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BABCOCK & WILCOX
NUCLEAR POWER GENERATION DIVISION

TECHNICAL DOCUMENT

SYSTEM DESCRIPTION

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for

AUXILIARY FEEDWATER SYSTEM

FOR

SACRAMENTO MUNICIPAL UTILITY DISTRICT

RANCHO SECO

BABCOCK & WILCOX
NUCLEAR POWER GENERATION DIVISION

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TABLE OF CONTENTS/EFFECTIVE PAGE LIST

NUMBER
15-1120580-00

TABLE OF CONTENTS/EFFECTIVE PAGE LIST

1.0 SCOPE

This document contains the preliminary design system description for auxiliary feedwater (AFW). The requirements for this system come from three sources - first, the functional requirements needed to properly interface the AFW system with the nuclear steam supply system (NSSS); second, NUREG-0578, Short Term Lessons Learned Report; third, NUREG-0667, Transient Response of B&W Designed Reactors. This document contains the criteria necessary to upgrade the AFW system to comply with the Standard Review Plan Section 10.4.9, Branch Technical Position ASB10-1 and other standards generally applied to new designs. In implementing these requirements, some exceptions may be taken where the improvement in system reliability is so small that the required modification is not justified for an operating plant. Note that "feedwater", as used in this document, refers to AFW unless otherwise stated.

2.0 SYSTEM REQUIREMENTS

The AFW system requirements are listed below. The items noted in brackets are subject to further specific evaluation.

2.1 NSS Interface Requirements

2.1.1 Maximum Feedwater Flow

The maximum allowable FW flow is 1650 gpm per steam generator (SG). This maximum FW flow limit is based on a tube vibration crossflow velocity limit of 5 ft/s. This limit must not be exceeded at any steam pressure.

2.1.2 Minimum Available Feedwater Flow

The AFW system must be sized so that a minimum of [760] gpm (total) can be delivered to either one or both SGs at a SG pressure of 1050 psig. This flow must be available for all accident conditions considered in the design basis for the plant even with a single active failure in the system.

[Note: BAW 1610, Analysis of B&W NSS Response to ATWS events, January 1980, used AFW flowrates of 1480 gpm at 15 sec for the loss of feedwater event and 740 gpm at 15 sec/1480 gpm at 40 sec for the loss of offsite power case on 177 FA plants. These are nominal flows assuming no failures. Any significant deviations from these values must be justified.]

2.1.3 Maximum Automatic Initiation Time

The system shall be designed so that the minimum AFW flow is established within [50] seconds after an initiation signal is reached. This requirement is based on:

A. Maintaining continuity in reactor coolant system (RCS) flow in the transition from forced to natural circulation when the RC pumps (RCPs) are tripped.

B. Reducing the probability of boil off of the entire inventory of water immediately following a loss of main FW occurrence.

C. Providing margin to prevent overpressurization of the RCS following a loss of main FW event and reactor trip.

NOTE: The [50] second delay includes instrumentation time delay, diesel startup, diesel sequencing, pump acceleration time and valve stroke time.

2.1.4 Initiation and Control Requirements

2.1.4.1 General Requirements

The requirements to which the AFW control system shall be designed are:

A. The system shall provide automatic actuation of AFW, for the conditions specified in Section 2.1.4.2. The capability for bypassing certain initiations shall be provided for unit startup or shutdown in accordance with the IEEE-279 provisions for shutdown bypasses.

B. The system shall be designed to minimize overcooling following a loss of main FW event. This feature of the system is not required to meet the single failure criterion.

C. The system, including control valve positioners, sensors, control and actuation signals and their auxiliary supporting systems, shall be designed as a safety grade (1E) system to the extent possible. As such, it shall be independent of the ICS, NNI, and other non-safety systems.

D iundancy and testability shall be provided to enhance the liability demanded of a safety grade system.

E. A single failure shall neither prevent actuation of AFW when required nor spuriously actuate the system. This criterion shall apply to the AFW system and its auxiliary supporting features. In addition to this single failure, all failures which can be predicted as a condition or a result of the initiating event requiring AFW shall be considered.

F. Indication of AFW status, flowrate and OTSG level shall be available to the operator.

G. The capability for a manual override of the automatic functioning of the system shall be provided. This condition shall be annunciated in the control room.

H. The capability for manual initiation of AFW shall be provided.

I. The capability for manual initiation and control shall be provided in the main control room. The capability for future installation of control from a remote shutdown panel shall be provided.

J. The system shall be designed to prevent or minimize cycling of the AFW control valves during normal plant operation when the AFW system is not in operation.

K. The system shall provide the capability to control the atmospheric dump valves to a single, predetermined setpoint and in addition shall have manual override capability.

2.1.4.2 Actuation Requirements

AFW shall be automatically initiated after the occurrence of any of the following conditions:

- o Loss of all main FW as a minimum, as indicated by the loss of both main FW pumps, i.e. low pump discharge pressure.
- o Low level in either SG.
- o Loss of all 4 RCPs.
- o Low pressure in either SG if main FW is isolated on this parameter.
- o [Any automatic signal that trips the RCPs for small LOCAs].

NOTE: NUREG-0667 recommends that additional AFW initiation signals be evaluated. The purpose of this evaluation is to permit automatic initiation of AFW in a more timely manner to preclude SG dryout. The required signals will detect a trip of the MfW pumps or a low SG level. Failures that stop main FW without tripping the MFW pumps (e.g., control system failures) may not be detected in time to prevent a SG dryout. The following signals, as a minimum, should be evaluated as possible actuation signals:

o [Power/SG level.]

2.1.4.3 Level* Requirements

Three adjustable level setpoints are required.

A. Following AFW actuation, the level setpoint shall be automatically selected to approximately 2 feet if one or more RCPs are running.

B. Following AFW actuation, the level setpoint shall be automatically selected to approximately 20 feet if all 4 RCPs are tripped.

C. Provision for manual selection of a high level setpoint of approximately [31 feet] shall be provided. This setpoint will be selected by the operator in accordance with operating guidelines.

*For the purpose of AFW design, "LEVEL" refers to the equivalent height of a saturated liquid column (900 psia) referenced from the top of the lower tube sheet.

2.1.4.4 Flowrate Requirement

The objective of flowrate control is to minimize overcooling for low DH conditions. The AFW flow rate is controlled by the rate of level increase (see Section 2.1.4.3 for level definition). A level rate of 4 inches/minute has been estimated to be a limit which provides adequate cooling for the conditions which require AFW. Since the level rate control is a first of a kind control scheme, the system must be tested in place to guarantee that the setpoint is sufficiently high to provide adequate cooling for the maximum heat load.

The level rate limit shall be adjustable under administrative control.

In operation, the AFW flowrate is modulated to hold the level rate at the setpoint.

At the present state of development, it may be necessary to manually reduce flowrate below this limit, after 10 minutes for some low decay heat conditions.

2.1.5 Steamline Break/Feedwater Line Break

A steamline break or FW line break that depressurizes a SG shall cause the isolation of the main steamlines and main FW lines on the depressurized SG. If isolation of the SG does not isolate the break, AFW shall be provided only to the intact SG. No single active failure in the system shall prevent AFW from being suppplied to the intact SG nor allow AFW to be supplied to the broken SG.

[To meet these requirements the following design shall be implemented:

A. Isolation - Low steam pressure (below approximately 600 psig) in either SG will isolate the main steamlines and main FW line to the affected SG.

B. SG Selection -

- If both SGs are above 600 psig, supply AFW to both SGs.
- If one SG is below 600 psig, supply AFW to the other SG.
- If both SGs are below 600 psig but the pressure difference between the two SGs exceeds a fixed setpoint (approximately 150 psig) supply AFW only to the SG with the higher pressure.
- If both SGs are below 600 psig and the pressure difference is less than the fixed setpoint, supply AFW to both SGs.]

2.1.6 Steam Generator Overfill

Provisions must be made in the design to terminate a main FW and AFW overfill condition.

2.2 Fluid System Requirements

2.2.1 Branch Technical Position ASB10-1

BTP ASB10-1 places the following requirements on the AFW system:

A. The auxiliary FW system should consist of at least two full capacity, independent systems that include diverse power sources.

B. Other powered components of the auxiliary FW system should also use the concept of separate and multiple sources of motive energy. An example of the required diversity would be two separate auxiliary FW trains, each capable of removing the afterheat load of the reactor system, having one separate train powered from either of two AC sources and the other train wholly powered by steam and DC electric power.

C. The piping arrangement, both intake and discharge, for each train should be designed to permit the pumps to supply FW to any combination of SGs. This arrangement should take into account pipe failure, active component failure, power supply failure, or control system failure that could prevent system function. One arrangement that would be acceptable is crossover piping containing valves that can be operated by remote manual control from the control room, using the power diversity principle for the valve operators and actuation systems.

D. The auxiliary FW system should be designed with suitable redundancy to offset the consequences of any single active component failure; however, each train need not contain redundant active components.

E. When considering a high energy line break, the system should be so arranged as to assure the capability to supply necessary auxiliary FW to the SG despite the postulated rupture of any high energy section of the system, assuming a concurrent single active failure.

NOTE: If the AFW system is not used (and therefore not pressurized) during startup, hot standby and shutdown conditions, then a high energy line break in the AFW system only needs to be considered between the SG and the first check valve upstream of the SG.

2.2.2 Water Sources

Seismic Category I water sources shall be provided of sufficient volume to remove decay heat for four hours and to subsequently cooldown the plant to the decay heat removal (DHR) system pressure.

2.2.3 AFW Pump Protection

The system design shall protect the AFW pump from runout and cavitation due to high energy line breaks or single failures in the system. Any automatic pump trip features must (a) not override automatic initiation of AFW, or (b) be designed as a Class 1E system.

2.2.4 AFW Support Systems

The requirements for diverse power sources and operation with a single failure also apply to the AFW support systems. These systems include:

- o Electrical power to support systems.
- o Compressed air.
- o [Environmental control.]

2.2.5 Cross Connects

AFW system shall be designed to allow either pump to feed either steam generator. Cross connects provided for this purpose shall include normally open remotely operated isolation valves.

2.2.6 Alarms

As a minimum, the following alarm outputs are required:

- o High SG level.
- o Low SG level.
- o Low source water level.
- o Low AFW pump discharge pressure.
- o Low AFW pump suction pressure.
- o Steam line valves HV-20569 and HV-20596 not open.
- o AFW cross connect valves HV-31826 and HV-31827 not open.

2.2.7 Indication

As a minimum, the following indication shall be provided to the operator.

- o AFW flow to each SG*.
- o Startup range SG level*.
- o Operate range SG level*.
- o Wide range SG level.
- o Key valve positions.**
- o Water source inventory.
- o Control system status (level setpoint selected).
- o Steam pressure to each SG.
- o AFW pump status indication.
- o Indications needed to check the status of AFW support systems.
- o Additional primary system indication as required to monitor system functions and operations*.
- o Status of the EFIC system (bypass, test, tripped, etc.)

*Depending on the extent of compliance to R.G. 1.97, these indications may be required to be safety grade.

**Direct position indication (e.g., valve stem position) shall be provided for all automatically operated valves and all remote manual power operated valves. Local manual valves in the flow path shall be locked open. Strict administrative control should be exercised over the use of these valves.

2.2.8 Physical Separation

System components and piping shall have sufficient physical separation or shielding to protect the essential portions of the system from the effects of internally and externally generated missiles.

Functional capability of the system shall also be assured for fires and the maximum probable flood.

2.2.9 Fluid Flow Instabilities

The system design shall preclude the occurrence of fluid flow instabilities; e.g., water hammer, in system inlet piping during normal plant operation or during upset or accident conditions.

2.2.10 Operational Testing

Provisions shall be made to allow periodic operational testing.

2.2.11 Water Chemistry

The requirements of the B&W Water Chemistry Manual, BAW-135, shall be met. The normal water source shall meet the requirements in Table 2-1.

2.3 Codes and Standards

The AFW system shall consider the requirements of the following codes and standards:

A. General Design Criterion 2*, Design Bases for Protection Against Natural Phenomena, as related to structures housing the system and the system itself being capable of withstanding the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, and floods.

B. General Design Criterion 4*, Environmental and Missile Design Bases, with respect to structures housing the system itself being capable of withstanding the effects of external missiles and internally generated missiles, pipe whip, and jet impingement forces associated with pipe breaks.

C. General Design Criterion 5*, Sharing of Structures Systems and Components, as related to the capability of shared systems and components important to safety to perform required safety functions.

D. General Design Criterion 19*, Control Room, as related to the design capability of system instrumentation and controls for prompt hot shutdown of the reactor and potential capability for subsequent cold shutdown.

E. General Design Criterion 44*, Cooling Water, to assure:

(1) The capability to transfer heat loads from the reactor system to a heat sink under both normal operating and accident conditions.

(2) Redundancy of components so that under accident conditions the safety function can be performed assuming a single active component failure. (This may be coincident with the loss of offsite power for certain events.)

(3) The capability to isolate components, subsystems, or piping if required so that the system safety function will be maintained.

F. General Design Criterion 45*, Inspection of Cooling Water System, as related to design provisions made to permit periodic inservice inspection of system components and equipment.

G. General Design Criterion 46*, Testing of Cooling Water System, as related to design provisions made to permit appropriate functional testing of the system and components to assure structural integrity and leak-tightness, operability and performance of active components, and capability of the integrated system to function as intended during normal, shutdown, and accident conditions.

H. Regulatory Guides

1.22, Feb 1972*	Periodic Testing of Protection System Actuation Functions
1.26, Rev 3, Sept 1978*	Quality Group Classifications and Standards for Water, Steam and Radioactive Waste Containing Components
1.29, Rev 3, Sept 1978*	Seismic Design Classification
1.47, May 1973	Bypassed and Inoperable Status Indication
1.53, June 1973	Application of the Single Failure Criterion
1.62, Oct 1973	Manual Initiation of Protective Actions
1.75, Rev 2, Sept 1978	Physical Independence of Electrical Systems
[1.97, Rev 1, Aug 1977	Instrumentation to Assess Plant Conditions During and Following an Accident]
1.102, Rev 1, Sept 1976	Flood Protection for Nuclear Power Plants

I. IEEE Standards

279-1971*	Criteria for Protection Systems for Nuclear Power Generating Stations (for initiation portions of AFW System)
323-1971*	General Guide for Qualifying Class I Electrical Equipment
338-1971	Trial Use Criteria for Periodic Testing of Protection Systems
344-1971*	Seismic Qualification of Class 1E Electrical Equipment
379-1972	Trial Use Guide for the Application of the Single Failure Criterion
384-1974	Separation of Class IE Equipment and Circuits

*As a minimum, B&W recommends that these standards be met.

TABLE 2-1

OTSG Emergency Feedwater Chemistry Requirements

pH at 77F	Same as normal requirement[a]
Dissolved oxygen (O_2)	
OTSG at < 250F	No requirement (see hydrazine)
OTSG at > 250F	
Normal	7 ppb max
Upset	100 ppb max for a period not to exceed 1 week
Total iron	100 ppb max
Hydrazine Catalyzed hydrazine	
OTSG at < 250F	Added to at least 300% of stoichiometric oxygen concentration
OTSG at > 250F	20-100 ppb residual
Cation Conductivity	1.0 mho/cm, max for a period not to exceed 24 hours

[a] 8.5-9.3 at 77F - Austenitic stainless steel feedwater heater tubes and stainless steel or copper-nickel reheater tubes.

9.3-9.5 at 77F - Carbon steel feedwater heater tubes or combinations of carbon steel and stainless steel feedwater and/or reheater tubes.

3.0 DESIGN DESCRIPTION

3.1 Summary Description

The AFW system consists of two interconnected trains, capable of supplying auxiliary feedwater (AFW) to either or both SGs from either water source under automatic or manual initiation and control. A piping and instrumentation diagram is included as Figure 3.1-1 of this report.

The system pumps (AFW pumps) take suction from either the condensate storage tank or from the Folsom South Canal and discharge to the SGs. In the flow path between the AFW pumps and the SGs there are isolation valves, check valves, control valves, flow instrumentation, and pressure instrumentation to control the flow of AFW to the SGs. The fluid system design is described in Section 3.2. The instrumentation system design is described in Section 3.4.

3.2 Fluid System Design

The AFW system is designed to provide a minimum of [760] gpm of AFW to the SGs at 1050 psig within [50] seconds of system initiation signal. The system is designed as two interconnected trains with redundant components to insure that the system will meet these requirements with a single failure. Figure 3.1-1, depicts the piping and instrumentation diagram.

3.2.1 Suction

The primary water source for both AFW trains is the Seismic Category I condensate storage tank, T-358. Although there are other connections to this tank, they draw through an internal stand-pipe which assures that a minimum of 250,000 gallons is held in reserve exclusively for the AFW system. Water is supplied from this tank to the AFW pumps by separate 8-inch lines containing locked open manual valves MCM-057, MCM-058, FWS-045, FWS-046, and check valves MCM-059 and MCM-060.

Alternative AFW system suction sources are available from the on-site reservoir and the Folsom South Canal. These alternate sources enter the cross connect in the suction piping between locked closed manual valves PWC-076 and PWC-079. Suction must be manually transferred from the condensate storage tank to the reservoir or the Folsom South Canal by opening the locked closed manual valves PWC-076 and PWC-079, closing the locked open manual valves MCM-057 and MCM-058, and either: (1) operating the Folsom South Canal transfer pumps and valves or (2) opening motor operated valve HV-43011 to obtain gravity flow from the on-site reservoir. The suction cross connect also includes pressure relief valves PSV-31800 and PSV-31900. The operators are alerted to perform this suction transfer by redundant, safety-grade low level alarm from the condensate storage tank. In addition, tank level is redundantly indicated in the control room.

3.2.2 Pumps and Discharge Cross-Connect

AFW Train A pump, P-318, is a combination turbine-driven motor-driven pump with both the turbine and electric motor on a common shaft. Either motive source can drive the pump at its rated capacity of 840 gpm at 1150 psig with a normal recirculation flow of 60 gpm. The turbine driver is used as the primary motive source for this pump. The motor driver can be manually initiated.

AFW Train B pump, P-319, is a motor-driven pump which has the same rated capacity and recirculation flow as the Train A pump.

The pumps discharge through check valves and locked open manual valves into 6-inch cross-connected discharge lines. The cross-connection line contains two normally-open motor-operated valves (HV-31826 and HV-31827). This cross-connect permits either pump to feed either or both steam generators.

3.2.3 Auxiliary Feedwater Flow Control Valves

The flow of AFW to each steam generator is controlled by normally closed pneumatically operated control valves (FV-20527, FV-20528, FV-X1, and FV-X2) in parallel paths. Initiation and control instrumentation for these valves is described in Section 3.4 of this report.

3.2.4 Auxiliary Feedwater Isolation Valves

Each steam generator can be isolated from AFW flow by normally-open motor-operated valves (FV-20577, FV-20578, FV-X3, and FV-X4). These valves are located in the parallel lines downstream of the AFW control valves. Initiation and control instrumentation for these valves is described in Section 3.4 of this report.

3.2.5 Recirculation and Test Lines

Recirculation and test lines are connected to the discharge piping of both pumps. Recirculation for pump protection is accomplished with normally open flow paths to the condensers consisting of small lines with check valves, restricting orifices, and locked-open manual valves.

Full flow test capability is provided through a 6-inch line which intersects the AFW system cross-connect between the two normally open motor-operated valves HV-31826 and HV-31827. This full flow test path is isolated from the cross-connect during normal operation by a normally closed pneumatically operated control valve (FWS-X5). Either AFW train can be full-flow tested by opening valve FWS-X5 and starting the appropriate AFW pump. The full capability of both AFW trains to supply AFW on demand is maintained during the test since either a channel A or B AFW initiation signal will result in automatic closure of valve FWS-X5 through its fail closed on loss-of-air design. The AFW systm is, therefore, automatically restored to its normal configuration.

3.2.6 Steam Supply for the AFWS Turbine

Steam supply for the AFW pump P-318 turbine is obtained from both steam generators through six-inch lines containing check valves MSS-051 and MSS-052, locked-open manual valves MSS-049 and MSS-050, and normally-open motor operated valves HV-20569 and HV-20596. The check valve and motor operated valve provide redundant isolation capability to preclude blowing down the good steam generator in the event of steam line or feed line break. Downstream of these valves the lines join to form a common supply to the pump turbine. Upstream of the turbine is a normally closed DC motor operated valve FV-30801. A description of the controls for this valve is contained in Section 3.4.

Turbine exhaust is vented to the atmosphere.

3.2.7 Key Valve Positions

Direct position indication (e.g., valve stem position) is required on all automatically operated and remote manual power operated valves. To comply with this requirement, the following valves require position indication:

FV-20527	FWS-X5
FV-20528	FV-30801
FV-20577	HV-20569
FV-20578	HV-20596
FV-X1	HV-31826
FV-X2	HV-31827
FV-X3	
FV-X4	

3.3 Supporting Systems

The AFW pumps, pump motor and turbine are self-contained entities without dependencies on secondary support systems. The bearings on the turbine and both pumps are lubricated by slinging oil from reservoirs near the bearings. Lube oil cooling is accomplished by heat transfer to the pumped fluid.

3.3.1 Power

The two AFW trains are powered from diverse power sources. AFW pump P-318 is turbine driven with an AC power back-up motor, and AFW pump P-319 is AC power motor driven with back-up power from the diesel generator. The following valves required to operate the AFW system are also on AC power with back-up power from the diesel generator: FV-20577, FV-20578, FX-X3, V-X4, HV-20569, HV-20596, HV-31826, HV-31827, and FWS-X5.

In the highly unlikely event of a loss of all AC power, the turbine driven pump AFW train derives its power from the steam generators for the pump and from a battery-backed DC buss for its steam supply valve. Valve FV-30801 requires battery backed DC power.

3.3.2 Service Air

AFW flow control valves FV-20527, FV-20528, FV-X1 and FV-X2 are connected to the qualified redundant air supply system with redundant valves in the same train being connected to a different air supply system.

3.4 Instrumentation Description

The emergency feed initiation and control system (EFIC) is an instrumentation system designed to provide the following:

1. Initiation of auxiliary feedwater (AFW),
2. Control of AFW at appropriate setpoints (approx. 2, 20 and [30] feet),
3. Level rate control when required to minimize overcooling,
4. Isolation of the main steam and main feedwater lines of a depressurized steam generator,
5. The selection of the appropriate steam generator(s) under conditions of steamline break or main feedwater or emergency feedwater line break downstream of the last check valve,

6. Termination of main feedwater to a steam generator on approach to overfill conditions,

7. Termination of AFW to a steam generator on approach to overfill conditions, and

8. Control of atmospheric dump valves to predetermined setpoint.

The emergency feed initiation and control system (EFIC) is illustrated in Figures 3.4-1 thru 3.4-7. Figure 3.4-1 illustrates the EFIC organization while the remaining figures illustrate the individual logics that comprise the system. The interface of the EFIC with the secondary plant is illustrated in Figure 3.1-1.

The EFIC - see Figure 3.4-1 - consists of four channels (A,B,C, & D). Each of the four channels are provided with input, initiate, and vector logics. Channels A and B also contain trip logics and control logics.

Each channel monitors inputs by means of the input logic, ascertains whether action should be initiated by means of the initiate logic and determines which SGs should be fed by means of the vector logic.

Channels A and B monitor initiate signals from each of the four initiate logics by means of the trip logics to transmit trip signals when required. Channels A and B also exercise control of emergency feedwater flow to the SG by means of control logics to maintain SG level at prescribed values once AFW has been initiated. In addition, Channels A and B also monitor SG A and B overfill signals originating in the Channel A, B, C and D initiate logics. By means of trip logics, Channels A and B terminate main feedwater to a steam generator that is approaching overfill.

3.4.1 Input Logic

The input logic, depicted in Figure 3.4-3, is located in each of the channels. The input logic:

1. Receives the input signals listed in Figure 3.4-3,

2. Provides input buffering as required,

3. Compares analog signals to appropriate setpoints to develop digital signals based on analog values,

4. Provides for the injection of test stimuli,

5. Provides buffered Class 1E signals and isolated non-1E signals, and

6. Provides the signals listed in Figure 3.4-3 for the remaining channel logic.

3.4.2 Initiate Logic

The initiate logic, depicted in Figure 3.4-4 is located in each channel. The initiate logic derives its inputs from the input logic and provides signals which result in the issuance of trip signals via the trip logics in Channels A and B.

The initiate logic issues a call for AFW trip (to the trip logic) when:

1. All four RC pumps are tripped.

2. Both main feedwater pumps are tripped (i.e. low discharge pressure).

3. The level of either steam generator is low.

4. Either steam generator pressure is low.

5. Either of two anticipatory trips (trips not yet assigned) are present.

Other functions of the initiate logic are:

1. Issue a call for SG A main feedwater and main steamline isolation when SG A pressure is low.

2. Issue a call for SG B main feedwater and main steamline isolation when SG B pressure is low.

3. Signal approach to SG A overfill when SG A level exceeds a high level setpoint.

4. Signal approach to SG B overfill when SG B level exceeds a high level setpoint.

5. Provide for manually initiated individual shutdown bypassing of RC pumps, main feedwater pumps, and SG pressure initiation of AFW as a function of permissive conditions. The bypass(es) are automatically removed when the permissive condition terminates.

6. Provide for maintenance bypassing of an EFIC initiate logic.

3.4.3 Trip Logic

The trip logic is illustrated in Figure 3.4-5. The trip logic of the EFIC employs a 2(1-out-of-2) format. This format provides for easy one step testing from input logic test switches to the initiated controllers. Testing is facilitated by locating the AND portion of the 2(1-out-of-2) logic in the controller. A characteristic of coincidence logic systems is that a test stimulii inserted at the input propagates to the first AND element of the system and no further. Since the first AND element of the EFIC is in the controller, test stimuli inserted at the input logic will be propagated to each controller. EFIC testing philosophy is discussed in Section 3.4.6.

The trip logic is provided with five 2(1-out-of-2) trip networks. These networks monitor the appropriate outputs of the initiate logics in each of the channels and output signals for tripping:

1. Auxiliary feedwater.

2. SG A main steamline isolation.

3. SG B main steamline isolation.

4. SG A main feedwater isolation.

5. SG B main feedwater isolation.

It should be noted, for the later discussion of the vector logic, that the trip logic outputs a signal when a 2(1-out-of-2) trip of AFW occurs. Also, note the presence of the vector enable switch.

Refer to Figure 3.4-1 - trip logics are contained in Channels A and B only per the two train AFW system.

For each trip function, the trip logic is provided with two manual trip switches. Thi- affords the operator with a means of manually tripping a selected function by depressing both switches. The use of two trip switches allows for testing the trip switches and also reduces the possibility of accidental manual initiation.

Once a trip of the trip bus occurs, the trip is latched. A manual reset switch is provided for breakdown of the latch. Once a trip occurs, the trip can only be removed by manual reset action following return of the initiating parameter to an untrip value except as described in the next paragraph.

So that the operator may resume manual control of EFIC initiated devices following a trip, each trip logic is provided with a manual pushbutton. Operation of the manual pushbutton:

1. Will have no effect on the trip logic so long as a trip condition does not exist.

2. Will remove the trip from the trip bus only so long as the switch is depressed in the case of a one half trip (either bus but not both tripped). This allows for testing the manual function.

3. Will remove the trip from both busses so long as a full trip (both busses are tripped) exists. This is accomplished by means of latching logic. Institution of the manual function also breaks the trip latches so that, if the initiating stimuli clears, the trip logic will revert to the automatic trip mode in preparation for tripping if a parameter returns to the trip region.

Trip signals are transmitted out of the EFIC by activating a relay thereby gating power onto trip busses. In this manner, the EFIC provides power to energize the control relays whose contacts form the AND gates in the controllers.

3.4.4 Vector Logic

The vector logic - Figure 3.4-6 - appears in each of the EFIC channels - Figure 3.4-1. The vector logic monitors:

1. SG pressure signals,

2. SG (A and B) overfill signals, and

3. AFW trip signals (vector enable) originating in Channel A and B trip logics.

The vector logic developes signals for open/close control of steam generator A and B auxiliary feedwater valves.

The vector logic outputs are in a neutral state until enabled by trip signals (vector enable) from the channel A or B trip logics. Once enabled, the vector logic will issue close commands to the valves associated with any SG for which an overfill signal exists.

When enabled and with no overfill signals present, the valve open/close commands are determined by the relative values of steam generator pressures as follows:

Pressure Status	SG A Valve Command	SG B Valve Command
SG A & B > Setpoint	Open	Open
SG A > Setpoint & SG B < Setpoint	Open	Close
SG A < Setpoint & SG B > Setpoint	Close	Open
SG A < Setpoint & SG B < Setpoint and SG A & B within 150	Open	Open
SG A 150 psi > SG B	Open	Close
SG B 150 psi < SG A	Close	Open

3.4.5 Control Logic

The control logic is depicted in Figure 3.4-2. The logic for operation of the transfers (T1, T2, T3, T4, T5, T6, T7, and T8) depicted in Figure 3.4-2a is illustrated in Figure 3.4-2b.

For each SG (A and B) there are two controls which are selectable by transfers T1 and T5 respectively. See Figure 3.4-2b - the two foot level setpoint control is automatically selected when an AFW trip occurs with one or more reactor coolant pumps operating. A level rate control with a twenty foot setpoint is selected when an AFW trip occurs with no reactor coolant pumps operating. The two foot level control requires no explanation. However, the rate control is more involved.

The characteristics of the rate limited follower are important in the following discussions. As the level signal changes, the rate output of the follower will follow it exactly so long as the rate of change does not exceed the predetermined rate limit values. The rate limit values given (4 inches per minute for increasing level rates and 200 inches per minute for decreasing level rates) are approximate for purposes of illustration. If level rate is increasing at greater than four inches per minute, the output of the rate limited follower will increase at four inches per minute. Once the rate of increase decreases to four inches per minute or less the output rate of increase will follow the input rate of increase. The function is similar for decreasing level except that the rate limit is approximately 200 inches per minute. A side benefit of the rate limited follower is attentuation of noise whose effective rate is in excess of four inches per minute or 200 inches per minute respectively.

Reference Figure 3.4-2b - with no RC pumps operating the twenty foot setpoint will be selected and applied to one input of the low selector. As SG level falls, the output of the rate limited follower will lag actual level by twelve inches (twelve inch bias added to the level signal in the summer). When the rate limited signal (level plus twelve inches) becomes less than twenty feet, the rate limiter signal will appear at the subtractor (delta). The output of the subtractor will be approximately a negative one foot level error signal which will start opening the control valve ever wider thru the proportional plus integral. The increasing flow should halt the drop in level and ultimately start the level to increase toward the setpoint.

If the level increase is more rapid than four inches per minute, the error signal out of the subtractor will decrease. This is due to the fact that the direct level input to the subtractor is not rate limited while the rate limited signal is. This action will control the control valve so that the rate of approach to the setpoint does not exceed four inches per minute.

When level exceeds nineteen feet, the low selector will lock the twenty foot setpoint into the subtractor. During the last foot of level increase the error output of the subtractor will gradually reduce.

See Figure 3.4-2b - transfer logics 4 and 8 allow for selection of a manually inserted setpoint (illustrated as a thirty foot setpoint). The logic is arranged so that manual may be selected before and after an AFW trip. However, the twenty foot setpoint will automatically be selected on the occurrence of an AFW trip.

See Figure 3.4-2b - transfer logics T2, T3, T6, and T7 allow for selection of hand control of emergency feedwater control valves before and after an AFW trip. However, automatic operation will automatically be selected on the occurrence of an AFW trip.

In addition, EFIC Channel A is provided with a pressure control loop for the steam generator A atmospheric dump valves. EFIC Channel B is provided with a pressure control loop for the steam generator B atmospheric dump valves. Transfer T9 describes provisions for future transfer of ADV control to a location outside the main control room.

3.4.6 EFIC Trip Testing

Figure 3.4-7 illustrates the trip philosophy of the EFIC in simplified form for one EFIC trip function (e.g., AFW trip). For purposes of the following discussion, the test pushbuttons associated with each bistable is capable of forcing the bistable input into the trip region. The bistables employ a low dead band so the bistable will reset once the pushbutton is released.

Complete trip testing (input to controllers) may be initiated from the input logic in each of the channels. Depressing the pushbutton in Channel A will trip the Channel A bistable and:

1. The Channel A initiate logic will transmit initiate signals to both the Channel A and B trip logics.
2. The Channel A and B trip logics will half trip (trip one of the two trip busses).
3. The Channel A and B trip logics will latch in the half trip. The half trip will be retained after reset of the bistable. This tests the latching circuit.
4. Each controller receiving the half trip will acknowledge the half trip by transmitting a test confirmation signal assuming all controllers are functioning properly.
5. A full complement of test confirm signals will satisfy the AND gate in both Channel A and B. The result is that the confirm lamps will indicate test success.
6. The trip logic reset switches can now be depresed to reset the half trip. The confirm lamp should go out.
7. If some but not all controllers were to respond due to a malfunction, the confirm lamp will flash. (Off normal may be indicated by some means other than flashing in the final design.)

8. The foregoing tests may be conducted from each channel in turn to test the ability to transmit trips from all channels.

9. The foregoing tests may be conducted for all trip functions from all channels for complete trip testing.

10. Tests as described above may also be conducted by use of the local and remote manual trip and reset switches.

NOTE: The utilization one out-of-two taken twice logic allows for the foregoing test philosophy while minimizing the probability of inadvertent initiation.

3.4.7 EFIC Signal Application

Figure 3.1-1 illustrates the application of EFIC signals to a simplified auxiliary feeedwater system. Salient features of the arrangement are:

1. The channel A AFW trip signal starts the electric emergency feedwater pump. Both the Channel A and B trip logics admit steam to the turbine powered auxiliary feedwater pump. With this arrangement, at least one pump will be started with a single failure of the A or B trip logics.

   Also, given a failure of channel A, B, C, or D initiate logics, both pumps will be started due to the 2(1-out-of-2) character of the trip logic. The cross-connect between the discharges of the two auxiliary feedwater pumps allows either pump to supply feedwater to both SGs.

2. If the cause of the AFW trip is low SG pressure in SG A, AFW will be tripped as in 1 above. In addition, the trip logics in channels A and B will issue SG A main steamline and main feedwater isolation trip signals. The channel A and B trip logics will redundantly isolate SG A main feedwater. With the occurrence of low pressure in SG A, main feedwater to that generator will be terminated in the presence of a single failure.

3. Isolation of SG B main steam and main feedwater lines occurs in the same way as described in 2 above for SG A except that the channel A and B SG B main feedwater and main steamline trip logics are employed.

4. Given the condition where both SG pressures are low, the events described in both 2 and 3 above will occur.

5. The auxiliary feedwater path to each SG consists of parallel control valves and parallel isolation valves. This allows feeding when required in the presence of a single valve failure. It also allows closure of the flow path when required in the presence of a single failure. Since each of the four valves receives vector close signals from different channels, the path will be closed when required by the vector logics in the presence of the failure of a single vector logic.

   In the open direction, the isolation valves receive open vector commands, from channels C and D, when feeding of the SG is required. The control valves, under these conditions will open as dictated by the control logics in channels A and B. In this way, a generator will be fed when required in the presence of a failure of channel A, B, C, or D.

3.4.8 OTSG Level Sensing

Figure 3.4-8 contains the proposed arrangement for OTSG level sensing. The acceptability of this design will depend on the accuracy of the measurement. This accuracy will be determined in the detailed design.

To provide for low level control and initiation signals for the auxiliary feedwater, four differential pressure transmitters (dP transmitters) will be added. The sensing lines for these transmitters will be connected between the unused existing level sensing connetions located 251 inches above the datum line of the OSTG (277" above the face of the tube sheet) and the drain line connections located 7-1/2" below the face of the tube sheet.

To provide high level control and overfill protection signals, four dP transmitters will be added. The upper sensing connections will be manifolded with the upper sensing line of the existing operating range level transmitters. The lower sensor connections will be connected to the drain line connections.

There are four drain line connections (located approx. 7-1/2" below the face of the tube sheet) which can be used for the lower sensing lines of all added transmitters. These will be manifolded as necessary to best serve the redundancy requirements.

3.4.9 Interface with Valve and Pump Controllers

All valve and pump controllers shall be designed such that signals from the EFIC system will override any other control signals. Also, when an EFIC signal is removed, the controller design shall be such that valves (other than the AFW control valve) will not change position and pumps will not change state without a specific manual command. When the vector logic close command to the AFW control valve is removed, the control valve shall be positioned as required by the AFW control system or the manual control as selected.

4.0 SYSTEM LIMITS, PRECAUTIONS AND SETPOINTS

4.1 Limits and Precautions

4.1.1 AFW Flow Limits

Maximum allowable flow -	1650 gpm/SG
Minimum allowable flow -	[760] gpm/SG

4.1.2 SG Level Limits

Maximum allowable level -	[31] feet
Low control (forced RC flow)	2 feet
Intermediate control (natural ciruclation)	20 feet
Manual selection (small break LOCA)	[30] feet

4.1.3 AFW Pump Suction Pressure

P-318 minimum NPSH -	18 feet
P-319 minimum NPSH -	18 feet

4.1.4 System Limits (Design)

Pressure -	[1600] psig
Temperature -	[316] F

4.1.5 Minimum Pump Recirculation

P-318 -	60 gpm
P-319 -	60 gpm

4.2 Setpoints

This section will be completed as part of the detailed design.

5.0 OPERATION

The AFW system operation will be defined as part of the detailed design. The following modes of operation will be considered.

5.1 Hot shutdown to full power.

5.2 Cooldown from hot shutdown to cold shutdown.

5.3 Heatup from cold shutdown to hot shutdown.

6.0 CASUALTY EVENTS AND RECOVERY PROCEDURES

This section will be completed as part of the detailed design.

7.0 MAINTENANCE

This section will be completed as part of the detailed design.

7.1 Periodic tests.

7.2 Maintenance at power.

7.3 Maintenance during cold shutdown.

FIGURE 3.3-1 AC POWER DISTRIBUTION TO COMPONENTS IN AFWS

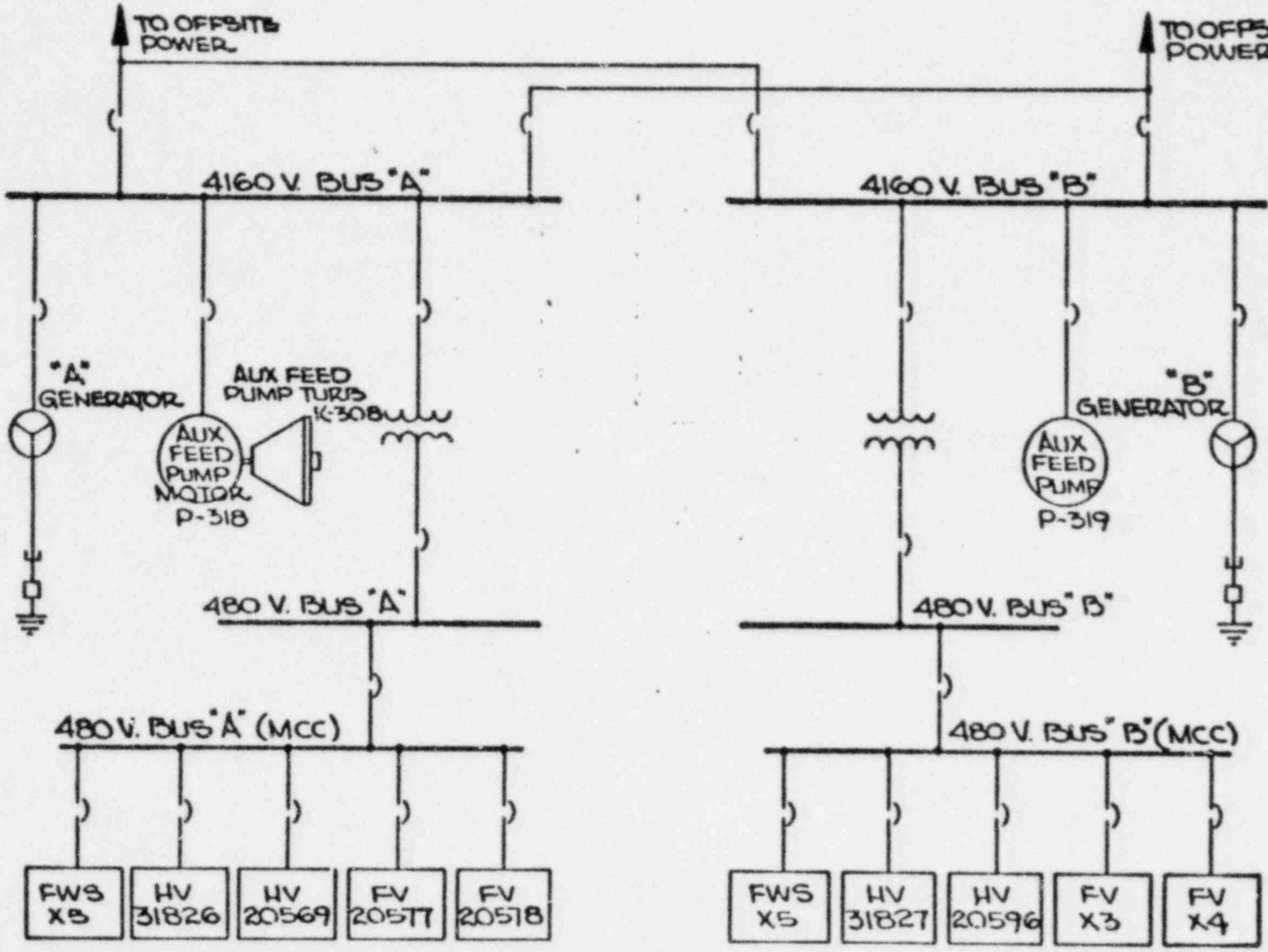

FIGURE 3.3-2 125 VDC AND VITAL 120 VAC POWER DISTRIBUTION