OPERATING PROCEDURES

FOR

COUNTER-FLOW PREHEAT STEAM GENERATOR

MAIN FEEDWATER BYPASS SYSTEM

WITH

CONCURRENT FEEDWATER FLOW

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SECTION 1

PURPOSE

The operating procedures furnished in this document are intended to assist plant operators in the preparation of detailed operating procedures for the feedwater bypass system. The procedures are written with specific applicability to the KRSKO feedwater system modifications.

After the Owner has prepared the procedures for the plant, using the procedures provided in this document as a basis, he is requested to forward them to Westinghouse.

SECTION 2

SYSTEM DESCRIPTION

2-1. BACKGROUND

Under certain operating conditions (without the recommended feedwater system modification), the possibility exists for pressure pulses (sometimes referred to as waterhammer) to be generated in the preheater section of the steam generator. If these generated pressure pulses are of sufficient magnitude and frequency, they could possibly result in equipment damage with resultant reduced efficiency, reduced electrical output, loss of plant availability, or other undesirable effe(:s. A mechanism which can produce pressure pulses in a confined space, such as in feedwater piping or a preheater, is the formation of one or more steam bubbles (voids) which subsequently come into contact with cold water (cold relative to the temperature of the steam in the bubble). Very rapid condensation of the steam bubble may cause a pressure pulse. This pressure pulse phenomenon is most likely to occur when the steam generator water level and/or pressure are low. In addition, steam voids can be formed in the preheater at low load conditions when the flow rates are very low. Continuous heat input from the reactor coolant fluid in the tubes causes evaporation to occur, with consequent forming of voids.

To minimize the potential for the conditions described above, the feedwater bypass system modifications shown in Figure 2-1 are incorporated to prevent cold feedwater from being introduced directly to the preheater (through the main feedwater nozzle) when voids may be present in the preheater. (However, the injection of cold feedwater at a very low, controlled rate is acceptable. Refer to paragraph 2-2.) During heatup, cooldown, hot standby, and low load operation the cold feedwater is injected through an auxiliary nozzle (located in the steam generator upper shell) and, therefore, the preheater region is bypassed. When the feedater temperature to the steam generator has increased to setpoint T_3 or higher (table 2-1), the feedwater isolation valve (FIV) will open and feedwater flow may be transferred from the auxiliary feedwater

LIMITATIONS AND SETPOINTS - MAIN FEEDWATER BYPASS SYSTEM - COUNTER-FLOW PREHEAT STEAM GENERATORS

Parameter		Setpoint
SG level	L_3	- 5% of narrow range span
SG pressure	P_L	- Low steamline pressure safety injection setpoint less 50 psi (but not less than 600 psig)
Feedwater temperature to main nozzle	T_3	- 250 F
FIV bypass flow (Figure 2-1)		
Nominal	W_B	- 90,000 lb/hr
Minimum	W_{BL}	- 80,000 lb/hr
Trip	W_{BT}	- 100,000 lb/hr
Timers		
Level	τ_L	- Zero seconds
Temperature	τ_T	- Twice time to purge volume (from temperature sensor nearest steam generator to steam generator)
Flow	τ_F	- Twice time to purge volume (from FCV to steam generator)
Preheater Flow Isolation	W_{PR}	- 12% of full load flow rate (~ 480,000 lb/hr)
Tempering flow to auxiliary nozzle	W_T	- 40,000 to 80,000 lb/hr

feedwater nozzle to the main feedwater nozzle (and preheater) by opening the feedwater control valve (FCV) and closing the feedwater control bypass valve (FCBV). Although voids may exist in the preheater when the transfer is made, the feedwater temperature should have increased to the point that the temperature differential between the steam and feedwater is sufficiently small that rapid condensation does not occur.

The feedwater bypass system incorporates logic to control the automatic opening and closing of the valves as required to minimize the possibility of injecting cold feedwater into the preheater when voids may be present. Functional requirements for this system are provided in Reference 1.

2-2. DESCRIPTION OF THE FEEDWATER BYPASS SYSTEM

The Feedwater Bypass System provides a connection between the upper feedwater nozzle and the main feedwater line, as indicated in Figure 2-1. This bypass line includes a feedwater control bypass valve (FCBV), a feedwater auxiliary control valve (FACV): a feedwater bypass flow element (FBFE), a feedwater preheater bypass valve (FPBV), and a feedwater bypass check valve (FBCV). The auxiliary feedwater system connects to the bypass line between the FBCV and the containment. A connection is provided upstream of the FBFE for feedwater tempering flow.

The main feedwater line to each steam generator originates at the main feedwater header, which is downstream from the high pressure feedwater heaters. Feedwater flows from the header through the feedwater control valve (FCV), the feedwater flow element (FFE), the feedwater preheater check valve (FPCV) and through the feedwater isolation valve (FIV), after which it enters the steam generator main feedwater nozzle and the preheater.

To minimize the potential for occurrence of pressure transients in the steam generator preheater and in the feedwater piping connecting to the steam generator, it is necessary to prevent the introduction of cold water to the steam generator through the main feedwater nozzle at any time when significant void may be present. (However, the injection of cold feedwater at a very low, controlled rate is acceptable). During startup, shutdown, and certain other operating conditions, feedwater is delivered via the bypass line and through the steam generator auxiliary nozzle. At low flow rates (e.g., startup and shutdown), feedwater flow is controlled by the FCBV. After the proper conditions have been established, feedwater flow is transferred from the bypass line to the main feedwater line by opening the FCV and the FIV, and closing the FCBV. Feedwater flow is controlled by the FCV from approximately 20 percent to 70 percent of rated loop feedwater flow rate. At high feedwater flow rates, the FACV is modulated open to permit operation at increasing power levels up to the maximum permissible power level while limiting flow to the preheater.

One of the conditions which must be assured prior to opening the FIV and FCV consists of establishing the minimum required feedwater temperature throughout the feedwater system to ensure that cold feedwater will not enter the preheater. This requires purging the cold feedwater from the main feedwater line between the FCV and the steam generator nozzle.

2-3. MAIN FEEDLINE PURGING

Replacing cold water in the main feedline with hot water at a temperature which is above the required value is accomplished as discussed below. It should be noted that all cold water must be removed, and no "pockets" allowed to remain. Redundant temperature measurements are provided in the feedline at each point which may resist the displacement of cold water to ensure that all water in the feedwater system is above the required temperature before the FIV is opened.

A small feedwater flow, bypassed around the FIV, may be employed to purge the cold water from the feedwater line between the FCV and the steam generator. The arrangement shown in Figure 2-1 utilizes a small bypass line containing, the feedwater isolation bypass flow element (FIBFE) and the feedwater isolation bypass valve (FIBV). The flow element provides a trip signal to the stop valve when the flow setpoint is exceeded. Because the feedwater control valve (FCV) is not opened at startup until all setpoints have been satisfied and the feedwater isolation valve (FIV) has been opened, a feedwater supply for purging the main feedline to the preheater is provided from the bypass line. Purge flow is provided by a small line, originating in the bypass line downstream from the feedwater control bypass valve (FCBV) and containing the feedwater purge valve (FPV). This line connects to the main feedline upstream from the feedwater flow element (FFE).

2-4. AUXILIARY NOZZLE TEMPERING

A small, tempering flow is to be provided to the auxiliary nozzle at all times when the feedwater control valve (FCV) is open, except when a feedwater isolation signal is activated. This flow cools the inner surfaces of the nozzle and adjacent connecting piping, while maintaining the water temperature in the piping connecting to the nozzle at approximately feedwater temperature, thereby greatly reducing the thermal stresses induced in the nozzle and connecting piping when main feedwater flow is initiated to the auxiliary nozzle through the feedwater control bypass valve (FCBV) or the feedwater auxiliary control valve (FACV).

A minimum tempering flow rate of 1 percent of rated loop flow (approximately 40,000 lb/hr) is required whenever the feedwater isolation valve (FIV) is open. Flow interruptions are to be minimized and, insofar as possible, to be limited to one minute duration.

The tempering flow plus potential feedwater control valve leakage may be of such magnitude as to make steam generator water level control difficult during periods of operation at very low power level. To minimize this possibility, automatic logic should be provided which closes the FBTV when the FCV is closed, and opens the FBTV whenever the FCV is opened.

Flow limiting and/or flow measuring devices (e.g., orifices, flow nozzles, etc.) used to establish tempering flow rates should be inspectable and provided with pressure taps for checking flows during operation.

Either a "low flow" or "FBIV closed" alarm should be provided.

The arrangement of the tempering line is to minimize the amount of cold water in the bypass line which will be delivered to the auxiliary nozzle when either the FCBV or FACV is opened.

2-5. LOGIC DESCRIPTION - STEAM GENERATOR PREHEATER WATER HAMMER CONTROL

The logic for a single loop is shown in Figure 2-2. The logic is designed to minimize the potential for occurrence of pressure transients by preventing the introduction of cold water to the steam generator through the main feedwater nozzle at any time when significant void may be present. Temperature measurement is provided in the feedwater piping between the FCV and SG at points where cold water may tend to resist displacement during the purging operation (TF). The basic concept is that feedwater flow is blocked from the main nozzle by closing the FIV at any time when the temperature of the water is low and the feedwater flow is low. Additional logic is provided to ensure that the feedwater line is warm prior to opening the FIV; to allow design transients, such as load rejections, without reactor trips; and to prevent the introduction of water to the preheater when either the steam generator water level or pressure is excessively low.

Feedwater temperatures (TF) and feedwater isolation bypass line flow signals are used to ensure that the line has been completely purged of cold water and filled with warm water from the main feedwater system before the FIV is opened. (Note: The feedwater temperature at all measured points must be equal to or above, the setpoint temperature before the FIV is opened.) Timers are provided in the logic for the FIV bypass flow and each feedwater temperature. The timer on the flow signal ensures that the flow has been present for a sufficient time to ensure that any false high temperature signals due to backflow from the steam generator (when the main feedwater pumps are off) are no longer present. The other timers ensure that the line is swept from the temperature sensor into the steam generator.

An interlock between feedwater flow and feedwater temperature is provided such that at any time when either feedwater temperature or feedwater flow drops after the plant is at power (temperature reduction due to a turbine runback, for example) feedwater is not isolated. This interlock is required to allow load rejections without reactor trips. The principle for this part of the logic design is that no voids can be formed if the feedwater flow is high and not interrupted, and rapid condensation of void will not occur when the feedwater temperature is above the setpoint. The feedwater temperature logic (discussed above) which is interlocked with feedwater flow, is to ensure closure of the feedwater isolation valve (FIV) in sufficient time to prevent introduction to the preheater of feedwater at a temperature less than the setpoint temperature when the feedwater is less than its setpoint value.

An interlock with steam generator water level is provided to prevent the introduction of water into the preheater when the water level is excessively low, and an interlock with steam generator pressure is provided to prevent introduction of water into the preheater when the pressure is excessively low. See Sections 2-7 and 2-8.

2-6. LOGIC DESCRIPTION - PLANT CONTROL AND PROTECTION

The feedwater system control and protection logic is defined in Reference 9.

2-7. STEAM GENERATOR LOW WATER LEVEL

A 2/3 low water level signal in one steam generator initiates feedwater isolation to the preheater in that loop consisting of automatic logic closure of the FIV, FIBV, FPV, FCV and FBTV.

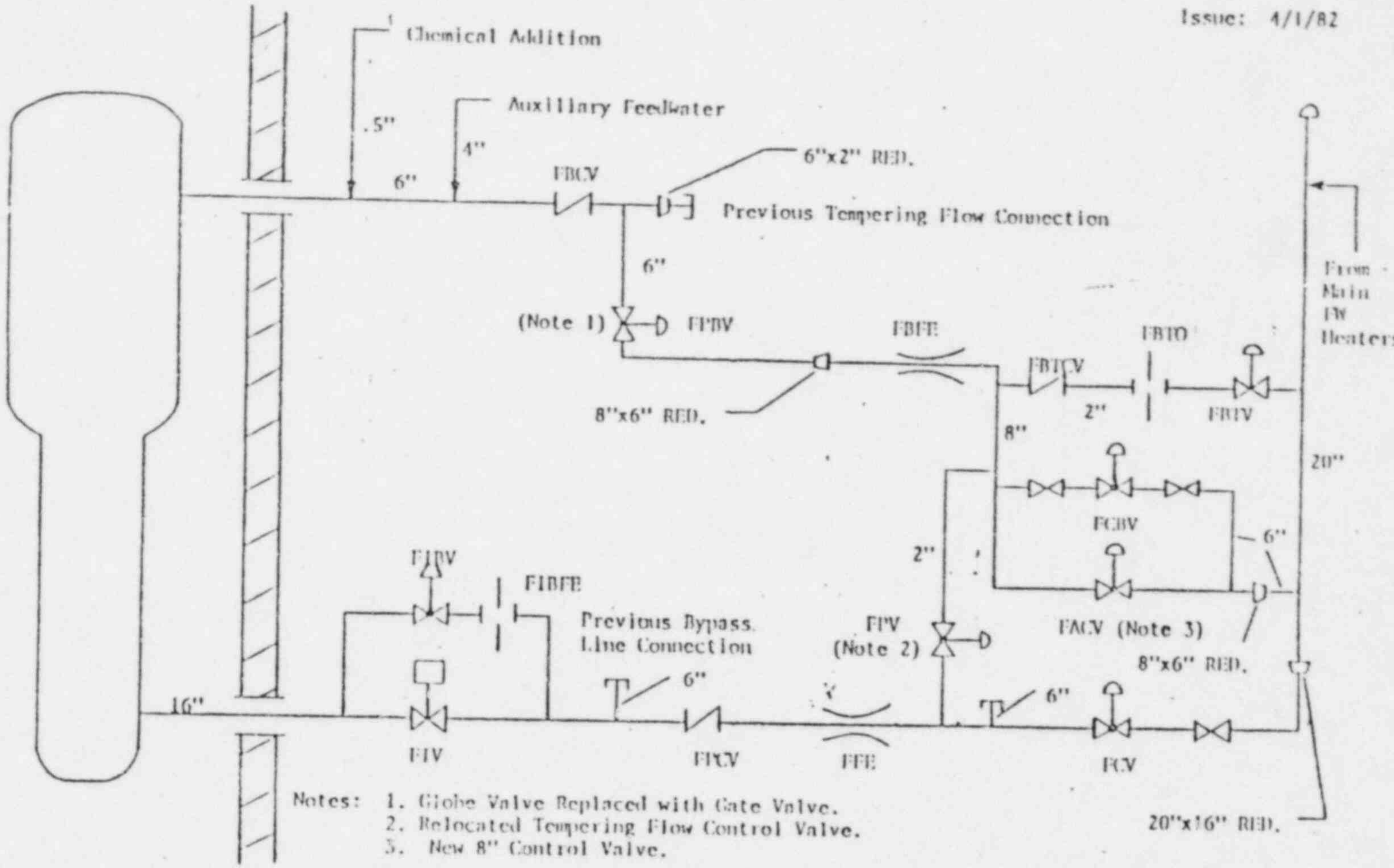
2-8. STEAM GENERATOR LOW STEAM PRESSURE

A 2/3 low steam pressure signal in one or more steam generators initiates feedwater system isolation to the preheater including automatic logic closure in all loops of the FIV, FIBV, FPV, FBIV, FCV and trip of main feed pumps.

2-9. FEEDWATER ISOLATION BYPASS LINE FLOW

A high flow rate throughthe FIBFE in any loop (that is, greater than or equal to W_{BT}) automatically closes the FIBV in that loop where the forward flushing arrangement is provided (Figure 2-1.) Re-opening of the FIBV to re-initiate bypass flow requires operator action.

KRSKO FEEDWATER BYPASS SYSTEM: PROPOSED ARRANGEMENT



PCV - FW Preheater Check Valve
IV - FW Isolation Valve
IBV - FW Isolation Bypass Valve
CV - FW Control Valve
CBV - FW Control Bypass Valve

FBFE - FW Bypass Flow Element
FFE - FW Flow Element
FBTV - FW Bypass Tempering Valve
FBCV - FW Bypass Check Valve
FPBV - FW Preheater Bypass Valve

FIBFE - FW Isolation Bypass Flow Element
FBTO - FW Bypass Tempering Orifice
FBTCV - FW Bypass Tempering Check Valve
FPV - FW Purge Valve
FACV - FW Aux. Control Valve

Figure 2-1. Main Feedwater Bypass Arrangement

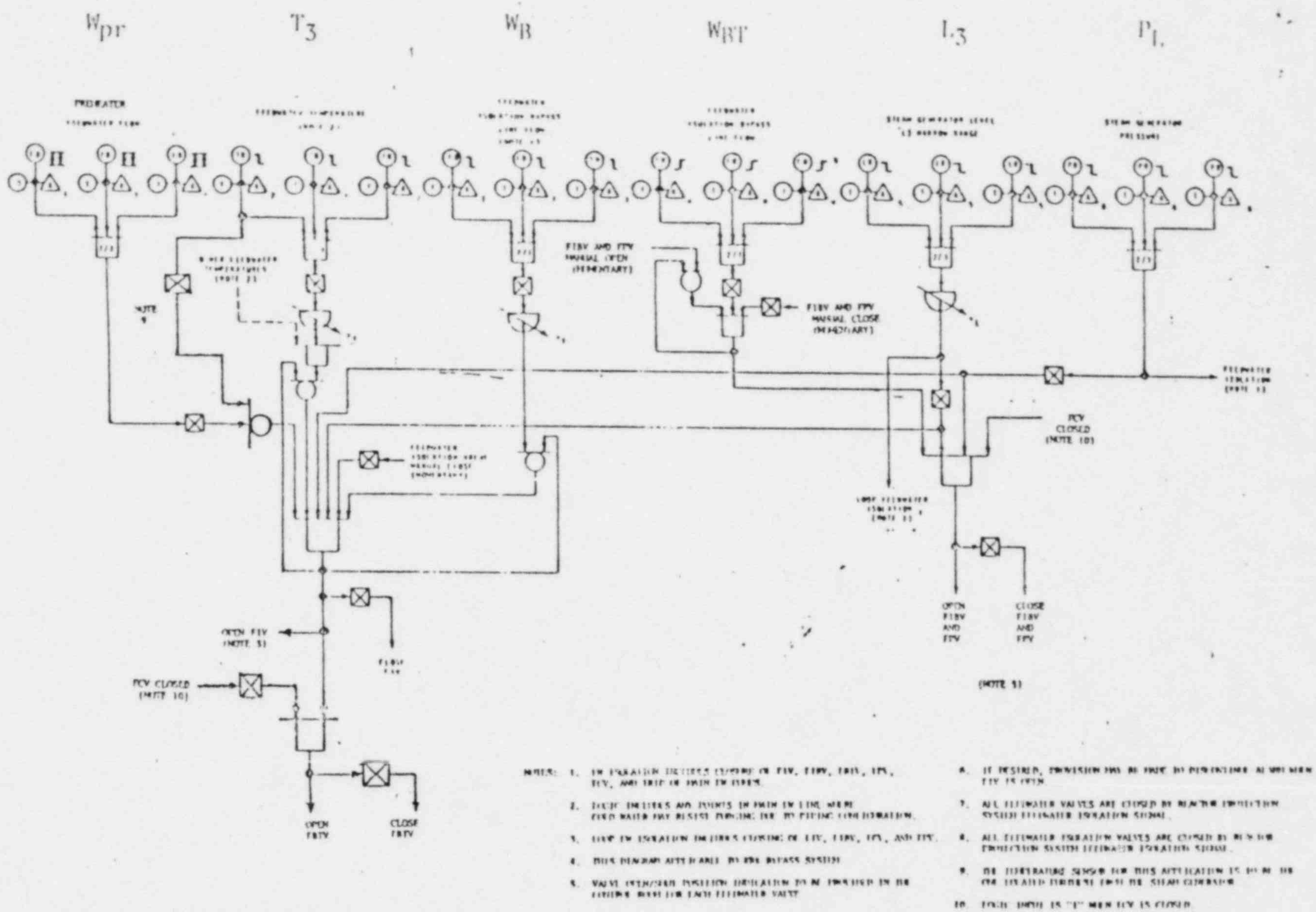


Figure 2-2. Logic Diagram - Steam Generator Preheater Waterhammer Control

SECTION 3

INSPECTIONS AND TESTS

3-1. INTRODUCTION

The following proposed test recommendations are intended to serve as a guide in the development of a preoperational and startup test program for the feedwater bypass system. The primary purpose of such a program is to demonstrate that the system is properly installed and adjusted during the plant startup so that it is capable of minimizing the potential for occurrence of pressure transients in the steam generator preheater and the feedwater piping connected to the steam generator. In addition, the program should help to ensure proper system operation and to improve plant availability.

In the following proposed tests, references are made to the Westinghouse NSSS Startup Manual, although the feedwater bypass sysyem is a BOP (balance of plant) system. Such a reference has been made since many of the inspections and tests suggested are considered good engineering and construction practice and are similar to those performed on NSSS systems as described in the startup manual. In addition, tests similar to those performed on NSSS safety systems and equipment are also suggested for the feedwater bypass system. Although the feedwater bypass system serves no safety function, its proper operation is important for maintaining plant availability. The guidelines supplied by Westinghouse for the NSSS, which serve as the basis for the Owner's detailed inspection and test procedures, can also serve as a general guide to the Owner in preparing detailed procedures for inspection and testing of the feedwater bypass system. Westinghouse NSSS Startup Manual sections which may be helpful to the Owner in developing test procedures are referenced in the following paragraphs.

3-2. SYSTEM ASSEMBLY INSPECTIONS AND TESTS

Following system assembly, inspections should be carried out to verify the following:

- o Mechanical components are in good condition and properly assembled to make up the system.
- o Layout of the system is satisfactory.
- o I&C equipment is properly installed and in conformance with industry standards.

General guidelines for carrying out such inspections on NSSS equipment are provided by the startup manual in Section 1.1, Installed Equipment Inspection Program. Applicable portions of this section may be used as a guide in developing detailed procedures for inspecting the feedwater bypass system.

After the system has been assembled and inspected, the individual mechanical components (primarily valves) should be tested and, if necessary, adjusted. The I&C equipment should also be tested and adjusted as necessary. The primary purpose for these tests is to establish that the system is properly calibrated and fully operable. General guidelines for carrying out such tests on NSSS equipment are provided by the start-up manual in Section 1.3, Integrity Test Program, and Section 1.4, Equipment Checkout, Initial Operationa, and Adjustment Program. Applicable portions of these sections may be used as a guide in developing detailed procedures for initial testing of the feedwater bypass system.

During this phase of testing and adjusting the equipment, the feedwater isolation valve and feedwater control valve opening and closing time should be verified to occur within the limits established by Westinghouse as presented in Reference 7. This document advises the maximum rates of flow change.

The inspections and test discussed above are to include the pressure transducer installations in the feedwater piping near the steam generator main feedwater nozzles as specified in Reference 7. This instrumentation is required to monitor the magnitude of pressure pulsations occurring in the feedwater piping.

3-10. SYSTEM LOGIC OPERATIONAL TEST AND SETPOINTS VERIFICATION

The following system logic operational test and setpoints verifications are to be conducted:

- o Prior to taking the plant critical following feedwater system modification, tests should be performed to operationally check the logic of the feedwater bypass sytem. Tests should include analog system tripping as well as logic train functioning.

- o Procedures for operational tests of the Reactor Protection System and Safeguards System are supplied in Reference 5, Westinghouse NSSS Startup Manual, Sections 2.7.2 and 2.7.3. These procedures are for informational purposes only and may be used as a guide in developing detailed test procedures for the feedwater bypass system logic operational test.

- o The safeguards (feedwater isolation) functions of the feedwater bypass system valves should be tested as part of the reactor safeguards systems functional test.

- o Feedwater bypass system setpoints should be verified using procedures similar to those described in Reference 5, Westinghouse NSSS Startup Manual, Section 2.7.5. Such reference procedures are for informational purposes only and may be used as a guide in the development of detailed procedures.

3.11. SYSTEM CHECKS DURING POWER ESCALATION (SUBSEQUENT TO FEEDWATER SYSTEM MODIFICATION)

A number of checks should be performed on the feedwater bypass system during the plant power escalation to ensure proper functioning.

(1) Ensure that there is no backflow leakage through system check valves. This is particularly important for valves which protect against backleakage of steam from the generator into the auxiliary feedwater line. This valve is the FBCV.

(2) Measure the FIV bypass line flow by independent means and recalibrate the flow instrumentation in the line, if necessary.

(3) Measure the time required to flush cold water from the main feedline and ascertain that it is in agreement with previously calculated values.

(4) Verify the purge flow timer settings in each loop.

(5) Tests should be performed to operationally check the logic of the feedwater bypass system. Tests should include checking analog system tripping as well as logic train functioning.

(6) Check the calibration of the narrow range feedwater flow channels used in the FIV interlock. This operation may be performed simultaneously with the calibration of the regular steam and feedwater flow instrumentation at power (Reference 5, Westinghouse NSSS Startup Manual, Section 2.9.4).

(7) Measure the bypass line tempering flow. This flow should be in the range of 40,000 to 80,000 lb/hr when the FCV, alone, is delivering feedwater to the steam generator (FCBV and FACV closed). The applicable power range is approximately 15 percent through 70 percent rated load.

(8) Check for leakage and excessive noise or vibration in the valves and lines.

(9) Carefully observe that the system operates satisfactorily when the FIV is initially opened. Any resulting steam generator level transient when the valve is opened should be small (less than plus or minus 10 percent level variation) and should not cause an inadvertent reactor trip. Readjust valve opening or closing times if necessary.

CAUTION

Adjustment of valve closing times (for waterhammer control purposes) must not cause the valve closure time for Reactor Protection System generated feedwater isolation signals to exceed the maximum permissible closure time (typically 5 seconds).

(10) During the plant transient test program verify the satisfactory operation of the feedwater bypass system during all normal operation transients. Operation of these systems should not result in any inadvertent reactor trips under normal transient conditions.

3-12. ONLINE TESTING OF FEEDWATER BYPASS SYSTEM

It is recommended that online testing of the feedwater bypass system instrumentation, controls, and remotely operated valves be performed periodically similar to the testing of the Reactor Protection System to demonstrate the continued reliability of the system (Note: It is recommended that a test period be selected which will ensure high reliability of performance of this equipment. It is further recommended that the maximum operating period between tests not exceed 3 months.)

Periodic measurement of the amplitude and frequency of BOP induced continuous pressure oscillations is recommended to verify that the actual magnitudes of the pressure oscillations at the steam generator inlet do not exceed the allowable magnitudes. See Reference 7.

After the online test procedures have been prepared for the feedwater bypass system, it is requested that copies be forwarded to Westinghouse.

SECTION 4
OPERATION

4-1. PREOPERATIONAL CHECKS

Prior to the initial startup, and before each subsequent startup, proper operation of the feedwater bypass system instrumentation, controls, and remotely operated valves is to be verified before commencing heatup.

Reference is to be made to Figures 2-1, 2-2, 4-1, and 4-2.

4-2. NORMAL OPERATION

Perform the normal operation procedures of paragraphs 4-3 through 4-15.

4-3. PLANT HEATUP

(1) Ascertain that the FIV and FIBV are closed. The FPBV is open and the FCBV may be available for controlling flow if the condensate pumps or main feed pumps are operating to provide feedwater to the steam generators prior to , or during, heatup. For these components to be available for operation, the low pressure trip logic (and possibly the low level trip logic) signals must be blocked. Alternately, the auxiliary feedwater system may be used to provide feedwater, in which case the FCV, FCBV, and FACV may be closed.

CAUTION

Water level is to be maintained above the tops of all steam generator tubes during heatup. Delay heatup, if necessary, until the required water level is attained. Failure to do so could result in tube corrosion.

(2) Establish water level in all steam generators, allowing for expansion during heatup, so that the water level will be at the programmed level when no-load conditions are reached at the end of heatup.

(3) Confirm that the feedwater automatic logic control system is energized and in service. Ensure that valve positions are as indicated on the logic diagram (Figure 2-2). This control system is to be in operation at all times (to minimize the possibility of delivering cold feedwater to the main feedwater nozzle) when the steam generator temperature is greater than 140°F. (SG temperature may be assumed to be the same as the RCS wide range cold leg temperature.)

(4) Proceed with heatup and no-load conditions. Adjust the water level, as required, using steam relief or blowdown to reduce level, or adding feedwater to increase level.

4-4. HOT STANDBY AND LOW POWER OPERATION (ZERO TO APPROXIMATELY 20 PERCENT MWt)

Perform the following steps to initiate hot standby and low power operation:

(1) Ascertain that the FIV, FPV and FCV are closed. All feedwater delivery to the steam generator must be made via the auxiliary nozzle. As long as the feedwater requirements are small (approximately 3 percent of rated feedwater flow or less), the auxiliary feedwater system may be used as the source of supply, or the main feed system may be used with flow through the FCBV and FPBV. The FCBV will normally be operated in the automatic mode with the Low Power Automatic Feedwater Control System controlling steam generator level.

(2) The FPBV, which receives protection grade feedwater isolation signals only, is open.

(3) Open the FIBV and FPV (operator action required) in each loop after the conditions of steps (4) through (7) have been established in that loop.

(4) Check that the steam generator pressure is above setpoint P_L.

(5) Check that the steam generator water level is above setpoint L_3.

(6) Maintain steady steam flow and steam pressure in each loop for approximately 5 minutes prior to establishing the flushing flow, and for about 5 minutes after the FIBV and FPV are opened. During this 10-minute flushing initiation period, the FIBV is to be closed immediately if a rapid decrease in steam pressure of 50 psi, or greater, occurs.

(7) Open the FIBV and FPV and establish bypass flushing flow immediately before synchronizing the main turbine-generator unit. (It is desirable to minimize the time at this low flow level to minimize any potential effect on feedline nozzle/piping.) Initiating the flushing flow at this time should provide a continuous purge of the main feedwater pipe downstream of the FCV as the feedwater temperature increases with load, thereby minimizing the potential for flow stratification during the flushing operation.

(8) In each loop ensure that the rate of flow through the FIBV is higher than the minimum flow but does not exceed the trip flowrate W_{BT}.

(9) Increase the power level until feedwater temperatures between the FCV and the steam generator exceed setpoint T_3. (Refer to paragraph 5-2 and table 2-1). The control logic in each loop will open the FIV when all the following conditions have been met:

- o Loop feedwater temperatures have been above setpoint T_3 for a period of time not less than the timer setting (τ_T).
- o Loop purge flow has exceeded the nominal setpoint value W_{BL} for a period of time not less than the timer setting (τ_T), and has not exceeded the trip setpoint value W_{BT} during this period.
- o Steam generator water level is above setpoint L_3.
- o Steam generator pressure is above setpoint P_L.

(10) Minimize operation at low power levels. (Refer to paragraph 5-2).

(11) Transfer control in each loop from the FCBV to the FCV at approximately 20 percent power by first placing the FCV in automatic control, the FCBV in manual control, and then slowly closing the FCBV. This transfer flow from the steam generator auxiliary nozzle to the main feedwater nozzle, closes the FPV and FIBV and opens the FBTV.

Alternatively, both the FCBV and FCV may be put in manual control. The FCV is slowly opened manually while the FCBV is slowly closed to maintain relatively constant flow to the steam generator. Once the FCBV is fully closed, the FCV can be put in AUTO control.

(12) Ensure that tempering flow is established to the auxiliary nozzle in each loop. This flow must be not less than 40,000 lb/hr per loop to limit thermal shock of the auxiliary nozzle.

4-5. POWER ESCALATION (LOW POWER OF APPROXIMATELY 20 PERCENT MWt TO APPROXIMATELY 70 PERCENT MWt)

Escalate power, as desired, in accordance with applicable procedures. Feedwater flow, between approximately 20 percent load and approximately 70 percent load, will be controlled by the FCV and delivered to the preheater. The maximum steady-state feedwater flow rate to the preheater is to be limited to 70 percent of loop rated ($\sim 2.8 \times 10^6$ lb/hr). The FBTV and FPBV are open delivering tempering flow to the auxiliary nozzle.

4-6. POWER ESCALATION (APPROXIMATELY 70 PERCENT MWt TO MAXIMUM POWER)

Escalate power, as desired, in accordance with applicable procedures. Feedwater flows in excess of 70 percent loop rated flow will be controlled automatically by the FACV and delivered to the auxiliary nozzle through the bypass line. (Steam generator level will be controlled by the FCV with the FACV acting to limit feedwater flow to the preheater to 70 percent of loop rated flow.)

If the plant is operated at the exact steady-state power level at which the FACV begins to open (setpoint in Reference 6), small flow oscillations may cause this to cycle. If this occurs, cycling can be stopped by increasing or decreasing the plant power level a small amount, or by putting the valve in manual control until the power level is changed.

4-7. POWER REDUCTION (MAXIMUM POWER TO APPROXIMATELY 70 PERCENT MWt)

Reduce power, as desired, in accordance with applicable procedures. The FCV will control automatically the steam generator level with the FACV acting automatically to limit flow through the FCV to the preheater to 70 percent of loop rated flow.

4-8. POWER REDUCTION (APPROXIMATELY 70 PERCENT MWt TO APPROXIMATELY 20 PERCENT MWt)

Reduce power, as desired, in accordance with applicable procedures. The FIV and FCV are open delivering feedwater to the main feedwater nozzle. The FBTV and FPBV are open delivering tempering flow to the auxiliary nozzle.

4-9. POWER REDUCTION (APPROXIMATELY 20 PERCENT MWt TO ZERO POWER AND HOT STANDBY)

The FIV, FCV, FBTV and FPBV are open delivering feedwater to the main feedwater nozzle and tempering flow to the auxiliary nozzle. The FCBV, FACV, FPV and FIBV are closed.

Transfer feedwater flow control in each loop from the FCV to the FCBV at approximately 20 percent power by first placing the FCBV in automatic control, the FCV in manual control, and then slowly closing the FCV. (Refer to paragraph 4-4(11) for alternate flow transfer procedure.) This transfers feedwater flow from the steam generator main feedwater nozzle (and preheater) to the auxiliary nozzle. The FIV will remain open until the feedwater temperature is reduced to a value less than the setpoint, at which time it will automatically close.

The FIBV and FPV will open automatically to re-establish purge flow and the FBTV will close automatically.

NOTE

> The FIV and FCV are closed. The FIBV and FPV are open. The FCBV and FPBV are open directing feedwater flow to the auxiliary nozzle. Feedwater flow control is on the FCBV. All feedwater delivery to the steam generator must be made via the auxiliary nozzle, with the exception of a small controlled flow through the FIBV. If the turbine-generator (T-G) unit is tripped (thereby terminating feedwater heating)

and the intention is to shortly return the plant to power, the FIBV should be closed until the T-G unit has been reloaded and feedwater heating reestablished. Then the FIBV should be opened as the feedwater temperature approaches the temperature of the water in the feedline between the FCV and the steam generator. The objective is to avoid displacing hot water in the feedline with cold water which may result in undesirable steam generator feedwater nozzle thermal stresses.

Minimize operation at low power levels. (Refer to paragraph 5-2.)

(1) When the determination is made to go to zero load hot standby, hot shutdown, or to cold shutdown, close the FIV, FIBV and FPV, if open.

(2) When the feedwater requirements have been reduced to approximately 3 percent of rated feedwater flow or less, the feedwater supply may be shifted to the auxiliary feedwater system, if desired.

4-10. PLANT COOLDOWN

Perform the following steps to achieve plant cooldown:

NOTE

The plant is at hot standby with the feedwater automatic logic control system in service. All feedwater delivery is to the auxiliary nozzle. The FIV, FCV, FIBV and FPV are closed. Use of the auxiliary feedwater may be preferred for cooldown. If the main feedwater system is used, it is necessary to temporarily block the low pressure trip logic signals to the FCBV and feedwater pumps. If the bypass piping is not used to provide feedwater through the FPBV to the auxiliary nozzle, then the FPBV and FCBV are to be closed.

(1) Maintain the feedwater automatic logic control system in service at all times (to prevent delivery of cold feedwater to the main feedwater nozzle) when the steam generator temperature is greater than 140°F.

(2) The water level in each steam generator is to be maintained above the tops of the highest tubes throughout the cooldown to 140°F. (Reference 3, paragraph 10.2.1). If lowering the water level, or draining the steam generator, is planned following cooldown, the steam generator water level must not be lowered to less than 30 percent of wide range level span until the steam generator temperature has been reduced to 140°F and nitrogen or air has been introduced into the steam generator shell. This should minimize the potential for a waterhammer to occur in the steam generator or the feedline.

4-11. TRANSIENT OPERATION

Perform the transient operation procedures of paragraphs 4-12 through 4-15 when appropriate.

4-12. LOAD REJECTION

The effect of load rejection on the feedwater system is influenced by the power level prior to the load rejection and the percentage power change. The effects are greatest for full load rejection from rated load, and are less for rejections of smaller percentage.

Immediately following load rejection, the steam generator steam pressure increases due to the reduction in steam flow to the turbine-generator unit. The increase in steam pressure causes a decrease in steam generator water level with a resultant increase in demand for feedwater flow.

reased steam generator pressure against which the fee[...]
livered tends to reduce the flow rate. If the load
s approximately 10 percent load, steam dump is activa-
which decreases the steam pressure.

ontrol from the FCV to the FCBV at the earliest oppor-
e power level has been reduced to less than approximately
ed power.

osed following load rejection, before it can be opened for
on it is necessary to open the FIBV and FPV, increase the
n the feedwater line above the setpoint, and allow the
mperature timer and the bypass line flow timer to time out.

tor decides to take the plant to hot standby, reference is
to the procedures of paragraph 4-2, Normal Operation.

WATER INTERRUPTION

flow and feedwater temperature are interlocked such that if
e is above the setpoint, the FIV will not be closed. There-
the feedwater temperatures are above the setpoint T_3, the FIV
be closed when a feedwater interruption occurs.

OSS OF LOAD WITH REACTOR TRIP

ng a reactor trip, the feedwater flow will rapidly decrease to
an the preheater flow setpoint. Due to the turbine trip, the
er temperature will decrease rapidly to less than its setpoint.
s time the automatic control logic should close the FIV in each
The FIBV and FPV are to be closed. All feedwater is to be
red to the steam generator via the auxiliary nozzle only. Perform
(1) and (2).

1) Transfer feedwater control from the FCVs to the FCBVs, if time
permits. Adjust steam generator water level to the startup

level. This may be accomplished with the auxiliary feedwater system if the main feedwater system is not available.

(2) For cooldown, hot standby, or low power operation, refer to the procedures of paragraph 4-2, Normal Operation.

11.577-9

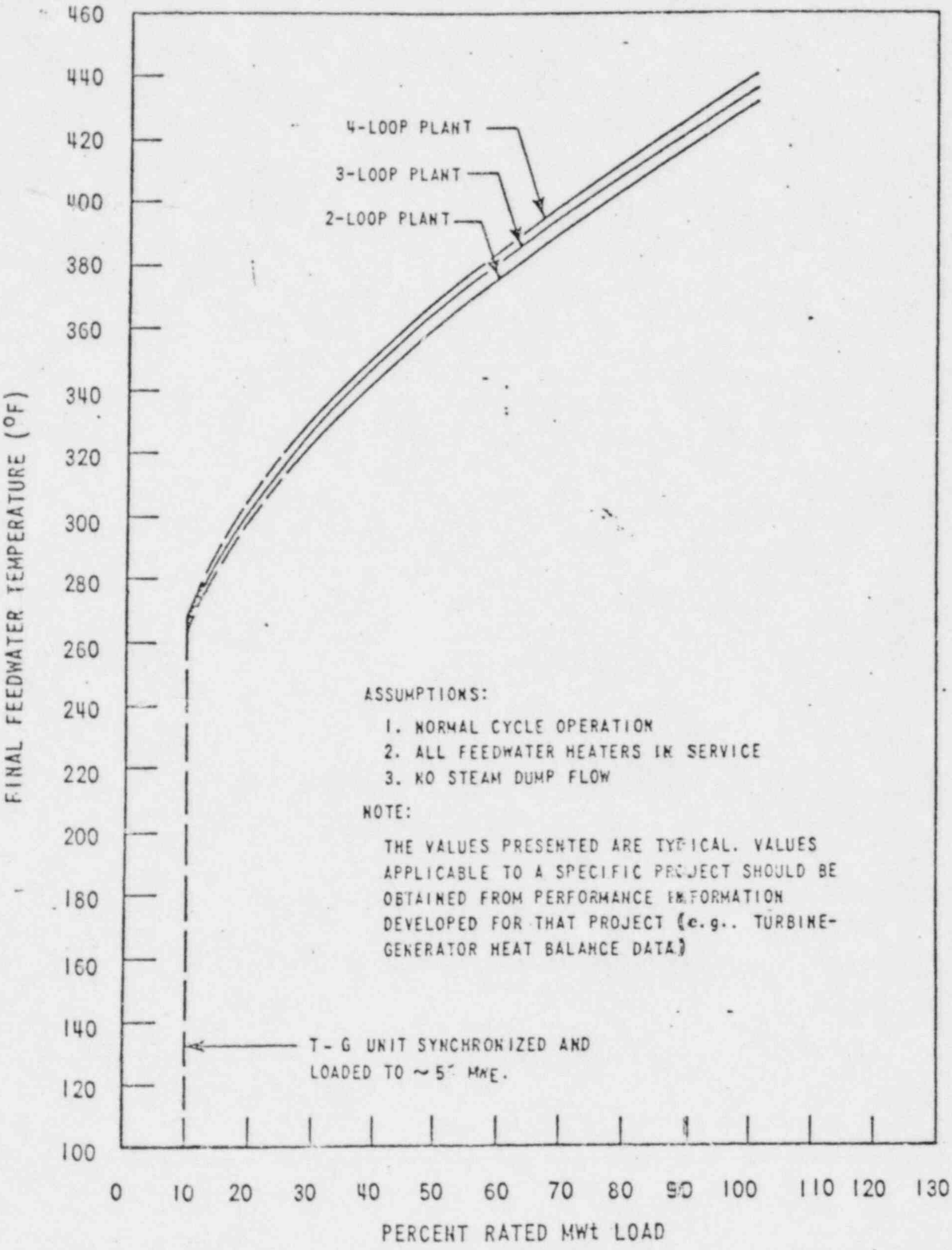
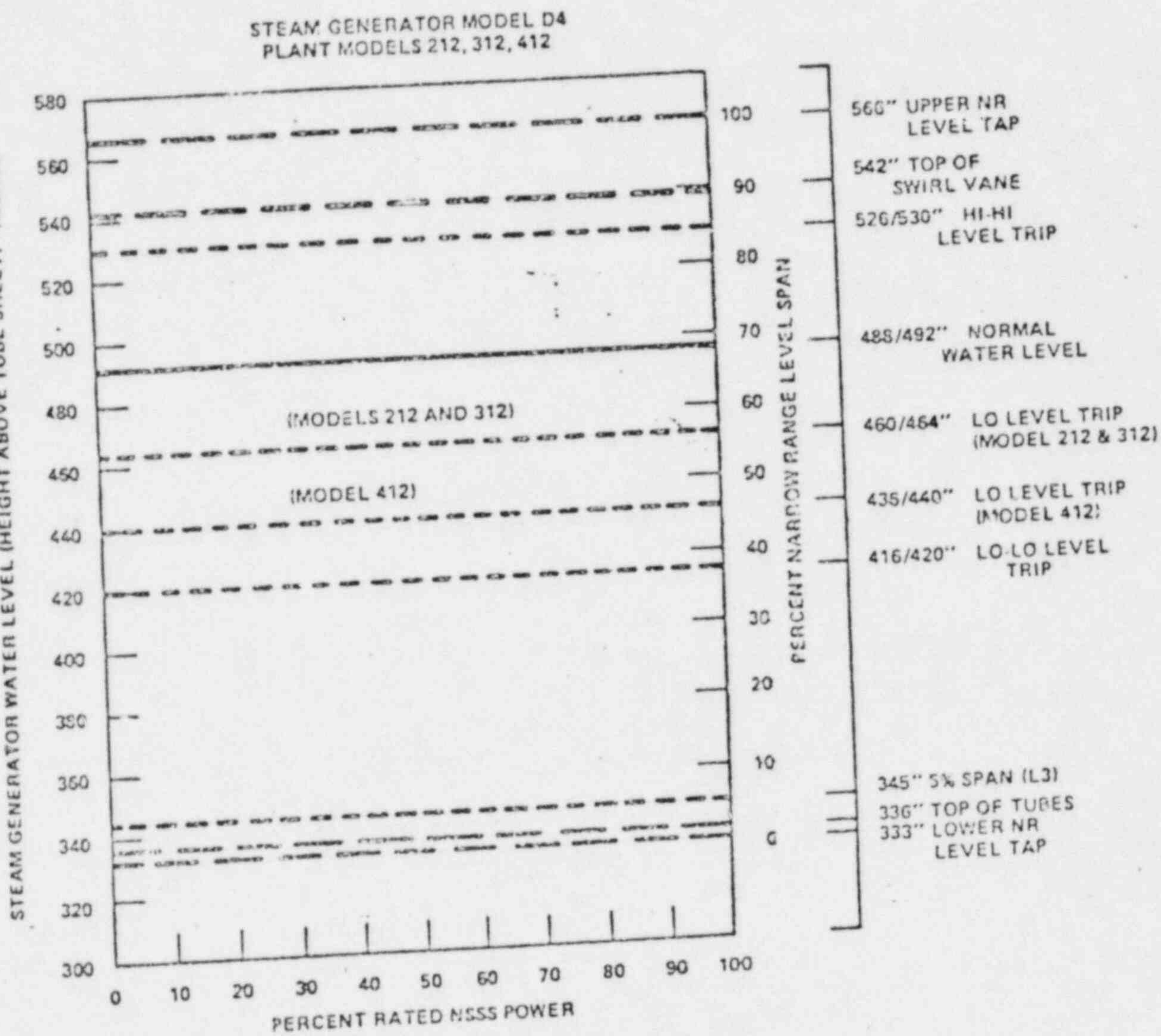


Figure 4-1. Typical Final Feedwater Temperature vs Percent Rated MWt Load



Note: When dual water levels are shown (e.g., 488/492"), the first value is the actual water level and the second value is the indicated water level. The difference is the velocity effect at the lower NR level tap in the downcomer.

This curve is provided as preliminary information. The setpoint values indicated may be superseded by the "Precautions, Limitations and Setpoints" document which provides the official values.

Figure 4-2. Steam Generator Programmed Water Level Versus Percent Rated NSSS Power (SG Model D4)

SECTION 5

PRECAUTIONS AND LIMITATIONS

5-1. LOGIC CONTROL SYSTEM OPERATION

The feedwater automatic logic control system must be in service at all times when the steam generator temperature is greater than 140°F to prevent delivery of cold feedwater to the main feedwater nozzle.

5-2. LOW POWER OPERATION

At low power levels, with feedwater delivery to the auxiliary nozzle, void may be present in the preheater. A potential exists for the preheater to be affected by void due to effects such as chemical concentration and deposition of impurities. To limit preheater exposure to these potential effects, prudent operating practice indicates limiting the period of operation at low power levels when feedwater flow is delivered only to the upper nozzle.

When feasible, consideration may be given to using steam dump to supplement turbine load to avoid operation in the low load range.

5-3. TRANSFER OF FEEDWATER FLOW CONTROL

It is recommended that the transfer of feedwater flow control between the feedwater control bypass valve (FCBV) and the feedwater control valve (FCV) be accomplished at approximately the 20 percent power level to enhance stable feedwater control throughout the transfer. (The transfer can be made at the power level where the linearity of the steam and feedwater flow signals permit the high power feedwater control system to function properly. This typically has been found to be in the range at 15 to 20 percent power.)

5-5. STEAM GENERATOR WATER LEVEL

The water level in each steam generator is to be maintained above the top of the tubes throughout cooldown to 140°F. If lowering the water level or draining the steam generator is planned following cooldown (for example, internal maintenance of the steam generator), the steam generator water level must not be lowered to less than 30 percent of wide range level span until the steam generator temperature has been reduced to 140°F and nitrogen or air introduced into the steam generator shell, thereby minimizing the potential for water hammer or feedline snapping in the steam generator or the feedline.

5-6. REDUCED FEEDWATER TEMPERATURE

Operation with reduced feedwater temperature to the steam generators (for example, with one or more HP feedwater heaters out of service) results in increased steam pressure at a constant MWt power level. The pressure increase is approximately 1 psi for each 1.5°F decrease in feedwater temperature. Should extended operation at reduced feedwater temperature be contemplated, consideration should be given to reducing the reactor coolant system average temperature to maintain steam pressure at the design value with all feedwater heaters in service.

Full load nominal steam pressure must not exceed 1000 psia with partial load steam pressures prorated accordingly.

5-7. OPERATOR BACKUP

Although the feedwater automatic logic control system is designed to automatically function to minimize the potential for occurrence of pressure pulses in the preheater, the operator should be fully aware of the conditions (Figure 2-2) to be avoided. Moreover, the operator should be fully aware of the functions which the control system is designed to perform when setpoints are exceeded so that the operator will be familiar with the control system and will recognize any nonperformance of the control system and take appropriate and timely manual action. The following criteria are presented to assist the operator in this regard:

- o The trip flowrate W_{BT} through the feedwater isolation bypass valve in any loop must not be exceeded.

- o If steam generator water level falls below the narrow range span in two or more level channels in any loop (thereby tripping the plant), then the main feedwater regulating valve, the feedwater isolation valve, and the feedwater isolation bypass valve should be closed in the affected loop (preferably in that order of initiation).

- o If steam generator pressure in two or more pressure channels in any loop decreases to the setpoint value, then the following actions should be taken (preferably in the following order of initiation):

(1) Trip all main feedwater pumps

(2) Close the main and bypass feedwater regulating valves in all loops.

(3) Close the feedwater isolation valve and the feedwater isolation bypass valves in all loops.

- o Tempering flow, at a flowrate not less than $\underline{W}_T$, is to be provided to the auxiliary nozzle at all times when the FCV is open, except when a feedwater isolation signal exists.

5-8. FEEDWATER DELIVERY AT LOW FLOW RATES

At very low load or hot standby conditions, when the feedwater flow to each steam generator is minimal, the operator may be inclined to slug feed the steam generators (intermittent feedwater delivery) if the plant design does not provide for feedwater control under these conditions. Slug feeding can cause large thermal stresses which may lead eventually to cracking of the steam generator feedwater nozzle or feedwater piping. Therefore, it is recommended that feedwater delivery (both main and auxiliary feedwater) to the steam generators at low flow conditions be continuous rather than intermittent. (Reference 2.)

5-9. PREHEATER EXCESSIVE FEEDWATER FLOW RATE

The maximum steady-state feedwater flow rate to the preheater is to be limited to approximately 70% of loop rated flow ($\sim 2.8 \times 10^6$ lb/hr). Any additional flow will be delivered through the bypass piping to the auxiliary nozzle. An automatic controller is provided for the FACV to perform this function. A preheater high flow alarm will be provided with a delay timer to alert the operator to an excessive flow condition such as might be caused by a falure in the FACV controller. The timer is provided to permit flow transients to stabilize before the alarm is activated in order to eliminate unnecessary alarms.

In the event the preheater excessive flow alarm is activated, the operator should confirm that flow to the preheater is, in fact, above the flow limt. If the preheater flow is above the flow limit and this condition is not the result of a plant transient, then the operator is to take prompt action to reduce the flow rate to the preheater to less than the flow limit. This may be accomplished by placing the FACV controller in the manual mode and adjusting the valve position to obtain an acceptable flow rate into the preheater.

If the FACV controller should be inoperative, the FCBV can be operated in the manual mode to obtain a higher power level than can be attained with the FCV alone. The alterntive is to reduce power level to a value consistent with preheater feedwater flow limit.

5-10. FAILURE OF FACV AUTOMATIC CONTROLLER

It is intended that the FACV will operate at all times in the automatic mode. However, an AUTO/MANUAL control station will be provided to permit the operator to operate the FACV in manual control should the automatic controller fail to operate properly. In this event, the operator should place the controller in the manual mode and adjust the valve position to maintain the flow to the SG preheater at a flow rate less than the preheater flow limit. Adjustment of the FACV position will be required as changes are made in the power level and changes in the condensate and feedwater systems operating parameters.

Care is to be exercised on decrease in power level so that, while the FACV is open, the feedwater flow to the preheater does not decrease below the total feedwater flow value at which the FACV is programmed to open on load increase and to close on load decrease. This flow rate is approximately 60% of loop rated flow (~2,400,000 lb/hr). The FACV is to be closed when the total feedwater flow rate is reduced to this setpoint value.

SECTION 6

RECOMMENDATIONS

The occurrence of low steam generator water level L_3 should automatically initiate isolation of preheater flow to the affected feedwater loop(s) as indicated in Figure 2-2. To reduce the impact on the steam generators an/or the feedwater lines, it is recommended that the isolation in the affected loop(s) be initiated in the order listed to reduce the severity of the transient. Close the main feedwater regulating valve (FCV) close the feedwater isolation and feedwater isolation bypass valves (FIV and FIBV). The adjustment of valve closure times may be required so that undesirable pressure pulses are not produced.

SECTION 7

REFERENCES

1. "System Description - Minimization of Counter-Flow Preheat Steam Generator Preheater Pressure Transients" Rev. 1 dated 1/31/78.

2. "Steam Systems Design Manual" PIP Vol. 10-1, Rev. 3 dated 3/78. (Westinghouse Proprietary)

3. "Steam Side Water Chemistry Control Specifications" PIP Vol. 5-4, Rev. 1 dated 1/75.

4. Project letter "On-Line Testing of Feedwater System Valves for Bypass Systems".

5. "_ NSSS Startup Manual". (Westinghouse Proprietary)

6. "High Pressure Water Hammer Test Program for the Counter-Flow Preheat Steam Generator" WCAP-9364 (Westinghouse Proprietary)

7. Steam Generator Feedwater System Interface Design Criteria - Plants with Model D4/D5 Preheat Steam Generators", SG-80-06-067.

8. "Precautions, Limitations and Setpoints" document.

9. "Control & Protection System Functional Requirements."