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SUBJECT: Forwards info re auxiliary feedwater sys flow requirements as appplicable to design basis transients & accident conditions.Info transmitted in response to Encl 2 of 790921 ltr.

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August 14, 1981

Mr. Darrell G. Eisenhut
Operating Reactors Branch #1
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Gentlemen:

Docket No. 50-305
Operating License DPR-43
Kewaunee Nuclear Power Plant
Information Regarding Auxiliary Feedwater System Flow Requirements

Please find attached information regarding auxiliary feedwater system flow requirements as applicable to the design basis transients and accident conditions at Kewaunee Nuclear Power Plant. This information is per the request of enclosure 2 in your September 21, 1979, letter.

Very truly yours,

E. R. Mathews
Senior Vice President
Power Supply & Engineering

jac

Attach.

cc - Mr. Robert Nelson, NRC Resident Inspector
RR #1, Box 999, Kewaunee, WI 54216

A001 S 1/1

ATTACHMENT

Response to request for information on the Auxiliary Feedwater System Flow requirements.

Response to 1.a

Plant transient and accident conditions used in establishing flow requirements for the Kewaunee Plant Auxiliary Feedwater System are as follows:

- Loss of Main Feedwater Transient (LMFW)
  - Loss of Main Feedwater with offsite power available
  - Loss of Main Feedwater without offsite power available (station blackout)
- Secondary system Pipe Ruptures
  - Feed line rupture
  - Steam line rupture
- Loss of all AC Power
- Loss of Coolant Accident (LOCA)
- Plant Cooldown

A description of the Auxiliary Feedwater System performance capabilities can be found in the Kewaunee Nuclear Power Plant FSAR, Section 6.6.

1) Loss of Main Feedwater (LMFW)

The Auxiliary Feedwater System is designed to deliver flow following a loss of main feedwater transient caused by:

- Interruption of the Main Feedwater System flow due to a malfunction in the feedwater or condensate system.
- Loss of offsite power or station blackout resulting in failure of the Feedwater System pumps, controls and valves.

The loss of main feedwater transient is a limiting plant condition where reliance in auxiliary feedwater flow is necessary for core protection. Therefore, this transient serves as the basis for establishing the minimum flow required for the smallest capacity, individual, auxiliary feedwater pump at the Kewaunee plant. The pumps are 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.

2) Loss of Main Feedwater with loss of offsite AC power

See the response to question (1) above. The loss of Main Feedwater transient is the limiting condition in this event.

3) Loss of Main Feedwater with loss of onsite and offsite AC power

This event does not impact the establishment of Auxiliary Feedwater System flow requirements. The blackout transient differs from a simple loss of main feedwater in that an emergency power source must be relied upon to operate vital equipment. The calculated transient would be similar for both the loss of main feedwater and the blackout condition, except the reactor coolant pump heat input is not a consideration in the blackout transient following loss of power to the reactor coolant bus.

4) Plant Cooldown

The Auxiliary Feedwater System may be required to cooldown the reactor coolant system following expected transients, certain accidents which could result in a loss of heat sink, or during normal cooldown prior to refueling or performing maintenance. Following reactor trip the Auxiliary Feedwater System is designed to remove plant sensible heat, decay heat produced by the reactor core, and reactor coolant pump heat in order to cool the Reactor Coolant System down to a hot leg temperature of approximately 350° F., while maintaining the steam generator level. At 350°F. the Residual Heat Removal system is placed into operation and completes the cool-down to cold shutdown conditions.

5) Turbine trip with and without bypass and

6) Main steam isolation valve closure

The transient conditions resulting from events (5) and (6) impose safety-related performance requirements on the Auxiliary Feedwater system, but they do not impact flow requirements of the Auxiliary Feedwater system. The system flow requirements are bound by other transients which are addressed in this question.

7) Main feed line break

A main feed line rupture will result in the following plant transients:

- loss of feedwater flow to the steam generators
- complete blowdown of one steam generator within a short time if the rupture occurs down stream of the last non-return valve in the main, or auxiliary feedwater piping to the steam generator
- Possible spilling of auxiliary feedwater out of the feedline break, if the auxiliary feedwater branch line is connected to the main feedwater line near the break.

Piping and valves are provided so that each of the pumps can supply either or both steam generators. This system design feature allows for terminating or limiting the amount of auxiliary feedwater which is delivered to a faulty loop or spilled through a break to ensure that sufficient flow is delivered to the remaining effective steam generator.

8) Main Steam Line Break

A main steam line rupture will result in the following plant transients.

- Initial plant cooldown
- Increase in containment pressure and temperature for an in-containment line break

During the initial phases of a main steam line rupture, auxiliary feedwater flow through the affected loop will contribute to the release of mass and energy to the containment atmosphere. Therefore, the steam line rupture conditions establish the upper (maximum) limit for auxiliary feedwater flow requirements.

Eventually the Reactor Coolant System will heat up again and auxiliary feedwater flow to the system will be required. Similar to the event of a main feedline break, piping and valves are provided so that each of the pumps can supply either or both steam generators. This system allows for terminating or limiting the amount of auxiliary feedwater which is delivered to the affected loop to ensure that sufficient flow is delivered to the remaining effective steam generator, and to prevent containment over-pressurization for incontainment steam line breaks.

9) Small Break Loss of Coolant Accident (LOCA)

A small break loss of coolant accident will result in the following plant transient:

- slow drop in the Reactor Coolant System pressure and liquid volume.

The Auxiliary Feedwater System functions basically the same following a small break loss of coolant accident as during hot shutdown; that is, maintaining a water level inventory on the secondary side of steam generators to provide a heat sink for removing decay heat. Therefore, the small break loss of coolant accidents do not impose any flow requirements on the auxiliary feedwater system in addition to those required by other events addressed in this response.

10) Loss of All AC Power

Total loss of AC power event results from accident conditions where the emergency power supply is lost in addition to onsite and offsite AC power. Battery power is assumed available for operation of protection circuits. The auxiliary Feedwater System design includes a turbine driven auxiliary pump which is not dependent on AC power and is capable of maintaining the plant in a hot shutdown condition until AC power is restored.

Response to 1.b

Talbe 1B-1 summarizes the general design basis criteria which was used in the response to Question 1.a above. Specific assumptions used will be discussed in response to Question 2.

TABLE 1B-1

Criteria for Auxiliary Feedwater System Design Basis Conditions

Condition or Transient	Classification*	Criteria*	Additional Design Criteria
1) Loss of Main Feedwater (LMFW)	Condition II	Peak RCS pressure not to exceed design pressure. No consequential fuel failure.	
2) Loss of Main Feedwater with AC loss of offsite AC power	Condition II	(same as LMFW)	
3) Loss of Main Feedwater with loss of onsite and offsite AC power	Condition II	(same as LMFW)	Establishes the need for an emergency power source to operate and control the vital equipment.
4) Cooldown	N/A	Removal of plant sensible heat, decay heat and reactor coolant pump heat.	100^{o}F/hr rate Cool RCS hot leg from 547^{o}F to appr. 350^{o}F
5) Turbine trip with & without bypass. 6) Main steam isolation valve closure		N/A	See response in Question 1.a
7) Main Feedline break	Condition IV	10CFR dose limits. Containment pressure not exceeded.	Core does not uncover Ability to terminate or limit the amount of feedwater flow to the faulted loop

TABLE 1B-1 (cont.)

Condition or Transient	Classification*	Criteria	Additional Design Criteria
8) Main Steam line break	Condition IV	10CFR dose limits. Containment design pressure not exceeded.	Ability to terminate or limit the amount of feedwater flow to the faulted loop.
9) Loss of Coolant Accident	Condition III	10CFR100 dose limits. 10CFR50 PCT limits.	
	Condition IV	10CFR100 dose limits. 10CFR50 PCT limits.	
10) Loss of All AC Power	N/A	Same as for a LMFW assuming a turbine driven pump.	Establishes the need for a pump and controls completely independent of AC power.

Response to 2

Analyses have been performed for the limiting transients which define the Auxiliary Feedwater System performance requirements. These analyses have been provided in the Kewaunee Nuclear Power Plant FSAR. Specifically, they include:

- Loss of Main Feedwater (Station Blackout)
- Rupture of a Main Feedwater Pipe
- Rupture of a Main Steam Pipe Inside Containment

In addition to the above transients, a LOCA analysis and analyses to determine the plant cooldown flow requirements (storage capacity), and the need for a turbine driven auxiliary feedwater pump (loss of all AC Power) were performed. The loss of AC power and the loss of coolant accident events do not impact the Auxiliary Feedwater System flow requirements. Each of the analyses listed above are explained in further detail in the following sections of this response.

Loss of Main Feedwater (Blackout)

A loss of feedwater analysis was performed in FSAR Section 14.1.10 for the purpose of showing that a single motor driven auxiliary feedwater pump delivering flow to one steam generator does not result in over-filling the pressurizer. Furthermore, the peak Reactor Coolant System 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. The 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, temperature and steam generator level at the time of reactor trip do not depend on the event sequence prior to trip. Although the time from the loss of feedwater until the reactor trip occurs cannot be determined from this analysis, this delay is expected to be 20-30 seconds. The analysis assumes that the plant is initially operating at 102% (calorimetric error) of the Engineered Safeguards design rating shown on table 2-1, a very conservative assumption for decay heat and stored energy in the Reactor Coolant System.

The reactor is assumed to be tripped on low-low steam generator level. For additional conservation steam generator level at the time of reactor trip was assumed to be 0% on the narrow range indication with allowance for level uncertainty. The FSAR shows that there is a considerable margin with respect to filling the pressurizer.

This analysis establishes the capacity for a single pump in the AFW system so that the analysis remains valid assuming a single active 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 condensate storage tank capacity 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 Residual Heat Removal System may complete the cooldown, i.e., 350° F in the Reactor Coolant System. Table 2-1 shows the assumptions used to determine the cooldown heat capacity of the Auxiliary Feedwater System.

The analysis assumed the maximum rated power, trip delays, and decay heat source terms 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 Auxiliary Feedwater System. See Table 2-2 for the items constituting the sensible heat stored in the Nuclear Steam Supply System. This analysis established the minimum condensate storage tank size requirements. In addition, the service water system provides an unlimited class 1 water source to the Auxiliary Feedwater System.

Main Feedline Break

The double ended rupture of a main feedwater pipe downstream of the main feedwater line check valve was analyzed. This accident is not considered a design basis event, but was analyized to determine the capability of the AFW System in handling the accident. Table 2-1 summarizes the assumptions used in the analyses performed for the Kewaunee plant. Reactor trip is assumed to occur as a result of a safety injection signal based on low steam main pressure in either loop at 20 seconds into the transient. This conservative assumption maximizes the stored heat prior to reactor trip and minimizes the ability of the steam generator to remove heat from the Reactor Coolant System following reactor trip due to a conservatively small total steam inventory. As in the loss of normal feedwater analysis, the initial power rating was assumed to be 102% of the Engineering Safeguards Design rating. The analysis assumes 400 gpm auxiliary feedwater delivered to the intact loop within 10 minutes of the reactor trip (10 minutes for operator action to reroute flow paths and to start the auxiliary feedwater pumps). The criteria listed in Table 1B-1 are met.

Main Steam Line Break Inside Containment

Because the steamline break transient is a cooldown, the Auxiliary Feedwater System is not needed to remove heat in the short term. Furthermore, addition of excessive auxiliary feedwater to the faulted steam generator will affect the peak containment pressure following a steamline break inside containment. This transient is performed for several break sizes. Auxiliary feedwater is assumed to be initiated at the time of the break, independent of system actuation signals to provide the most conservative assumptions used in this analysis. At 10 minutes after the break, it is assumed that the operator has isolated the Auxiliary Feedwater System from the faulted steam generator which subsequently blows down to ambient pressure. The criteria stated in Table 1B-1 are met.

This transient establishes auxiliary feedwater flow rate to a single faulted steam generator assuming all pumps operational and establishes criteria so that the flow requirements may be met considering the worst single active failure.

TABLE 2-1

Summary of Assumptions Used in AFWS Design Verification Analyses

	Transient	Loss of Feedwater (station blackout)	Cooldown	Main Feedline Break	Main Steamline Break (containment)
a.	Max reactor power	102% of ESD rating (102% of 1722 MWt)	1650 MWt	102% of ESD rating (102% of 1722 MWt)	0,100% of 1650 MWt
b.	Time delay from Rx trip signal to rod motion	2.0 sec	2 sec	2 sec (20 sec from event to Rx trip)	1.5 sec
c.	AFWS actuation signal/time delay for AFWS flow	lo-lo SG level 1 minute	N/A	Operator action/ 10 minutes after reactor trip	Assumed immediately, 0 sec (no delay)
d.	SG water level at time of reactor trip	(lo-lo SG level) 0% NR Span	N/A	N/A	N/A
e.	Initial SG inventory	61,000 lbm/SG	38,532 lbm/SG @ 510.8°F	92,500 lbm/SG	153,600 lbm/SG - 0% power case 108,500 lbm/SG - 100% power case
	Rate of change before & after AFWS actuation	see FSAR figure 14.1 - 46c	N/A	see figure 2-2	N/A
	decay heat	see figure 2-1	N/A	see figure 2-1	see figure 2-1
f.	AFW pump design pressure	see cooldown	1100 psia	see cooldown	see cooldown
g.	Minimum # of SGs which must receive AFW flow	1 of 2	N/A	1 of 2	1 of 2
h.	RC pump status	Tripped @ reactor trip	Tripped	Tripped @ reactor trip	All operating
i.	Maximum AFW temperature	100°F	80°F	100°F	80°F
j.	Operator action	none assumed	N/A	10 min.	10 min.
k.	MFW purge volume/temp.	100 ft^3/410.4 Btu/lbm	none assumed	100 ft^3/410.4 Btu/lbm	1250 ft^3/383.8 Btu/lbm
l.	Normal blowdown	none assumed	none assumed	none assumed	none assumed
m.	Sensible heat	see cooldown	Table 2-2	see cooldown	see cooldown
n.	Time at standby/time to cooldown to RHR	see cooldown	2 hr/4 hr	see cooldown	see cooldown
o.	AFW flow rate	200 GPM - constant (min. requirement)	variable	400 GPM at ten minutes from reactor trip	650 gpm

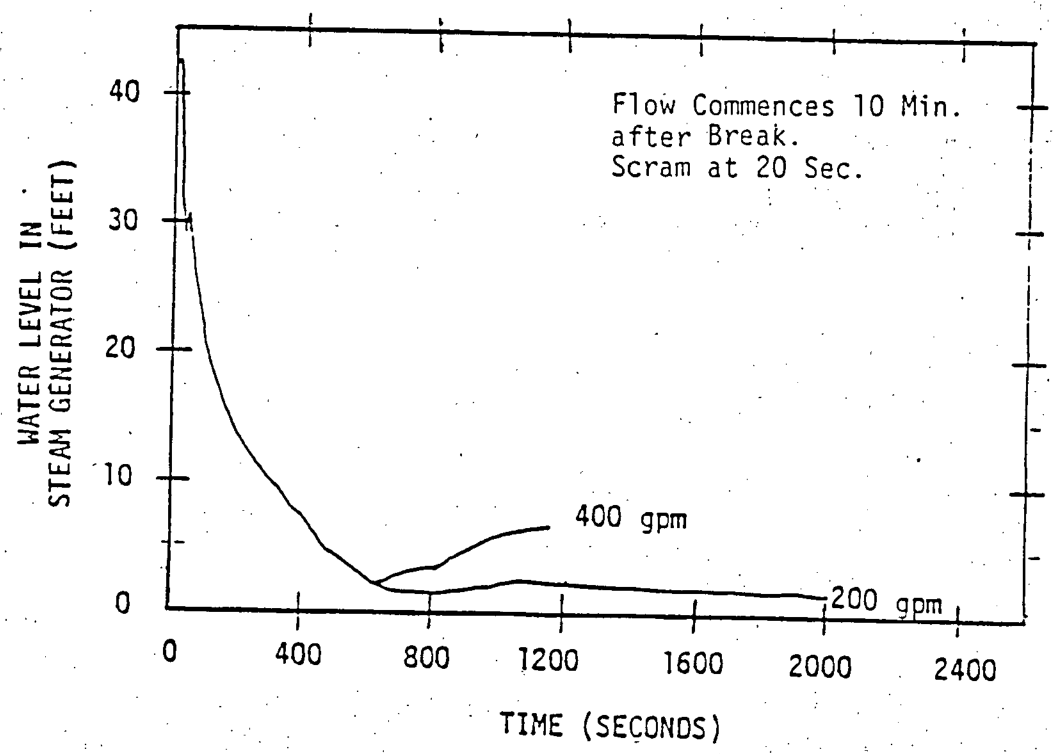

FIGURE 2-2 SG LEVEL VS TIME FOR FEEDLINE BREAK

TABLE 2-2

Summary of Sensible Heat Sources

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

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

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

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

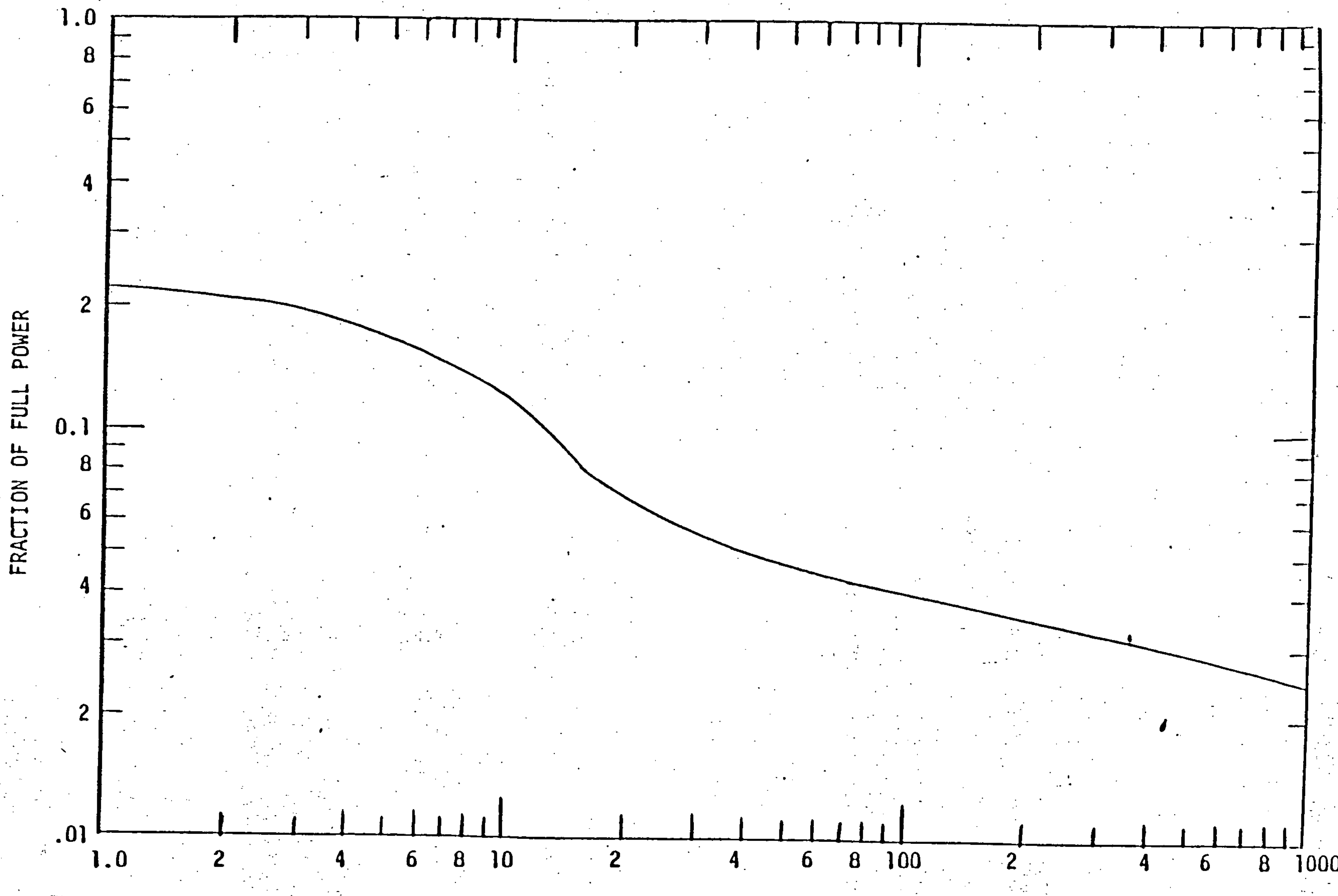

FIGURE 2-1a

DECAY HEAT CURVE

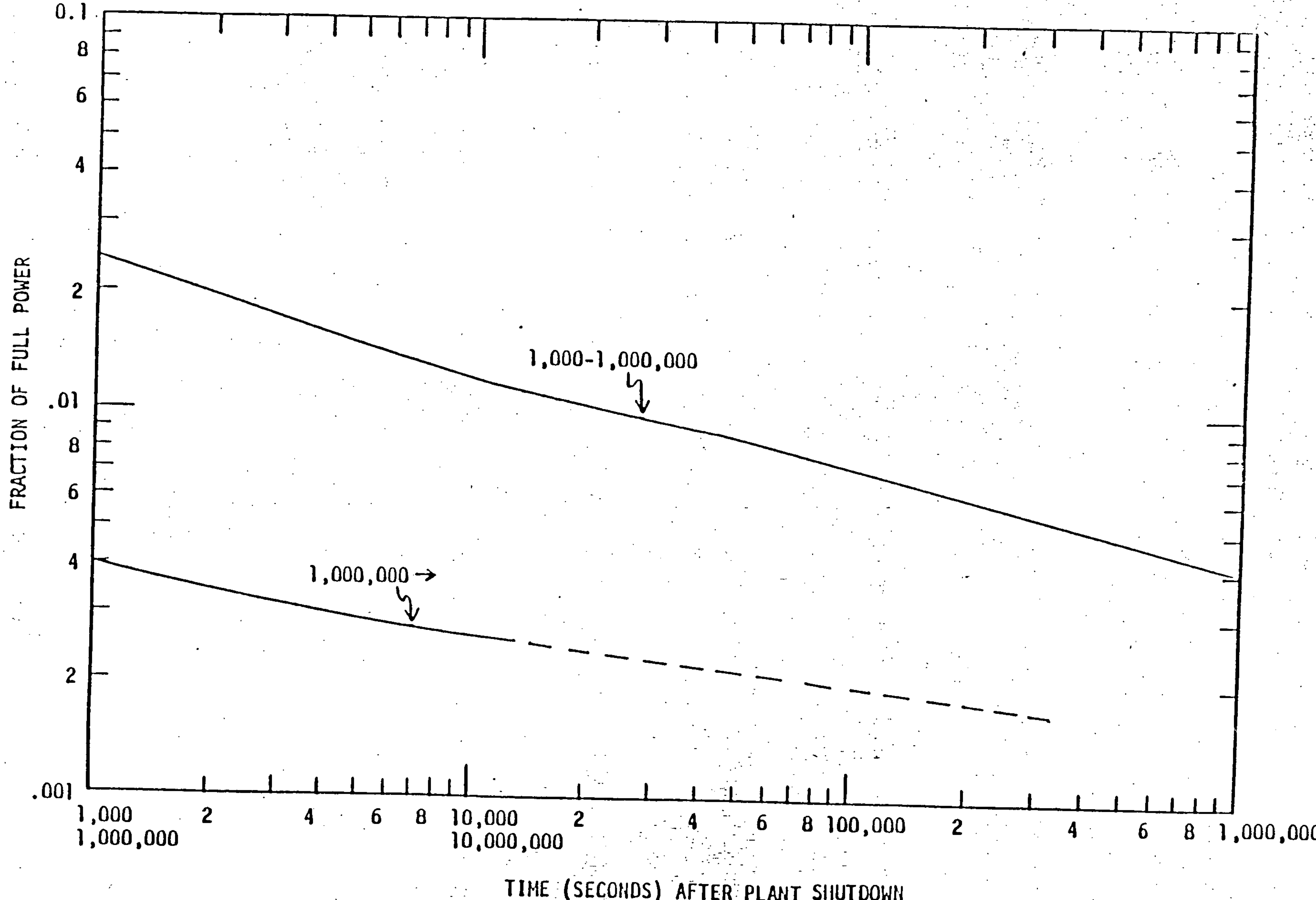
0.1
8
6
4
2
.01
8
6
4
2
.001
FRACTION OF FULL POWER
1,000-1,000,000
1,000,000
1,000
1,000,000
2
4
6
8
10,000
10,000,000
2
4
6
8
100,000
2
4
6
8
1,000,000
TIME (SECONDS) AFTER PLANT SHUTDOWN

FIGURE 2-1b

Response to 3

As stated in Section 6.6.3 of our FSAR and our letter from E. R. Mathews to D. G. Eisenhut dated December 14, 1979, decay heat removal requires 160 gallons per minute of feed flow to the steam generators (or 80 gallons per minute per Steam generator). Since any one of the three auxiliary feedwater pumps is capable of delivering this flow, there is no single failure which will result in the loss of system function.

All three of the pumps, two motor driven and one turbine driven, are rated at 240 gallons per minute output. Each of the pumps provides a small continuous recirculation flow of up to 40 gallons per minute which returns to the condensate storage tank. A portion of the pump recirculation flow is used to cool the pump sleeve-bearing oil coolers and the turbine bearings. Thus, oil cooling is available whenever the pump is running.

This leaves an available 200 gallons per minute flow to the steam generators which is sufficient to fulfill the safety related functions of the Auxiliary Feedwater System. The KNPP auxiliary feedwater system design includes two motor-driven pumps and a supplemental turbine driven pump, each one of which is capable of delivering 200 gallons per minute to either steam generator.