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SUBJECT: Forwards responses re main steam line break reanalysis,per 880301 commitment.

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Docket Nos. STN 50-528/529/530

161-01041-EEVB/BJA
May 22, 1988

U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Document Control Desk

References: (1) Letter from E. E. Van Brunt, Jr., ANPP, to USNRC Document Control Desk dated March 1, 1988 (161-00846). Subject: Schedule for ANPP Responses to NRC Steam Line Break Questions.
(2) Letter from E. A. Licitra, NRC, to E. E. Van Brunt, Jr., ANPP, dated February 10, 1988. Subject: Request for Additional Information - Palo Verde Steam Line Break Reanalysis.
(3) Letter from E. E. Van Brunt, Jr., ANPP, to G. W. Knighton, NRC, dated September 30, 1985 (ANPP-33611). Subject: Main Steam Line Break Analyses Results - Chapter 15 Reanalyses.

Dear Sirs:

Subject: Palo Verde Nuclear Generating Station (PVNGS)
Units 1, 2 and 3
ANPP Responses to NRC Main Steam Line Break Questions
File: 88-A-056-026

By Reference (2), the NRC Staff has requested additional information concerning the main steam line break reanalysis that had been previously submitted to the NRC by Reference (3). In response to this NRC Staff request, ANPP responded in Reference (1) by stating that the requested information would be provided to the NRC by May 31, 1988. The attachment to this letter provides the ANPP responses.

If you have any additional questions on this matter, please contact Mr. A. C. Rogers of my staff at (602) 371-4041.

Very truly yours,

E. E. Van Brunt

E. E. Van Brunt, Jr.
Executive Vice President
Project Director

EEVB/BJA/dlm
Attachment

cc: G. W. Knighton (all w/a)
E. A. Licitra
J. B. Martin
T. J. Polich
A. C. Gehr

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ATTACHMENT

ANPP RESPONSES TO NRC MAIN STEAM LINE BREAK QUESTIONS

1. <u>NRC QUESTION</u>

Reference 1 contains a two sentence statement that the PVNGS AFW model explicitly models the AFW systems, accounting for variation in flow with SG pressure and pump speed. Describe in detail that model and justify it on the basis of plant specific data.

<u>ANPP RESPONSE</u>

The AFW model that was previously used for the CESSAR analysis was not PVNGS specific. The previous CESSAR analysis model assumed a constant flow rate of 243 lbm/sec to the intact steam generator. For the new model, the PVNGS Auxiliary Feedwater (AFW) system was modeled as shown in Figures 1 through 4. The computer model utilized the PVNGS specific piping configuration to establish elevation differences and friction losses for each section of piping. Vendor supplied pump characteristic curves were used to establish the response of the AFW pumps to changes in steam generator pressure. The pump curve that was used was based on plant test data. The analysis model assumed that the AFW regulating and block valves were fully open and that the two safety-grade AFW pumps were operating in parallel. The model equations were treated quasi-statically since fluid momentum was ignored (i.e., flow derivatives equal to zero).

Since the development of the PVNGS specific AFW model, CE has established that the differences in the two AFW models do not significantly affect the reactivity during the transient. Current reload analyses for PVNGS utilize the CESSAR AFW flow table in lieu of the PVNGS specific AFW model.

FIGURE 1 PVNGS AFW SYSTEM MODEL

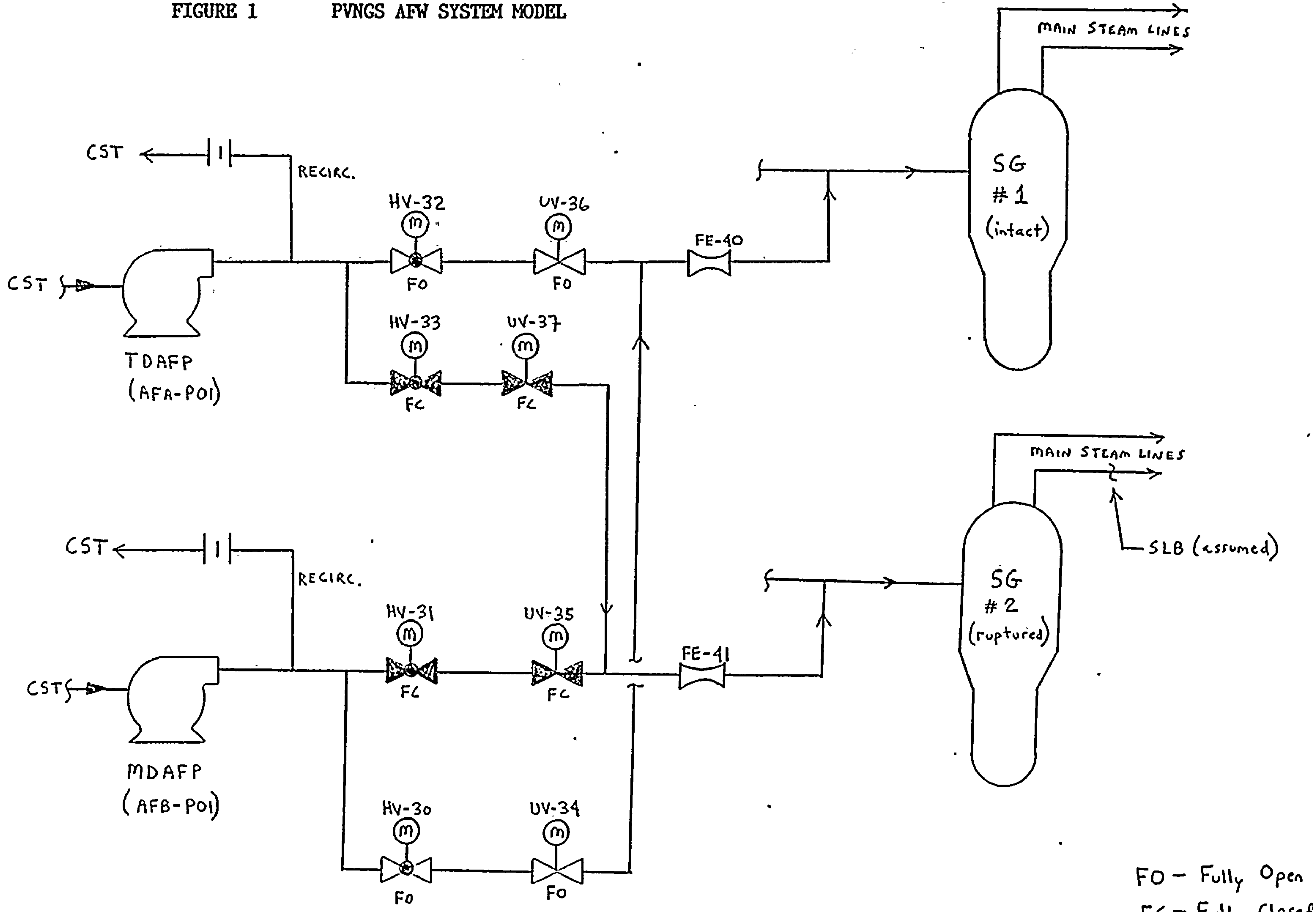
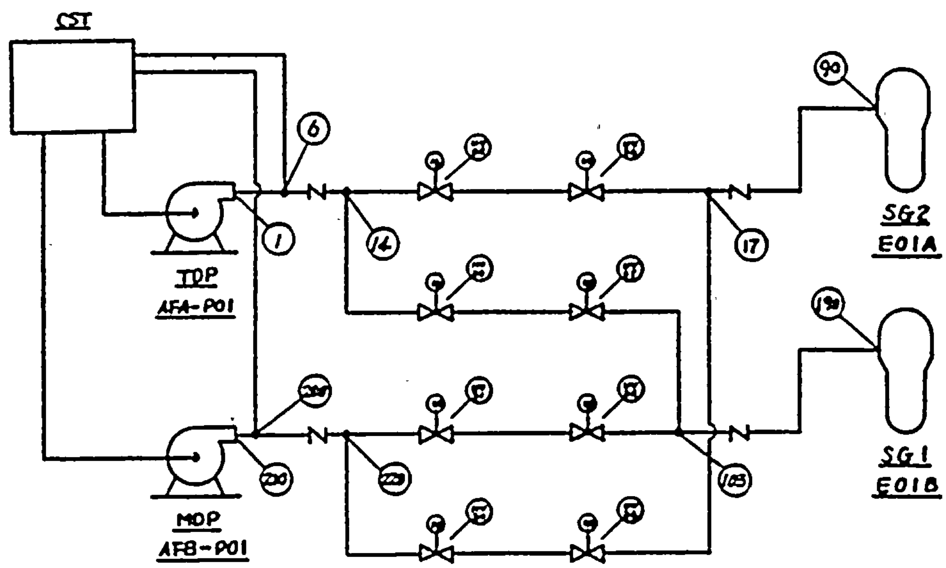


FIGURE 2 AFW SYSTEM FRICTION LOSSES

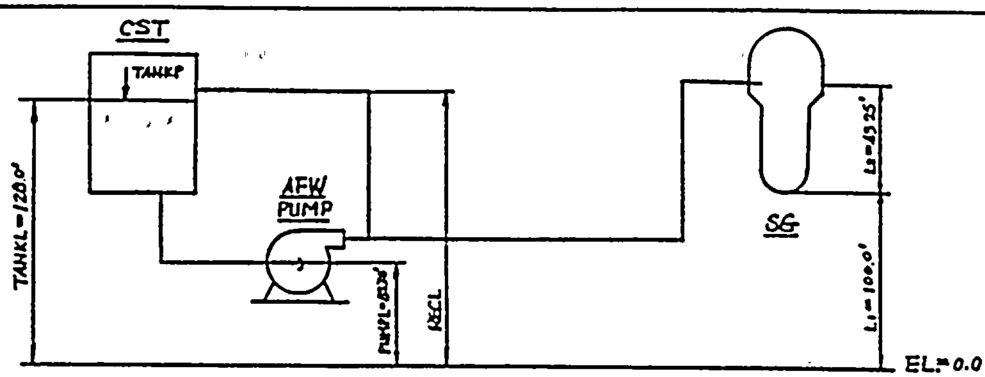


PIPELINE FRICTION LOSSES

1 – 6	DPBASE(2) =	0.2974×10^{-3} PSI/(LBM/SEC)^2
6 – 14	DPBASE(3) =	0.4237×10^{-3} PSI/(LBM/SEC)^2
14 – 17	DPBASE(4) =	2.9879×10^{-3} PSI/(LBM/SEC)^2
14 – 103	DPBASE(5) =	3.0290×10^{-3} PSI/(LBM/SEC)^2
17 – 90	DPBASE(17) =	0.5832×10^{-3} PSI/(LBM/SEC)^2
200 – 210	DPBASE(9) =	0.2985×10^{-3} PSI/(LBM/SEC)^2
210 – 220	DPBASE(10) =	0.3571×10^{-3} PSI/(LBM/SEC)^2
220 – 103	DPBASE(7) =	3.0017×10^{-3} PSI/(LBM/SEC)^2
220 – 17	DPBASE(11) =	3.1446×10^{-3} PSI/(LBM/SEC)^2
103 – 190	DPBASE(6) =	0.6791×10^{-3} PSI/(LBM/SEC)^2

THE RECIRCULATION PIPELINE FRICTION LOSSES ARE CALCULATED BASED UPON AFW PUMP HEAD CURVE (FIG.4) AND THE FOLLOWING GIVEN CONDITIONS: AT 3560 RPM, TDAFW PUMP DELIVERS 814 GPM TO SGs WITH 246 GPM RECIRCULATION FLOW; MDAFW PUMP DELIVERS 849 GPM TO SGs WITH 211 GPM RECIRCULATION FLOW.

FIGURE 3 AFW SYSTEM STATIC HEADS



1. AUXILIARY FEEDWATER PUMP SUCTION STATIC HEAD, PSOUR

PSOUR = TANKL + TANKP − PUMPL

WHERE :

TANKL = CST WATER LEVEL EL. (@ 330,000 GAL) = 128.0 ft

TANKP = CST TANK PRESSURE = 33.4 ft

PUMPL = AUX. FW PUMP SUCTION EL. = 83.75 ft

THEREFORE :

PSOUR = 128.0 + 33.4 − 83.75 = 77.65 (ft, @ 120 °F)

2. STEAM GENERATOR ELEVATION HEAD, ELEVL

ELEVL = L1 + L2 − PUMPL

WHERE :

L1 = STEAM GENERATOR EL. (BOTTOM) = 100 ft

L2 = FW. NOZZLE EL. (ABOVE SG BOTTOM) = 43.25 ft

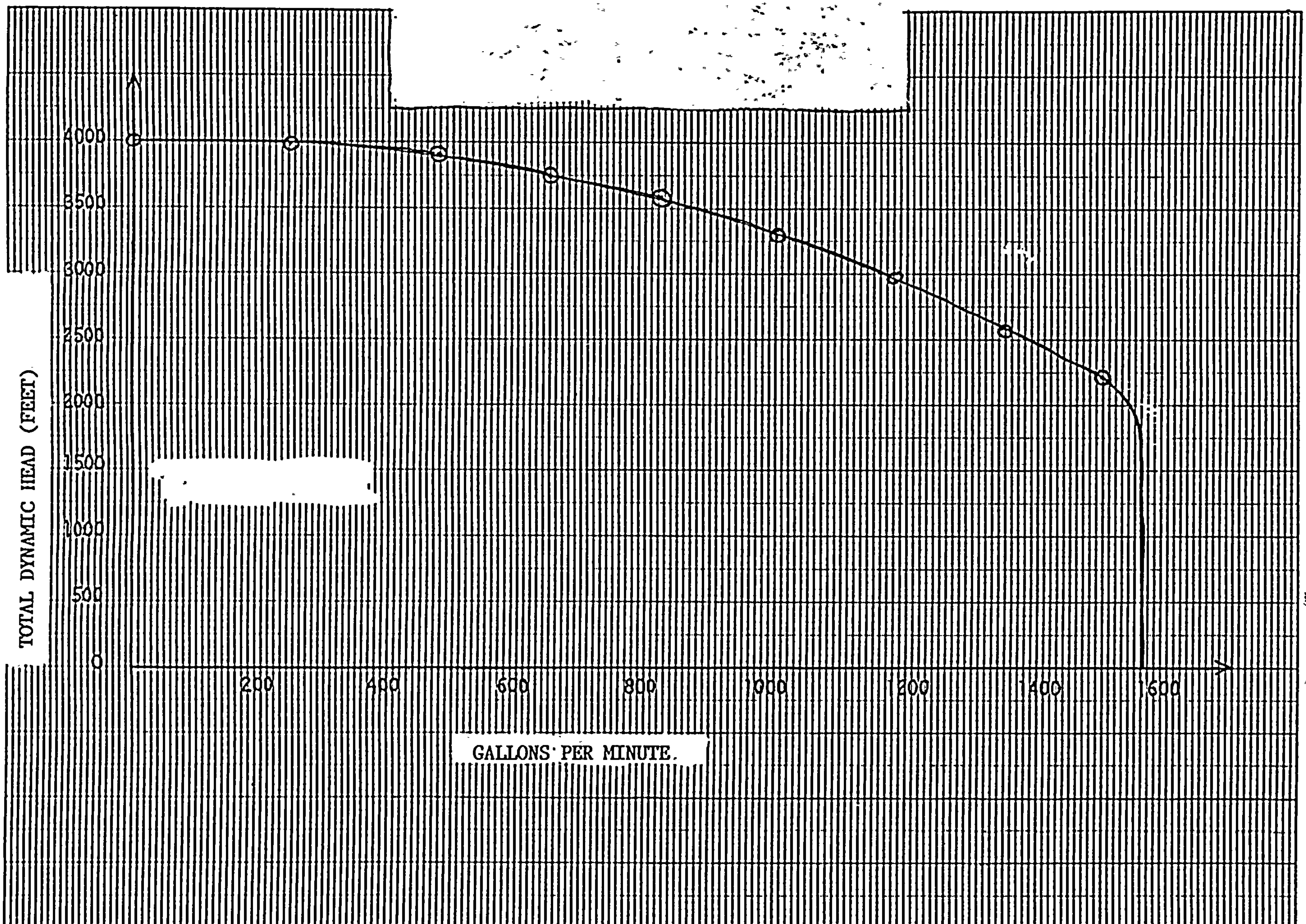
PUMPL = AUX. FW PUMP SUCTION EL. = 83.75 ft

THEREFORE :

ELEVL = 100 + 43.25 − 83.75 = 59.5 (ft, @ 120 °F)

= 20.49 (PSI)

FIGURE 4 AFW PUMP HEAD VS. FLOW



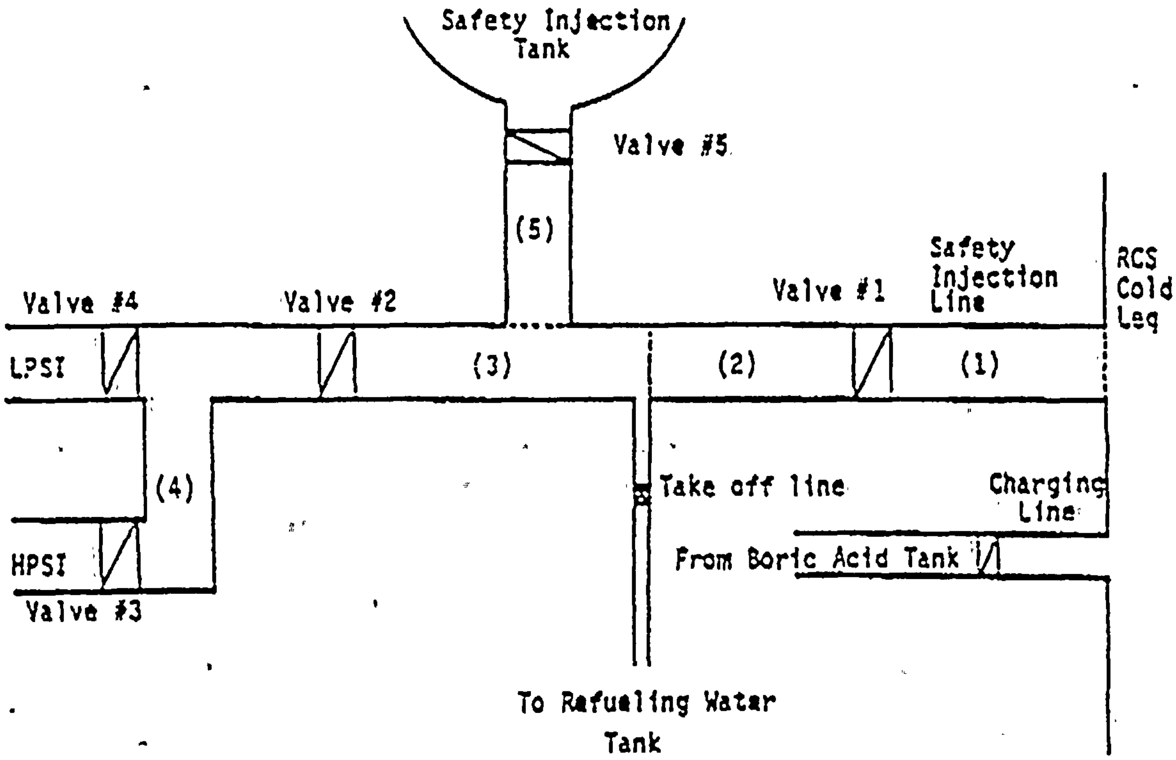
2. NRC QUESTION

Reference 1 states that (a) the safety injection lines have been nodalized to account for boron concentration gradient during injection, and (b) the primary system cold leg nodalization has been altered to force boron to mix only with the portion of a node downstream (toward the vessel) of the injection point. Explain and justify this renodalization and its effect upon the transient.

ANPP RESPONSE

The boron injection model was modified to more accurately represent the actual physical processes involved. The previous boron injection model assumed a single sweep-out volume in each injection line. Boron would not reach the RCS until the safety injection flow had traversed the sweep-out volume. The boron would then be instantaneously mixed into the entire RCS nodal volume into which it was introduced.

The modified boron injection model is shown in Figure 5. The initial boron concentration may be independently selected for each of the nodes in the safety injection lines. For the subject MSLB analysis, volumes (1) and (2) were assumed to contain no boron, volume (3) was assumed to contain a boron concentration of 2000 ppm, and volume (4) was assumed to contain a boron concentration of 4000 ppm. In the previous analysis, volume (1) had no boron and the remaining volumes were assumed to contain a boron concentration of 4000 ppm. Additionally, the revised boron injection model does not assume that the boron introduced into the RCS cold legs by the safety injection line mixes instantaneously into the entire RCS node. Instead, the injected boron is assumed to be convected only into that portion of the nodal volume located downstream of the injection point. Therefore, only that portion of the RCS cold leg volume downstream of the injection point is used for boron mixing. These modifications to the boron injection model produce a more realistic model. The model is conservative due to the choice of initial boron concentrations in volumes (1) to (4) utilized as an initial condition of the analysis.



Valve #1: SI-217, SI-227, SI-237, SI-247

Valve #2: SI-540, SI-541, SI-542, SI-543

Valve #3: SI-113, SI-123, SI-133, SI-143

Valve #4: SI-114, SI-124, SI-134, SI-144

Valve #5: SI-215, SI-225, SI-235, SI-245

FIGURE 5

SAFETY INJECTION LINE CONFIGURATION FOR MODIFIED CESEC BORON INJECTION MODEL

3. NRC QUESTION

The licensee, in lieu of using a non-equilibrium upper head model (which would produce higher upper head pressures thus limiting boron injection) has modified the CESEC code to artificially shift steam created in the upper head to the pressurizer. Describe in depth how this methodology differs from that used in CESEC-III and its impact on the resultant pressure computation.

ANPP RESPONSE

In the conclusion of Appendix H of the CESSAR SER, Supplement 2 (CESSAR SSER 2), the NRC staff has found the CESEC-III computer program to be acceptable in performing licensing evaluations of the postulated Steam Line Break (SLB) events. The methodology accepted included a homogeneous-equilibrium thermodynamic representation of the Reactor Vessel Upper Head (RVUH). A comparison, performed by the NRC's consultants, between CESEC-III and RELAP5 results is presented in CESSAR SSER 2. The CESEC-III predictions of RCS pressure response is higher than the RELAP5 results. Higher RCS pressure delays the safety injection actuation signal and reduces the safety injection flow rate. This increases the potential for a post-trip return to power and is therefore conservative.

The RVUH fluid and metal walls are conservatively initialized at the core exit temperature and a 10% heat transfer area increase is assumed to conservatively reduce the RCS depressurization rate. During the first part of the SLB event, the RCS pressure decreases rapidly and voids form in the RVUH due to flashing and by boiling (due to metal heat). As long as the steam voids are expanding (i.e., liquid is being removed from the RVUH) the liquid and steam are in thermal equilibrium at the saturation temperature. Therefore, during this time period, the RVUH equilibrium model is accurate for determining pressure. The code uses the calculated homogeneous void fraction to determine an equivalent collapsed liquid level and steam void volume.

The homogeneous equilibrium model does not realistically represent the possible conditions during refilling of the RVUH. During refilling by the safety injection pumps, compression of the voids in the RVUH and the pressurizer could cause saturated steam to exist over sub-cooled water. Simultaneously, relatively cold RCS liquid enters the RVUH node. Because of the arrangement of the reactor vessel there is no mixing of the incoming cold liquid with the steam as the void is compressed.

The previous version of CESEC, in effect, mixed the incoming cold water with the steam assumed to be at a saturated condition. Quenching the steam reduced the void volume and drew more RCS liquid into the node, resulting in rapid void collapse, faster RCS depressurization and, consequently, higher safety injection flow rates.

In lieu of a non-equilibrium RVUH model, the steam line break methodology utilizes the two region non-homogeneous non-equilibrium pressurizer model, to account for the higher RVUH pressures anticipated during the refill part of the SLB event. The steam void, existing in the RVUH at

the time that the refill begins and the voids start collapsing, is transferred to the pressurizer. The RVUH and pressurizer mass, energy and volumes are corrected to account for the transfer as follows:

- The mass of the RVUH node is decreased by the mass of steam in the node, M_s.

- The total energy of the node is decreased by the enthalpy of the steam in the node. That is $\Delta E = M_s \cdot H_{steam}$ where H_{steam} is the enthalpy of saturated steam at RCS pressure.

- The volume of the node is decreased by the volume of the steam in the node. That is $\Delta V = M_s v_{steam}$ where v_{steam} is the specific volume of saturated steam at the RCS pressure.

- The mass, energy and volume of the pressurizer are increased by M_s, ΔE and ΔV, respectively.

As the refill proceeds, the total steam volume in the RCS (i.e., pressurizer plus RVUH) is compressed utilizing the non-equilibrium pressurizer model and a more realistic pressure transient is predicted during this time as shown in Figure 6.

The important factor during the refill part of the SLB event simulation is the impact of the modeling on the RCS pressure, which directly governs the amount of the safety injection fluid entering the system. Utilization of the pressurizer model to determine both of these parameters yielded higher RCS pressures and lower safety injection flow rates (Figure 7), consequently increasing a potential for post-trip return to power, and therefore, produced more conservative results than the previous CESEC model. Although it is difficult to quantify separate effects, at the time of the peak reactivity, the modified version predicts core reactivity to be more positive by approximately 0.1% $\Delta\rho$.

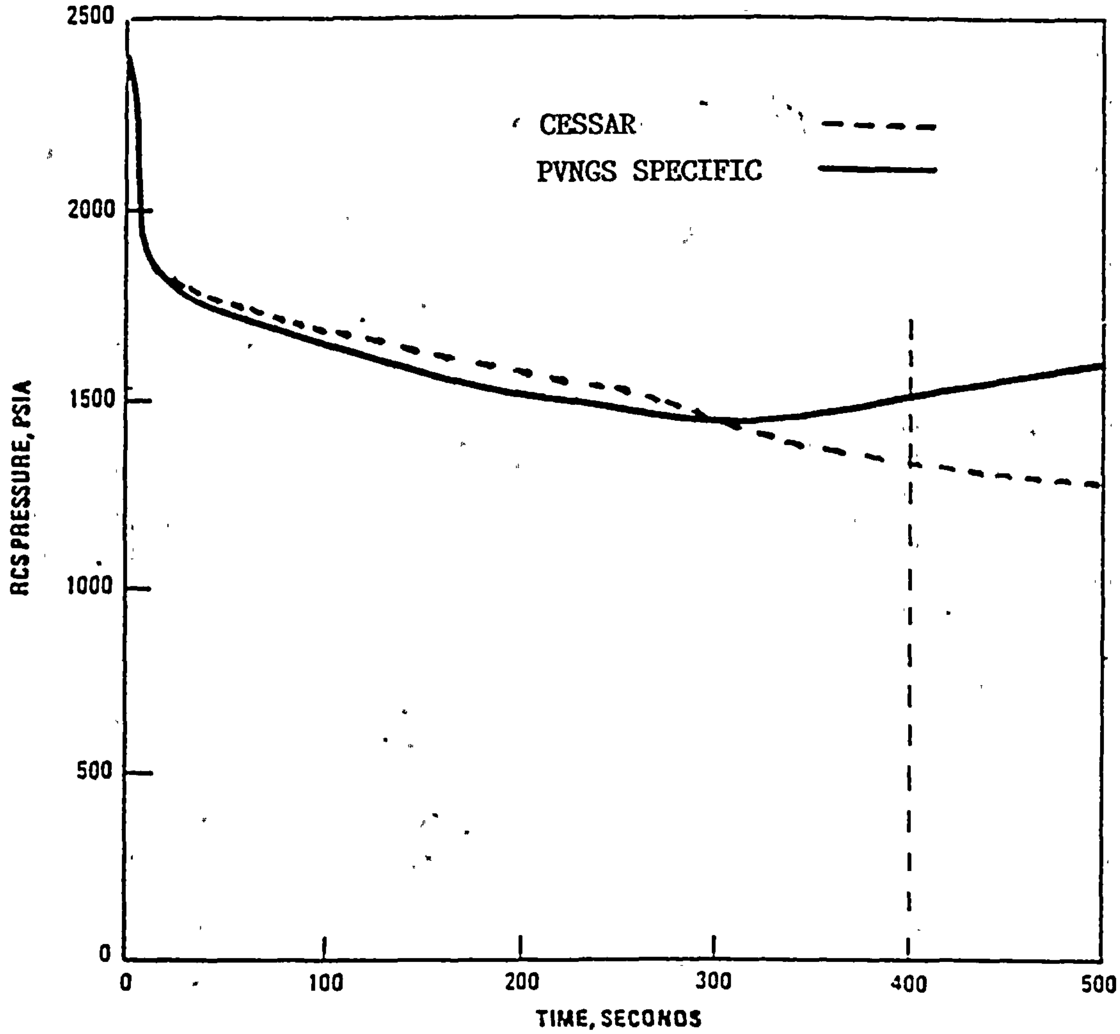


FIGURE 6

RCS PRESSURE

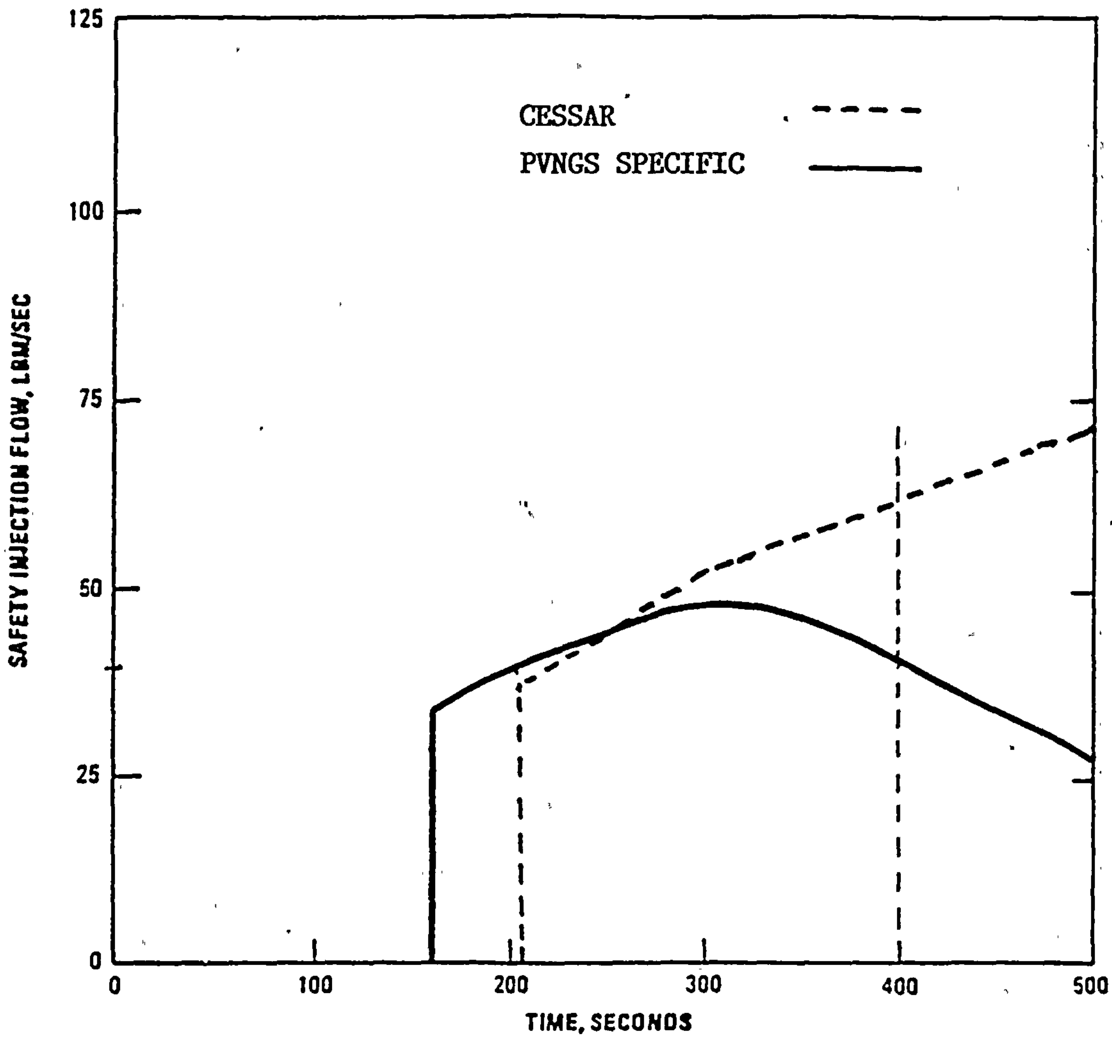


FIGURE 7 SAFETY INJECTION FLOW

4. NRC QUESTION

The licensee stated that maximum AFW flow per pump was reduced from 875 to 750 gpm. Reference 1 does not define what AFW was used, but references the models in Appendix 15C. The feedwater flow rate curves plotted in Figure 15.1.1-11 indicate flow rates in the range of 350 lbm/sec which is roughly 50% higher than the old Figure 15.1.1-11. Explain these flow rates and discuss if this analysis has included the reduced flow rate assumption.

ANPP RESPONSE

The minimum required AFW flow rate (not the maximum as stated in the question) was reduced from 875 to 750 gpm at a steam generator design pressure of 1270 psia. During preoperational testing of the PVNGS Unit 1 AFW pumps, the piping systems connected to both safety-grade pumps experienced hydraulic resonance when operating in the normal minimum flow recirculation configuration with the discharge block valve open and the regulating valves closed. To correct the resonance problem, the multi-stage orifices in the minimum flow recirculation lines were modified to increase the recirculation flow. This resulted in a decrease in the net flow delivered to the steam generator by the AFW pumps. At a steam generator design pressure of 1270 psia, the minimum AFW flow per pump was reduced from 875 to 750 gpm. This single point on the pump head curve satisfies safety design basis seven of PVNGS FSAR Section 10.4.9.1.1. The higher AFW flowrates are due to the lower SG pressures as compared to 1270 psia. The previous CESSAR analysis assumed a constant AFW mass flowrate of 243 lbm/sec. This flowrate was independent of the SG pressure (see response to Question #1). Note that a reduction in the minimum required AFW flow rate does not necessarily imply a corresponding reduction in the maximum AFW flow rate which is conservatively high for the steam line break analyses.

5. NRC QUESTION

Examination of the changes in Figures 15.1.1.7 indicates a reduction in the negative reactivity insertion accompanying safety injection at a rate causing a change of slope of roughly 1/3. However, changes in Figure 15.1.1.15 indicate that the safety injection flowrate, although varying, is roughly 50% lower in the new computation at, for example, 400 seconds than it was in the original computation, indicating that the new computation may use a higher boron concentration. Explain this result and its connection with the boron transport model changes discussed in Question 2.

ANPP RESPONSE

The safety injection flow rate decreased by roughly 1/3 (not 1/2 as stated in the question) at 400 seconds compared to the previous analysis (Figure 7). This decrease in the safety injection flow rate is due to the combination of the reduced HPSI delivery curve (required by Technical Specifications for the minimum HPSI ECCS performance) and higher RCS pressure (Figure 6) as explained in response to Question #3.

Although the safety injection flow rate decreased by approximately 1/3 at 400 seconds, the rate of the negative reactivity insertion by the safety injection flow decreased by roughly 2/3 (from -0.75% $\Delta\rho$/sec to -0.28 % $\Delta\rho$/sec) at 400 seconds (Figure 8). This decrease is due to the combined effect of the modified RVUH model (see response to Question #3) and the modified safety injection model discussed in Question #2. The previous analysis used an input boron concentration value of 4000 ppm after the safety injection flow swept out the water volume between the RCS cold legs and the first check valves away from the RCS cold legs. For the reanalysis, boron concentrations of 0, 2000, and 4000 ppm were used for the volumes between the cold leg and the Refueling Water Tank (RWT) return line, between the RWT return line and the second check valve, and upsteam of the second check valve, respectively (as shown in Figure 5).

At 400 seconds into the transient, the safety injection flow had not swept out the volume downstream of the second check valve. Therefore, at 400 seconds, the safety injection flow boron concentration was 2000 ppm compared to the 4000 ppm used in the previous analysis.

In summary, the decrease of the negative reactivity insertion rate is due to the combined effect of the reduced HPSI delivery curve, the higher RCS pressure predicted by the modified RVUH model, and the conservative (lower) boron concentration used in the modified safety injection model discussed previously.

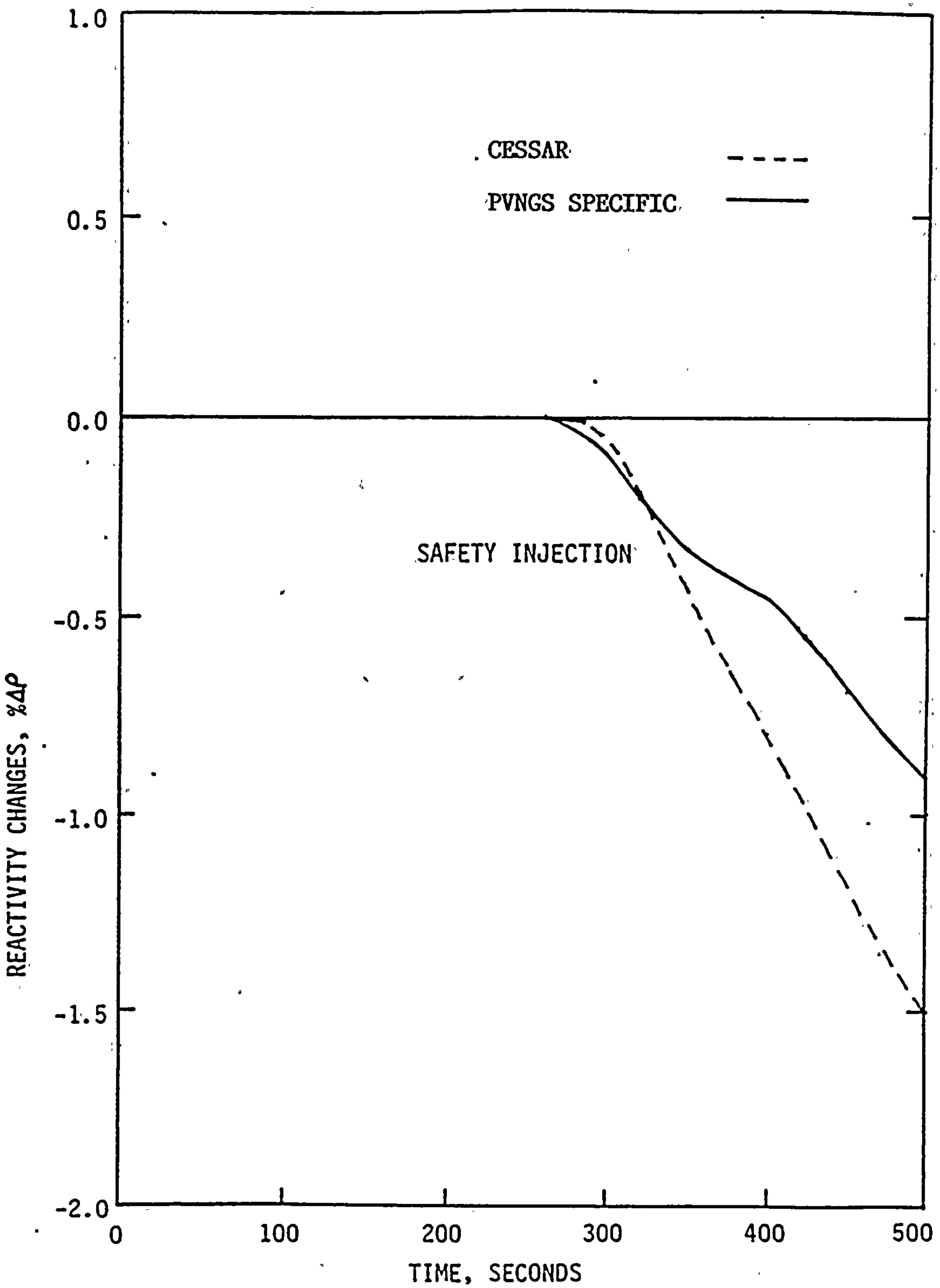


FIGURE 8 REACTIVITY CHANGES