-Erosion Plates

To prevent damage to the heat exchange tubes from impacts caused by steam and upstream drain, stainless steel anti-erosion plates are installed at the steam and upstream drain inlets.

2.1.7 Supports

The installation of the high heater can be vertical or horizontal. Vertical installations utilize skirt or ear support structures; horizontal high heaters are equipped with three saddle supports to secure the high heater in place. The supports located beneath the high heater's tube sheet are fixed supports, while sliding supports are installed in the middle and at the end of the shell (the rollers on the middle sliding support are removed during operation) to allow for axial movement during thermal expansion, ensuring safe operation of the equipment. The shell can also be withdrawn.

2.1.8 Accessories

(1) Instrumentation - Local pressure gauges and temperature gauge interfaces are provided at the inlet and outlet of the equipment, as well as at the steam and drain ports.

(2) Liquid Level Control - Each piece of equipment is equipped with multiple liquid level device interfaces. The control description for the drain liquid level interlock is detailed in the accompanying drawings. The construction of the related control system is provided in the thermal control professional construction documents.

(3) Safety

a. Safety valves are installed on the shell side to prevent sudden pressure increases that could lead to pipe bursts; safety valves on the pipe side prevent overpressure caused by heated feedwater.

b. The equipment is equipped with normal and emergency drainage devices to prevent high water levels that may threaten safe operation.

c. Each piece of equipment is provided with liquid level device interfaces to activate or deactivate various safety devices, ensuring safe operation of the equipment.

2.2 Factory Documentation

a. Product qualification certificate;

b. Quality certificate;

c. Completion drawings;

d. Installation, operation, maintenance, and user manual;

e. Shipping list.

3. Installation

3.1 Pre-Installation Inspection

(1) Check if the external appearance of the equipment meets the drawing requirements and if any damage occurred during transportation.

(2) Inspect for rust at each interface that might affect sealing.

(3) Check if all fasteners are loose, rusty, or show other anomalies.

3.2 Site and Foundation

(1) Sufficient space should be left at both ends after installation to meet disassembly and maintenance needs based on the structural form of the

equipment.

(2) Foundation dimensions should correspond to the support dimensions; the foundation can be poured concrete or made of steel structure. When using a concrete foundation, the base plate for the movable support should be pre-embedded, and the base plate must be kept flat and smooth.

3.3 Equipment Hoisting

(1) Equipment hoisting must strictly comply with on-site operational norms.

(2) When hoisting the equipment, pay attention to the position of the equipment's center of gravity.

(3) Use lifting lugs for hoisting when available. If not, the equipment body or other safe methods must be used for hoisting. At no time should components, lifting lugs, or piping connections be used for lifting the equipment.

3.4 Positioning and Installation of Equipment

(1) Place the equipment on the foundation, leveling it so that the centerline deviation is less than ±4 mm.

(2) If there are anchor bolts on the movable support, two locking nuts should be installed, with a gap of 1 to 3 mm between the nuts and the base plate.

(3) After installation, the movable or rolling support end should not hinder the thermal expansion of the equipment.

(4) Connect pipelines and accessories to the equipment in a stress-free state, avoiding excessive force during assembly.

(5) Prior to commissioning, valves and instruments should be installed according to the drawings and system control requirements.

4. Operation

4.1 Commissioning

4.1.1 Check the operation of the check valve and inlet valve on the extraction steam pipeline and conduct a linkage test.

4.1.2 Check the opening and closing of the valves on the drain pipeline to ensure that the drainage flows in the specified direction.

4.1.3 Verify that the drain adjustment system and liquid level alarm system are functioning correctly.

4.1.4 Open the control valves for the water level gauge and pressure gauge; all measuring instruments, thermometers, and lighting should be in good condition.

4.1.5 Before steam enters each high heater, drain the condensate in the extraction pipe; the high heater inlet valve, vent valve, and drain valve should operate normally.

4.2 Startup

4.2.1 Open the air vent valve on the water chamber (pipe side).

4.2.2 Slowly introduce feedwater into the heat exchange tubes. When the air is completely vented from the water chamber, close the air vent valve on the water chamber side, open the feedwater inlet and outlet valves, close the bypass, and allow water to flow through the high heater. At this point, the protection system remains in standby mode.

4.2.3 Open the extraction steam valve of the steam turbine to introduce heating steam; slowly open the valve over a sufficient duration to control the outlet temperature rise to no more than 3°C/min to ensure that thermal stress does not exceed safe limits.

4.2.4 The drain valve should be slightly open, operating in an automatic adjustment state.

4.3 Operation and Maintenance

(1) The equipment must not operate beyond the conditions specified on the nameplate.

(2) During operation, regularly check that all valves and measuring instruments are functioning correctly and that there are no leaks; if any abnormalities are found, timely repairs or replacements should be made.

(3) Continuously monitor the medium temperature, pressure, flow, and vibration of the equipment during operation. If anomalies are discovered, analyze the causes and, if necessary, perform repairs and maintenance; maintenance must occur during downtime.

(4) Regularly monitor the water level in the high heater to prevent operation at low or high water levels.

(5) Record or monitor the following instrument readings of the high heater regularly: (7) When the equipment stops running, drain and dry the internal

water completely, and promptly close all valves to prevent air from entering the steam and water systems, maintaining the internal humidity below 20%.

(6) Normal Operation Maintenance

a. Feedwater pH value: For subcritical unit copper-free feedwater systems, maintain a pH of 9.2–9.6; for systems with copper, it should be 8.8–9.2; for supercritical units, it should be ≥9.4. (Higher pH values promote the formation of a strongly adherent oxide film on carbon steel, preventing material corrosion.)

b. Feedwater oxygen content should not exceed 5–7 ppb to reduce corrosion of carbon steel pipes.

c. During operation, continuously vent the air from the equipment (smaller equipment may not require this); each high heater is equipped with air venting interfaces, and should discharge air to the deaerator or condenser separately. The appropriate amount of venting air is approximately 0.2% to 0.5% of the total steam flow.

(7) Shutdown

Shut down sequentially from high to low extraction pressure.

a. Slowly close the inlet steam valve to ensure gradual temperature changes, controlling the feedwater temperature drop to no more than 2°C/min to prevent cracks at the weld joints between the heat exchange tubes and the tube sheets due to thermal stress.

b. Close the air vent valve on the shell side.

c. Open the feedwater bypass valve.

d. Close the feedwater inlet and outlet valves, and close the drain adjustment valve.

e. Open the water side air vent valve to prevent steam valve leakage and overpressure from thermal expansion of the feedwater.

(8) Preventive Measures

a. After the extraction steam valve is opened, as the turbine load increases, the internal pressure and temperature of each feedwater heater will also rise. At this time, check for leaks at the seals of the manhole covers.

b. During startup and shutdown of the unit or with fluctuations in turbine load, the feedwater temperature will also change, continuously generating thermal stress in the high-pressure feedwater heater. The thermal stress arises during transient periods when the feedwater temperature changes. The magnitude of thermal stress depends on the amplitude of the feedwater temperature change. With each temperature change, the feedwater heater experiences a new thermal stress.

c. Regularly monitor the closed feedwater bypass valve for leaks; this can be checked by measuring the temperature at points downstream of the bypass valve or by comparing the temperature of the high heater outlet water. If the outlet temperature decreases due to a leaky bypass valve, the defect should be addressed promptly.

d. Continuously monitor and check the temperature difference at the drain cooling section of the high heater (the difference between drain outlet temperature and feedwater inlet temperature); if the temperature difference increases, analyze the cause and take corrective action.

e. Pay attention to the relationship between load and drain valve opening; if the load remains constant while the valve opening increases, it may indicate slight leakage in the tube bundle.

(9) When the equipment is out of service for an extended period, anti-corrosion measures should be implemented.

a. Nitrogen charging method: Completely drain and dry the water, prevent rusting agents and moisture absorbers from entering the equipment, close all valves, and charge with nitrogen to maintain a purity of not less than 99% at a pressure of 0.05 MPa.

b. Wet maintenance: Fill the deaeration equipment and feedwater system with a solution of hydrazine at a certain concentration, and charge with nitrogen to maintain a pressure of 0.05 MPa.

(10) Regular Inspection

a. Regular inspections of the equipment shall be conducted in accordance with the "Safety Technical Supervision Regulations for Fixed Pressure Vessels."

b. Internal inspections focus on checking for cracks in the welding seams of the deoxygenation head's rotary membrane components and for damage to packing materials, etc.

c. Check the effectiveness of safety valves, liquid level controllers, adjustment valves, etc.

5. Precautions:

5.1 Maintenance Methods for High-Pressure Feedwater Heater Tube Leaks

To safely and effectively plan and implement the maintenance and inspection of the high heater, the following measures are established:

General requirements:

① Carefully check work items before starting.

② Ensure that the high heater has been depressurized to atmospheric pressure.

③ Verify that all water in the high heater has been drained.

④ Detect the oxygen content in the high heater before entry.

⑤ Maintain normal ventilation in the high heater throughout all work periods.

⑥ Ensure safety measures and prevent foreign objects from entering the high heater.

⑦ Prohibit unnecessary items from being brought into the high heater; tools and other necessities should be kept to a minimum.

⑧ Strictly prohibit working alone inside the high heater.

⑨ Comply with the regulation of checking all items and tools carried in and out of the high heater one by one.

5.2 How to Verify Tube Leaks

5.2.1 Determining Leaks in Operating Tubes

a. Increased opening of the condensate regulating valve.

b. Rise in high heater water level.

c. Generation of vibration and abnormal sounds.

d. Decrease in feedwater pressure (when experiencing low feedwater flow).

e. Changes in feedwater flow (comparing the flow between the deaerator outlet and boiler inlet).

5.2.2 Methods for Detecting High Heater Tube Leaks

<1> Drain the condensate from the shell side, and use feedwater for a pressure test in the high heater. Based on changes in water side pressure and the drainage from the drain valve, it can be determined whether there is a leak in the high heater and to estimate the leak's severity. Generally, a large amount of leakage is from the tube itself, while a small amount indicates leakage at the weld joints at the tube ends.

<2> After confirming a leak in the high heater, drain any accumulated water from the tube section through the drainage outlet. Use specialized disassembly tools to remove the water chamber manhole cover, disassemble the upper partition cover of the water chamber, and remove the anti-erosion device. Supply compressed air at 0.5~0.8 MPa from the shell side, apply soap water to the tube ends, and use a 10x magnifying glass to carefully observe the welded joints on

the tube sheet. If air is expelled from the tube diameter, it indicates a leak in the tube itself; if a small amount of air breaks through the soap film at the welded joint, it indicates leakage at the tube end weld, and the leak location can be determined.

<3> Power plants with conditions may also use endoscopes for detection.

<4> During leak detection, mark the exact locations of identified leaks at the tube end welds and record the corresponding locations on the tube sheet layout diagram.

5.3 Repair Procedures for Tube Leaks

5.3.1 The high heater heat exchange tubes and tube end welds may exhibit one of the following three leak states.

5.3.2 Minor leaks at the tube end welds (water seeps from cracks or non-penetrating pores).

5.3.3 Larger leaks at the tube end welds (tubular holes eroded on the tube sheet).

5.3.4 Leaks caused by pinholes or fractures in the tube.

5.3.5 Based on different situations, the following two repair methods are adopted

<1> When the leak point is less than 6mm from the water chamber side tube sheet plane, it is generally a leak at the tube end weld.

a. Use a step drill with a diameter of Φ16mm/Φ11mm to remove the original weld joint and leak point defects (if there is an anti-wear sleeve, the corresponding flange part must also be removed).

b. Dry the tube end, clean off water stains, oil, rust spots, and other impurities affecting welding quality, exposing metallic luster. Weld the tube end joint with manual TIG welding or electrode arc welding.

<2> When the leak point is more than 6mm from the water chamber side tube sheet plane, it is generally a leak or fracture in the tube, and a sealing weld should be used:

5.3.6 When a leak occurs in the tube itself, protective sealing must be applied to the leaking tube and surrounding tubes.

5.4 When there are leaks in the high heater tubes or seal failures at the manhole, the high heater must be shut down, residual water in the water chamber must be cleared, and the manhole cover opened for necessary repair work.

5.5 Sudden pressure drops in equipment are strictly prohibited.

5.6 When disassembling equipment, if the gasket has been loosened, it must be replaced with a new one upon reinstallation.