Commonwealth Edison
One First National Plaza, Chicago, Illinois
Address Reply to: Post Office Box 767
Chicago, Illinois 60690

March 18, 1980

Mr. D. G. Eisenhut, Acting Director
Division of Operating Reactors
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Zion Station Units 1 and 2
Response to NRC Generic Request
For Information on Auxiliary Feedwater
System Flow Requirements
NRC Docket Nos. 50-295 and 50-304

Reference (a): September 18, 1980 letter from D. G.
Eisenhut to C. Reed

Dear Mr. Eisenhut:

Enclosure 2 of Reference (a) contained a generic NRC Staff request for additional information regarding auxiliary feedwater system flow requirements. Commonwealth Edison Company's response to the Staff's request for Zion Station is contained in the Attachment to this letter.

Please address any questions that you might have regarding this matter to this office.

One (1) signed original and thirty-nine (39) copies of this letter are provided for your use.

Very truly yours,

William F. Naughton

William F. Naughton
Nuclear Licensing Administrator
Pressurized Water Reactors

Enclosures

P

8003270 582

ATTACHMENT

Commonwealth Edison Company Response

to

NRC REQUEST FOR INFORMATION ON
BASIS FOR AUXILIARY FEEDWATER
SYSTEM FLOW REQUIREMENTS

FOR

Zion Station Units 1 and 2

NRC Docket Nos. 50-295 and 50-304

Question 1

a. Identify the plant transient and accident conditions considered in establishing AFWS flow requirements, including the following events:

1) Loss of Main Feed (LMFW)
2) LMFW w/ loss of offsite AC power
3) LMFW w/ loss of onsite and offsite AC power
4) Plant cooldown
5) Turbine trip with and without bypass
6) Main steam isolation valve closure
7) Main feed line break
8) Main steam line break
9) Small break LOCA
10) Other transient or accident conditions not listed above.

b. Describe the plant protection acceptance criteria and corresponding technical bases used for each initiating event identified above. The acceptance criteria should address plant limits such as:

1) Maximum RCS pressure (PORV or safety valve actuation)
2) Fuel temperature or damage limits (DNB, PCT, maximum fuel central temperature)
3) RCS cooling rate limit to avoid excessive coolant shrinkage
4) Minimum steam generator level to assure sufficient steam generator heat transfer surface to remove decay heat and/or cooldown the primary system.

Response to 1a

The Auxiliary Feedwater System serves as a backup system for supplying feedwater to the secondary side of the steam generators at times when the feedwater system is not available, thereby maintaining the heat sink capabilities of the steam generator. As an Engineered Safeguards System, the Auxiliary Feedwater System is directly relied upon to prevent core damage and system overpressurization in the event of transients such as a loss of normal feedwater or rupture of a main steam line and to provide a means for plant cooldown following any plant transient.

Following a reactor trip, decay heat is dissipated by evaporating water in the steam generators and venting the generated steam either to the condensers through the steam dump or to the atmosphere through the steam generator safety valves or the power-operated relief valves. Steam generator water inventory must be maintained at a level sufficient to ensure adequate heat transfer and continuation of the decay heat removal process. The water level is maintained under these circumstances by the Auxiliary Feedwater System which delivers an emergency water supply to the steam generators. The Auxiliary Feedwater System must be capable of functioning for extended periods, allowing time either to restore normal feedwater flow or to proceed with an orderly cooldown of the plant to the reactor coolant temperature where the Residual Heat Removal System can assume the burden of decay heat removal. The Auxiliary Feedwater System flow and the emergency water supply capacity must be sufficient to remove core decay heat, reactor coolant pump heat, and sensible heat during the plant cooldown. The Auxiliary Feedwater System can also be used to maintain the steam generator water levels above the tubes following a LOCA.

DESIGN CONDITIONS

The reactor plant conditions which impose safety-related performance requirements on the design of the Auxiliary Feedwater System are as follows for Zion Station Units 1 and 2:

- o Loss of Main Feedwater Transient
  - Loss of main feedwater with offsite power available
  - Station blackout (i.e., loss of main feedwater without offsite power available)
- o Rupture of a main steam line
- o Loss of all AC Power
- o Loss of Coolant Accident (LOCA)
- o Cooldown

Loss of Main Feedwater Transients

The design loss of main feedwater transients are those caused by:

- o Interruptions of the Main Feedwater System flow due to a malfunction in the feedwater or condensate system
- o Loss of offsite power (LOOSP) with the consequential shutdown of the system pumps, auxiliaries, and controls

Loss of main feedwater transients are characterized by a rapid reduction in steam generator water levels which results in a reactor trip, a turbine trip, and auxiliary feedwater actuation by the protection system logic. Following reactor trip from high power, the power quickly falls to decay heat levels. The water levels continue to decrease, progressively uncovering the steam generator tubes as decay heat is transferred and discharged in the form of steam either through the steam dump valves to the condenser or through the steam generator safety or power-operated relief valves to the atmosphere. The reactor coolant temperature increases as the residual heat in excess of that dissipated through the steam generators is absorbed. With increased temperature, the volume of reactor coolant expands and begins filling the pressurizer. Without the addition of sufficient auxiliary feedwater, further expansion will result in water being discharged through the pressurizer safety and relief valves. If the temperature rise and the resulting volumetric expansion of the primary coolant are permitted to continue, then (1) pressurizer safety valve capacities may be exceeded causing overpressurization of the Reactor Coolant System and/or (2) the continuing loss of fluid from the primary coolant system may result in bulk boiling in the Reactor Coolant System and eventually in core uncovering, loss of natural circulation, and core damage. If such a situation were ever to occur, the flow from the Emergency Core Cooling System would be inadequate because the primary coolant system pressure exceeds the shutoff head of the safety injection pumps, the nitrogen over-pressure in the accumulator tanks, and the design pressure of the Residual Heat Removal Loop. Even though the charging pump will still provide some flow to the RCS, the timely introduction of sufficient auxiliary feedwater is necessary to arrest the decrease in the steam generator water levels, to reverse the rise in reactor coolant temperature, to prevent the pressurizer from filling to a water solid condition, and eventually to establish stable hot standby conditions. Subsequently, a decision may be made to proceed with plant cooldown if the problem cannot be satisfactorily corrected.

The loss of offsite power transient differs from a simple loss of main feedwater in that emergency power sources must be relied upon to operate vital equipment. The loss of power to the electric driven condenser circulating water pumps results in a loss of condenser vacumm and condenser dump valves. Hence, steam formed by decay heat is relieved through the steam generator safety valves or the power-operated relief valves. However, the evaluated LOOSP transient is similar to the simple loss of main feedwater transient, except that the reactor coolant pump heat input is not considered.

The loss of offsite power transient serves as the basis for the minimum flow required for the smallest capacity single auxiliary feedwater pump for Zion Units 1 and 2. The pump is sized so that any single pump will provide sufficient flow against the steam generator safety valve set pressure (with 3% accumulation) to prevent water relief from the pressurizer. The same criterion is met for the loss of feedwater transient by the operation of any single pump, where A/C power is assumed available.

Loss-of-Coolant Accident (LOCA)

The loss of coolant accidents do not impose on the auxiliary feedwater system any flow requirements in addition to those required by the other accidents addressed in this response. The following description of the small LOCA is provided here fro the sake of completeness to explain the role of the auxiliary feedwater system in this transient.

Small LOCAs are characterized by relatively slow rates of decrease in reactor coolant system pressure and liquid volume. The principal contribution from the Auxiliary Feedwater System following such small LOCAs is basically the same as the system's function during hot shutdown or following spurious safety injection signal which trips the reactor. Maintaining a water level inventory in the secondary side of the steam generators provides a heat sink for removing decay heat and establishes the capability for providing a buoyancy head for natural circulation. The auxiliary feedwater system may be utilized to assist in a system cooldown and depressurization following a small LOCA while bringing the reactor to a cold shutdown condition.

Cooldown

The cooldown function performed by the Auxiliary Feedwater System is a partial one since the reactor coolant system is reduced from normal zero load temperatures to a hot leg temperature of approximately 350°F. The latter is the maximum temperature recommended for placing the Residual Heat Removal System (RHRS) into service. The RHR system completes the cooldown to cold shutdown conditions.

Cooldown may be required following expected transients, following an accident such as a main feedline break, or it may be a normal cooldown prior to refueling or performing reactor plant maintenance. If the reactor is tripped following extended operation at rated power level, the AFWS is capable of delivering sufficient AFW to remove decay heat and reactor coolant pump (RCP) heat following reactor trip while maintaining the steam generator (SG) water level. Following transients or accidents, the recommended cooldown rate is consistent with expected needs and at the same time does not impose additional requirements on the capacities of the auxiliary feedwater pumps, considering a single failure. In any event, the process consists of being able to dissipate plant sensible heat in addition to the decay heat produced by the reactor core.

Rupture of a Main Steam Line

Because a rupture of a main steam line may result in a complete blowdown of one steam generator, a partial loss of a plant heat sink is a concern. The main steam line rupture accident conditions are characterized initially by a plant cooldown and hence, AFW flow is not needed during the early stage of the transient to remove decay heat from the Reactor Coolant Systems. Provisions must be made in the design of the auxiliary feedwater system to allow termination of flow to the faulted loop and to provide flow to the intact steam generators during the controlled cooldown following the steamline break accident.

Loss of All AC Power

The loss of all AC power is postulated as resulting from accident conditions wherein not only onsite and offsite AC power is lost, but also AC emergency power is lost as an assumed common mode failure. Although this accident scenario is not a design basis for the Zion Units, several features are incorporated into the design to mitigate the effects of such a sequence. For example, in the event of complete loss of AC power, an air operated, fail open valve admits steam from two steam generators to power a steam turbine driven auxiliary feedwater pump, which delivers flow to all steam generators through a common header. In addition, a modification is now in progress where the cooling water supply to the turbine driven auxiliary feedwater pumps bearing coolers shall originate from an AC independent source.

Response to 1b

Table 1B-1 summarizes the criteria which are the general design bases for each event, discussed in the response to Question 1a, above. Specific assumptions used in the analyses to verify that the design bases are met are discussed in response to Question 2.

The primary function of the Auxiliary Feedwater System is to provide sufficient heat removal capability for heatup accidents following reactor trip to remove the decay heat generated by the core and prevent system overpressurization. Other plant protection systems are designed to meet short term or pre-trip fuel failure criteria. The effects of excessive coolant shrinkage are evaluated by the analysis of the rupture of a main steam pipe transient. The maximum flow requirements determined by other bases are incorporated into this analysis, resulting in no additional flow requirements.

TABLE 1B-1

CRITERIA FOR AUXILIARY FEEDWATER SYSTEM DESIGN BASIS CONDITIONS

Condition or Transient	Classification*	Criteria*	Additional Design Criteria
Loss of Main Feedwater	Condition II	Peak RCS pressure not to exceed design pressure. No consequential fuel failures	
Loss of Offsite Power	Condition II	(Same as LMFW)	Pressurizer does not fill with 1 single motor driven aux. feed pump feeding 2 SGs.
Loss of all A/C Power	N/A	Note 1	
Loss of Coolant	Condition III	10 CFR 100 dose limits 10 CFR 50 PCT limits	
	Condition IV	10 CFR 100 dose limits 10 CFR 50 PCT limits	
Cooldown	N/A		100°F/hr 547°F to 350°F

* Ref: ANSI N18.2 (This information provided for those transients performed in the FSAR).

Note 1 Although this transient establishes the basis for AFW pump powered by a diverse power source, this is not evaluated relative to typical criteria since multiple failures must be assumed to postulate this transient.

Question 2

Describe the analyses and assumptions and corresponding technical justification used with plant condition considered in 1a above including:

a. Maximum reactor power (including instrument error allowance) at the time of the initiating transient or accident.

b. Time delay from initiating event to reactor trip.

c. Plant parameter(s) which initiates AFWS flow and time delay between initiating event and introduction of AFWS flow into steam generator(s).

d. Minimum steam generator water level when initiating event occurs.

e. Initial steam generator water inventory and depletion rate before and after AFWS flow commences -- identify reactor decay heat rate used.

f. Maximum pressure at which steam is released from steam generator(s) and against which the AFW pump must develop sufficient head.

g. Minimum number of steam generators that must receive AFW flow; e.g., 1 out of 2? 2 out of 4?

h. RC flow condition -- continued operation of RC pumps or natural circulation.

i. Maximum AFW inlet temperature.

j. Following a postulated steam or feed line break, time delay assumed to isolate break and direct AFW flow to intact steam generator(s). AFW pump flow capacity allowance to accommodate the time delay and maintain minimum steam generator water level. Also identify credit taken for primary system heat removal due to blowdown.

k. Volume and maximum temperature of water in main feed lines between steam generator(s) and AFWS connection to main feed line.

l. Operating condition of steam generator normal blowdown following initiating event.

m. Primary and secondary system water and metal sensible heat used for cooldown and AFW flow sizing.

n. Time at hot standby and time to cooldown RCS to RHR system cut in temperature to size AFW water source inventory.

Response to 2

Analyses have been performed for the loss of main feedwater and the loss of offsite AC power to the station, the transients which define the AFWS performance requirements. These analyses have been provided for review and have been approved in the Zion FSAR.

In addition to the above analyses, calculations have been performed specifically for Zion Units 1 and 2 to determine the plant cooldown flow (storage capacity requirements. The LOCA analysis, as discussed in response 1b, incorporates the system flow requirements as defined by other transients, and therefore is not performed for the purpose of specfying AFWS flow requirements. Each of the analyses listed above are explained in further detail in the following sections of this response.

Loss of Main Feedwater and Loss of Offsite AC Power

A loss of feedwater and also a loss of power to the reactor coolant pumps transient analysis was performed in FSAR Section 14.1.9 for the purpose of showing that for this transient, a single motor driven auxiliary feedwater pump delivering flow to two steam generators does not result in filling the pressurizer. Furthermore, the peak RCS pressure remains below the criterion for Condition II transients and no fuel failures occur (refer to Table 1B-1). Table 2-1 summarizes the assumptions used in this analysis. This transient analysis begins at the time of reactor trip. This can be done because the trip occurs on a steam generator level signal, hence the core power, temperatures and steam generator level at time of reactor trip do not depend on the event sequence prior to trip. Although the delay time from loss of feedwater until the reactor trip occurs is not a consideration in this analysis, the delay time is expected to be 20-30 seconds. This analysis assumes that the plant is initially operating at 102% (calorimetric error) of the Engineered Safeguards Design (ESD) rating shown on the table, a very conservative assumption in defining decay heat and stored energy in the RCS. The reactor is assumed to be tripped on steam/feed mismatch coincident with low steam generator level, allowing for level uncertainty. The FSAR shows that there is a considerable margin with respect to filling the pressurizer. A loss of normal feedwater transient with the assumption that the two smallest auxiliary feedwater pumps and reactor coolant pumps are running even results in additional margin.

This analysis establishes the capacity of the smallest single pump and also establishes train association of equipment so that this analysis remains valid assuming the most limiting single failure.

Plant Cooldown

Maximum and minimum flow requirements from the previously discussed transients meet the flow requirements of plant cooldown. This operation, however, defines the basis for tankage size, based on the required cooldown duration, maximum decay heat input and maximum stored heat in the system. As previously discussed in response 1A, the auxiliary feedwater system partially cools the system to the point where the RHRs may complete the cooldown, i.e., 350°F in the RCS. Table 2-1 shows the assumptions used to determine the cooldown heat capacity of the auxiliary feedwater system.

The cooldown is assumed to commence at rated power, and maximum trip delays and decay heat source terms are assumed when the reactor is tripped. Primary metal primary water, secondary system metal, and secondary system water are all included in the stored heat to be removed by the AFWS. See Table 2-2 for the items consituting the sensible heat stored in the NSSS.

This operation is analyzed to establish minimum tank size requirements for auxiliary feedwater fluid source which are normally aligned.

TABLE 2-1

SUMMARY OF ASSUMPTIONS USED IN AFWS DESIGN VERIFICATION ANALYSES

Transient	Loss of Feedwater (station blackout)	Cooldown
a. Max reactor power	102% of ESD rating (102% of 3391 MWt)	3315 MWt
b. Time delay from event* to Rx trip	2 sec	2 sec
c. AFWS actuation signal/ time delay for AFWS flow	lo-lo SG level 1 minute	N/A
d. SG water level at time of reactor trip	(lo SG level + steam-feed mismatch) 0% NR span	N/A
e. Initial SG inventory	63,000 lbm/SG (at trip)	108,600 lbm/SG @ 506.3°F
Rate of change before & after AFWS actuation	See FSAR Section 14.1.9	N/A
Decay heat	FSAR Section 14.1.9	FSAR Section 14.1.9
f. AFW pump design	1123 psia (Min. Requirement)	1123 psia
g. Minimum # of SGs which must receive AFW flow	2 of 4	N/A
h. RC pump status	Tripped @ reactor trip	Tripped
i. Maximum AFW temperature	100°F	100°F
j. Operator action	None	N/A
k. MFW purge volume/temp.	800 ft^3/435°F	280 ft^3/428.6°F
l. Normal blowdown	None assumed	None assumed
m. Sensible heat	See cooldown	Table 2-2
n. Time at standby/time to cooldown to RHR	2 hr/4 hr	2 hr/4 hr
o. AFW flow rate	420 GPM - constant (min. requirement)	Variable

* Event - Steam/feed mismatch

TABLE 2-2

Summary of Sensible Heat Sources

Primary Water Sources (initially at rated power temperature and inventory)
- o RCS fluid
- o Pressurizer fluid (liquid and vapor)

Primary Metal Sources (initially at rated power temperature)
- o Reactor Coolant piping, pumps and reactor vessel
- o Pressurizer
- o Steam generator tube metal and tube sheet
- o Steam generator metal below tube sheet
- o Reactor Vessel internals

Secondary Water Sources (initially at rated power temperature and inventory)
- o Steam generator fluid (liquid and vapor)
- o Main feedwater purge fluid between steam generator and AFWS piping.

Secondary Metal Sources (initially at rated power temperature)
- o All steam generator metal above tube sheet, excluding tubes.

Question 3

Verify that the AFW pumps in your plant will supply the necessary flow to the steam generator(s) as determined by Items 1 and 2 above considering a single failure. Identify the margin in sizing the pump flow to allow for pump recirculation flow, seal leakage, and pump wear.

Response to 3

Figure 3-1 schematically shows the major features and components of the Auxiliary Feedwater System for the Zion Units. Flow rates for all of the design transients described in Response 2 have been met by the system for the worst single failure. The flows for those single failures considered are tabulated for the various transients in Table 3-1, including the following:

A. A/C Train Failure
B. Turbine Driven Pump Failure
C. Motor Driven Pump Failure
D. AFWS check valve failure (failure to close on reverse flow).

Reference Table 3-2 for the pump flow sizing margin.

Summary

As indicated in Table 2-1, the minimum required AFW flow rate is 420 gpm. Table 3-1 illustrates that during the analyzed transients and projected single failues there is, at minimum, 840 gpm available. Sufficient AFW flow is available in the Zion Station design.

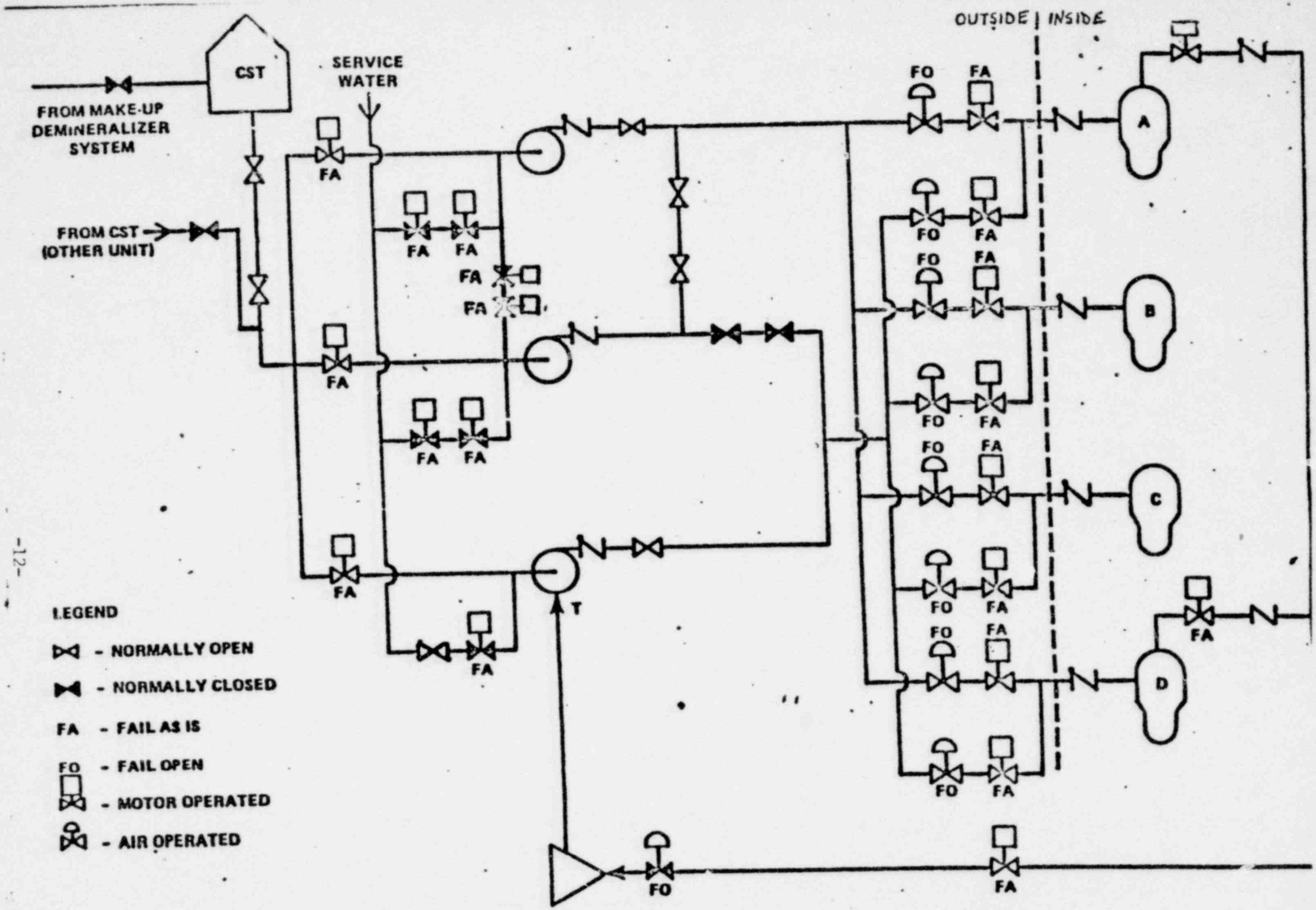

Figure 3-1

Zion Auxiliary Feedwater System

TABLE 3-1

Auxiliary Feedwater Flow(1)(3) to Steam Generators Following an Accident/Transient with Selected Single Failure - GPM

Accident/Transient	Single Failure Elec. Train Failure A	TD Pump Failure B	MD Pump Failure C	CV(2) Failure D
1. Loss of Main FW	840	840	840	1260
2. Loss of Offsite AC Power	840	840	840	1260
3. Cooldown	840	840	840	1260

Notes:

(1) Items 1 thru 3 are minimum expected flows to intact loops.

(2) Including only those CVs in the AFWS. "Failure" is interpreted as failure to close on reverse flow; failure of the CV to open to permit flow in the normal direction is not considered.

(3) These flows are adjusted to represent the condition that all pumps are throttled to 420 gpm to minimize feedwater hammer potential.

TABLE 3-2

Auxiliary Feedwater Pump Flow Capacities
(Reference FSAR 6.7.3)

	Turbine Driven Pump	Motor Driven Pump
1. Net developed head (design)	3100 ft.	3100 ft.
2. Recirculation flow	90 GPM	45 GPM
3. Available for leakage/pump wear	60 GPM	60 GPM
4. Total flow to steam generator	840 GPM	420 GPM
5. Total flow of pump (certified)	990 GPM	525 GPM