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AUTH.NAME AUTHOR AFFILIATION
MEDFORD,M.O. Southern California Edison Co.
RECIP.NAME RECIPIENT AFFILIATION
KNIGHTON,G.W. Licensing Branch 3

SUBJECT: Forwards response to NRC 830627 request for addl info to satisfy requirements of NUREG-0737,Item II.D.1 "Relief & Safety Valve Testing."

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Southern California Edison Company

P. O. BOX 800
2244 WALNUT GROVE AVENUE
ROSEMEAD, CALIFORNIA 91770

M.O. MEDFORD
MANAGER, NUCLEAR LICENSING

TELEPHONE
(213) 572-1749

October 14, 1983

Director, Office of Nuclear Reactor Regulation
Attention: Mr. George W. Knighton, Branch Chief
Licensing Branch No. 3
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Gentlemen:

Subject: Docket Nos. 50-361 and 50-362
San Onofre Nuclear Generating Station
Units 2 and 3

SCE's letter of June 29, 1982 transmitted the "San Onofre Nuclear Generating Station, Units 2 and 3 Pressurizer Safety Valve Operability and Safety Valve Discharge Piping Adequacy Report," which provided an evaluation of the EPRI/CE program test results and demonstrated, (1) satisfactory operability of the San Onofre Units 2 and 3 safety valves, and (2) the adequacy of the safety valve discharge piping system. The report satisfied the requirements of Item II.D.1, Relief and Safety Valve Testing, of NUREG-0737.

Subsequently, on June 27, 1983, as a result of their review of SCE's June 29, 1982 submittal, the NRC Staff requested that SCE, (1) provide additional information (thirteen questions) and (2) meet with the staff to discuss the responses. Consistent with this request, enclosed please find seven (7) copies of SCE's responses to the NRC's questions regarding the San Onofre Units 2 and 3 pressurizer safety valves and discharge piping. In addition, we are available to meet with you following your review of the enclosed information.

If you have any questions or comments, please let me know.

Very truly yours,

M.O. Medford

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RESPONSES TO NRC QUESTIONS ON

PRESSURIZER SAFETY VALVES

SAN ONOFRE NUCLEAR GENERATING STATION
UNITS 2 AND 3

The information provided below responds to the NRCs June 27, 1983 request for additional information (thirteen questions) regarding peformance testing of pressurizer relief valves and discharge piping adequacy.

NRC Question No. 1

In the justification presented to show that only steam flow through the safety valves need be considered, no discussion is given on the consideration of single failures after the initiating event. NUREG-0737 requires selection of single failures that produce maximum loads on the safety valves.

A discussion should be provided describing how the single failure considerations required by NUREG-0737 are met.

Response

Only steam flow through the safety valves needs to be considered for the following reasons. A review of Chapter 15 of the FSAR indicated that the feedwater line break (FWLB) accident has the greatest potential for driving the pressurizer water level to the safety valve inlet. Therefore, the FWLB accident was conservatively reanalyzed with the extended blowdown to clearly demonstrate that only steam conditons will exist at the safety valve inlet. The FWLB scenario includes the loss of offsite electrical power which causes a coastdown of all four reactor coolant pumps. As a result, the only remaining active mechanism credited for mitigation of the pressurizer level increase is the opening of the main steam safety valves. Failure of these valves to open is not considered credible. Therefore, other than the loss of offsite electrical power there are no credible single failures which could further increase the pressurizer level. Even with this limiting accident scenario and the very conservative analytical assumptions discussed in Appendix B-2 of Reference A, the fluid conditions at the valve remain as steam. The resulting loads on the valves were considered and found to be well within the valve design limits.

NRC Question No. 2

The peak pressure calculated for FSAR events was 2760 psia. The maximum pressure for the test series with ring settings corresponding to the ring settings of the plant valves was 2667 psia. The conditions used in the analysis for discharge piping loads was saturated steam at 2600 psia. How are these pressures compatible?

The submittal concludes that blowdowns as high as 12% can be expected with the ring setting used on the plant safety valves compared to 5% considered in the FSAR. A discussion is presented to verify that the pressurizer water level will not rise sufficiently to reach the safety valve inlet line. No discussion is given to assure that adequate core cooling will be achieved during the increased blowdown. A discussion should be provided that describes how plant safety is assured with the increased blowdown.

Response

The FSAR peak pressurizer pressure for San Onofre Units 2 and 3 is 2670 psia, as discussed in FSAR Section 15.2.2.3, and was inadvertently stated as 2760 psia in References (A) and (B). The EPRI Test Condition Justification Report, April 1982, concluded that the test pressure of 2667 psia was representative of the FSAR peak pressure. The following reasoning is presented here to substantiate the EPRI conclusion for San Onofre Units 2 and 3. With a set pressure of 2500 psia the valves reach their full open position at 2575 psia (3% accumulation). Further increase in pressure will have no effect on valve operation. Flow will increase, since it is a function of pressure. There is no concern regarding the structural integrity of the valve at 2670 psia. The primary membrane stress intensity in the valve body is 57% of the allowable value at the design pressure of 2500 psia. By ratioing, this stress intensity is 61% of the allowable value at 2760 psia. Hence the minor difference between test pressure and FSAR peak pressure (3 psia) would not affect either valve operation or structural integrity.

The maximum discharge piping loads occur upon valve opening (i.e. at 2500 psia). The final peak pressure is reached after the maximum piping loads have occurred and does not affect the piping analysis. Accordingly, 2600 psia is conservatively high for use in evaluating the discharge piping loads.

Extending the primary safety blowdown initially gave rise to a concern for inadequate core cooling due to possible interruption of coolant flow caused by steam void formation during depressurization to the safety valve closure. Subsequent review of plant transients in Chapter 15 of the FSAR (which were analyzed for 5% blowdown) identified that the feedwater line break accident produced the maximum reactor coolant temperatures while the safety valves are open. This event was conservatively reanalyzed with 12% valve blowdown. The calculated minimum degree of subcooling within the RCS (excluding the pressurizer) remained greater than 30°F throughout the depressurization. Therefore, steam void formation will not occur due to 12% safety valve blowdown, and adequate core cooling is assured.

NRC Question No. 3

During pressurization transients, the pressurizer sprays come on. Since the sprays put water into the steam volume, wet steam will pass through the relief valves. This effect should be included in the evaluation of the discharge piping loads.

Response

The operation of pressurizer spray will not increase the discharge piping loads because the peak load occurs prior to the time when any wet steam due to entrained spray can reach the safety valve.

As mentioned in the response to Question 2, Paragraph 1, the maximum discharge piping loads occur upon valve opening. This means that the peak force in a given piping segment occurs when the initial pressure surge due to valve opening reaches that segment. The inlet piping for the safety valve will initially contain saturated steam. In order for any postulated wet steam to reach the discharge piping, the initial quantity of saturated steam must pass through the safety valve. For San Onofre Units 2 and 3 this would take at least 0.030 seconds after the valve initially opens. By the time the postulated wet steam reaches the valve, the valve is fully open and the initial pressure surge has already occurred. This is further substantiated by EPRI safety valve test data for steam-to-water transition tests. In these tests the safety valve actuated on saturated steam followed by a transition of saturated water after the valve opened. The peak loads occurred when the valve initially opened prior to the transition to water. Therefore, the operation of pressurizer spray will not result in discharge piping loads in excess of those values previously presented in the Reference A San Onofre safety valve report.

In addition to the ASME Code report, the EPRI test program demonstrated the structural adequacy of the safety valve during valve actuation transients.

The bending moments predicted to act on the safety valve discharge flange in the San Onofre piping analysis are less than those measured during the test program. The operability of the safety valves is therefore not impaired by the calculated piping loads.

NRC Question No. 4

The feedwater line break is reported as the transient that would produce the largest rise of pressurizer water level and it is used to demonstrate that the level would not rise to the safety valve inlet line. The method of determining that the feedwater line break is the limiting transient is not given. Also no discussion is given on the analysis methods used to compute the rise in the water level. Details of these analyses should be provided or appropriate references cited.

Response

A review of Chapter 15 of the FSAR was undertaken to determine the limiting transient with respect to the maximum increase in pressurizer level. FSAR Section 15.2 addresses the class of events that cause a decrease in heat removal by the secondary system. This section includes those transients that result in both an increase in pressurizer level and a challenge to the primary safety valves. Of these transients, the feedwater line break (FWLB) results in the maximum increase in pressurizer level, and therefore, was selected as the limiting transient.

The method used to analyze the FWLB for the extended safety valve blowdown is the same conservative methodology discussed in FSAR Section 15.2 and Appendix 15E.2.

Additional assumptions to maximize the predicted pressurizer level increase are discussed in Appendix B-2 of the submittal. These include:

(a) Subcooled water surging into the pressurizer from the RCS hot leg does not mix with the saturated liquid initially present in the pressurizer.

(b) Steam formation calculated to occur during depressurization to safety valve closure is assumed to remain within the liquid region of the pressurizer.

Thus the method utilized conservatively over estimates the pressurizer level increase. However, even with these conservatisms, only steam conditions are predicted for the safety valve inlet for blowdowns up to 12%. Therefore, safety valve blowdowns to 12% are considered acceptable.

NRC Question No. 5

The calculated backpressure for the simultaneous lifting of two safety valves exceeds the maximum backpressure for the tests conducted with the ring settings of the plant valves. A linear plot of the limited test data was used to extrapolate to higher backpressure and corresponding smaller blowdowns. The reported blowdown, with 2% tolerance, was 3.5%. Small blowdowns can result in unstable valve operations; therefore, justification should be given for the linear extrapolation. The trend of blowdown versus backpressure as predicted by the methods of the ASME Paper 82-WA/NE-9 would be appropriate.

Also the maximum pressurizer pressure for the FSAR transient is 93 psia higher than the maximum pressure for the test series. The rationale for concluding that the tests demonstrate adequate operation for the higher pressure should be provided.

Response

The theoretical work presented in ASME Paper 82-WA/NE-9 indicated a trend of linearly decreasing blowdown with increasing back pressure up to a threshold back pressure of approximately 550 psia. Based on this paper and on experience with the test data, it is concluded that the maximum calculated back pressure for San Onofre Units 2 and 3 of 427 psig is within the range where linear extrapolation is valid.

The stability question was addressed in Part B, Section 6.2 of the San Onofre Safety Valve Operability Report. This section concluded that stable safety valve operation would be predicted with a 3.5% minimum blowdown based on a comparison of the maximum expected pressure drop at the valve inlet with the predicted blowdown pressure (i.e., the maximum expected drop of 66 psi is less than the predicted minimum blowdown of 87.5 psi.) This means that the inlet pressure will not drop below the reseat pressure on opening and hence the safety valve will operate in a stable manner.

As discussed in the response to Question No. 2, the FSAR peak calculated pressurizer pressure is 2670 psia, and differed from the test pressure of 2667 psia by only 3 psia, this minor difference would not affect valve operation, structural integrity, or discharge piping loads.

NRC Question No. 6

During the test series, valve repairs or modifications were made to correct problems related to proper valve operation. The thickness of the disc holder was reduced to reestablish the clearance between the valve disc and the disc holder. The thrust bearing adapter was remachined to prevent the outer surface of the spacer from contacting the inner surface of the adapter. The lower lip of the disc holder was machined to reestablish the gap between the disc and the disc holder. Are similar repairs or modifications necessary to insure reliable operation of the plant valves?

Response

The reason that the thickness of the disc holder was reduced and the lower lip of the disc holder was machined to reestablish the clearance between the valve disc and the disc holder was that the new bellows which was previously installed had elongated after the valve was cycled. This resulted in reduced clearance and is a normal occurrence for a new bellows. To avoid this problem new valves are cycled several times at Dresser prior to shipment. The test valve was refurbished during testing and did not have the benefit of Dresser Standard factory practice. All the plant valves were subjected to this cycling prior to final production tests at Dresser. In addition, in the unlikely event this problem occurred in the field, it would not impair valve operability, but would show up as seat leakage when the valve is closed. No repairs or modifications are required to the plant valves.

The reason that the thrust bearing adapter was remachined to prevent the outer surface of the spacer from contacting the inner surface of the adapter was to remove a burr which was noted during reassembly. The burr was most likely caused by the numerous set pressure adjustments made to the valve during the test program. This problem would likely not be present on the plant valves; however, in the unlikely event it did occur, it would have no effect on proper valve operation and would show up as difficulty in making set pressure adjustments or seat leakage due to misalignment of internal parts when the valve is closed. No repairs or modifications are required to the plant valves.

NRC Question No. 7

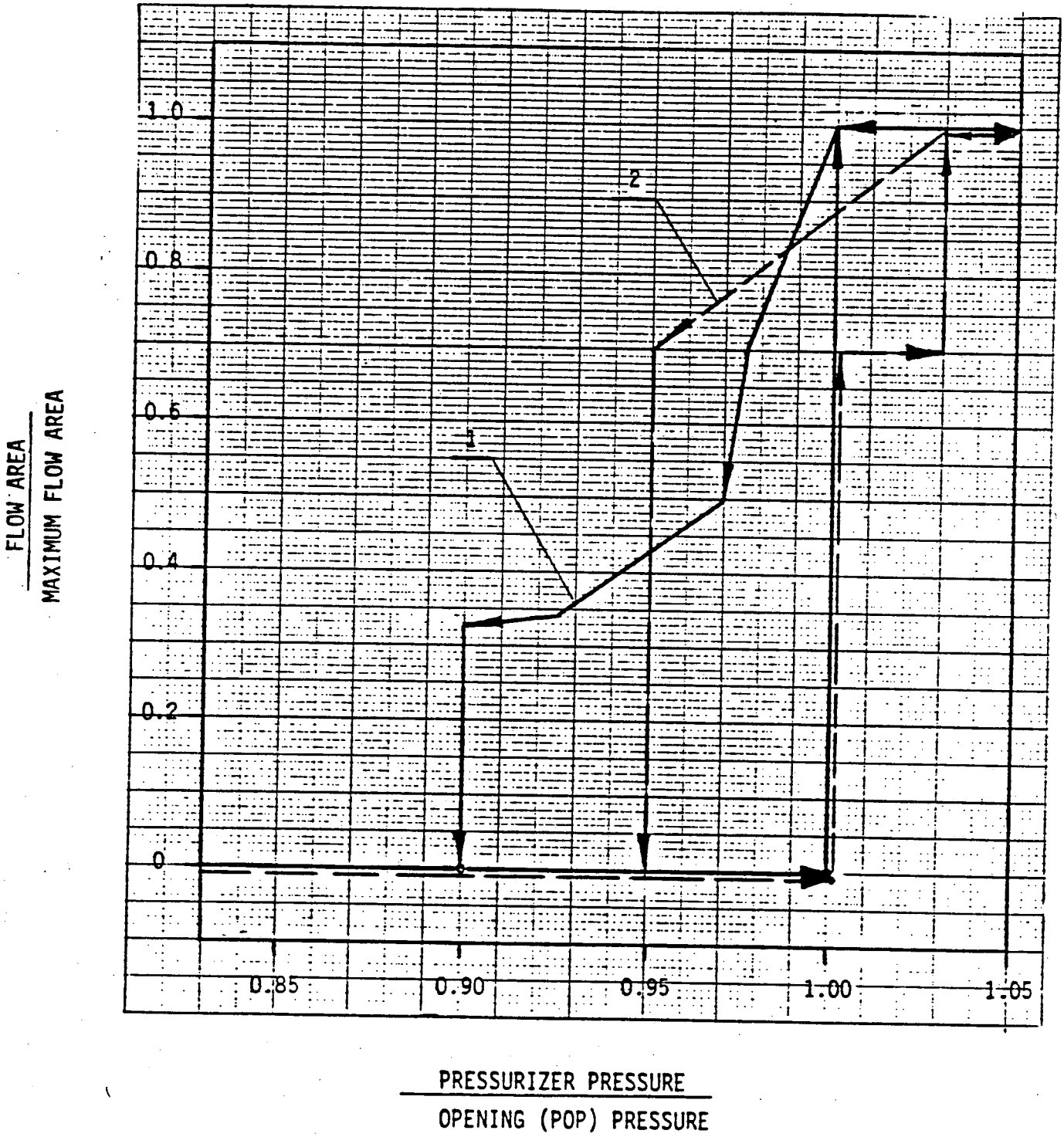
The ability of the valves to pass the flow to be compatible with the FSAR analyses that demonstrate the overpressure transients will be limited to 110% of the design pressure is inferred from data of Tables 3.3. and 3.5 of the submittal. However, no direct comparison was presented and considerable interpretation is required to reach this conclusion. A specific comparison of the measured flow characteristics with the characteristics used in the FSAR should be included in the submittal.

Response

A direct comparison of the measured safety valve flow characteristics with the characteristics used in the FSAR is shown in Figure 1. The dashed line illustrates the FSAR assumption that the valve initially opens to only 70% of the maximum flow area at the set pressure until 3% overpressure is reached when the valve opens fully. The operating characteristic observed in the EPRI tests, depicted by the solid line, indicates that the valve pops open to the maximum flow area at the set pressure and remains there as the inlet pressure accumulates. Since the actual valve flow area will be greater than or equal to the valve flow area assumed in the FSAR analyses for pressures greater than the set pressure, it is concluded that valve will pass flow greater than or equal to the analysis flows. Therefore, the peak pressures calculated in the FSAR analyses are conservative.

Figure 1

COMPARISON OF THE SAN ONOFRE UNITS 2 AND 3 FSAR SAFETY VALVE FLOW MODEL AND DRESSER 31709NA VALVE OPERATING CHARACTERISTIC OBSERVED IN EPRI TESTS



Notes: 1 - Operating characteristic, observed in tests (at 10% blowdown)

2 - FSAR assumption

NRC Question No. 8

The Energy Incorporated Version of RELAP 4, E115P, was used for the thermal hydraulic analysis. Considerable effort has been expended on RELAP 5 to determine the acceptability for use on safety valve piping and the effects of many parameters have been studied to establish proper modeling techniques. The San Onofre submittal does not discuss similar work for RELAP 4.

A comparison of RELAP 4 with RELAP 5 results is included in the submittal of the analysis of one of the EPRI/CE tests. The comparison showed reasonable agreement. However, comparison for one test does not, in itself, prove the adequacy of RELAP 4. The problem chosen for comparison does not bound the conditions for the San Onofre conditions in that the pressure and flow are less than the maximum values for the San Onofre transients. In addition, significant differences exist in the modeling between the two analyses that could affect the comparison. The node spacing for the RELAP 4 solution appear to be relatively long. For example, the first horizontal leg, a 5 foot section, was modeled using one volume node. Studies for RELAP 5 indicate 8 nodes should be used for a pipe leg to obtain a reasonable representation.

The conclusion that the RELAP 4 force versus time functions are more conservative than RELAP 5 is not obvious from the data given in the report. The absolute magnitude of the element forces is not the only parameters that affect the response of the piping system. The difference in forces at various nodes as a function of time and the rate the forces are applied often have a more important effect on the response.

Additional justification for the use of RELAP 4 is required before the analysis of the San Onofre safety valve piping can be considered adequate.

Response

The completion of the EPRI verification of the RELAP 5 applicability to the safety/relief valve problem was delayed until April, 1982. At that time there was no assurance that RELAP 5 would have been available for the San Onofre Units 2 and 3 safety valve study (Reference (A)). Also, RELAP 5/MOD 1 was not commercially verified at that time. The RELAP 4 code was therefore used for the San Onofre safety valve/discharge piping anlysis. The RELAP 4 code is a standard code widely utilized throughout the nuclear power industry for steam flow analysis. Based upon its usage, it was judged that an extended analysis to determine the acceptability of its use for safety valve piping (and the effect of many parameters to establish the proper modeling technique) was not necessary.

The problem chosen for the comparison of RELAP 4 and RELAP 5 does not bound the San Onofre Units 2 and 3 conditions. However, the techniques of extension and extrapolation are rountinely applied for establishing validity of a computer code through a small scale test or simplified theoretical close-form solution. Time and cost constraints did not allow development of a code specifically for the San Onofre Units 2 and 3 conditions. The only available reference used for the San Onofre study was "Evaluation of RELAP 5/MOD 1 for Calculation of Safety and Relief Valve Discharge Piping Hydrodynamic Loads" by ITI, published in February, 1982. In this reference, only case 1411 (the only case using steam discharge) is applicable to San Onofre Units 2 and 3. Common practice using RELAP 4 is to use a volume node 3 to 5 times the pipe diameter. Since the RELAP 4 results envelope the RELAP 5 results; they also

envelope the test results. It was therefore judged that the RELAP 4 results are conservative since comparisons are made on the net force for each piping segment. The amplitude and duration of the net forces are higher in the RELAP 4 results. It is in this sense that the RELAP 4 results envelope the RELAP 5 results.

NRC Question No. 9

Adequacy of the thermal hydraulic and the structural analyses could not be verified since sufficient details were not provided in the submittal. To provide for a more complete evaluation, additional discussions should be provided for the rationale used in selecting key parameters such as node spacing, time steps and choked flow nodes for the thermal hydraulic analysis and reduced degrees of freedom and damping for the structural analysis. Computer printouts of input and output for selected key problems should also be provided.

Key problems for which printouts should be provided should include PIPES solution for San Onofre steam discharge, RELAP 4/ANSYR solution for case 3 (San Onofre steam discharge with second valve opening after first valve has reached 50% open) and ANSYS solutions for case 3 and the seismic analysis both with and without the snubber at node point 60.

The inlet pressure drop and the backpressure were utilized in the analysis of safety valve operability, not in the discharge piping loads analysis. The inlet pressure drop was calculated from the PIPES code and is discussed in Appendix B-1 of Reference (A). The peak backpressure was developed from calculation M11.5 as discussed in Section 5.5, Part B, Reference (A).

A specific concern is the use of saturated steam at 14.7 psia in the downstream piping prior to valve lift. Higher loads may result if air is assumed in the downsteam piping. Also the inlet pressure drop and the reported backpressure could not be verified because the details of the analysis were not provided.

Response

The methodology used in the analysis is consistent with industry practice and state-of-the-art. Calculations and other documentation are part of a 10 CFR 50 Appendix B quality assurance program. The calculations and documentation are available for review.

Key parameters used in the thermal-hydraulic analysis are node spacing, time steps and choked flow nodes. The minimum calculation time step (t) was used based upon Courant criteria ($C\ t \leq \Delta X$), where C is the pressure wave propagation speed (ft/sec) and ΔX is the minimum nodal spacing. In the San Onofre Units 2 and 3 analysis, the minimum volume length is 3.5 feet and the wave speed is calculated to be approximately 1400 ft/sec. Thus, the allowable time step should be approximately 2.5 msec ($\Delta t = \Delta X/C = 3.5/1400$). The minimum time step actually specificed in the San Onofre analysis is 0.1 msec - far below the required time step of 2.5 msec. Moody's choking flow model is used in the analysis since the fluid condition is in the saturated region.

Key parameters used in the structural analysis are the reduced degrees of freedom and the damping coefficient. The reduced degrees of freedom for the piping structural analysis are addressed in Reference (A), pages C-3, C-30 and C-58. A damping ratio of 1% (based upon Regulatory Guide 1.61) and assuming the most dominant natural frequency is 50 Hz resulted in a damping coefficient of $\beta = 0.000064 = .01/(\pi \times 50)$.

RELAP 4, rather than the PIPES code, was used for analysis of the discharge piping. The piping structural analysis, including safety valve discharge and

seismic loads without the snubber in the Y-direction at node point 60, are documented by formal calculation.

For the San Onofre Units 2 and 3 analysis, steam was used in the downsteam piping prior to valve lift. RELAP 4 does not have the capability to model air. It should be noted however, that the difference in the inertia of air versus that of steam in the discharge piping compared to the flow momentum through the valve is very small. Also, the wave speed in air at a given temperature is approximately the same for steam. Therefore, use of air or steam for developing the piping force leads to essentially the same result. Consequently this methodology is considered adequate to address the specific concern.

NRC Question No. 10

Three valve opening sequences were considered in the submittal; however, these sequences were not shown to bound the forces for all possible valve opening sequences. The experience of EG&G Idaho indicates the maximum forces are obtained when the sequence of opening is such that the initial pressure waves from the two valves opening reach the tee connection of the branch piping simultaneously. Additional justification should be provided to demonstrate that the sequences considered are adequate.

Response

The valve opening sequences used for the San Onofre Units 2 and 3 analysis were chosen based upon engineering judgement. Extensive analysis with a fluid structure interactive code would be required to develop a bounding case for all possible valve opening sequences. No such verified code was available for use at the time the San Onofre analysis was done. However, a comparison of the results for the three cases analyzed shows that the differences in maximum forces generated are within 5 percent. Additionally, conservatism in the piping support design should cover the uncertainties in the analysis. Therefore, it is our judgement that the valve opening sequences analyzed are sufficient.

NRC Question No. 11

The submittal did not discuss the effect of the safety valve transients on the Section III Class 1 stress analysis of the piping from the pressurizer connections to the safety valve inlets nor did it discuss the effect of the transients on the stress analysis of the safety valve.

In addition to the primary stresses, of special concern is the large displacement of the piping at the connection to the pressurizer due to the thermal expansion of the pressurizer when heated to operating conditions. The stresses from this displacement, the stresses from the thermal expansion of the safety valve piping and the stresses from the valve discharge should be appropriately combined and compared to the ASME Section III limits.

Response

Reference (A) addresses only the safety valve discharge piping and as such, did not include discussion of the ASME Class 1 inlet piping.

The ASME Class 1 piping stress analysis was performed and considered the safety valve discharge load in the design condition (primary stress). The safety valve discharge loads were also considered in the fatigue analysis which includes movement of the pressurizer nozzle caused by thermal expansion. The stresses from this displacement, the stresses from the thermal expansion of the safety valve piping and the stresses from the valve discharge were appropriately combined. This analysis complies with the rule of paragraph NB 3650 of the ASME Section III Code, 1974 Edition. Therefore, the fatigue analysis results meet the requirements of ASME Section III and adequately address the subject concerns. The results of this stress analysis are documented by calculation for San Onofre Units 2 and 3 and is subject to the 10 CFR 50, Appendix B quality assurance program.

In addition to the ASME Code report, the EPRI test program demonstrated the structural adequacy of the safety valve during valve actuation transients. The forces and moments predicted to act on the safety valves in the San Onofre Units 2 and 3 piping analysis are less than those measured during the test program. The operability of the safety valves is therefore not impaired by the calculated piping loads.

NRC Question No. 12

Justification should be provided for the load combination considered in the stress analysis. What is the rationale for not combining an operating basis earthquake with the dynamic loads from the relief valves discharge.

Response

The design loading combinations considered for the stress analysis of the ASME code class piping are specified in the San Onofre project design specifications. For a closed system, such as the pressurizer safety valve discharge piping, combination of the Operating Basis Earthquake (OBE) load with the dynamic loads resulting from relief valve discharge is not required. This is consistent with the load combinations provided in the San Onofre 2 and 3 Final Safety Analysis Report (FSAR), Paragraph 3.9.3.1.2 and Table 3.9-10. The loading combination considered in the stress analysis is also consistent with the EPRI "Guide for Application of Valve Test Program Results to Plant Specific Evaluations, Revision 1, Interim Report, March 1982 (Research Project V102).

NRC Question No. 13

The stress analysis used an equation of ANSI B31.1 that considered only the primary stresses in the piping downsteam of the safety valve. The rationale for not considering the thermal and other secondary stresses should be provided.

Response

As indicated in Reference (A), page C-32, an allowable stress of 1.8 S_h was used for ANSI B31.1 piping. This allowable is based upon the low probability of actual safety valve actuation. This is compatible with EPRI's recommendations for service level C for which only primary stresses need be considered.

References: (A) Pressurizer Safety Valve Operability and Safety Valve Discharge Piping Adequacy Report, Southern California Edison, June, 1982, San Onofre Nuclear Generating Station, Units 2 and 3.

(B) Valve Inlet Fluid Conditions for Pressurizer Safety and Relief Valves in Combustion Engineering Designed Plants, EPRI NP-2318-LD, Project V102-20, Interim Report, April, 1982.

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