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A. Edward Scherer
Manager of
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December 23, 2003

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C., 20555-0001

Subject: **Docket Nos. 50-361 and 50-362**
Additional Information Regarding Generic Letter 96-06 "Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions,"
San Onofre Nuclear Generating Station, Units 2 and 3
(TAC Nos. M96862 and M96863)

Dear Sir or Madam:

This letter provides additional information to support the Southern California Edison (SCE) final summary report to Generic Letter (GL) 96-06, which was submitted by letter from A. E. Scherer (SCE) to the Document Control Desk (NRC) dated September 29, 2003.

In discussions between the NRC staff and SCE staff, the NRC requested additional information to support the NRC review and closure of GL 96-06 with regards to the San Onofre Nuclear Generating Station.

Enclosed with this letter are the questions and answers that were discussed with the NRC staff.

If you have any questions or would like additional information, please feel free to contact Mr. Jack Rainsberry at (949) 368-7420.

Sincerely,

[signature]

Enclosure

cc: B. S. Mallett, Regional Administrator, NRC Region IV
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Enclosure

Response to the Request for Additional Information Regarding the September 29, 2003 Supplemental Response to Generic Letter 96-06 "Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions"

Response to the Request for Additional Information

Request for Additional Information (RAI) Question 1.

Page 3 [of the referenced Southern California Edison (SCE) September 29, 2003, submittal] indicates that a maximum closure velocity for waterhammer of 8.9 ft/second was determined. Further discussions indicate that maximum waterhammer pressures were determined using both the EPRI rigid body model (RBM) and using the HSTA [Hydraulic System Transient Analysis] computer code. HSTA is a Bechtel computer program which the NRC staff has not review[ed] for this application. Please provide more details of the comparison of the HSTA results to those of the EPRI rigid body model which the NRC staff has reviewed and approved.

Southern California Edison (SCE) Response to Question 1:

SCE used the HSTA computer code, which is based on the Method of Characteristics (MOC) numerical scheme, to evaluate the closure velocity in a cavity of pure steam that does not allow for any cushioning effects. The HSTA analysis models the cavity closure as instantaneous and does not allow for a finite rise time for the pressure wave to develop fully. The EPRI methodology was then used to calculate the mitigation effects due to rise time and air-steam cushioning. EPRI has approved the MOC as an accepted method of evaluation for cavity closure waterhammer (CCWH), as stated on page xvii of the EPRI GL-96-06 User's Manual (listed as Reference 6.5 in the September 29, 2003 submittal). In section 7.3.1 (page 7-4) of the EPRI GL-96-06 User's Manual it is explicitly mentioned that the use of commercially available programs is acceptable for evaluating the initial closure velocity. The EPRI Reports cited as References 6 and 7 in the EPRI GL-96-06 User's Manual provide a description of the capabilities and validation of the HSTA computer code, which provide additional assurance of acceptance of the code by the industry.

Further, page 9-20, EPRI Report NP-6766 Volume 3, 1992 (listed as Reference 7 in the EPRI GL-96-06 User's Manual), gives a comparison of HSTA predictions of pressure due to cavity closure of pure steam with experimental data, from which we see that the agreement between the two results is excellent.

Also, the EPRI hand calculation methodology does not provide instructions for evaluating the location of cavity collapse and Section 2.2 (page 2-2) of the EPRI GL-96-06 User's Manual states the following:

> "The flow rates and velocities of the refilling water should be determined from the pump curves and system hydraulic model. Determine anticipated location of closure. This effort should be performed on an individual plant basis-specific guidance is not provided in this User's Manual."

SCE response to Question 1 (continued):

The HSTA computer program is a generalized finite difference code based on the MOC numerical scheme. The main features of the HSTA computer code are discussed below:

To analyze one-dimensional transient flow problems, the HSTA code uses the mass and momentum conservation equations to obtain pressure and velocity as functions of time and distance. The MOC method is well known for its ability to accurately analyze fast transients. The pressure and velocity at each node are then used internally by the code to calculate forcing functions. The HSTA code has the ability of performing water column separation and rejoining calculations using both a traditional approach with vapor bubbles forming/staying at each node or "line filling" approach in which a discrete vapor pocket is defined by a water/vapor interface at its beginning and a vapor/water interface at its end. This type of vapor pocket allows for its transport along the pipe and leads to more accurate calculations for bubbles that are longer than a nodal distance. For the SONGS CCWH analysis each vapor pocket was defined by two liquid/vapor interfaces at the upstream and the downstream ends of the cavity.

The HSTA computer code models a piping system by dividing it up into equally distant nodal points or "nodes". The distance between two adjacent nodes is known as a "reach length" or "nodal distance". A "link" consists of a set of adjacent nodes with the same diameter. However, the calculations are performed for all the nodes comprising a link. At the end of each link is an identified boundary condition. Reservoirs, dead ends, etc., are examples of "external" boundary conditions, which are between the beginning/end of a link and the system boundary. Internal boundary conditions exist between two adjacent links. Some examples of these are valves, branches, flow restrictions (such as orifices), pumps, and air/surge tanks. The boundary condition, called the "continuation," simply connects two links without any pressure loss at the junction. This arises from the possible need to break long links into two or more shorter ones.

There is also precedence for the use of HSTA in response to GL 96-06.

Response to the Request for Additional Information

RAI Question 1 a:

In particular provide the following information:

a. Provide numerical values for the speed of sound determined using both methods

SCE Response to Question 1a:

The following derivation of the sonic velocity is taken from Section 8.3.8 (component cooling water (CCW) Train A calculations) of SCE calculation M-0027-032, Revision 0, listed as Reference 6.18.4 in the referenced September 29, 2003 submittal.

The sonic velocity, C, will be derived for the ECU inlet/outlet header pipe size (10 inch), using equations 2-35 and 2-37 from "Fluid Transients in Systems", Wylie, Streeter, 1993.

$C = \text{sqrt}(144 / (\rho_{wtr} * (1/K + (c2/E) * (D/b))$
$C = \text{sqrt}(144 / (1.94 * (1/316{,}000 + (0.93/28{,}500{,}000) * (10.02/0.365))$
$C = 4276$ [ft/s]

where:

$\rho_{wtr} = \rho / g = 1.94$ [slugs]

$\rho = 62.4$ [lbs/ft^3]	density of the fluid
$g = 32.1$ [ft/s^2]	gravitation constant
K=316,000 [psi]	modulus of elasticity of water (Marks Standard Handbook for Mechanical Engineers, 10th Edition)

$c2 = 1 - \mu^2 = 1 - 0.265^2 = 0.93$ (Poisson constant $\mu = 0.265$)

E= 28,500,000 [psi]	modulus of elasticity of steel (Marks Standard Handbook for Mechanical Engineers, 10th Edition)
D=10.02 [in]	ID of the ECU inlet/outlet pipe
b=0.365 [in]	wall thickness of 10 inch Sch 40 pipe

Derivation of sonic velocity per EPRI method:

Sonic speed derivations by the EPRI method per Section 5.2.4 of the EPRI GL-96-06 User's Manual (equations 5-1 and 5-2) are similar to the above derivations; with the exception that SCE used the correction for the rigidly supported pipe. This correction is identified above as a factor c2, which has a derived value 0.93. For the case of a pipe with expansion joints throughout, the value of c2 would be 1.0, which would match the sonic velocity derived by the EPRI equations.

SCE Response to Question 1a (continued):

Derivation of sonic velocity per EPRI method: (continued)

Using the EPRI terminology and formula along with the SCE-specific values, the equation for sonic speed would result in the following sonic speed:

Cpipe = sqrt [144 * (B / ρ_{wtr}) / (1 + (B*OD)/ (E*t))]
Cpipe = sqrt [144 * (316,000 / 1.94) / (1 + (316,000*10.02)/ (28,500,000*0.365))]
Cpipe = 4241 [ft/s]

where:

ρ_{wtr}= 1.94 [slugs]	density of the fluid
B=316,000 [psi]	modulus of elasticity of water
E= 28,500,000 [psi]	modulus of elasticity of steel
OD=10.02 [in]	ID of the ECU inlet/outlet pipe
t=0.365 [in]	wall thickness of 10 inch Sch 40 pipe

Should the correction coefficient c2 be employed for the rigidly supported pipe, just as SCE did, the sonic velocity would come out the same, or 4276 [ft/s]

RAI Question 1 b:

Provide the maximum waterhammer pressures determined using both methods.

SCE Response to Question 1b:

As previously discussed, the HSTA program was only used to calculate the cavity closure (CCWH) due to pure steam. Since the HSTA analysis is based on a pure steam cavity the waterhammer due to cavity closure is instantaneous. The EPRI methodology was then used to calculate the mitigation effects due to rise time and air/steam cushioning. The HSTA code was not used to independently calculate the cushioning or the effects due to the rise time.

The following comparison is between the verification of the waterhammer pressure SCE calculated using the HSTA code and the value derived by the Joukowski equation for the impact velocity of 8.9 ft/sec:

Response to the Request for Additional Information

SCE Response to Question 1b (continued):

The SCE verification using the HSTA code:

dh = k * C * dV /g [ft]

where:

k is a coefficient dependent on whether the water impacts a fixed pipe end (k=1), or, the water impacts water, as in our case (k=0.5)

C is the sonic velocity = 4276 [ft/s]

dV is the impact velocity [ft/s], which is obtained from the HSTA runs.

For the piping downstream of the cooler E-401, the estimated dh is:

dh= 0.5* 4276 *8.9 /32.1= 593 [ft]

The HSTA prediction of increase in head near the location of impact, (Link 177 node 3), is 596 [ft] at ~3.1 [seconds]. Thus, the HSTA prediction of waterhammer head of 596 [ft] is in good agreement with the 593 [ft] of head calculated by using the Joukowski equation.

RAI Question 1 c:

For the RBM identify the nomograph used to determine the effect of steam and air cushioning and justify that the conditions for entry into the nomograph are appropriate for San Onofre.

SCE Response to Question 1c:

Based on the closure velocity calculated by the HSTA program, which assumes the cavity consists of pure steam, the EPRI methodology was used to account for the mitigation effects due to the rise time (equation 5.4 of EPRI GL-96-06 User's Manual). Additionally, the impact mitigation due to gas/steam cushioning was done per the EPRI RBM analysis given in the EPRI GL-96-06 User's Manual and is documented in Section 8.7 of SCE calculation M-0027-032, Revision 0.

SCE Response to Question 1c (continued):

The values Lwo, Lao, Gas mass and void temperature are calculated/determined in Sections 8.7.1, 8.7.2, 8.7.4 and 8.7.6 of SCE calculation M-0027-032, Revision 0, (for Train A as an example). The value of impact velocity (8.9 ft/s max) has been determined by the HSTA code. The values calculated for the plant are compared against the RBM analysis limits (see EPRI GL-96-06 User's Manual, pg. 5-12). Satisfaction of the analysis limits permits use of EPRI graphical results given in Figures in Appendix A of the EPRI GL-96-06 User's Manual, which graph cushioning as a function of gas evolved. The summary of the comparison of the plant values versus RBM analysis limits is presented below.

Comparison of Plant Data with RBM Analysis Limits

Parameter	Plant Value	Should be	RBM limit	OK?
Lwo [ft]	393	≤	400	Yes
Lao [ft]	13.8	≤	100	Yes
Impact velocity [ft/s]	8.9	≤	10	Yes
Gas Content [mg]	2685	>	1506	Yes
Void Temp [F]	240	≥	200	Yes

The cushioning also depends on the overall resistance over the water column length. The values of K for both of the emergency cooling units (ECUs) E399 and E401 are derived in Section 8.7.8 of SCE calculation M-0027-032, Revision 0. The flow resistance created by pipe friction is conservatively ignored (see EPRI GL-96-06 User's Manual page. 6-5).

The results are:

$K_{399} = 4.1$
$K_{401} = 5.18$

The conclusion of the cushioning mitigating effects is presented in Section 8.7.9 of SCE calculation M-0027-032, Revision 0.

The results show that the CCW Train A system meets the gas cushioning criteria, thus the cushioning effects will be considered. The applicable figure is Figure A-43 of EPRI GL-96-06 User's Manual, for a 10" pipe, Gas and Steam Cushioning, initial Velocity 10 fps, and Lwo=400 ft.

SCE Response to Question 1c (continued):

The cushioned velocity is derived for the gas content 2685 mg of N2 and Total K=40, as that is the lowest K value on the chart. The gas cushioning correction factor is 0.89. The velocity reduction directly translates to a force reduction, thus 11% force reduction may be applied in the stress calculations, if required. After applying the EPRI methodology for the maximum impact velocity of 8.9 ft/sec, the following is obtained:

Vcushion = 8.9 * 0.89 = 7.921 ft/s
Rise time = 0.5 * $(\text{Vcushion})^{-1.3}$ = 0.0339 s

RAI Question 2:

Page 7 [of the Southern California Edison (SCE) September 29, 2003, submittal] discusses calculation of heat transfer from the containment atmosphere for both a large break LOCA and main steam line break (MSLB). These discussions state that more heat would be transferred to the fan cooler units for the LOCA case than the MSLB case even though the containment temperature for the MSLB case is higher. Please provide the following information concerning these calculations:

SCE Response to Question 2:

The condensation heat transfer coefficients (for saturated steam) are significantly greater than the sensible heat convective heat transfer coefficients for superheated vapor. As shown in the attached figures (see page 12), the saturation temperatures for the MSLB are much lower than the containment temperatures. Thus, the steam in MSLB is significantly superheated. Hence, for steam to begin condensing over the ECU tubes it has to first pass over successive cooler tubes to cool down to the saturation temperature and loose the superheat by convection.

1. During the early stages (first 40 seconds) of the postulated transient, even though the containment MSLB temperatures are higher than the LOCA case, the saturation temperatures for MSLB are much smaller than for the LOCA case, thus resulting in reduced heat transfer rates to the tube wall.

2. The steam saturation temperatures for the LOCA case are very close to the containment temperatures which means that the steam is not superheated and will readily condense over the cooler tubes it will initially be in contact.

Hence, to evaluate the occurrence of boiling in the ECU tubes, the LOCA case is bounding, as compared to the case of MSLB.

Response to the Request for Additional Information

<u>RAI Question 2a:</u>

Provide graphs showing the containment atmospheric temperature and pressure as a function of time for both the LOCA and MSLB case.

<u>Answer to Question 2a:</u>

The MSLB and LOCA pressure and temperature curves are provided on pages 12 and 13, respectively, of this response.

<u>RAI Question 2b:</u>

Provide the heat and mass transfer correlations used to predict condensation and heat flow to the fan cooler coils during the period when internal steam voids might form.

<u>SCE Response to Question 2b:</u>

<u>Condensation Heat Transfer Coefficient</u>

The condensation heat transfer coefficients used in the analysis are based on the NRC Standard Review Plan (SRP) 6.2.1.5. If t_p is the time (secs) when the blow down ends, in the time interval of 0 to t_p seconds, the outside heat transfer coefficient between the vapor and the tube wall (h_{out}) of 4 times the Tagami condensing heat transfer coefficient (h_c) should be used. If h_{max} is the maximum heat transfer coefficient, which occurs at the time t_p, for times t greater than t_p, NRC SRP 6.2.1.5 suggests that the heat transfer coefficient h_{out} should be evaluated by the following equation:

$$h_{out} = h_s + (h_{max} - h_s)e^{-.025(t-t_p)}$$

where:

$h_s = 1.2 \times h_{Uchida}$

and,

h_{Uchida} is the Uchida heat transfer coefficient.

SCE Response to Question 2b (continued):

Condensation Heat Transfer Coefficient

The heat transfer rate from the containment to the cooler tube wall is:

$$q_o = h_{out}(A_b + \eta_f A_f)\cdot(T_g - T_m)$$

where:

q_o = heat transfer rate Btu/hr from the containment to tube
A_b = bare tube outside surface area ft^2
η_f = fin efficiency
A_f = fin surface area ft^2
T_g = vapor temperature F
T_m = metal temperature of tube F

The calculations are performed for 1 foot of cooler tube.

Heat Transfer Inside Tube

The heat transfer rate from the tube wall to the water inside the tube is calculated by the following equation:

$$q_w = h_{in} \times A_i \times (T_m - T_w)$$

where:

q_w = heat transfer rate Btu/hr from the tube wall to the water
h_{in} = heat transfer rate Btu/hr ft^2 F from the tube wall to the water
A_i = tube inside surface area ft^2
T_w = water temperature F

Convective Heat Transfer

The convective heat transfer coefficient between the inside of the tube wall and the water inside the tube h_i is calculated by the Catton equation given below (see I. Catton, "Natural Convection in Enclosures", Proceedings 6th International Heat Transfer Conference, Toronto, Vol 6, 1978.)

$$Nu = 0.18\{Pr \times Ra/(0.2 + Pr)\}^{0.29}$$

SCE Response to Question 2b (continued):

Convective Heat Transfer (continued)

where:

Nu = Nusselt Number
Pr = Prandtl Number
Ra = Rayleigh Number

Note that:

$$Nu = h_i \times d_i / k$$

where:

d_i = Inside diameter of tube
k = Thermal conductivity

Boiling Heat transfer

When the excess temperature, defined as the temperature difference between the tube wall and the saturated water temperature, reaches 10^0F, the nucleate boiling heat transfer equation is used to calculate the heat flux between the tube wall and water. This is based on the EPRI recommendation of the GL-96-06 Report. The boiling heat transfer coefficient is calculated from the following equation taken from the Principles of Heat Transfer, F. Kreith, Intext Educational Publication, 3rd edition)

$$q' = \{C_f/(C_{fs} * h_{fg} * Pr)\}^{3} * (\Delta T^3) * \mu_f * h_{fg} * \{(g(\rho_f - \rho_g)/ g_c \sigma)^{.5}\}$$

where:

q' =heat flux
ΔT= excess temperature
Tsat = saturation temperature
C_f = specific heat
C_{fs} = fluid/surface constant
Pr = Prandtl no.
μ_f = viscosity
ρ_f = density of liquid
ρ_g = density of vapor
g_c =gravitational acceleration
g =conversion factor
σ = liquid vapor surface tension

Response to the Request for Additional Information

RAI Question 3

Explain your basis for load combinations.

SCE Response to Question 3:

The load combinations were based on the Updated Final Safety Analysis Report (UFSAR), the seismic load is not added to the waterhammer load due to:

1. SONGS UFSAR Table 3.9-10 prescribes the guidelines for the design loading combination for ASME Code Class 1, 2, and 3 Non-NSSS components. The following four (4) design loading combinations are applicable for the faulted condition per Table 3.9-10.

   PO + DW + DBE + RVO
   PO + DW + DBE + DF (applicable to components of the reactor coolant pressure boundary only)
   PO + DW + DF
   PO + DW + TOS

   Where

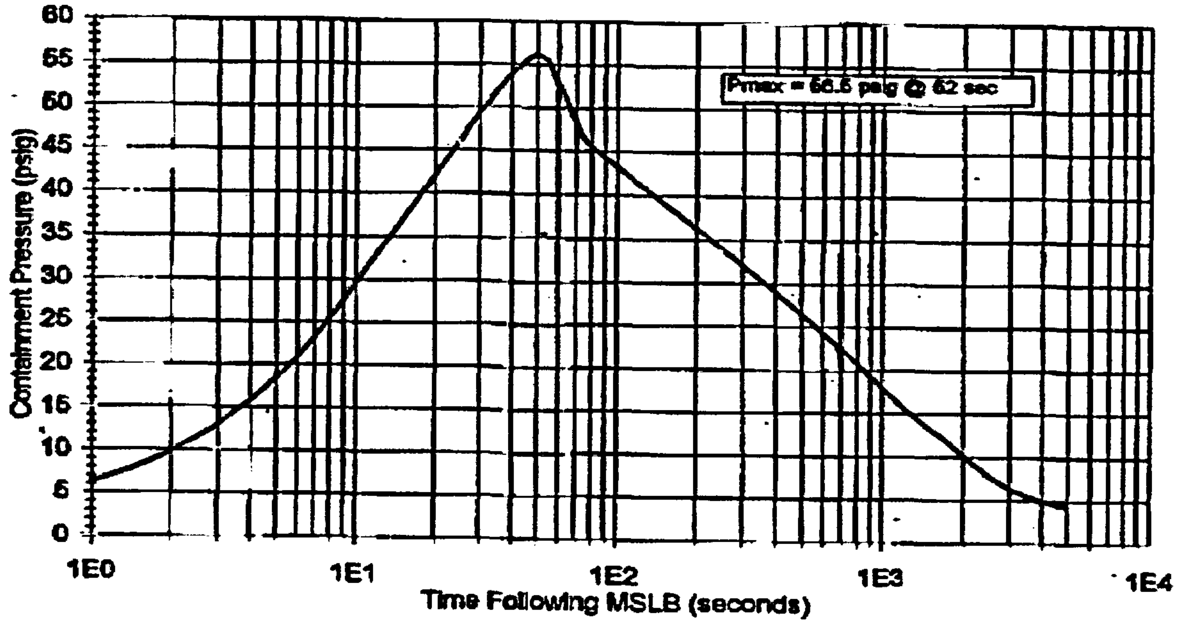
PO	-	operating pressure
DW	-	dead weight
DBE	-	design basis earthquake (inertia)
RVO	-	relief valve (open system - sustained)
DF	-	dynamic events associated with a LOCA during which or following which the piping system, being evaluated must remain intact
TOS	-	the seismic event turbine driven AFW pump overspeed

2. The peak seismic event is considered dynamically decoupled from the peak waterhammer event due to the timing of the events. An acceptable scenario is that the seismic event is the initiating event for a LOCA. The CCW pump starts at 30.9 seconds later; therefore, it is reasonable not to combine loads from the two events.

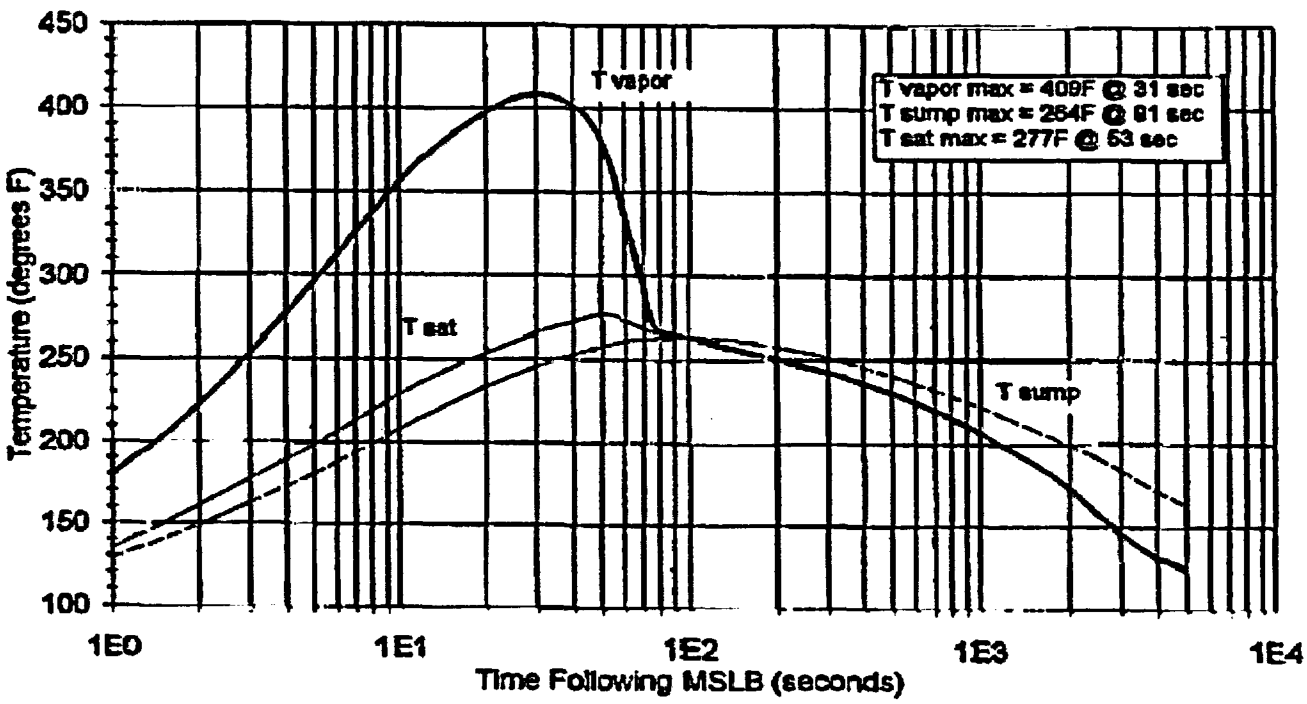
Reference:

Letter from A. E. Scherer (SCE) to the Document Control Desk (NRC) dated September 29, 2003; Subject: Docket Nos. 50-361 and 50-362, Supplemental Response to Generic Letter 96-06 "Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions," San Onofre Nuclear Generating Station, Units 2 and 3, (TAC Nos. M96862 and M96863)

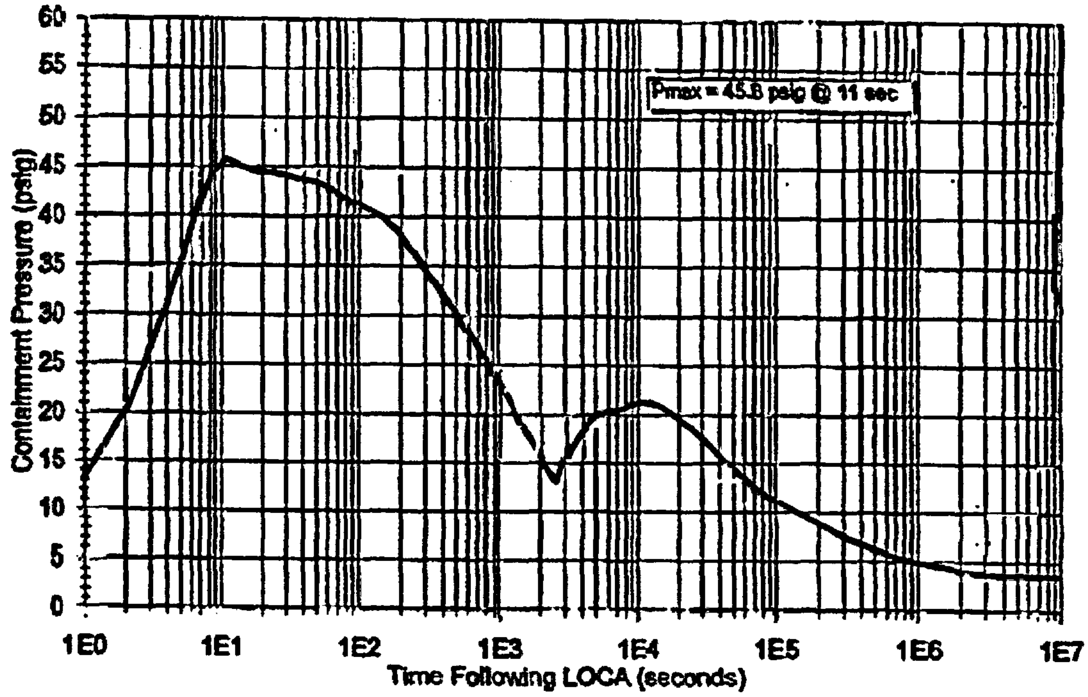
MSLB @ 102% POWER W/MSIV FAILURE
CONTAINMENT PRESSURE
CASE 7



MSLB @ 102% PWR W/MSIV FAILURE
CONTAINMENT TEMPERATURES
CASE 7



CASE 7 - DEHLS LOCA W/LOP & DG FAILURE
CONTAINMENT PRESSURE



CASE 7 - DEHLS LOCA W/LOP & DG FAILURE
CONTAINMENT TEMPERATURES