PARTIALLY
SAFETY RELATED

GAI FLUID SYSTEM DIAGRAM D-302-081

SYSTEM DESIGN DESCRIPTION

MAIN FEEDWATER SYSTEM

PREPARED FOR
WESTINGHOUSE ELECTRIC CORPORATION
POWER SYSTEMS PROJECTS DIVISION
PITTSBURGH, PENNSYLVANIA

FOR

KRSKO NUCLEAR POWER PLANT
KRSKO, YUGOSLAVIA

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System Designation FW

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Users Comments

1.0 INTRODUCTION

This document presents a description of the Main Feedwater System for the Krsko Nuclear Power Plant. It includes functions, details of components, controls, instrumentation, operation modes, design, safety, and maintenance requirements. The system is shown on GAI System Diagram D-302-081 sheets 1 and 2.

1.1 SYSTEM FUNCTION

The Main Feedwater System is designed to take suction from the condensate system increasing fluid pressure, via the feedwater pumps, to overcome system resistance and steam generator pressure and supply the steam generators with adequate feedwater during all modes of power operation including transient conditions. It also provides one stage of feedwater heating.

1.2 CRITERIA REQUIREMENTS

Criteria, codes and standards that were followed in designing the Main Feedwater System are presented in a separate document, "Design Criteria and Function, Feedwater System (Nuclear & Non-Nuclear), SCF-103".

1.3 SUMMARY DESCRIPTION OF SYSTEM

NOTE: Throughout this system design description, various modes of plant operation are discussed with respect to plant power level. It should be noted that the points listed are approximate values which may be modified prior or subsequent to plant operation to optimize system stability and performance.

The Main Feedwater System consists of three 50 percent motor driven centrifugal feedwater pumps, two 50 percent feedwater heaters with

bypass, separate feedwater control stations and preheater bypass control stations for each steam generator, piping, valves and associated instrumentation.

The main feedwater system is designed to provide feedwater to the steam generator under all operating conditions from 0 to 100 percent power. For loads below approximately 20 percent power feedwater is delivered to the 6 inch auxiliary feedwater nozzle on the steam generator. Between 20 and 70 percent power, flow is delivered through the 16 inch main feedwater nozzle on the steam generator. Above 70 percent power; approximately 70 percent of the required flow is maintained to the 16" nozzle and the difference is supplied through the 6" auxiliary nozzle. The main feedwater control valves control flow in the 16" main feedwater line. Flow in the bypass line is controlled through the feedwater bypass control valves for plant loads from 0 to 20 percent or through the feedwater auxiliary control valve for plant loads above 70 percent.

Each of the three feedwater pumps take suction from a common manifold through locked open suction isolation valves, flow measuring elements and strainers, and discharge into a common header through tilting disc check valves and motor operated stop check valves. Separate minimum flow recirculation lines to the condenser are located between the pump discharge nozzles and the tilting disc check valve. These recirculation lines are fitted with an air operated diaphragm control valve, pressure breakdown orifices and a locked open isolation valve at the condenser.

A feedwater pump bypass line equipped with a check valve and a manual stop check valve connects the feedwater pump suction header (condensate side) with the feedwater pump discharge header. This line is used to fill the steam generator and to provide a supply of feedwater from the condensate system during start-up.

A single pipe connects the feedwater pump discharge header with feedwater heaters 1A and 1B. At the feedwater heaters the flow path is divided and passes through the two half capacity heaters. A common bypass permit either heater to be isolated while maintaining full flow to the steam generators.

After the feedwater heaters and/or bypass the feedwater is recombined into a single pipe to ensure an even temperature distribution of water being supplied to the steam generators. Above 20 percent load two separate main feedwater control stations regulate the flow of feedwater to their respective steam generators. Each main control station consists of a flow measuring element, an air operated diaphragm control valve, and associated manual isolation valves. As plant load is increased above 70 percent a similiar control is maintained on the feedwater control valves with the feedwater auxiliary control valves regulating bypass flow to maintain approximately 70 percent flow through the main 16 inch nozzle.

A three element feedwater regulating system controls the position of the main feedwater control valve. The three elements are steam flow, steam generator water level, and feedwater flow.

Each feedwater control station also contains a feedwater bypass control valve and a feedwater auxiliary control valve which are used during periods of operation below 20 percent load and above 70 percent load respectively. The feedwater bypass control valve is controlled remote manually or automatically in accordance with steam generator level demand when plant operation is below 20 percent. When plant operation is above 70 percent, the feedwater auxiliary control valve is automatically controlled to maintain steam generator flow through the 16 inch nozzle to approximately 70 percent. The feedwater auxiliary control valves can also be manually controlled.

Downstream from the main feedwater control valve, the feedwater passes through a check valve. At that point, the piping changes from non-safety to class 2 and remains class 2 to the 16 inch connection on the steam generator. Similiarly, downstream from the feedwater bypass control valve and the feedwater auxiliary control valve, flow passes through the feedwater preheater bypass valves at which point the piping changes from non-safety to safety class 2. It then remains class 2 to the 6 inch auxiliary nozzle on the steam generator.

During plant startup and low power operation, feedwater flow is directed through the 6 inch preheater bypass line. A very small warmup flow passes through the main feedwater line via the feedwater isolation bypass valve and the feedwater purge valve. This mode prevents cold water from being injected into the preheater section of the steam generator during low power operation and potential water hammer damage. When power reaches approximately 20 percent and the main feedwater line is sufficiently warmed, all flow is transferred to the 16 inch main feedwater line. Once flow exceeds 70 percent of full load flow, the preheater bypass line will flow that amount required to maintain approximately 70 percent flow through the main feedwater nozzle.

During reduction from full power, feedwater flow is automatically transferred from both steam generator nozzles at 70 percent load and then is manually transferred from the main nozzle to the auxiliary nozzle at approximately 20 percent power. At any time the main feedwater isolation valve is open and the FCV is opened, a low flow is maintained through the auxiliary feedwater nozzle via the feedwater tempering valve. This flow, taken upstream of the feedwater control valves, prevents thermal shock to the auxiliary nozzle if flow is suddenly transferred from the main nozzle or if auxiliary feedwater is required.

Auxiliary feedwater flow and chemical feed to the main feedwater system is accomplished through separate injection lines on each 6 inch preheater bypass line.

2.0 DETAILED DESCRIPTION OF SYSTEM

2.1 COMPONENTS

2.1.1 Steam Generator Feedwater Pumps, INOP FW 105 PMP-001, 002, 003

The pumps are single stage centrifugal type pumps with a vertically split casing, have top suction and discharge nozzles, and are driven through a speed increasing gear by an electric motor. Each pump has an independent seal injection system and lubricating oil system. The lubricating oil system is complete, including reservoir, and supplies the lubricating oil requirements of the pump, speed increasing gear, and motor.

Two out of the three 50 percent capacity feedwater pumps are required to meet the system demands for full load conditions. One pump can supply the demands of the system up to approximately 65 percent load.

a. Pump Design Data

Quantity	3	
Number of stages	1	
Capacity	10,302 GPM	(2339.6 m^3/hr)
TDH	2,108 ft.	(642.5 m)
Suction temp.	344° F	(173.3° C)
Speed, rpm	4825	
Required NPSH at design	110 ft.	(33.5 m)
Shutoff head	2520 ft.	(768 m)
Size of suction nozzle	18 in.	(457 mm)
Size of discharge nozzle	16 in.	(406 mm)

Minimum required flow	3740 GPM	(849.4 m^3/hr)
Seal water required	17 GPM	(3.9 m^3/hr)
Cooling water flow	72 GPM	(16.5 m^3/hr)

b. Gear Design Data

Speed ratio	3.2222
Service factor	1.7

c. Coupling Design Data

High speed (Type)	Sealed Gear
Low speed (Type)	Sealed Gear

d. Motor Design Data

Rated horsepower,	6000 hp	(4475 KW)
Voltage	6000 volts	
Speed,	1500 rpm	(1500 o/min)

2.1.2 High Pressure Feedwater Heaters, INO^2 FW 100 HEX-001, 002

Two 50 percent capacity feedwater heaters, arranged in parallel, provide the last stage of feedwater heating. The heaters are designed, fabricated, inspected, tested and stamped in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 in effect as of October 1, 1973 and in accordance with Westinghouse Standards for Closed Feedwater Heaters.

The feedwater heaters are horizontal two pass heaters with an integral drain cooling section. Extraction steam from the high pressure turbine issued as the heat source. The condensate from the high temperature reheating section of the moisture separator-reheater drains into these heaters. The heaters have baffles to protect against the flashing mixture. The drains from these heaters are cascaded down to the next lower heater.

Operating Data

a. Tube Side		
Design pressure	1800 psig	(126.6 kp/cm^2)
Design temp.	460° F	(237.8° C)
Feedwater Flow	4,282,225 lb/hr	(1,942.4 t/h)
Inlet temp.	347.2° F	(175.1° C)
Outlet temp.	434.5° F	(223.6° C)
b. Shell Side		
Design pressure	450 psig	(31.6 kp/cm^2)
Design temp.	460°	(237.8° C)
Steam flow	444,693 lb/hr	(201.7 t/h)
Steam inlet temp.	439.5	(226.4° C)
Reheater drain flow	184,622 lb/hr	(82.8 t/h)
Outlet temp.	357.2° F	(180.7° C)
Drain cooler (approach)	10° F	(5.55° C)

2.1.3 Piping and Valves

Piping and valves designated as non-nuclear safety class are designed, fabricated and erected in accordance with the ANSI B31.1-1973 and B16.5-1968 standards. The piping and valves designated as nuclear safety class are designed, fabricated and erected in accordance with ASME Boiler and Pressure Vessel Code Section III, Class 2, 1971 Edition, including the Winter 1972 Addenda. The Safety Class boundaries are indicated on the System Diagram.

2.2 INSTRUMENTS, CONTROLS ALARMS AND PROTECTIVE DEVICES

Instruments, controls, alarms and protective equipment are furnished to ensure that the various systems and components function properly and safely.

2.2.1 Instruments (Reference GAI Instrument List)

a. Pressure Indicators:

Direct reading pressure indicators are provided on the feed pump suction (PI 3621, PI 3631, PI 3642), discharge (PI 3616, PI 3627, PI 3638), and on the #1A & 1B feedwater heater outlets (PI 3648, PI 3652). Differential pressure indicators are located on the pump suction strainers (DPI 3624, DPI 3234, DPI 3645) and across feedwater heaters 1-A and 1-B (DPI-3610, -3612).

b. Pressure Transmitters:

Pressure transmitters mounted on the discharge lines of the main feedwater pumps (PT 3617, PT 3628, PT 3639) provide for indication of main feed pump discharge pressure on the local feedwater control panel (PI 3617B, PI 3628B, PI 3639B) and transmit signals to main control room indicators (PI 3617A, PI 3628A & PI 3639A). A pressure transmitter (PT 3656) is also located on the main feedwater heater downstream of heater #1 for computer input and control room indication (PI 3656). A differential pressure transmitter (DPT 3659) is located across the suction and discharge piping of the feedwater pumps for computer input on pump performance.

c. Temperature Indicators:

Direct reading temperature indicators are installed on the inlet side of the feedwater pumps (TI 3625, TI 3635, TI 3646), and on the common header upstream and downstream of the #1A & 1B heaters (TI 3614, TI 3607).

d. Temperature Elements and Temperature Transmitter:

Temperature elements are provided on the heater #1 inlet (TE 3613) and outlet (TE-3611, -3609) piping and the steam generator inlet piping (TE-3622A, -3622B) of the feedwater system for input to plant computer for secondary plant performance calculations. Temperature elements are provided for recording on the Main Control Board (TR 3600) of feed pump suction temperature (TE-3618, -3629, -3640), heater inlet (TE-3615) and outlet (TE-3606) temperature and feedwater temperature entering the steam generators (TE-3600, -3603).

Temperature elements are provided for utilization with the feedwater preheater bypass logic to limit main steam generator flow until the main line has been purged of all cold water. Six elements are provided for steam generator loop 1, four elements for steam generator Loop 2 (Loop 1; TE 3678, TE 3679, TE 3680, TE 3681, TE 3683, TE 3684; Loop 2; TE 3682, TE 3685, TE 3692, TE 3693). All are inputed to the plant temperature monitoring system (TR 7099) for logging. In addition, one indicator is provided per loop for display of water temperature entering the steam generators (TI 3678, TI 3682) on the Main Control Board.

e. Test Wells and Connections:

Temperature test wells are conveniently located near temperature sensing devices and temperature indicators to check their response.

f. Pressure Test Connections:

Test connections (with valves) are conveniently located to check system pressures.

g. Pressure Switches:

The following pressure switches have been located in the system:

1. Feed Pump Suction Header Low Pressure Switch (PS-3657) The pressure switch is set at approximately 235 psig. The switch is intended to monitor feed pump suction header pressure and provide an input signal for the activation of valve FCV-3993 (Fluid System Diagram D-302-091). This valve opens the bypass line around the low pressure heaters allowing the condensate pumps to runout to approximately 9700 gpm each thus maintaining 97 percent of full feed flow during a load rejection.

2. Feed Pump Inlet Piping Low Suction Pressure Switch (PS 3619A, 3619B, 3630, 3641)

   The pressure switches are set at approximately 155 psig to prevent the feedwater pumps from cavitating either by shutting down an operating pump or preventing the start of an idle pump.

3. Feedwater Preheater Bypass Valve Actuator Pressure Switches (PS 3694A and B, PS 3695A, B)

   The feedwater preheater bypass valves are provided with pressure switches on the valve actuator hydraulic and nitrogen lines. The hydraulic pressure switches (PS 3694A, PS 3695A) cycle the hydraulic pump to maintain pressure in the valve actuator to keep the valve open. The nitrogen pressure switches provide an alarm to the Main Control Board prior to the nitrogen pressure available at the accumulator becoming insufficient for valve closure.

h. Flow Elements, Transmitters, Indicators and Switches:

1. Flow elements (FE 3623, 3633, 3644) and the associated tansmitters are provided on the suction of each main feedwater pump for minimum flow monitoring and to provide a modulation signal to the main feed pump recirculation valves FCV 3623, 3633 and 3644. These flow elements also provide indication of each feed pump's flow on the local feedwater control panel (FI 3623, FI 3633, FI 3644). A flow switch (FS 3623, FS 3633, FS 3644) is also provided on each pump suction providing a control room alarm when a feed pump's flow drops below 3800 gpm.

   Pressure switches (FS 3623A, FS 3623B, FS 3633A, FS 3644A) with adjustable differential also monitor feedwater pump flow to interface with the control of the feedwater pump recirculation valves to ensure a minimum flow through these valves to prevent flashing.

2. Flow elements (FE 510, 520) and the associated transmitters (FT 510, FT 520) are provided by WPWRSD on the 16 inch main feedwater line to each steam generator to provide signals for computer input and measurement of steam flow/feedwater flow mismatch for modulation of main feed flow control valves FCV 551, 552.

   Three additional narrow range flow transmitters are provided for each steam generator loop (Loop 1; FT 3676, FT 3686, FT 3687; Loop 2: FT 3677, FT 3688, FT 3689) to interface with feedwater preheater bypass logic. One narrow range flow indicator is provided on the Main Control Board per loop (FI 3676, FI 3677).

3. Flow elements (FE 511, FE 521) and their associated transmitters (FT 511, FT 521) are provided on the

feedwater preheater bypass line to provide signals for computer input and for summation with the main feedwater line flow signals for main and auxiliary nozzle control valve controls. Flow indicators FI 511 and FI 521 are provided on the Main Control Board. These indicators read total steam generator flow; i.e. the sum of the main feedwater flow transmitters (FT 510 & FT 520) and the preheater bypass flow transmitters. (FT 511 & FT 521)

4. Flow elements (FE 3670, FE 3671) and their respective transmitters (FT 3670, FT 3671) have been placed in the feedwater bypass tempering line to provide indication on the Main Control Board of tempering flow (FI 3670, FT 3671) and alarm if flow becomes high or low.

5. Flow elements (FE 3672, FE 3674) are utilized to monitor feedwater isolation valve bypass flow. Flow transmitters (FT 3672, FT 3673, FT 3674, FT 3675) provide interlocks to close the feedwater isolation bypass valves and the feedwater purge valves alarm on hi bypass flow. Additionally, they provide inputs to the preheater bypass logic to determine when main flow may be permitted through the main line rather than the preheater bypass line. An output is provided for indication on the Main Control Board (FI 3672, FI 3674).

i. Steam Generator Instrumentation:

One wide range (LT 501, LT 502) and four narrow range (LT 517, 518, 519, 527, 528, 529, 531, 532) level transmitters are provided on each steam generator by WPWRSD for inputs to the NSSS Process Control System. Three of the transmitters on each loop interface with the plant protection system for two out of three low-low steam generator level reactor trip. The remaining transmitter on each steam generator (LT 531, LT 532) is used for steam generator level control.

j. Main Feed Pump Package Instrumentation:

The following instrumentation is provided to monitor the pump operation:

1. Feedwater Lube Oil Pressure Instrumentation:

Each pair of lube oil pumps incorporates 3 sets of vendor supplied pressure switches. Two pressure switches per pump set (Pump 1 switches PS 3663 A&D; Pump 2 switches PS 3664 A&D and Pump 3 switches PS 3665 A&D) provide for low lube oil pressure alarms on the local feedwater control panel. Two additional switches (Pump 1 PS 3663 B&E, Pump 2 PS 3664 B&E, and Pump 3 PS 3665 B&E) provide an interlock to start the backup lube oil pump on Lo-Lo lube oil pressure. Finally, pressure switches (Pump 1 PS 3663 C&F; Pump 2 PS 3664 C&F, and Pump 3 PS 3665 C&F) alarm and trip their respective main feedwater pump on Lo-Lo-Lo feedwater lube oil pressure.

2. Bearing Temperature Detectors:

Monitoring is provided for bearing temperatures on the feedwater pumps by means of the plant temperature monitoring system.

3. Vibration Detectors:

Vibration Detectors are provided on each pump with remote process equipment located on the Misc. Control Panel in the main control room to monitor and alarm high pump vibrations.

4. Casing Temperature Detectors:

Monitoring is provided on the plant temperature monitoring system. Casing thermocouples are provided to allow monitoring of pump casing metal temperatures during pump heatup as required by the pump instruction manual.

2.2.2 Controls

a. Feedwater Preheater Bypass Control Logic:

The preheater bypass control logic consitutes a subsystem within the overall feedwater system. It encompases control of the Main feedwater control valve (FCV), the bypass control valve (FBCV), the feedwater auxiliary control valve (FACV), the Main Feedwater isolation valve (FIV), the feedwater preheater bypass valve (FPBV), the feedwater isolation bypass valve (FIBV), the feedwater bypass tempering valve (FBTV) and the feedwater purge valve (FPV). Basically, the system functions to divert or split flow between the main and auxiliary steam generator nozzles for various operating plant load conditions.

From 0 to 20 percent plant operation, feedwater flow is to enter the steam generator through the auxiliary nozzle. Flow passes through the FBCV and the FPBV for these conditions. FBTV, FACV, FCV and FIV are closed. As feedwater temperature increases, it is necessary to purge the main feedwater line of all cold water prior to transferring feedwater flow to the main nozzle. In order to accomplish this, a small purge flow is established around the FIV by opening the FIBV and the FPV. This purging flow is maintained until a volume of water equal to two times the piping volume between the FCV and the steam generator has passed and the temperature of all piping low points which might form pockets of cold water has been warmed to a predetermined value for a given period of time. Once

these conditions are met, the FIV opens and feedwater flow to the steam generator may be transferred from the auxiliary to the main steam generator nozzle. This is accomplished by placing the FBCV in the manual control mode while switching the FCV from manual closed to automatic. The FBCV can then be dialed closed while the FCV responds to steam generator level requirements. Once the FCV begins to open, the FIBV and the FPV closes.

Once the FIV and the FCV opens and the FBCV is closed, no flow will be present to the auxiliary steam generator nozzle. In order to protect this nozzle from thermal shock which would take place if flow were transferred from the main to the auxiliary nozzle or if auxiliary feedwater is required; a small tempering flow is supplied to the auxiliary nozzle via FBTV and FPBV. This tempering flow remains as long as FIV and the FCV remain open.

As plant load increases to approximately 70 percent; steam generator flow is required to be split between the main and auxiliary feedwater nozzle connections. (While for purposes of discussion, 70 percent is used for the switchover point; the actual point will be somewhat lower to permit smoother transfer and better feedwater auxiliary flow controllability by stepping the FACV to the 5 or 10 percent total flow position. With the setpoint less than 70 percent, system operation will require an ultimate 70/30 main vs auxiliary flow split for 100% flow.) System operation will now be such that as total steam generator flow requirements increase; they will be met by the FACV through the auxiliary nozzle, there by attempting to maintain approximately 70 percent through the main nozzle. Flow through the main nozzle is monitored by the plant annunciator to alert the operator if flows greater than 70 percent are achieved and maintained for a period of time.

The reverse procedure is followed on the way down in power.

The system also generates a variety of feedwater isolation signals in addition to the safeguard feedwater isolation signal. The safeguard feedwater isolation signal is generated by the NSSS reactor protection logic and actuates on safety injection or steam generator high-high level. Two additional feedwater isolation signals are generated and are identified as control and loop feedwater isolation.

Loop feedwater isolation is generated by a low steam generator level and acts to close the FIV, FIBV, FPV, FCV, & FBTV in the affected steam generator loop.

Control feedwater isolation is generated by a low pressure in one of the steam generators and acts to close the FIV, FCV, FPBV, FBTV, FIBV and FPV as well as trip the Main feedwater pumps in both steam generator loops.

1. Main Feedwater Control Valves (FCV-551 and FCV-552):

   At a plant load above approximately 20 percent, the steam generator water level is controlled by feedwater control valves FCV-551 and FCV-552. In steady state, the feedwater control valves, one for each steam generator, are used to maintain water levels, and also compensate for different pressure drops through the steam generators, feedwater and steam pipes, caused by the difference in piping layouts.

   Feedwater flow is controlled automatically above 20 percent load by a three element controller using steam generator water level (LT-531, -532), steam flow (FT-512, -522, -513, -523) and feedwater flow (FT-510, -520, -511, -521) to control the feedwater regulating valve (FCV-551

and FCV-552) to each steam generator. (See Westinghouse Drawing 7250D72 Sheets 22, 23 & 24).

Signals from the control systems will provide outputs to the main control valves thru electric to pneumatic converters. The Main Feedwater control valves will be supplied with 4 solenoid valves in the air signal line to ensure that the valves will close on receipt of a feedwater isolation signal or a control or loop feedwater isolation signal generated by the feedwater preheater bypass logic. Two solenoid valves are safety related train A; the other two solenoid valves are safety related train B.

The main feedwater control valves have a stroke time of 20 seconds opening or closing over a pressure range of 0-1600 psig (0-112.5 kp/cm^2) under normal feedwater control.

The main feedwater control valves are provided with handwheels for local emergency operation.

The main feedwater control valves and the associated safeguards control system are designed to Safety Class 3 requirements.

2. Feedwater Bypass Control Valves (FBCV) FCV-3602, FCV-3605:

The feedwater bypass control valves are sized for 20 percent flow and are normally controlled by steam generator level (See Westinghouse Dwg. 7250D72 Sheets 23 & 24). Signals from the control system will provide outputs to the bypass control valves thru electric to pneumatic convertors. The Bypass Control Valves are supplied with 2 solenoid valves in the air signal line to

ensure that the valves close within 5 seconds on receipt of a feedwater isolation signal. The Feedwater Bypass Control Valves are complete with the necessary circuitry for remote manual control from the Main Control Board.

Valve position indicating lights are provided at the local feed pump control panel and in the main control room.

The bypass valves have handwheels for local emergency control.

The bypass control valves have a stroke time of 20 seconds opening or closing over the range of 0-1600 psig (0-112.5 kp/cm^2) under normal feedwater control.

The feedwater bypass control valves and the associated safeguards control system are designed to Safety Class 2 requirements.

3. Feedwater Auxiliary Control Valves (FACV) FCV 551B, FCV 552B:

The feedwater auxiliary control valves are sized for 30 percent flow and are normally operated between 70 and 100 percent plant load conditions. Valve control is established to maintain approximately 70 percent flow through the main nozzle with the balance being passed through the feedwater auxiliary control valve. Signals from the control system will provide outputs to the bypass control valves through electric to pneumatic converters. The feedwater auxiliary control valves are supplied with two solenoids in the air line to ensure that the valves close within 5 seconds on receipt of a feedwater isolation signal. The feedwater auxiliary control valves are complete with the necessary circuitry for remote manual control from the Main Control Room.

Valve position indicating lights are provided in the main control room.

The auxiliary control valves are provided with handwheels for local emergency control.

The feedwater auxiliary control valves and the associated safeguards control system are designed to Safety Class 3 requirements.

4. Feedwater Isolation Valves (FIV 21136, 21137):

The feedwater isolation valves and the feedwater preheater bypass valve, in conjunction with the main feedwater control valves, the feedwater bypass control valves, the feedwater auxiliary control valve, the feedwater purge valve, and the feedwater bypass tempering valve provide redundant isolation of main feedwater flow to the steam generator during emergency conditions.

As steam generator flow is increased from 0 to approximately 20 percent flow, the supply to the generator is directed through the upper 6 inch nozzle and the feedwater isolation valve is held closed.

During this period a small flow is bypassed around the main isolation valve to warm the lower 16 inch main line and cool the generator inlet nozzle. Measurements of the isolation bypass flow and main line temperatures downstream of the main isolation valve are monitored until they reach a minimum temperature for a given amount of time and a minimum bypass flow. Once these minimum flows are sustained for a time equal to approximately 2 purge volumes (one purge volume is equal to the time it takes the water at the feedwater isolation bypass flow rate to

travel from the feedwater control valve to the main steam generator nozzle) and flow is increased above approximately 20 percent, the feedwater isolation valve is permitted to open. Operation on the way down in steam generator Feedwater flow is similar with transfer to the tempering line occuring at approximately 20 percent flow.

The feedwater preheater tempering valve follows the operation of the main isolation valve.

Each isolation valve closes on receipt of either a safeguards, control, or loop isolation signal and has the ability to be manually closed from the main control room.

Status and monitor lights are provided for the valve on the main control board and an alarm is sounded whenever the preheater timer logic is not engaged.

The feedwater isolation valves employ an hydraulic control scheme to actuate the valves. An air pump provides pressurization for an oil system which is used to open and close the valve against a nitrogen gas "spring". Redundant alarms are provided on the Main Control Board for low nitrogen pressure with local alarms on the Feedwater Control panel for low hydraulic pressure and low oil reservoir level. The local feedwater panel annunciator rings back to the Main Control Room whenever any point on the local system is in alarm.

5. Feedwater Preheater Bypass Valves (FPBV) 21212, 21214:

The preheater bypass valves are open during all normal plant operating conditions.

Each valve will close within the 5 second requirement on receipt of a safeguards, control, or loop isolation signal.

The feedwater preheater bypass valves actuators are similar to those on the feedwater isolation valves except that the valves open hydraulically rather than on air. A nitrogen precharge system furnishes the driving force necessary to the close valves. Two solenoids coupled for parallel operation (one train A, the other train B) permit injection of the nitrogen from an accumulator tank to the valve piston to drive the valve closed. Valve opening is accomplished hydraulically by means of de-energizing two additional safety related solenoids tc force hydraulic pressure to work against the nitrogen blanket and open the valve. Energizing either set of hydraulic/nitrogen solenoids will close the valve.

Status and monitor lights are provided on the Main Control Board for the preheater bypass valves.

6. Feedwater Bypass Tempering Valves (FBTV) HCV 3670, HCV 3671:

The feedwater bypass tempering valves follow the main feedwater isolation and feedwater control valves such that whenever the isolation and feedwater control valves are open, FBTV opens to cool the upper steam generator nozzle since the FBCV and the FACV will be closed.

In addition, each valve receives a safeguard feedwater isolation signal and has valve status displayed in status light boxes on the main control board.

7. Feedwater Purge Valves (FPV) 21276, 21277:

The feedwater purge valves are open only during plant operation between 0 and 20 percent to establish a flow through the FIBV for purging of the main feedwater line. These valves directly follow the FIBV's and are provided with status indication in the Main Control Room.

8. Feedwater Isolation Bypass Valves (FIBV) FCV 3672 & 3674:

The feedwater isolation bypass valve in each l s opened manually from the main control board pro ded the feedwater control valve is not opened and no f edwater isolation signals are present. An additional interlock closes the isolation bypass valve in the event flow through this line exceeds a maximum set valve. Once opened the valve remains opened until aproximately the 20 percent flow at which point flow is manually transferred to the main flow path through the feedwater isolation valve. When the feedwater control valve begins to open, the isolation bypass valve closes. The operator has the capability of manually closing the valve from the main control board. Status and monitor lights are provided for the valve on the main control board with annunciator whenever the FIBV logic is not engaged.

b. Main Feedwater Recirculation Valves:

The feedwater pumps recirculation valves control system is comprised of FE-3623 and FCV-3623 for pump C, FE-3633 and FCV-3633 for pump B, and FE-3644 and FCV-3644 for pump A.

Feed pump recirculation flow is returned to the condenser.

The respective flow elements and recirculation flow control valves function to accomplish the following:

1. Maintain a minimum pump flow of 3740 gpm.

2. Maintain a minimum recirculation flow of 1450 gpm to prevent a flashing fluid condition between the recirculation control valve and the recirculation orifice during the recirculation mode.

3. Limit recirculation flow during plant operation by modulating the recirculation valve position and recirculation flow from a maximum of 3740 gpm to a minimum of 1450 gpm. The feedwater recirculation valve controller attempts to regulate total flow at 3850 gpm until demand on the recirculation valve goes below the 1450 gpm minimum flow limit. At this point, the valve is held at the minimum position until generator flow is above the minimum pump flow requirement. The recirculation valve then reopens to the minimum position and holds until generator flow is sufficiently reduced to warrent the opening of the recirculation valve above the minimum position in an attempt to maintain the 3850 controlled setpoint.

The recirculation flow control valves modulate from approximately 100 percent open at 3740 gpm recirculation flow to approximately 30 percent at a recirculation flow of 1450 gpm. Additional interlocks hold the recirculation valve closed whenever the feedwater pumps are not running and also open the recirculation valve to the 100 percent open position for 10 seconds after the pumps are started. Open/close status is provided on the main control board.

c. Feedwater Pumps and Motor Drives:

These pumps are supplied with two electrically-driven oil pumps which are controlled from the Main Control Board in conjunction with the local Feed Pump Panel.

The starting permissives are as follows:

1. One oil pump running.
2. Suction valve fully open.
3. Suction pressure within limits (greater than approximately 155 psig).
4. Oil pressure is within limits.
5. A Safety injection signal does not exist.
6. A High-high steam generator level does not exist.
7. A control feedwater isolation signal does not exist.

While 3 feedwater pumps are provided, only two (FW105PMP001 and FW105PMP002) are operated at any given time with one (FW105PMP003) established as a standby unit. In order to provide maximum reliability in interfacing with the auxiliary feedwater system, the main feedwater pump control circuitry has been made train A associated for all three pumps. The power feeds to the number 1&2 pumps come from the two individual non 1E plant distribution buses. The third pump has the ability to be automatically aligned to either. Two control switches are provided for operating pump FW105PMP003, one for each switchgear control.

Main feedwater pumps FW105PMP001 and FW105PMP002 are provided with an interlock to start the standby pump. When either FW105PMP001 or FW105PMP002 is tripped, FW105PMP103 will automatically start and will automatically be aligned to the same bus as the tripped pump (if in the "standby" position). A MCB panel alarm annunciates the pump trip condition.

A trip of all main feedwater pumps will cause the auxiliary feedwater pumps to automatically start provided all of the main feedwater control switches are not in the "pull to lock" position.

Indication is provided on the main control board for pump status.

Tripping of feedwater pumps will occur on:

1. Motor overload.
2. Suction valve not fully open.
3. Bearing oil pressure low.
4. Train "A" Safety Injection, Steam Generator Level High, or control feedwater isolation.
5. Train "B" control feedwater isolation.
6. Under voltage.
7. Low suction pressure.
8. Pump manual control switch placed in stop position.
9. Lube oil pumps not running.

d. Feedwater Pump Discharge Valves 21177, 21178, & 21179:

These valves are controlled from the Main Control Board and are interlocked with the feedwater pumps. The valves are manually opened from the MCB control switch during plant startup (see section 3.1) and remain open until they are either manually closed or automatically close if its associated feedwater pump trips or if all three feedwater pumps have been manually stopped.

Indication is provided on the Main Control Board for discharge valve status.

e. Feedwater Lube Oil Pumps:

Two electrically driven lube oil pumps are provided for each of the three feedwater pumps. These pumps are controlled jointly from the Main Control Board and a locally mounted selector switch.

The local switch is used to select one of the two oil pumps as the main pump while the other remains on standby. The selected pump is then started from the Main Control Board. An alarm is provided for lo lube oil pressure and an interlock is sent to the backup pump to start if pressure drops to a lo-lo level. If pressure continues to drop, the feedwater pump is tripped.

The lube oil pumps are powered similiarly to the Main Feedwater pumps, thus requiring four selector switches for the three sets of pumps.

Indication is provided on the Main Control Board for lube oil pumps status.

2.2.3 Alarms

Alarms are provided for the following on the main control board or on the local feed pump control panel.

a. Lo feedwater tempering flow.
b. Hi feedwater tempering flow.
c. Hi-Hi feedwater isolation valve bypass flow.
d. Main feedwater pump control switch in pull to lock or breaker disconnected.
e. Main feedwater pump trip.
f. Lo condensate flow to the main feedwater pumps.
g. Feedwater isolation valve CLOSE signal generated.
h. Feedwater preheater flow HIGH.

i. Feedwater isolation bypass valve CLOSE signal generated.
j. Hi feedwater pump vibration.
k. Feedwater pump motor and bearing hi temperature.
l. Feedwate pump motor overload in progress or trip.
m. Feedwater lube oil pump Lo pressure.
n. Feedwater lube oil pump Lo-Lo-Lo pressure.
o. Feedwater lube oil pump normal pump tripped.
p. Feedwater isolation valve actuator pressure LO/HI.
q. Feedwater preheater bypass valve actuator pressure LO.

3.0 MODES OF OPERATION

3.1 STARTUP

The operator action required will be determined by the water inventory in the steam generator. The water level may be high, low or normal depending on the duration and purpose of the shut down.

In the case of high level, the normal water level can be reestablished by draining the steam generator through the blowdown system with the feedwater system shut down.

In the event that the steam generator has a very low water condition or requires complete filling, the water should be added using a condensate transfer pump if the steam generator is not pressurized or a condensate pump if the steam generator is at a low pressure. Although the capacity of a single condensate pump is high for this application the low head of the pump, as compared to the auxiliary feedwater pumps, makes it more desirable. Using a condensate pump minimizes wear on the auxiliary feedwater control valves by reducing the pressure drop across them.

To initially fill the steam generator with a condensate transfer pump the flow path should be set up by-passing the feedwater pumps, through both feedwater heaters 1A and 1B, throught the feedwater

bypass control valves and through the feedwater preheater bypass line into the steam generators through the auxiliary feedwater nozzle.

During the initial stages of plant warm-up the condensate pumps will be operated only when required to feed water to the steam generator. This will occur on an as needed basis since the swell of the water due to the thermal expansion will tend to maintain the water level in the steam generator. As the unit approaches time for turbine roll the condensate pumps will be placed into continuous operation to service other pieces of equipment. Prior to establishing a vacuum in the condenser the condensate pumps will be taking suction from water stored in the condenser. This water will be replaced by gravity with water from the condensate storage tanks.

After the steam generator has reached a temperature of approximately 400° F (204.44° C) plant warm-up and turbine roll may begin. At this time feedwater is admitted to the steam generator on a continuous basis rather than intermittently to prevent temperature transients. The feedwater is controlled by the feedwater by-pass control valve which is operated manually from the control room or automatically in accordance with steam generator level demand.

As the steam generator approaches 450 psig (31.64 kp/cm^2) the available head of the condensate system will be exceeded. At this time the main feedwater pumps are placed in service in the following manner:

1. Select one of the two lube oil pumps associated with each feedwater pump as the main lube oil pump at the local control panel. For feedwater pump FW105PMP003 select one lube oil pump on one bus.

2. Start one lube oil pump to each feedwater pump (001, 002, 003).

3. Assure that feedwater pump discharge valves 21177, 21178, and 21179 are closed, and feedwater pump suction valves 21153, 21154 and 21155 are open.

4. After allowing sufficient time for lube oil pressure to develop, start feedwater pump FW105PMP001 or FW105PMP002 (whichever has been chosen to carry low plant load) against the closed discharge valve, with recirculation flow back to the condenser.

5. Place both control switches for feedwater pump FW105PMP003 in the standby mode.

6. Open the feedwater pump discharge valve for the running pump and for pump FW105PMP003. The feedwater control valves should be closed when transferring to the feedwater pumps to avoid a pressure surge entering the steam generator.

7. The feedwater pumps are now aligned for low load operation with feedwater pump FW105PMP003 ready for automatic start if the operating pump trips.

When no-load temperatures are established, the turbine generator speed can be increased from 600 rpm (600 o/min) to 1500 rpm (1500 o/min). The feedwater bypass control valves will be manually controlled from the control room to maintain steam generator water levels. After verification that level is being controlled by the individual bypass control valves, the feedwater system control may be placed in the automatic mode.

Nuclear power may be adjusted to between 2 and 4 percent while increasing turbine speed with the steam dump system in the pressure control mode and set for no load pressure. Excess steam will be dumped to the condenser at a progressively lower rate as more steam is being used by the main turbine to automatically hold set

pressure. Prior to synchronization, the power level can be raised to about 10 percent in anticipation of an immediate turbine loading of 5 percent following going on the grid. The steam dump valves would initially open more fully in response to the pressure increase caused by the power unbalance and would then close down again after the turbine picks up the 5 percent load and the steam pressure drops. Nuclear power and turbine load are manually controlled for further loading to 15 percent and with adequate power matching, the steam dump valves will close and remain closed. At approximately 20 percent power flow control is transferred to the main feedwater control valves. Further increases in flow are automatically controlled.

During plant heatup and low power operation feedwater flow is delivered to the steam generator through the feedwater preheater bypass piping and auxiliary feedwater nozzle. A small warmup flow supplied through the feedwater purge valve is allowed to bypass the main feedwater isolation valve and heat the main feedwater piping. As the plant approaches 20 percent power and the main feedline has been purged, and temperature sensors in the main feedwater piping and timers confirm that no cold water exists in those lines; the main feedwater isolation valves are opened. Flow may then be manually transferred to the main nozzle. The feedwater bypass control valve controller is then placed into manual and the main feedwater control valve is placed in automatic. The bypass valve may then be dialed closed and the main feedwater control valve will open to maintain steam generator level. As the feedwater control valves begins to open, the feedwater isolation bypass valves and feedwater purge valves close. The feedwater bypass valves remain closed at all power levels above the setpoint.

Whenever the main feedwater isolation and feedwater control valves are open a small tempering flow is maintained through the auxiliary feedwater nozzle on the steam generator. This flow keeps the nozzle at feedwater temperature to prevent thermal shock if the main

feedwater flow is suddenly switched to the auxiliary nozzle. Tempering flow originates upstream of the feedwater control valves. This provides sufficient pressure differential to ensure that tempering flow exists at all power levels.

As the plant is loaded above 70 percent, flow is now required to be split between the main and auxiliary steam generator nozzles. This is accomplished with the feedwater auxiliary control valve which will automatically modulate to compensate for any increases which are sensed by the 16 inch main feedline instrumentation. Valve position is the established by means of a preprogramed function generator which characterizes for valve trim, feedwater temperature, system pressures, etc.

One feedwater pump will permit operation of the plant up to approximately 65 percent load. Above this loading feedwater pumps FW105PMP001 and FW105PMP002 are operated, with feedwater pump FW105PMP003 in standby ready for automatic starting if feedwater pumps 1 or 2 trips. The second feedwater pump is placed into operation as follows:

1. Assure one lube oil pump is running and the feedwater pump suction valve is open.

2. Start the feedwater pump with the control switch on the Main Control Board.

3. Open the feedwater pump discharge valve.

3.2 HOT STARTUP

Hot startup begins with the steam generator at no-load pressure and temperature. The condensate pumps are in operation, a vacuum is established in the main condenser, and the steam piping and turbine are warmed up. One main feed pump is placed in operation and pump

FW105PMP003 placed on standby service. The system is lined up the same as for a cold start except that the feedwater pump by-pass line is not used.

3.3 NORMAL OPERATION

The normal operation of the system is fully automatic with all pump isolation and feedwater heater valves fully open and the by-pass valves around the heaters closed. The feedwater control valves will be automatically modulated in response to the three element controller. The preheater bypass sytem will automatically split flow between the steam generator nozzles in response to their controls for operation between 20 and 100 percent plant operation. However, transfer between the auxiliary and main nozzle at approximately 20 percent plant operation does require manual operation.

The system is capable of supplying adequate feedwater to the steam generators for 5 percent per minute load changes and a 10 percent step change.

3.4 HOT SHUTDOWN

Hot shutdown conditions are subcritical at zero power and no-load pressure and temperature. A small amount of steam is relieved automatically to maintain this steam pressure by operation of the condenser steam dump system in the pressure control mode. The turbine shafts are sealed and condenser vacuum is maintained. A small amount of feedwater flow is delivered to the auxiliary feedwater nozzle by the main feedwater system to maintain steam generator level. One feedwater pump (FW105PMP001 or FW105PMP002), running on recirculation, is used. If this condition is to be maintained for an extended period an alternate means of continuous feedwater supply is available using the motor driven auxiliary feedwater pumps.

3.5 COLD SHUTDOWN

Continuous feedwater delivery is required when bringing the plant to a cold shutdown in order to maintain steam generator inventories while heat is being removed. Decay heat and sensible heat from the plant is removed by steam release via the steam dump system to the condenser. In the usual case, the rate of feedwater flow during cooldown drops below 3 percent of full flow within one hour after reactor shutdown. After this point, the auxiliary feedwater system may be used to supply the feedwater makeup to the steam generators and the main feedwater system shutdown. Steam pressure is reduced to 450 psia (31.64 kp/cm^2) in approximately two hours at which time the feedwater flow of approximately 2-1/2 percent can be supplied by the condenser pumps, bypassing the feedwater pumps. After approximately four hours, the steam pressure is 100 psia (7.04 kp/cm^2). At this point steam dump is discontinued and operation of the residual heat removal system is initiated.

3.6 SPECIAL OR INFREQUENT OPERATION

The system is designed to operate with one of the two heaters out of service by using the heater bypass. The piping is fitted with drain lines, vents and bypasses around the isolation valves to safely take a heater in or out of service.

The procedures for removing a heater from service varies depending on the main unit loading and the purpose for which the heater is to be taken out of service. If the main unit load is less than 70 percent the extraction steam isolation valve and the isolation valves of the heater to be taken out of service need only be closed. If the unit is to operate above 70 percent load the heater bypass valve will have to be opened and care taken so that the turbine loading does not exceed the maximum guaranteed rating.

The pump suction strainer is fitted with a 14 mesh 16 gauge wire basket designed for a normal operating pressure drop of 4 psi. If the pressure drop exceeds 8 psi, the strainer should be removed from service and cleaned.

The feedwater isolation valves have hydraulic actuators which are powered by a pneumatic pump. Whenever these valves are closed instrument air is continually exhausted through the pump. To reduce air consumption the air supply to the valves should be manually isolated whenever the valves are to remain closed for long time periods.

When a feedwater pump, or appurtenances thereof, require maintenance while above 65% load, no automatic start of a feedwater pump exists. The associated feedwater pump discharge and suction valve may be closed and the lube oil pumps removed from service.

After feedwater pump maintenance is complete, one lube oil pump must be started and the feedwater pump discharge valve must be opened. If feedwater pump FW105PMP003 was being operated to maintain load above 65%, the pump being brought back from maintenance should be returned to service and feedwater pump FW105PMP003 should be returned to the standby mode.

3.7 EMERGENCY

If power to all feedwater pumps is lost, a low-low steam generator level signal will occur. The reactor and turbine will immediately trip when this signal is generated.

Loss of control of feedwater flow will cause a feed pump trip at high steam generator level and a turbine/reactor trip at high-high steam generator levels.

4.0 SAFETY PRECAUTIONS

4.1 HAZARDS

No special hazards are considered to exist in the feedwater system beyond those normally observed around high temperature and high pressure piping.

4.2 PRECAUTIONS

Startup, normal operation, and shutdown must be in accordance with instructions received fro manufacturers furnishing equipment for this system.

One bearing lube oil pump for each feedwater pump must be operating during normal plant operation to prevent possible damage to feedwater pump bearings.

Failure to manually open the discharge valve and start one lube oil pump of pump FW105PMP003 per the sequence outlined in section 3.1 will cause the automatic start feature to be defeated.

After a safety injection signal has been initiated, the control switches for pump FW105PMP003 should be placed in "pull to lock" and the sequence outlined in section 3.1 followed to re-establish feedwater flow. Failure to do so will result in an auto start of FW105PMP003 immediately after the Safety Injection signal is reset.

Operation of the plant for extended periods of time near or at the approximate 70 percent switchover point should be avoided to preclude cycling of the ECV and FACV.