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7.3 STARTUP FEEDWATER SYSTEM

Learning Objectives:

1. State the purposes of the startup feedwater system.
2. List the two sources of water for the startup feedwater system, and state when each is used.
3. List the automatic start signals for the startup feedwater system.

7.3.1 Introduction

The purposes of the startup feedwater system are:

1. To provide feedwater to the steam generators during transients in the event of main feedwater system unavailability, and
2. To provide feedwater to the steam generators during plant startup, hot standby, and shutdown conditions.

7.3.2 System Description

Startup feedwater is defined to be feedwater that passes through the startup feedwater control valves; it can be supplied either of two ways. Startup feedwater can be supplied by a booster/main feedwater pump drawing from the deaerator storage tank and delivering through cross-connect piping to the startup feedwater header. Also, startup feedwater can be supplied by one or both startup feedwater pumps drawing from the condensate storage tank and delivering to the startup feedwater header. The startup feedwater header is defined to be the common segment of startup feedwater piping downstream of the startup feedwater pumps. The cross-connection piping between the main feedwater pump discharge header and the startup feedwater header contains a check valve and a non-safety-related, air-operated isolation valve. The check valve prevents the startup feedwater pumps from supplying the main feedwater header, and the isolation valve automatically closes upon receipt of a main feedwater isolation signal to isolate the main feedwater system from the startup feedwater system.

Two parallel startup feedwater pumps are provided. Each takes a suction from the condensate storage tank. Each startup feedwater pump discharges to the startup feedwater header through a venturi flow element, an automatic recirculation valve, and a remotely operated isolation valve. The venturi flow element provides a flow measurement signal at normal flow rates, and cavitates at a flow rate near pump runout to choke the flow and avoid a further flow increase. The automatic recirculation valve functions both as a check valve to prevent reverse flow through the pump and also as a minimum flow control valve for pump protection; during conditions of low forward flow to the system, sufficient flow from the pump is automatically recirculated to the condensate storage tank to meet pump minimum

flow requirements. The discharge isolation valve is closed when the associated pump is not operating; the valve automatically opens when the associated pump starts.

The startup feedwater header branches into individual lines to the two steam generators. Each line contains a startup feedwater control valve, a check valve, and a startup feedwater isolation valve. Startup feedwater flow in each line is controlled by the associated startup feedwater control valve to maintain level in the associated steam generator (see subsection 8.5.7.2).

7.3.3 Component Descriptions

From the connections at the steam generators back to the startup feedwater isolation valves, the startup feedwater system is designed in accordance with the requirements of ASME Code, Section III for Class 2 components and Seismic Category I requirements. From upstream of the startup feedwater isolation valves to the restraints at the interface between the auxiliary building and turbine building, the system is designed in accordance with ASME Code, Section III for Class 3 components and Seismic Category I requirements. The remaining portion of the startup feedwater system is not safety-related.

7.3.3.1 Startup Feedwater Pumps

Each startup feedwater pump is a multistage, centrifugal pump driven by an ac motor. Each pump can supply 100 percent of the required flow to the two steam generators to meet the decay heat removal requirements. The pumps automatically start on (1) low-low steam generator level and (2) low level with low feedwater flow. Isolation valves at the pump suction and discharge allow each startup feedwater pump to be individually serviced. The discharge isolation valve for each pump is powered by the train of the onsite standby ac power supply which powers the associated pump.

7.3.3.2 Startup Feedwater Control Valves

The startup feedwater control valves are air-operated, modulating control valves with the dual purposes of controlling the startup feedwater flow rate and isolating the startup feedwater system. Each valve body is a globe design that provides the required range of startup feed control, as well as positive isolation. Each startup feedwater control valve's operator is equipped with an auxiliary air accumulator to provide independent operation of the valve upon a loss of the normal instrument air supply.

The startup feedwater control valves automatically maintain water level in the steam generators during operation of the startup feedwater system, in response to signals generated by the plant control system.

In the event of a secondary-side pipe rupture inside the containment, the startup feedwater control valves provide a backup to the startup feedwater isolation valves for limiting the quantity of high-energy fluid that enters the containment through the

broken pipe. For emergency closure of each valve, a solenoid is de-energized. The electrical solenoid is energized from a Class 1E source.

7.3.3.3 Startup Feedwater Isolation Valves

One startup feedwater isolation valve is installed in each startup feedwater line outside containment and downstream of the associated startup feedwater control valve and startup feedwater check valve. The following primary functions are performed by the valve:

- The startup feedwater isolation valve is provided to prevent the uncontrolled blowdown from more than one steam generator in the event of a startup feedwater line rupture. The startup feedwater control valve provides backup isolation.
- The startup feedwater isolation valve and the startup feedwater control valve provide isolation of the non-safety-related portions of the system from the safety-related portions.
- In the event of a secondary pipe rupture inside containment, the startup feedwater isolation valve and startup feedwater control valve provide isolation to limit the quantity of high energy fluid that enters the containment.
- In the event of a steam generator tube rupture, the closure of the startup feedwater isolation valve and startup feedwater control valve limits overfill of the steam generator by terminating startup feed flow.

Each startup feedwater isolation valve is a remotely operated gate valve. The valve operator is designed to stroke against steam generator pressure or startup feedwater pump shutoff head. To provide the safety function actuation (closure) as well as reliable alignment, and redundant and independent actuation, the startup feedwater isolation valve and startup feedwater control valve are powered from separate Class 1E power sources.

7.3.4 System Operation

The startup feedwater system supplies the steam generators with feedwater during conditions of plant startup, hot standby and shutdown, and during transients in the event of main feedwater system unavailability. The startup feedwater system also supplies feedwater during low-power operation under conditions when the startup feedwater control valves regulate the feedwater flow to the steam generators.

7.3.4.1 Startup

During reactor startups and at low power levels, feedwater is supplied to the steam generators through the startup feedwater control valves using either the startup feedwater pumps drawing from the condensate storage tank, or a booster/main feedwater pump drawing from the deaerator storage tank. The feedwater pump(s) in use operate on minimum flow recirculation as necessary while maintaining the water

level of the steam generators. Feedwater is controlled by the startup feedwater control valves, which are operated either manually from the control room or automatically in accordance with steam generator level demand. If the startup feedwater pumps are initially in use, a transfer is made to a booster/main feedwater pump prior to exceeding the capacity of the startup pumps. As power increases, feedwater continues to be supplied through the startup feedwater control valves until control of feedwater is automatically transferred from the startup feedwater control valves to the main feedwater control valves. As the main feedwater control valves open and assume responsibility for maintaining steam generator water level, the startup feedwater control valves close. Position indication is available in the main control room for the main and startup feedwater control valves.

7.3.4.2 Hot Standby

During hot standby conditions, feedwater is supplied to the steam generators through the startup feedwater control valves using either one or both startup feedwater pumps drawing from the condensate storage tank, or a booster/main feedwater pump drawing from the deaerator storage tank. The startup feedwater control valves operate to maintain the steam generator levels, and minimum flow recirculation is automatically utilized as required to protect the feedwater pumps that are in use.

7.3.4.3 Shutdown

Operation during power descent and shutdown is generally the reverse of the operation during startup and power ascent. At low feedwater flows, control of feedwater is automatically transferred from the main feedwater control valves to the startup feedwater control valves. Feedwater is supplied by an operating booster/main feedwater pump drawing from the deaerator storage tank. Feedwater can continue to be supplied by a booster/main feedwater pump during the shutdown process; alternatively, the feedwater supply can be transferred to the startup feedwater pumps when flow demand has decreased to within their capacity. Feedwater is supplied for heat removal until the normal residual heat removal system is placed in service.

7.3.4.4 Automatic Starts

The startup feedwater pumps automatically start upon conditions resulting from insufficient main feedwater flow to the steam generators. An automatic pump start signal is generated by the plant control system (PLS). The signal is generated on low main feedwater flow coincident with low steam generator level. As a backup to this logic, it is also initiated on steam generator level alone, at a setpoint below the low steam generator level setpoint.

The rate of startup feedwater flow delivered to each steam generator is determined by the associated startup feedwater control circuit, which sends a signal to modulate the startup feedwater control valve (Figure 7.3-1) in response to steam generator water level control signals. The control valve is modulated as required to maintain the steam generator water level at the programmed setpoint.

Following a reactor trip that is not the result of a main feedwater system malfunction and in which the main feedwater system remains available, the startup feedwater pumps do not automatically start. In this case, the startup feedwater control valves take control and open to supply the steam generators using feedwater delivered from a booster/main feedwater pump through cross-connect piping. The startup feedwater pumps remain on standby as backups, and can be manually started if desired by the plant operators.

7.3.4.5 Emergency Operation

The startup feedwater system is not required to supply feedwater under accident conditions. However, the startup feedwater system is expected to be available as a non-safety-related first line of defense to provide feedwater to the steam generators. Coordinated operation of the startup feedwater system, if available, and the main steam supply system is employed to remove the primary-loop sensible heat and reactor decay heat. A minimum condensate storage tank volume of 325,000 gallons is required for defense-in-depth purposes.

**Table 7.3-1
NOMINAL COMPONENT DESIGN DATA – STARTUP FEEDWATER SYSTEM**

Startup Feedwater Pump	
Type	Multi-stage, centrifugal
Driver	Electric Motor
Quantity	2
Capacity	520 gpm @ 80°F
Head	3250 ft
Motor hp	800