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Consumers Power Company

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January 24, 1978

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Director of Nuclear Reactor Regulation
Att: Mr Albert Schwencer, Chief
Operating Reactors Branch No 1
US Nuclear Regulatory Commission
Washington, DC 20555

DOCKET 50-255 - LICENSE DPR-20 - PALISADES PLANT - FEED-WATER LINE WATER HAMMER

Additional information relating to water hammer in feed-water lines and feed-water spargers was requested by the NRC on September 2, 1977. The information requested is similar to that requested by the NRC by letter dated May 13, 1975 and responded to by Consumers Power on July 16, 1975.

In our continuing review of potential water hammer problems, a consultant was engaged to evaluate the Palisades Plant. Their report entitled, "Evaluation of Auxiliary Feedwater and Main Feedwater Water Hammer Potential at Palisades Plant," dated February 24, 1977, is attached as a reference.

As a result of our consultant's report, Palisades Plant Administrative Procedures were modified to limit steam generator reflooding rate to 100 gpm. (See Attachment 2 for a comparison of various reflood rates and plant trips.)

It was also concluded in the NSC report that some additional testing should be done. Consumers Power has concluded that this would not be appropriate for the following reasons:

1. The exact causes of documented feed-water water hammer are not known.

2. The Palisades Plant has previously experienced several cases in which conditions were supposedly conducive to water hammer without any actual water hammer occurrences.

3. The Palisades Plant Administrative Procedures have been modified to restrict steam generator reflood rates to rates below those which supposedly cause water hammer.

In addition to the plant conditions discussed in the NSC report, there was a plant outage (No 77-17) which resulted from loss of off-site power. (See ER-77-047.) Water hammer in the condensate system was extensive but the only

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damage was the loosening of the mountings for the gland seal exhauster. Reflooding of the steam generators occurred without incident and there wasn't any water hammer in the feed-water piping.

Consumers Power will continue to use Administrative Procedures that will limit the steam generator reflooding rate to 100 gpm and will report any occurrences of water hammer per the requirements specified in our Technical Specifications and the form attached to the NRC letter of September 2, 1977.

Additional procedural or design changes are not anticipated at this time.

Eilish McKnight for

David P Hoffman
Assistant Nuclear Licensing Administrator

CC: JGKeppler, USNRC

CONTROLLED No. 3

MDL # E77-006

CPC-01-07

February 24, 1977

EVALUATION OF
AUXILIARY FEEDWATER AND MAIN FEEDWATER
WATER HAMMER POTENTIAL AT
PALISADES PLANT

Prepared for

CONSUMERS POWER COMPANY

by

NUCLEAR SERVICES CORPORATION

Campbell, California

Prepared by R. A. Uffer
R. A. Uffer

Reviewed by VKChexal
V. K. Chexal

Approved by Henry J. Thailer
H. J. Thailer

Issued by G A Randall
G. A. Randall

Date 2/24/77

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1.0 INTRODUCTION

This report, prepared for the Consumers Power Company, presents the results of an investigation which was performed to determine the potential for a water hammer event for the Palisades Plant.

The recent Nuclear Regulatory Commission inquiry (Reference 1) requested information concerning the potential for a water hammer occurrence in the feedwater systems for the Palisades Plant caused by the uncovering of the feedwater sparger. Water hammer occurrences have been observed in several PWR steam generators. However, in only one of these plants was the water hammer event severe enough to cause a breach of the feedwater system pressure retaining boundary. In other plants, damage to valves, insulation, and supports has resulted, but the pressure retaining integrity of the systems was maintained. In all these cases, the steam generator water levels dropped below the feedwater sparger and the water hammer event occurred during the steam generator water level recovery phase.

A steam water slugging mechanism has been associated with these occurrences. Additional experimental data is required, before the mechanism for the steam-water slugging type of water hammer is fully understood and the sensitivity of all the parameters associated with the problem can be quantified. Until such time as this data is available, conservative methods must be employed to define both the potential of water hammer occurrence and the forces resulting from such occurrences. The evaluation reported herein utilizes presently available information on the subject.

This report considers the potential for the occurrence of the aforementioned water hammer event based upon an evaluation of the Palisades piping configuration and operating procedures.

2.0 PIPING AND SYSTEMS DESCRIPTION

2.1 Piping Description

2.1.1 Main Feedwater System (FW)

The feedwater system provides water to the steam generators for removal of reactor coolant system heat and generation of steam.

The FW piping system originates at the two boiler feed pumps located at Elevation 590' of the turbine building. Two 18 inch lines run from the boiler feed pumps to a common header. The header divides into two branches each feeding a high pressure heater and continuing on through the containment. Each line enters the containment at Elevation 601'6" and after a horizontal run rises to Elevation 653'9". The piping after another horizontal run enters the steam generators at this elevation as shown in Figure 2-1. Each line contains a feedwater control valve and shut off valve between the pump and the high pressure heater. There is a check valve in each line just outside the containment penetration.

Inside each steam generator two 12" piping branches carry flow from the feedwater line to the feedwater sparger which is located two feet below the feedwater nozzle as shown in Figure 2-2.

2.1.2 Auxiliary Feedwater (AFW)

The AFW system provides water to the steam generator when the main boiler feed pumps are not being used. Both AFW pumps (one of which is redundant) are located in the condensate sump area of the turbine building. Discharge (six inch) lines from each pump join into a common six inch diameter header. The header splits into two six inch lines, each joining a main feedline between the main feed check valve and the containment penetration.

2.2 Operation

2.2.1 Normal Plant Operation

During normal plant operation, the two boiler feed pumps are in operation supplying feedwater to the steam generators. The low flow bypass control valves are closed. All other valves in the main feedwater flow path are open. The feedwater control valves are in an automatic control mode and are regulating steam generator flow. The AFW pumps are on standby and the AFW system is isolated from the main feed system by the AFW control valves.

Simplified flow diagrams of the FW and AFW systems are shown in Figure 2-3 and 2-4 respectively.

The feedwater sparger is six feet below the normal steam generator water level. The main feedwater line and sparger are filled with 419°F water at full load conditions. The steam generator pressure will vary from 600 psig at 700 MWe to 900 psig at hot standby. The AFW lines upstream of their various shutoff valves are filled with water at ambient temperature and pressure.

2.2.2 Feedwater Operation Following a Plant Trip

Following a plant trip, the turbine stop valves are closed. Thus, the normal steam exhaust path from the steam generators through the turbine stop valves is unavailable. This condition causes secondary system pressure to rise. The increasing pressure causes the water level in the steam generators to drop rapidly, since a significant portion of the steam generator water is a two phase mixture containing steam bubbles which are collapsed by the increase in pressure, thus shrinking the volume of the two phase mixture water. The sparger, however, is sufficiently (six feet) below the normal water line so that it is normally not uncovered following a turbine trip.

Simultaneously, a signal is automatically initiated which will ramp feedwater flow to 5% of normal rated flow within 30 seconds.

2.2.3 Feedwater Sparger Uncovering

During the history of the Palisades Plant, there have been several instances in which a reactor trip occurred due to low steam generator level. All of these instances occurred as a result of a feedwater component malfunction. Table 2-1[2] is a summary of the low steam generator level trips experienced at the Palisades Plant. An evaluation of sparger draining and refill following these low level trips is presented in Section 3.2 of this report.

2.2.4 Refill Following Loss of Steam Generator Level

The steam generator low level set point is at the centerline of the feedwater sparger. A low steam generator level initiates a reactor trip. Following receipt of a low level signal, feedwater control is switched from automatic to manual and level is recovered using either the main boiler feed pumps if available or the auxiliary feedwater pumps.

A procedural modification is being implemented that would limit feed flow to 100 gpm if the steam generator level has been below the sparger centerline for more than one minute. An evaluation of this procedure is presented in Section 3.5 of this report. X

Table 2-1

PALISADES PLANT

PLANT TRIP HISTORY RESULTING FROM
LOW STEAM GENERATOR LEVEL

Trip No.	Cause of Trip		Reflood Rate Through Sparger Level (Inches/Min)	Time Below Feed-water Sparger (Min)	Minimum Level During Transient (In)
72-1	Loss of Condensate Pump Suction	A	4.5	<5	-8
	At 15% Power	B	9*	<5	-8
72-4	Feedwater Pump Trip At 20% Power	A	-	-	N/A
		B	1.39	21	-24
72-6	A Feedwater Regulating System Failure	A	9*	<5	-16
	At 20% Power	B	-	-	+46
72-10	Feedwater Pump Trip at 60% Power	A	.32	60	>-48
		B	.49	113	>-48
72-14	Feedwater Valve Failure	A	9*	<5	-28
	At 15% Power	B	-	-	+38
72-21	Feedwater Valve Failure	A	3.01	<5	-14
	At 20% Power	B	-	-	+69
72-23	Feedwater Valve Failure	A	.76	69	-44
	At 82% Power	B	-	<5	-6

*Note: Reflood rate of 9"/min is the maximum detectable due to 7/8"/min chart speed.

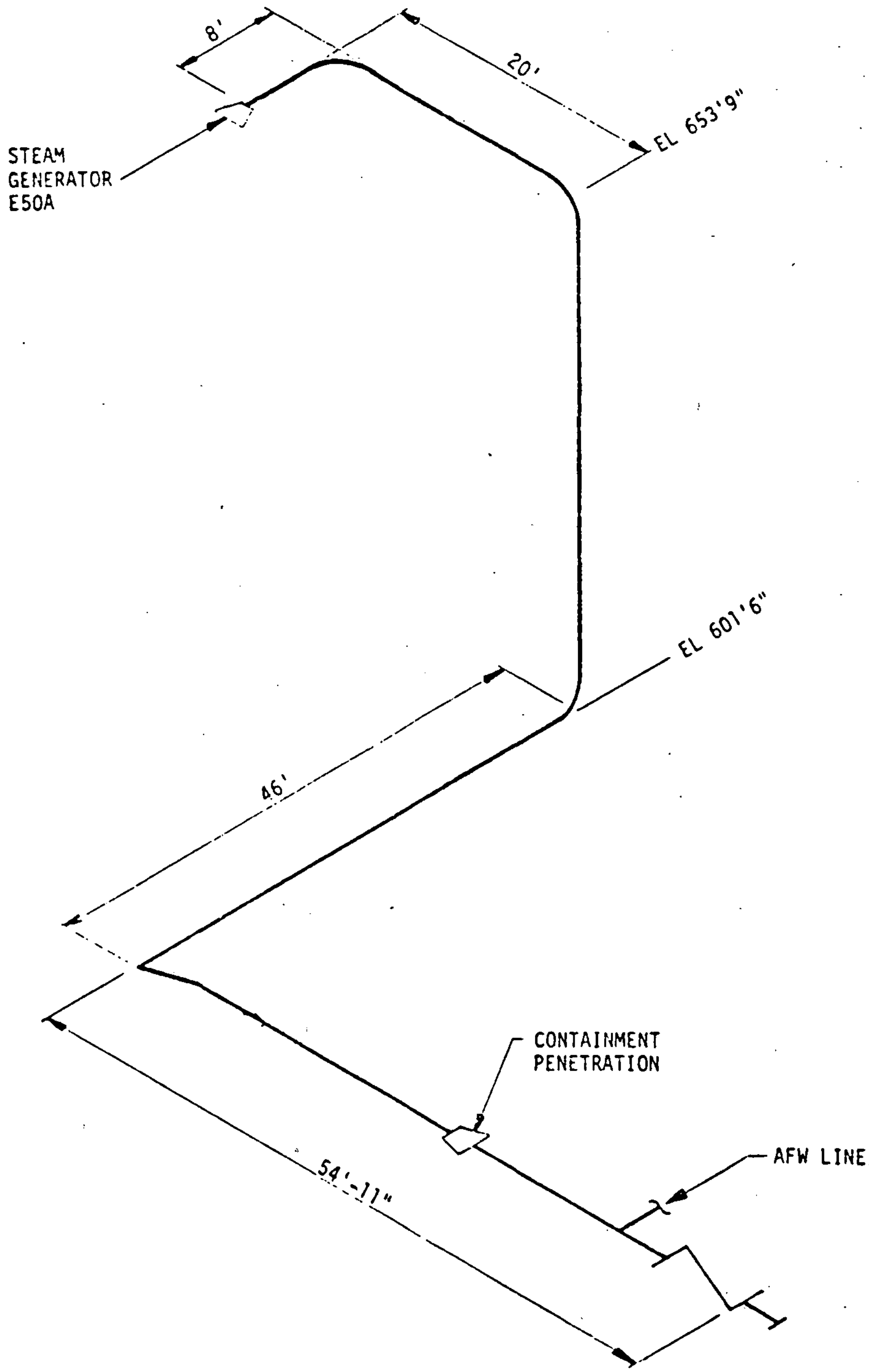
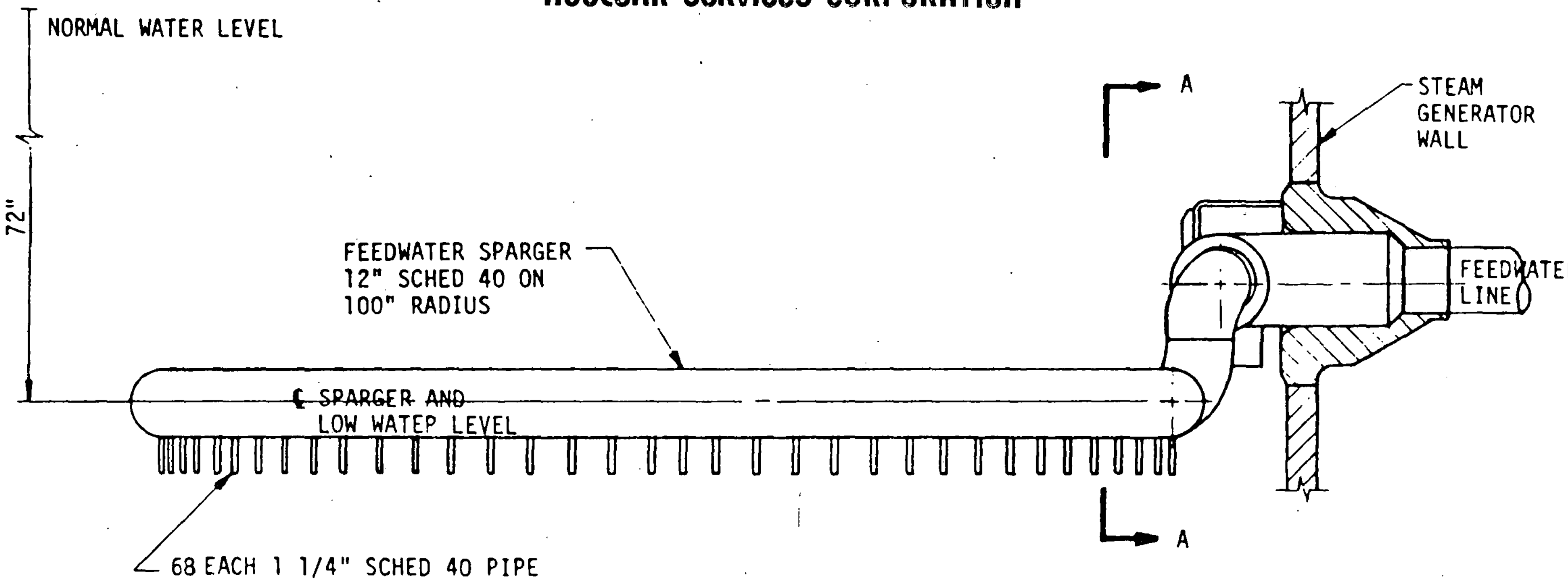
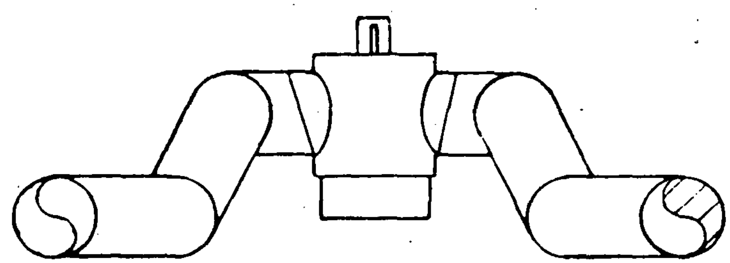


Figure 2-1. Palisades Plant
Feedwater Piping Inside Containment
Loop A (Loop B Opposite Hand)





SECTION A-A

Figure 2-2. Palisades Plant Feedwater Sparger

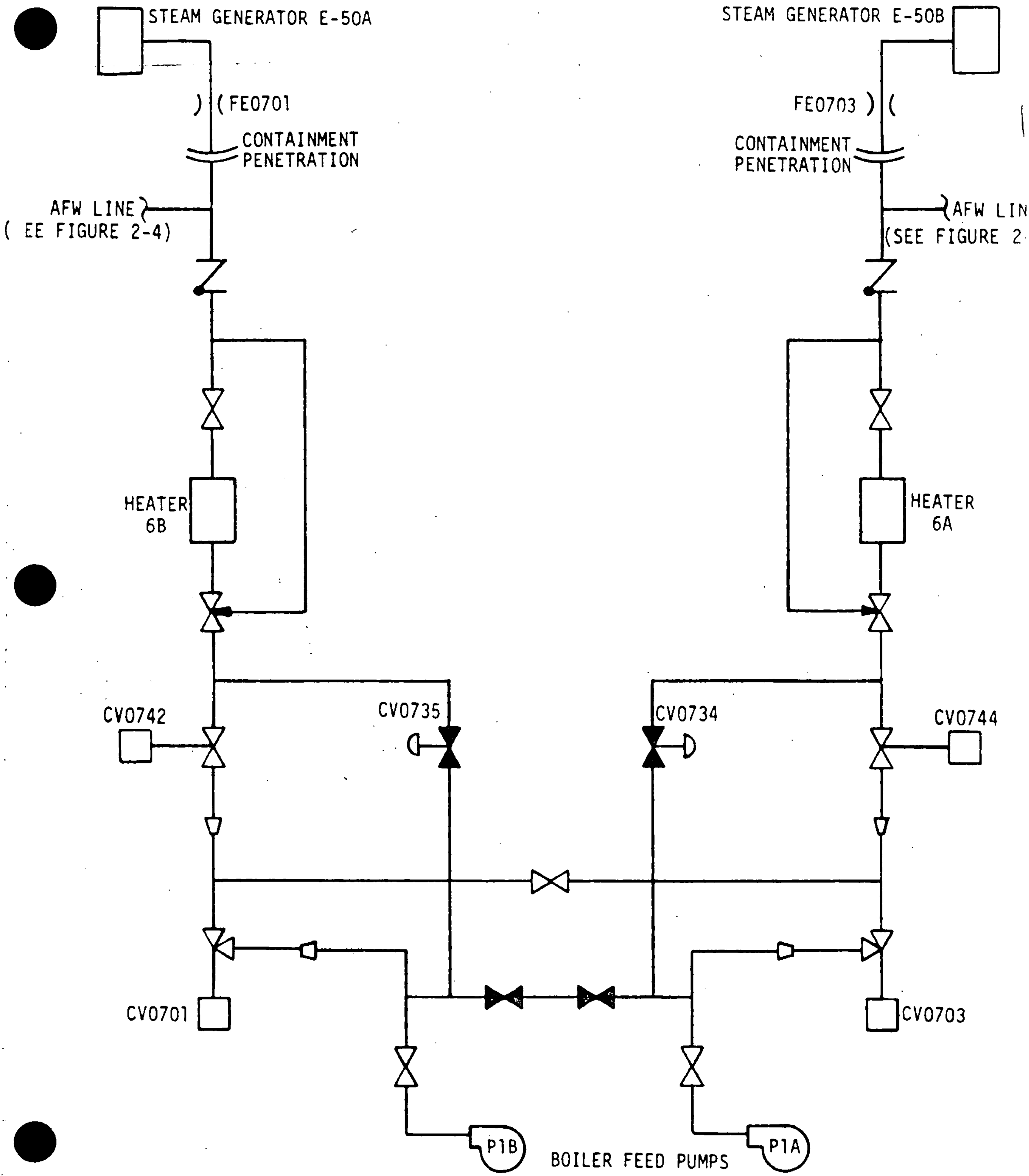


Figure 2-3. Palisades Plant Simplified Feedwater Flow Path

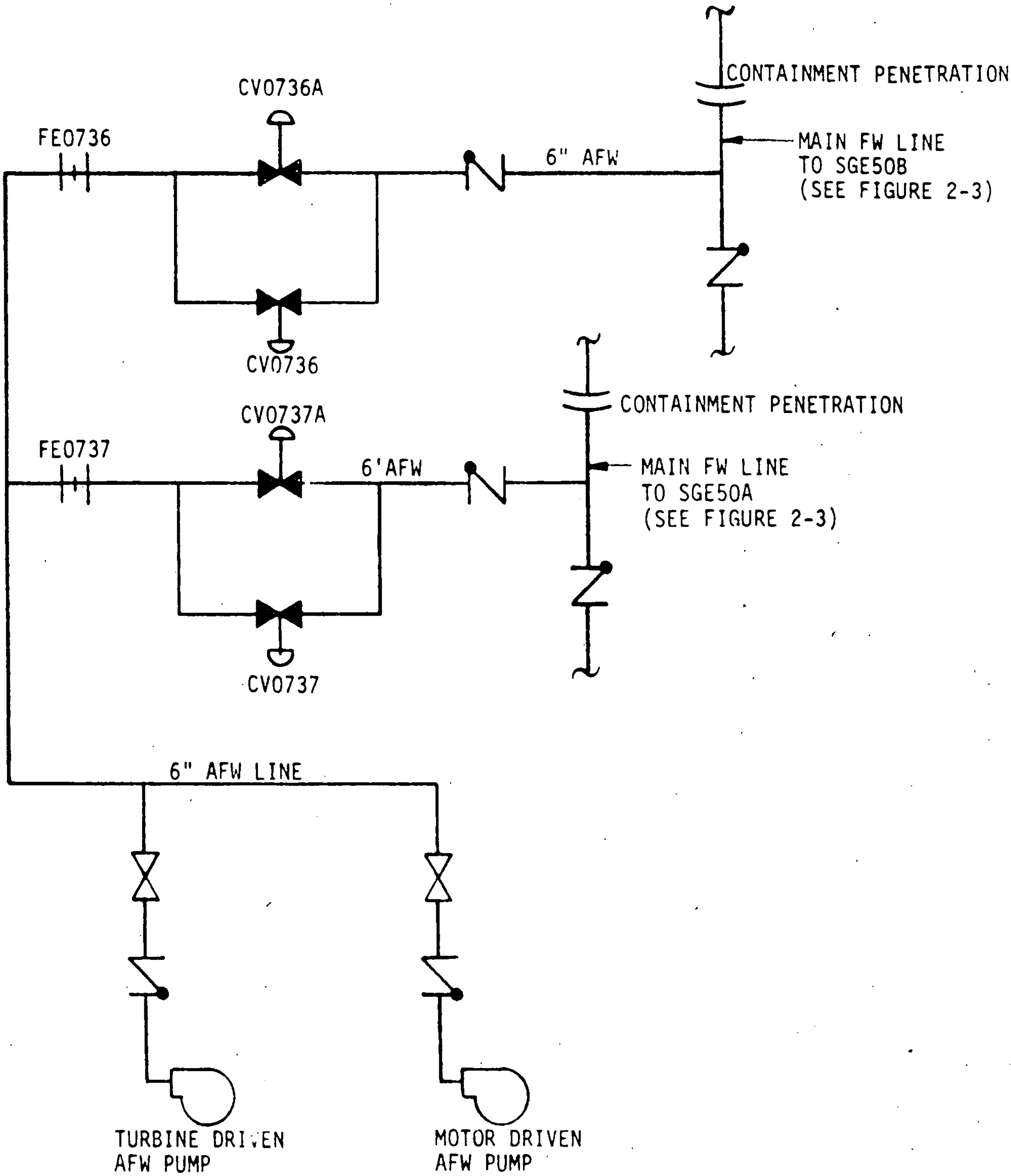


Figure 2-4. Palisades Plant
Simplified Auxiliary
Feedwater Flow Path

3.0 WATER HAMMER EVALUATION

3.1 Water Hammer History

Steam water slugging induced water hammers have been observed in several domestic and foreign pressurized water reactor plants. Table 3-1 gives a listing of these occurrences. In only one of these plants was the water hammer event severe enough to cause a breach of the feedwater system pressure retaining boundary. In other plants, damage to valves, insulation, and supports has resulted, but the pressure retaining integrity of the systems was maintained. In all these cases, the steam generator water levels dropped below the feedwater sparger and the water hammer event occurred during the steam generator water level recovery phase. Testing at various plants has also indicated a sensitivity to auxiliary feedwater flow rate. Flow rates of 100 gpm to 160 gpm have generally been found to be the minimum threshold for initiation of this slugging water hammer phenomenon.

3.2 Water Hammer History at Palisades

No water hammers or evidence of water hammer occurrence has been observed at the Palisades Plant. There have been several occurrences listed in Table 2-1 in which the feedwater sparger has been uncovered.

Calculations show the time for significant feedline and sparger drainage to be 5 to 20 minutes depending upon plant load prior to loss of level. Therefore, during several of these occurrences, the sparger was uncovered for sufficient time to assure significant draining of the sparger and feedwater line. For these occurrences, however, the reflood rate was relatively low, less than the rate believed necessary to initiate this phenomenon. It, therefore, cannot be concluded that both of the conditions conducive to water hammer occurrence have occurred simultaneously at the Palisades Plant, namely, sparger draining and rapid level recovery.

3.3 Mechanism of Water Hammer Occurrence

Insufficient data is available to quantitatively identify all parameters and mechanisms conducive to the steam-water slugging water hammer occurrence. However, a mechanism as discussed below is generally accepted as the mechanism for water hammer occurrence. Figure 3-1 shows the sequence of events in the vicinity of the sparger which leads to the uncovering of the sparger and subsequent draining of the feedwater line prior to steam generator water level recovery. Figures 3-2a and 3-2b show the feedline conditions prior to and at the start of feedline slug formation, respectively. The slug seals the main feedwater line and prevents the normal flow of steam from the steam generator to replenish the entrapped steam being condensed by the cold water layer. As steam is condensed at the steam-water interface, the pressure of the entrapped steam drops, accelerating the water slug away from the steam generator, as shown in Figure 3-2c and 3-2d. As the pressure continues to drop, more feedwater flow is accelerated into the entrapped steam bubble increasing the depressurization process until the bubble eventually reaches zero pressure. The slug continues to travel down the feedline until it impacts the column of feedwater upstream of the bubble as shown in Figure 3-2d. The rapid deceleration of the slug causes an overpressure spike to form. This pressure wave is then propogated down the piping.

3.4 Comparison of Palisades Feedwater System Layout with Other Plants

The design of the Palisades feedwater and auxiliary feedwater system is similar to that of many other pressurized water reactors. The Palisades sparger, however, differs from most plants in its connection to the feedline. In the most common sparger design the sparger centerline is coincident with the feedwater line centerline as shown in Figure 3-3. The Palisades sparger is approximately two feet below the feedline and connected by two branches as shown in Figure 2-2. A study of this design indicates that it contains no unique features that will preclude the water sealing condition conducive to initiation of slugging type water hammers observed in other designs. The remainder of the sparger design is similar to that of other plants examined and should have no unique effects on the probability of water hammer occurrence.

3.5 Effect of Recovering Steam Generator Level

If the level in a steam generator has been below the feedwater sparger center line for more than one minute, new operating procedures will limit flow to the uncovered sparger to less than 100 gpm until the steam generator is above the top of the main feedline.

If the 100 gpm feed rate is inadequate to control primary loop temperatures, the feed rate may be increased to 150 gpm, provided: a) the sparger has been uncovered for at least 15 minutes, b) the trip occurred at greater than 85% power, and c) the steam generator level is maintained at least two feet below the sparger center line. These provisions prevent the availability of a water slug to seal the steam line.

The reduced cooling capacity will have no adverse effect on core or primary loop cooling requirements, as defined in the Palisades FSAR.

This procedure will preclude the combination of rapid feed flow and a partially drained line that is generally considered conducive to water hammer occurrence.

Table 3-1

Feedwater-Steam Water Hammer Occurrences[4,6]

Plant	Type	Date	Reactor Status	Damage	Modifications
*Mihama 2	Mitsubishi 2 loop	10/11/71	Hot Functional	Minor to snubbers, AFW pump seal, AFW pump pressure gauge	Administrative controls on AFW flow rate
Surry	Westinghouse 3 loop	10/1/72	Preoperational Testing	feedline check valve, local piping displacement	Modify piping to add loop seal
Indian Point 2	Westinghouse 4 loop	11/13/73	Operating	piping failure, FW containment penetration	Modify piping to reduce length of horizontal piping; added J tubes to sparger
Turkey Point 3 and 4	Westinghouse 3 loop	(3 occurrences)	Operating	feedwater check valves anchor bolts pulled out; plastic deformation of piping	Modified piping to reduce length of horizontal piping; Modified restraints and supports
*Tihange 1	ACLF Westinghouse 3 loop	2/75	Hot Functional, Low Power	pipe support, insulation	Administrative Controls on AFW flow rate
*Ringhals 2	Westinghouse 3 loop	3/29/75	Operating	restraint rod, insulation	Administrative Controls on AFW flow rate
Calvert Cliffs 1	Comp. Eng. 2 loops	5/12/75	Operating	Motor operators; both stop valves; hand wheel; one stop valve; 1-1/2" permanent piping set; insulation; valve regulator; hangers	Administrative Controls to 1) limit refill rate 2) Use EFW nozzle only to recover level; add standpipes to sparger

*Foreign plant not under Nuclear Regulatory Commission jurisdiction.

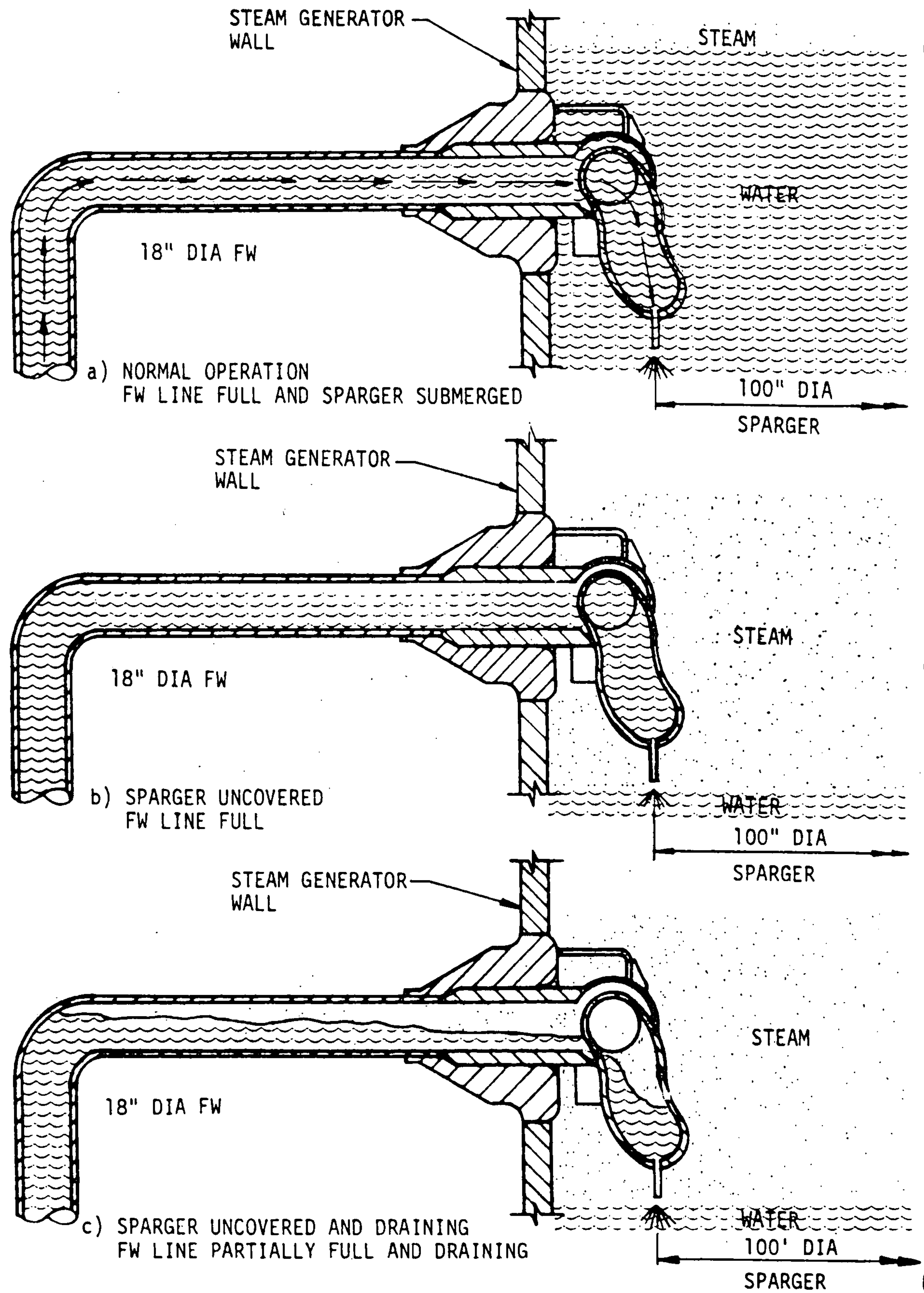
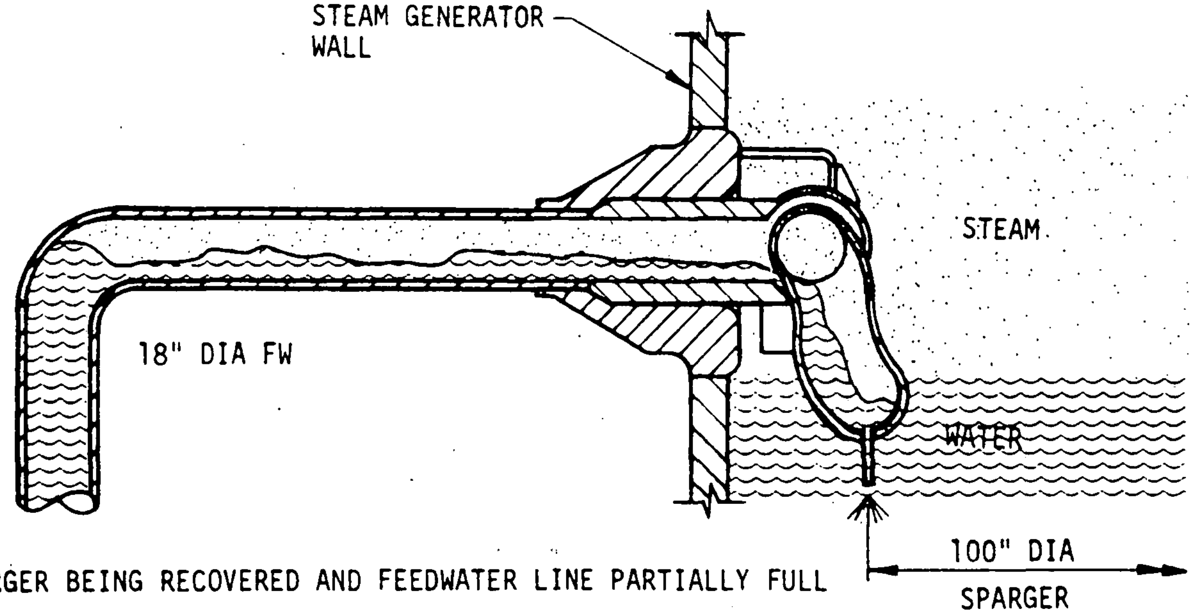
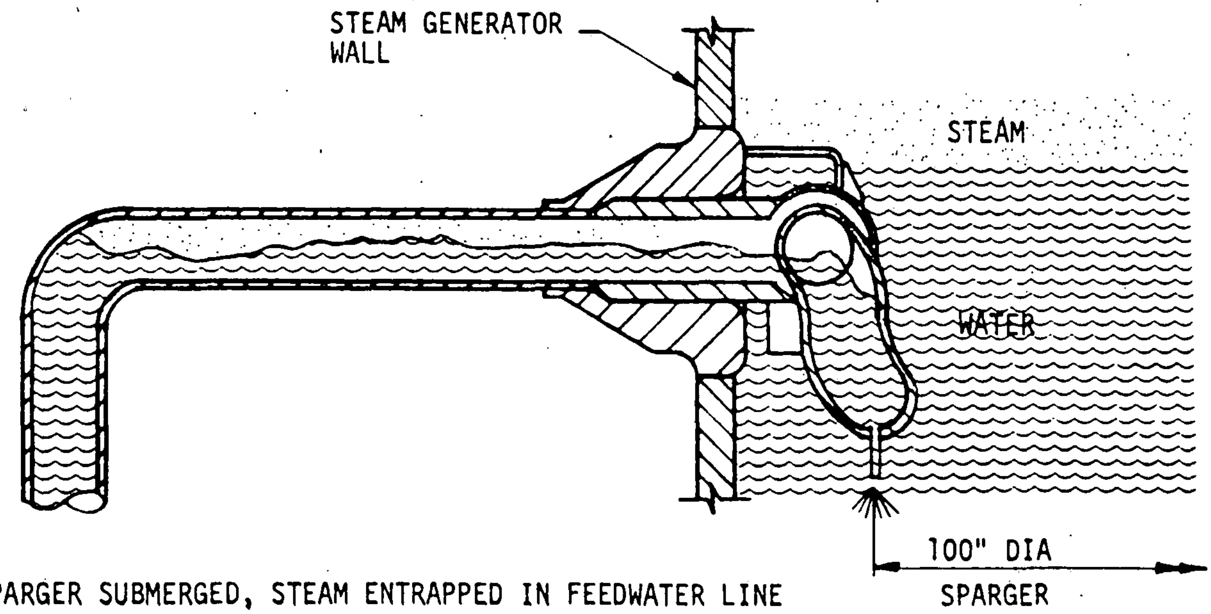


Figure 3-1. Palisades Plant
Sheet 1 Feedwater Sparger Conditions Following Level Drop

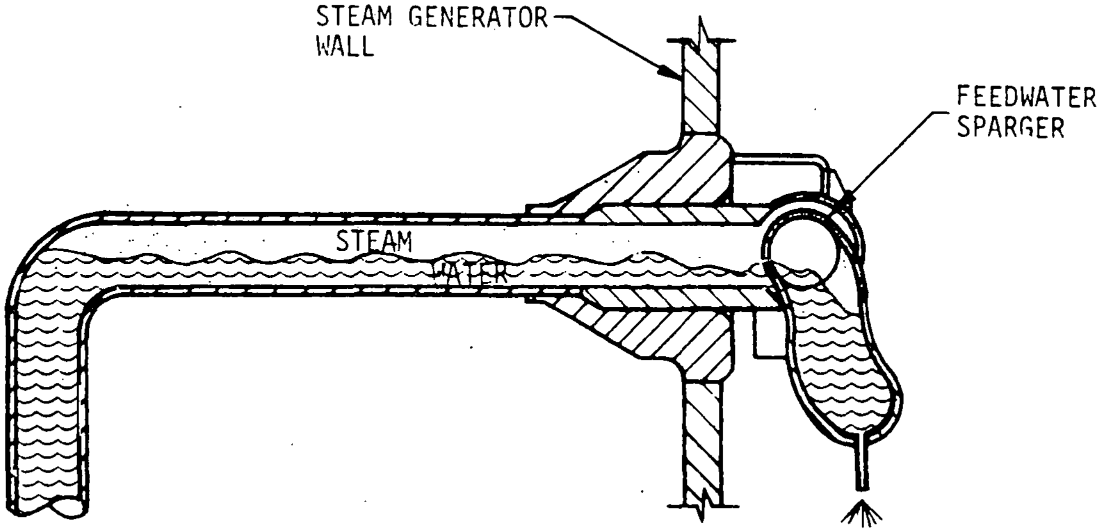


d) SPARGER BEING RECOVERED AND FEEDWATER LINE PARTIALLY FULL

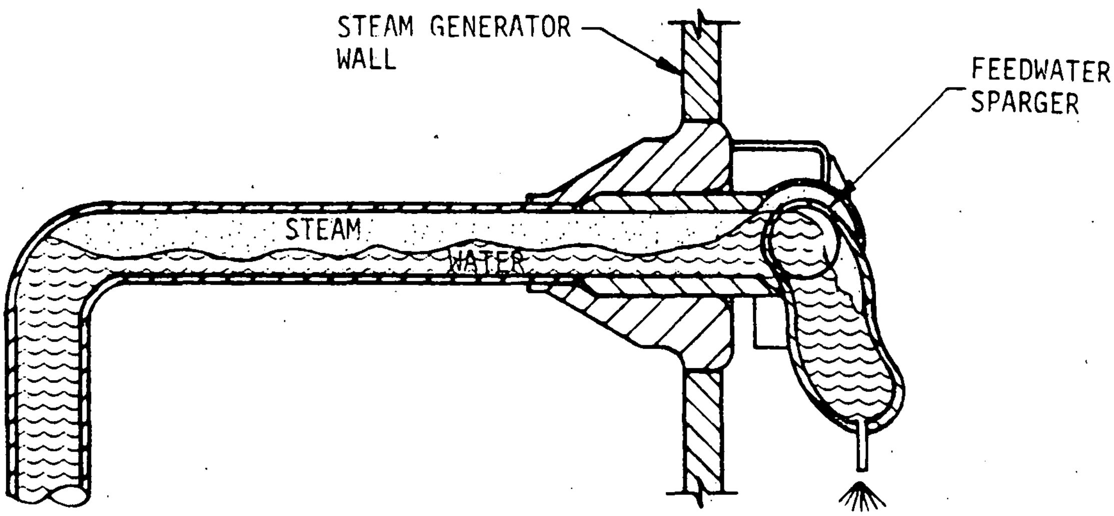


e) SPARGER SUBMERGED, STEAM ENTRAPPED IN FEEDWATER LINE

Figure 3-1. Palisades Plant
Sheet 2 Feedwater Sparger Conditions Following Level Drop

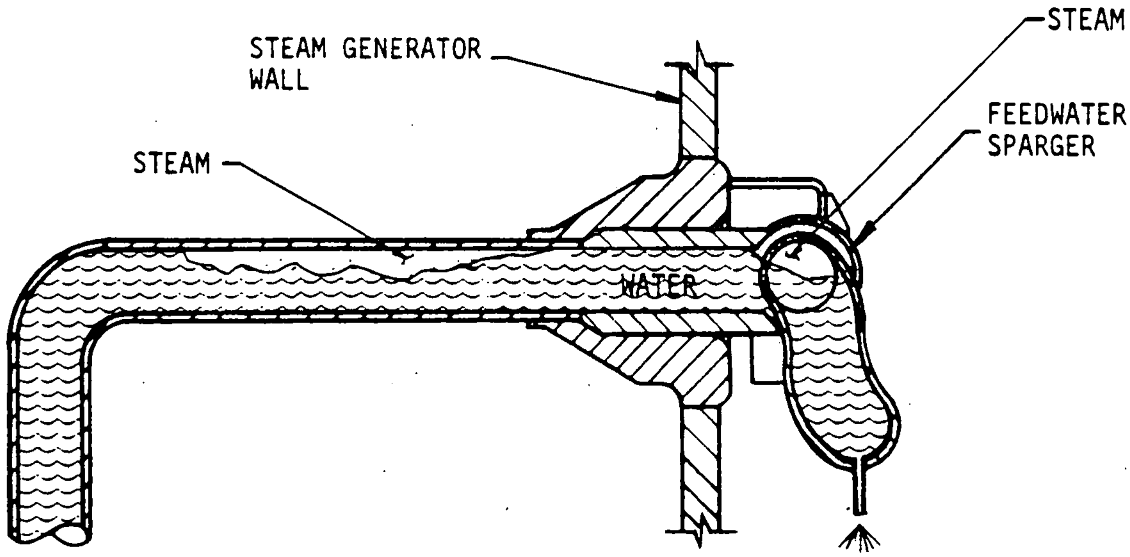


a) FEEDWATER LINE RUNNING PARTIALLY FULL

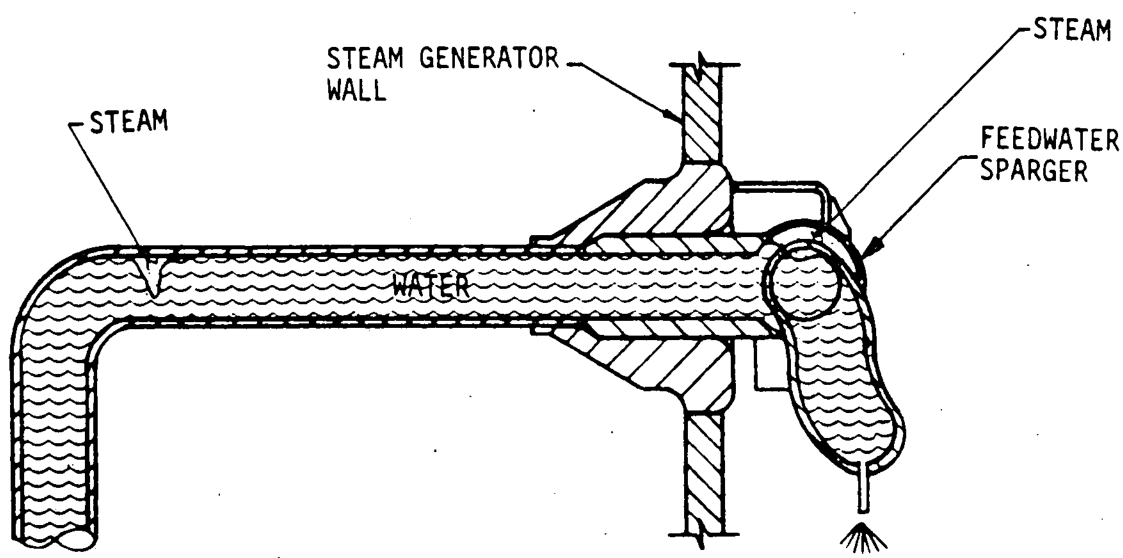


b) START OF SLUG FORMATION
PIPE IS SEALED BY SLUG

Figure 3-2. Palisades Plant
Sheet 1 Postulated Slug Formation
In Feedwater Line



c) SLUG BEING ACCELERATED THRU FEEDWATER LINE AS STEAM BUBBLE IS BEING DEPRESSURIZED



d) FEED LINE CONDITIONS PRIOR TO SLUG IMPACT

Figure 3-2. Palisades Plant
Sheet 2. Postulated Slug Formation In Feedwater Line

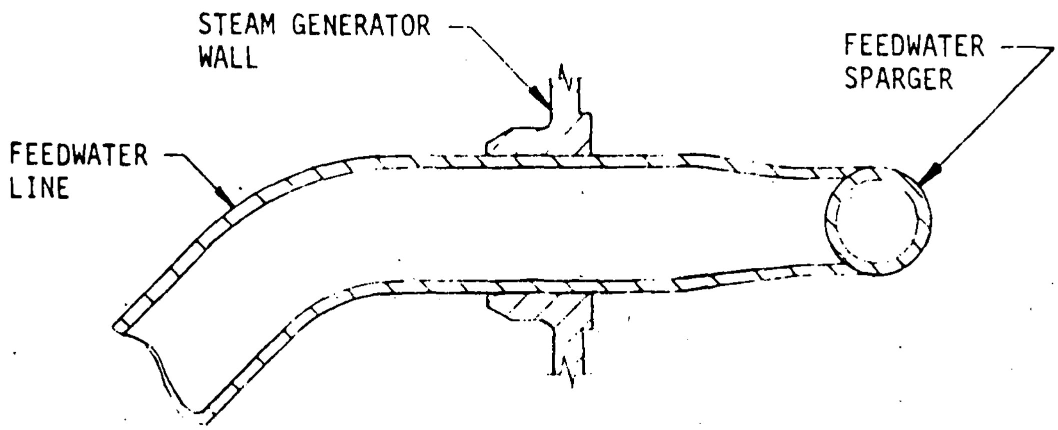


Figure 3-3. Common Feedwater Sparger Design
(Not Used at Palisades Plant)

4.0 CONCLUSIONS

The evaluation results indicate that a potential for a steam-water slugging water hammer may exist in the Palisades Plant However, operating procedures being implemented for recovering steam generator level, preclude the combination of high feed rate and a partially drained feed line that is generally considered conducive to water hammer occurrence.

Testing should be implemented to assure that the level recovery procedures prevent water hammer occurrences.

5.0 REFERENCES

1. Letter, R. A. Purple, Division of Reactor Licensing U.S. Nuclear Regulatory Commission to R. B. Sewell, Consumers Power Company dated May 13, 1975. Docket No. 50-255.

2. Letter, R. B. Sewell, Consumers Power Company to U.S. Nuclear Regulatory Commission, dated July 16, 1975, Docket No. 50-255.

3. Report of Steam Generator Feedwater Hammer Design Considerations for Trojan Nuclear Plant. Portland General Electric Company, dated August 1975.

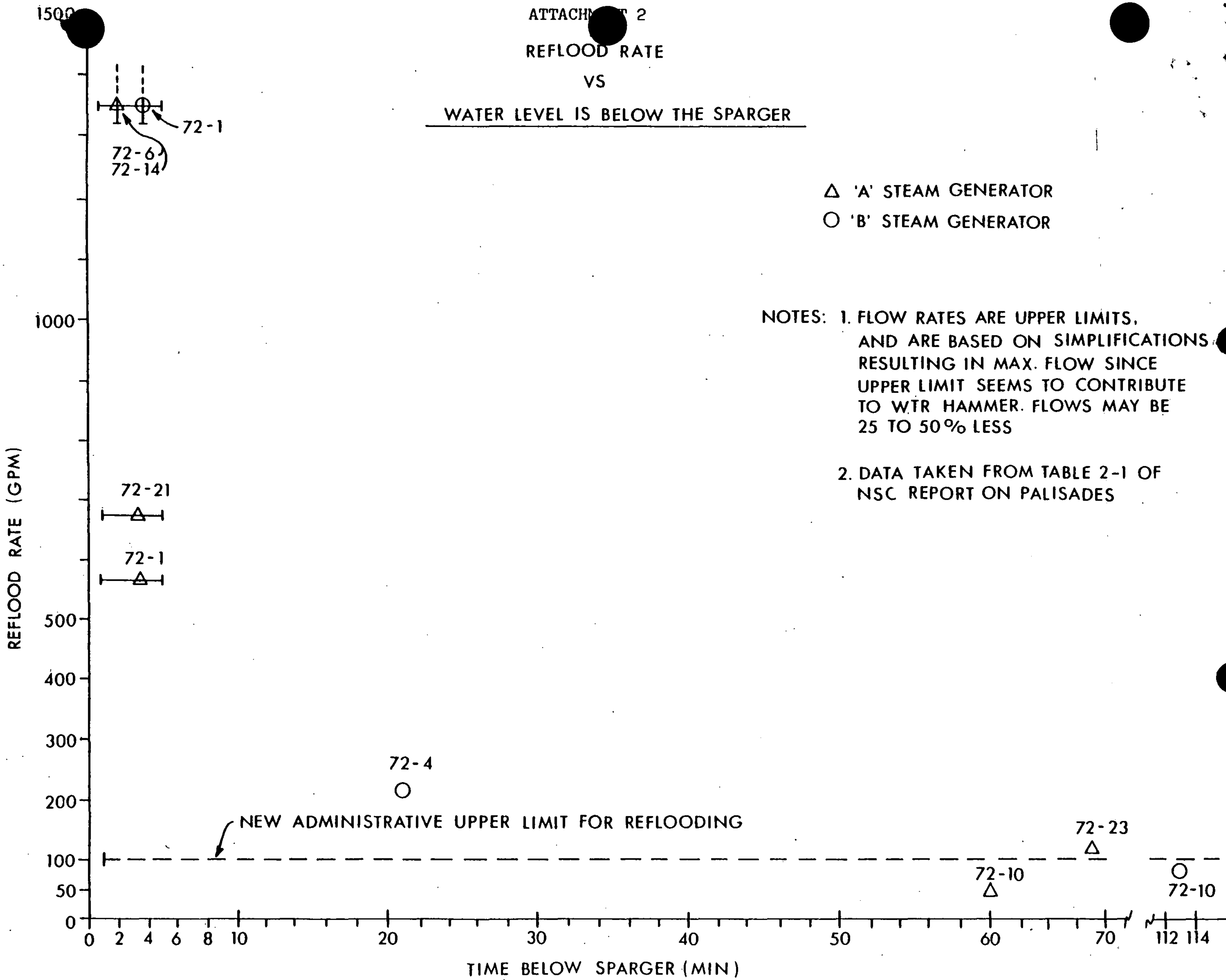
4. Abnormal Occurrence Report No. 50-317/75/36 dated May 23, 1975.

ATTACHMENT 2

REFLOOD RATE

VS

WATER LEVEL IS BELOW THE SPARGER



NOTES: 1. FLOW RATES ARE UPPER LIMITS, AND ARE BASED ON SIMPLIFICATIONS RESULTING IN MAX. FLOW SINCE UPPER LIMIT SEEMS TO CONTRIBUTE TO WTR HAMMER. FLOWS MAY BE 25 TO 50% LESS

2. DATA TAKEN FROM TABLE 2-1 OF NSC REPORT ON PALISADES