Enclosure 1-NP to LD-83-036

SYSTEM 80

CESSAR FSAR

DOCKET STN 50-470

RESPONSES TO QUESTIONS ON SLB METHOD

APRIL 1983

COMBUSTION ENGINEERING, INC.
NUCLEAR POWER SYSTEMS
WINDSOR, CONNECTICUT

LEGAL NOTICE

Question 440.6

Section 15C.2.3 (page 15C-2) of the CESSAR FSAR states:
"...Average core heat flux, reactor coolant flow rate, RCS pressure, and core inlet temperature, and core inlet temperature from CESEC are provided as input to TORC..."

Relative to reactor coolant flow rate, provide detailed documentation, definition and derivation of the core flow rate shown in Fig. 15.1.5-5.4. The flow rate shown in Fig. 15.1.5-5.4 does not appear to be the average core flow rate, but a flow rate based on flow splitting or flow to the hot assembly, etc.

Response:

The core flow rate shown in Fig. 15.1.5-5.4 is the average core flow rate versus time. The flow rates for both affected and intact steam generator loops are calculated by the CESEC flow model. The core flow rate is the sum of the loop flow rates minus the bypass flow rate, i.e.,

$$\text{Core flow rate} = (1\text{-Bypass fraction}) \times \sum \text{SG loop flow rates.}$$

In general the flow rate variations are due to density effects. For example, both core flow rate and loop flow rates dip at about 30 seconds. This was due to the decrease in fluid density in the cold legs caused by the temporary reduction in cooldown rate following turbine trip.

Question 440.7

Section 15C.2.3 (page 15C-2) of the CESSAR FSAR states:
"...Macbeth correlates critical heat flux to mass flux, inlet subcooling, pressure, heated diameter, and channel length. Application of a channel heat balance allows the correlation to be converted to a "local conditions" form. Using this local conditions form of the correlation, critical heat flux as a function of height in the hot channel (which is located near the stuck CEA location) is calculated, where the effect of non-uniform axial heating is incorporated using the method applied by the Lee (Ref. 3)..."

Provide a FORTRAN listing of the portion of the code where the effect of non-uniform axial heating is incorporated using the method applied by Lee to the Macbeth correlation.

Response:

The calculation of the critical heat flux (CHF) and consequent critical heat flux ratio (CHFR), as described in Section 15C.2.3 (page 15C-2) of the CESSAR FSAR has been mechanized in the HRISE (enthalpy rise) FORTRAN program. The effect of non-uniform axial flux is incorporated using the method applied by Lee (Ref. 440.7-1).

The total heat flux, $\phi(z,t)$ used in HRISE is calculated from the core average fission and decay heat fluxes by

$$\phi(z,t) = F_{PB}[(F_{RD}q_D''(t)\phi_{AD}(z) + F_{RF}q_F''(t)\phi_{AF}(z)],$$

where:

z is distance along hot channel, measured from core inlet (in),
F_{PB} is a dimensionless common multiplier for decay and fission heat fluxes,
F_{RD} is the dimensionless, 2-D integrated radial peaking factor for decay heat flux,
F_{RF} is the dimensionless, 2-D integrated radial peaking factor for fission heat flux,
$q''_D(t)$ is the core average decay heat flux (BTU/hr ft^2) at time t,
$q_F''(t)$ is the core average fission heat flux (BTU/hr ft^2) at time t,
$\phi_{AD}(z)$ is the nomalized axial decay heat flux distribution, and
$\phi_{AF}(z)$ is the nomalized axial fission heat flux distribution.

Using this total heat flux the local quality, Y(z) can be found from a channel heat balance:

$$x(z) = \frac{1}{h_{fg}}[h_{in} + \frac{4}{GD}\int_0^z \phi(\zeta)\,d\zeta - h_f],$$

where

D is the channel effective diameter (in),
G is the mass flux (lbm/hr ft^2),
h_f is the enthalpy of saturated liquid (BTU/lbm),
h_{fg} is the latent heat of vaporization (BTU/lbm), and
h_{in} is the channel inlet enthalpy (BTU/lbm).

This quality is used in the local conditions form of the Macbeth correlation for (axially) uniformaly heated rod bundles (Ref. 440.7-2) to calculate the CHF, $\emptyset_c(z)$:

$$\emptyset_c(z) = [f_3 + f_4 \; x\,(z)] \times 10^6,$$

where:

$$f_3 = f_1/(1 - af_2),$$

$$f_4 = -h_{fg} \; f_2/(1 - af_2),$$

$$f_1 = 67.6D^{.83} \; (G \times 10^{-6})^{\;0.57}/b,$$

$$f_2 = 0.25D \; (G \times 10^{-6})/b,$$

$$a = 4 \; z_{in}/(G \times 10^{-6}) \; D,$$

$$b = 47.3D^{\;0.57} \; (G \times 10^{-6})^{\;0.27} + z_{in},$$

D is heated equivalent diameter (inch),
G is mass flux (lbm/hr ft^2),
h_{fg} is the latent heat of vaporization (BTU/lbm), and
z_{in} is the distance from the inlet to the node

The local CHFR is then

$$CHFR = \frac{\emptyset_c \; (z)}{F(z) \; \emptyset(z)}$$

where F(z) is Lee's ratio of burnout flux for uniform flux to burnout flux for non-uniform flux (Eq. 5 of Ref. 440.7-1).

The basic formulations and the computation procedure for the non-uniform flux ratio, F, are outlined in the Section 8 of Reference 440.7-1. The applicable portions of the FORTRAN statements of the HRISE main program and the subroutine and function which are related to the calculation of F are shown in Table 440.7-1. Comment cards have been used to relate the FORTRAN statements to the equations of Ref. 440.7-1. Table 440.7-2 is a brief glossary of equivalence FORTRAN names to algebraic symbols.

References:

440.7-1, D. H. Lee, "An Experimental Investigation of Forced Convection Burnout in High Pressure Water" Part IV. AEEW-R479, UKAEA, Atomic Energy Establishment, Winfrith, (1966).

440.7-2, R. V. Macbeth, "An Appraisal of Forced Convection Burnout Data," Proc Inst Mech Engrs, Vol. 180 pt 3c, (1965-66).

TABLE 440.7-1

LISTING OF PORTION OF PROGRAM HRISE WHERE THE EFFECT NO -FORM AXIAL HEATING IS INCORPORATED

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H R I S E

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TABLE 440.7-1 (CONT.)

TABLE 440.7-1 (CONT.)

TABLE 440.7-1 (CONTI.)

TABLE 440.7-2

EQUIVALENCE OF KEY FORTRAN
NAMES TO ALGEBRAIC SYMBOLS

FORTRAN	Algebraic	Definition	Units
AXD(I)	$\phi_{AD}(z)$	Nomalized axial decay heat flux distribution	—
AXF(I)	$\phi_{AF}(z)$	Nomalized axial fission heat flux distribution	—
DH	D	Heated equivalent diameter	in
FACT	F_{PB}	Common multiplier for decay and fission heat fluxes	—
FFAC	F	Ratio of burnout flux for uniform flux to burnout flux for non-uniform flux	—
FLOW	G	Channel mass flux	lbm/hr ft^2
FLUX(I)	$\phi(z)$	Local heat flux	BTU/hr ft^2
FLUXD	q''_D	Core average decay heat flux	BTU/hr ft^2
FLUXF	q''_F	Core average fission heat flux	BTU/hr ft^2
HITE	—	Active core height	in
N	—	Number of axial nodes	—
PRES	—	Uniform system pressure	psia
RADD	F_{RD}	2-D integrated radial peaking factor for decay heat flux	—
RADF	F_{RF}	2-D integrated radial peaking factor for fission heat flux	—
ZIN	z_{in}	Distance from channel inlet to node	in

Question 440.8

Section 15C.2.3 (page 15C-3) of the CESSAR FSAR states:
"...Hot channel inlet enthalpy is set equal to the average enthalpy predicted by CESEC for the fluid at the core inlet for that half of the core on the side associated with the affected steam generator.

Provide parametrics or experimental results that indicate the conservatism in the above method fordetermining the hot channel inlet enthalpy.

Response:

A typical core inlet enthalpy profile diagram at the time of the minimum CHFR is shown on Figure 440.8-1. The hot channel inlet enthalpy is set equal to the value at point d (mid point on the side associated with the affected steam generator). The values of the CHFR obtained using the enthalpies of Figure 440.8-1 are given in Table 440.8-1.

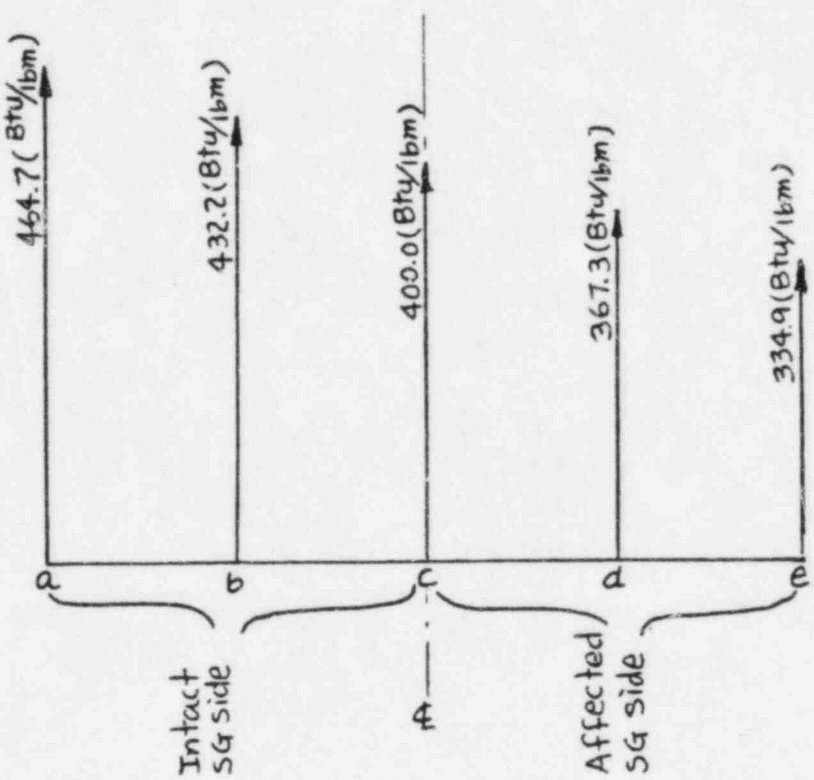


FIGURE 440.8-1

CORE INLET ENTHALPY PROFILE
DIAGRAM AT THE TIME OF MCHFR

Table 440.8-1

CHFR BASED ON INLET ENTHALPIES AT VARIOUS POINTS IN CORE INLET PLANE

Point	a	b	c	d	e
Enthalpy	464.7	432.2	400.0	367.3	334.9
CHFR	2.67	2.71	2.73	2.80	2.86

The CHFR values of Table 440.8-1 were all calculated using the same values of all other parameters except enthalpy (i.e., power, pressure flowrate, peaking factor, etc). However the reactivity calculation is based upon the assumption that the stuck CEA is on the cold edge of the core (i.e., near point e) this means that the peaking factor is applicable only somewhere between points d and e. The actual CHFR at points a, b, and c would be much greater than the values shown in the table because of much smaller peaking factors at these locations. The minimum CHFR would be at the location of the stuck CEA with its associated very large peaking factor. Therefore use of the enthalpy at point d will produce a conservatively low minimum CHFR.

Question 440.9

Section 15.C.3.2 (page 15C-4) of the CESSAR states:
"The minimum DNBR resulting from a steam line break is insensitive to the initial steam generator water level. Confirm this conclusion by providing a plot of minimum DNBR as a function of initial steam generator water level.

Response:

The minimum pre-trip DNBR as a function of steam generator initial water mass is presented in Figure 440.9-1.

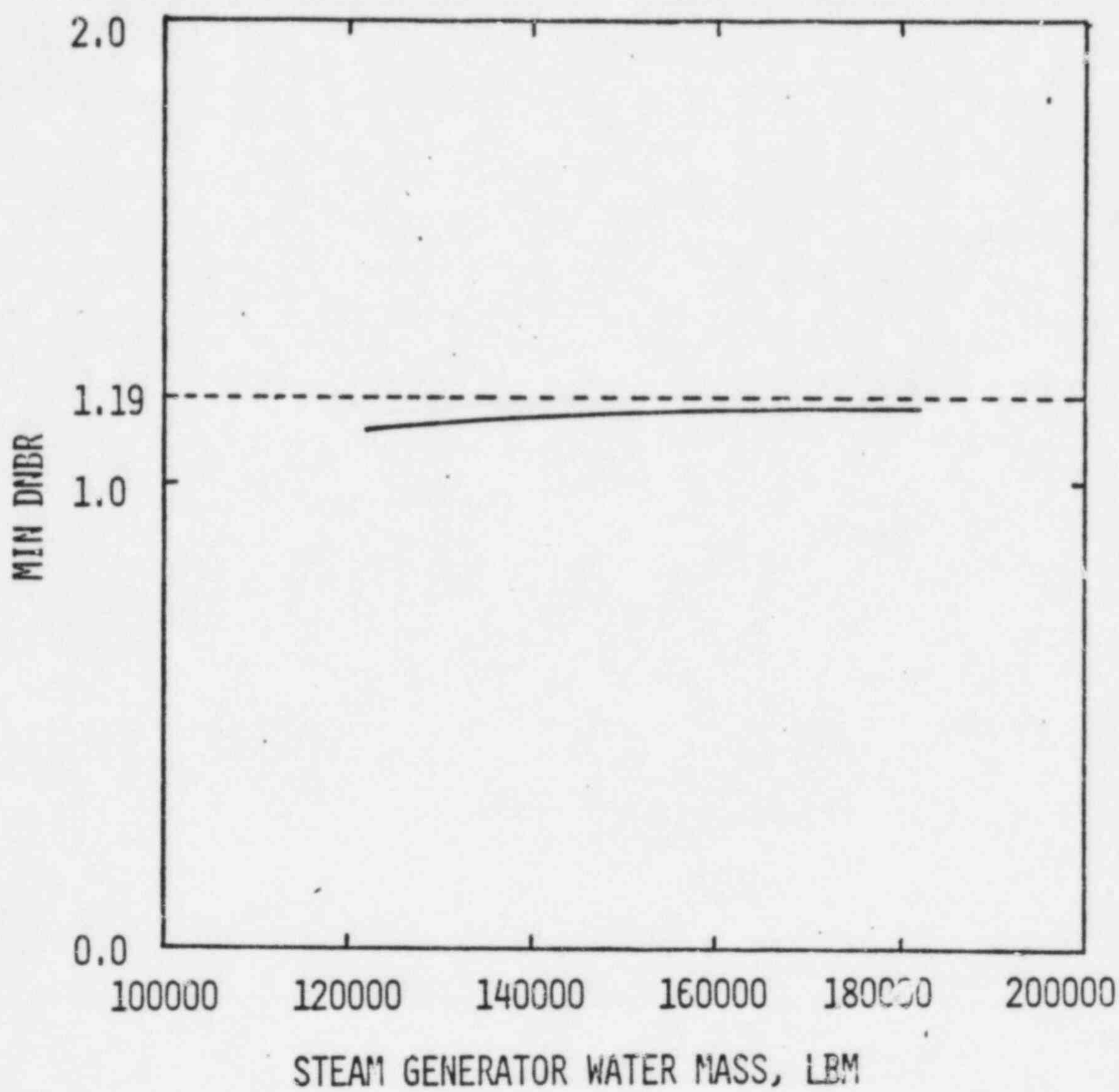


FIGURE 440.9-1
THE MINIMUM PRE-TRIP DNBR vs
STEAM GENERATOR INITIAL WATER MASS

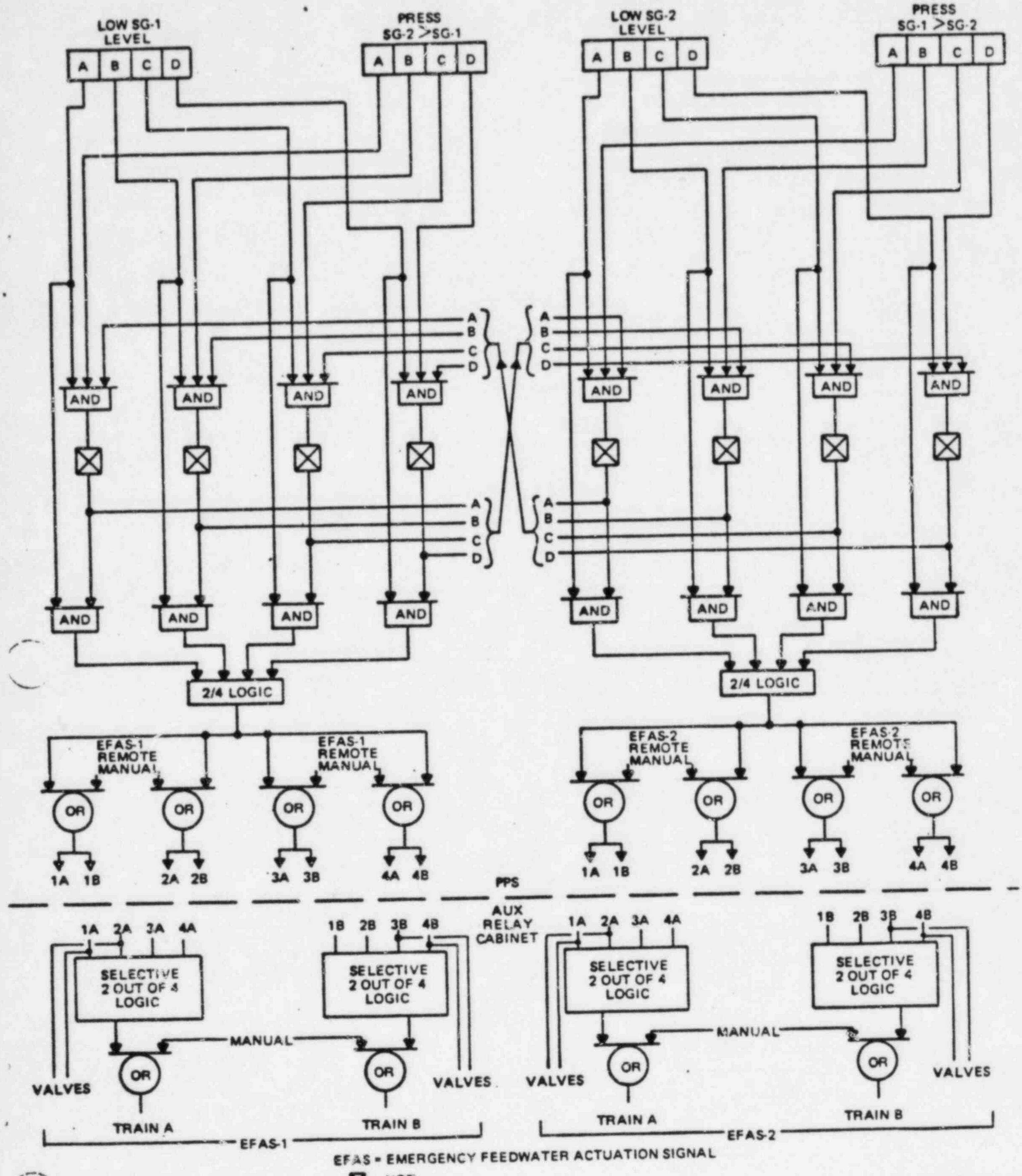
Question 440.13

Provide a plot of minimum transient DNBR as a function of time for inadvertent actuation of auxiliary feedwater to the affected steam generator. The emergency feedwater actuation signal (ESFAS) logic may prevent feeding the affected steam generator, but may not preclude manual override.

Response:

The Emergency Feedwater Actuation Signal (EFAS) is one of the six signals of the Engineered Safety Features Actuation System (ESFAS). (See Section 7.3.2.2.6 of the CESSAR FSAR.) Manual override of the ESFAS is not part of the design bases for safety analysis.

The emergency (auxiliary) feedwater system (EFWS) is actuated by an EFAS as shown in Figure 440.13-1 (CESSAR Figure 7.3-1d). The EFAS actuates emergency feedwater on low water level to the intact steam generator(s). The Emergency feedwater actuation is based on the following condition: When a low steam generator water level signal exists the emergency feedwater is actuated to the steam generator with the low level only if the pressure of that steam generator is not lower than that of the other steam generator pressure by a pre-set value.



C-E SYSTEM 80	ESFAS SIGNAL LOGIC (EFAS 1, EFAS 2)	Figure 440.13-1