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SUBJECT: Forwards addl info re performance testing of relief & safety valves per NUREG-0737,Item II.D.1, "Relief & Safety Valves."

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J. O. SCHUYLER
VICE PRESIDENT
NUCLEAR POWER GENERATION

January 23, 1984

PGandE Letter No.: DCL-84-027

Mr. George W. Knighton, Chief
Licensing Branch No. 3
Division of Licensing
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Re: Docket No. 50-275, OL-DPR-76
Docket No. 50-323
Diablo Canyon Units 1 and 2
NUREG-0737, Item II.D.1 - Relief and Safety Valves

Dear Mr. Knighton:

As requested by your letter dated November 15, 1983, enclosed is the additional information regarding performance testing of Relief and Safety Valves (Item II.D.1 of NUREG-0737). If upon completion of your review, you feel a meeting is required, please notify PGandE.

Kindly acknowledge receipt of this material on the enclosed copy of this letter and return it in the enclosed addressed envelope.

Sincerely,

J. O. Schuyler

Enclosure

cc: Service List

B001
1/1

PGandE Letter No.: DCL-84-027

ENCLOSURE

RESPONSE TO NRC REQUEST
FOR ADDITIONAL INFORMATION

NUREG-0737, ITEM II.D.1
PERFORMANCE TESTING OF RELIEF AND SAFETY VALVES

Question 1

The limiting transient for the safety valves and PORVs could not be verified since it was not identified and since no discussion was provided describing the methods used to select the limiting transient. A discussion identifying the limiting transient and providing the rationale leading to the selection of the transient should be provided.

Response

The limiting transients for the safety and relief valves have been identified and discussed in EPRI Report NP-2296-LD, "Valve Inlet Fluid Conditions for Pressurizer Safety and Relief Valves in Westinghouse Designed Plants", dated March 1982. Additional discussion of the limiting transient for the safety valves is provided in the Westinghouse report WCAP-10105 "Review of Pressurizer Safety Valve Performance As Observed in the EPRI Safety and Relief Valve Test Program", June 1982 (generic) and Section 15.2.7 of the Diablo Canyon Final Safety Analysis Report (plant specific).

Question 2

Overpressure transients will cause the pressurizer sprays to activate adding moisture to the steam volume. When the safety valves (SRVs) lift or the power operated relief valves (PORVs) are opened they would be passing a steam-water mixture. Was this effect considered in the analyses done to select the transient that produced maximum loads on the discharge piping?

Response

The effect of a steam-water mixture was considered in the analysis performed for the relief valve discharge piping. However, the limiting case for discharge piping loads is loop seal discharge and not steam or steam with entrained water discharge; therefore the effect of water entrainment has been determined to be minimal. Furthermore, including entrained water in the upstream steam space would result in lower downstream piping loads during and subsequent to water slug discharge because of the reduced fluid velocity for the two phase mixture.

The safety valves will not be challenged when the pressurizer sprays and PORVs function as designed.

Question 3

The submittals do not include a discussion of 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

The limiting Condition II transient that incurs safety valve actuation is the loss of external load event (FSAR 15.2.7). The analyses assumed an initial core power of 102 percent of rated with no direct reactor trip (on turbine trip). In addition, the pressurizer spray and power-operated relief valves were assumed inoperable. The combined effect from these assumptions produced the greatest (fastest) reactor coolant pressurization rate.

As the peak pressure is observed within a few seconds of transient initiation, single failures within the engineered safeguards systems would have little, or no effect, on the pressurization rate or peak pressure observed.

Question 4

The effect of SRV blowdown in excess of the ASME code limits of 5 percent should be considered to determine if any adverse effects on plant safety exist. An increased blowdown would also cause a higher rise in the pressurizer level during transients that result in the SRVs lifting. No discussion is provided discussing whether the level will reach the discharge piping connection resulting in a transition of flow through the SRVs from steam to a water-steam mixture. Details of the analyses evaluating the effects on safety and details of the analyses evaluating whether the water level will reach the discharge piping should be provided.

Response

The overpressure analyses conducted for Diablo Canyon Units 1 and 2 utilized a safety valve blowdown of zero percent. Consequently, specific effects of safety valve blowdown in excess of the ASME code limit of 5 percent are unknown for Diablo Canyon.

Analyses to determine the effects of increased valve blowdown were performed within the Westinghouse Owners Group (WOG) program on safety valves. The analyses utilized valve blowdowns in excess of 10 percent for a 4-loop plant virtually identical to the Diablo Canyon design. The results from these analyses showed no adverse effects on plant safety. The peak water level calculated remained below the pressurizer inlet piping to the safety and relief valves. Discussion of the WOG program is contained in the Westinghouse report WCAP-10105, "Review of Pressurizer Safety Valve Performance As Observed in the EPRI Safety and Relief Valve Test Program", dated June 1982.

Question 5

The safety valve evaluation did not address operation of the PORVs under water discharge conditions, such as cold overpressure protection. Will the PORVs be subjected to any water discharge transient when used for cold overpressure protection? If so, is the system adequate?

Response

The PORVs will be subjected to water discharge transients when used for cold overpressure mitigation. As noted in Section 5.2.2.4 of the FSAR, whenever the Low Temperature Overpressure Protection (LTOP) system is enabled and reactor coolant temperature is below 330°F, a high pressure signal (above 450 psig) will automatically actuate the PORVs.

PORV actuation during normal plant operation (setpoint - 2350 psig) will result in a water seal discharge followed by steam. The loop seal discharge case envelopes both the steam discharge case and the low temperature overpressure case.* As such, the PORV system is adequate for cold overpressure protection.

Question 6

The submittals do not state what ring settings are to be used for the SRVs. The specific ring settings to be used should be provided. The backpressures are not given in the submittals. The submittals do not discuss the test valve performance to verify that the valve did perform satisfactorily. A comparison should be provided that demonstrates, with the specific ring settings and appropriate backpressures, that the valves will have stable operation for the Final Safety Analysis (FSAR) transients and will pass rated steam flow.

Response

The ring settings supplied by Crosby for the Diablo Canyon safety valves were established by the same methods as the "as shipped" final ring settings for the Crosby Model 6M6 safety valve tested at EPRI. These methods included the performance of a steam operational test on each Model 6M6 pressurizer safety valve to determine the best suited ring settings to assure proper and stable valve performance. The final "as shipped" ring settings will vary between valves as a result of these tests to compensate for slight variations in valve internals dimensions and other factors critical to valve performance.

Comparisons should be made only on those EPRI tests performed with final "as shipped" ring settings. The 900 series tests performed with the lowered ring positions are not representative of present field ring settings.

Based on the above and noting that the Diablo Canyon loop seal arrangement is enveloped by that used in the EPRI tests for the Model 6M6 valve, the present "as shipped" ring settings would result in valve performance similar to that experienced in the EPRI tests.

*The present configuration is sloped to form water seals immediately upstream of the relief valves.

Question 7

NUREG-0737 requires qualification of the block valve. Specific data demonstrating qualification of the block valve is not given in the submittals. A reference is made to a report by R. C. Youngdahl indicating satisfactory performance for a similar valve. The EPRI tests demonstrated closure only with steam. Additional information should be provided to verify that testing with steam only provides adequate assurance that the valve will perform satisfactorily for the required plant conditions.

Response

In a June 1, 1982 letter from R. C. Youngdahl to Mr. H. Denton, several block valve test submittals were made which included an explanation as to why block valve tests beyond the Marshall tests were not considered necessary, as well as an EPRI summary report covering Westinghouse gate valve closure testing. The Westinghouse report, transmitted to the NRC by the Youngdahl submittal, also includes a section on friction testing of stellited seating parts.

The Velan block valve tested at EPRI is similar to the Diablo Canyon block valve having the same model number (B10-3054B-13MS) and same model Limitorque operator (SMB-00-15). This valve underwent steam cycle testing at the Marshall Steam Station and is reported to have fully opened and closed for the 21 cycles of the evaluation test.

Friction testing done by Westinghouse on stellite coated test specimens (Note the Velan valve has stellite seats) indicates that over the initial 200 cycles of testing, water test specimen friction factors increased from as low as 0.12 until a level of 0.4 to 0.75 is reached. With 550°F steam the friction factor starts in the 0.5 to 0.6 range (higher than the water tests) and drops to approximately 0.35 over the 200 cycle range. Considering the 21 test cycles completed at Marshall Steam Station, and in view of the above frictional data, the thrust required to cycle the valve during the steam tests would be similar to that if the test medium were water.

Question 8

The opening times of the Masoneilan relief valves were found to be sensitive to the air supply pressure and the size of tubing used in the air supply system. Both the pressure and tubing size had to be increased during tests to reduce opening times to reasonable values. Are similar measures being taken on plant valves to assure sufficiently short opening times?

Response

Similar measures have been taken. The Diablo Canyon design specifically addresses this concern. The actuator housing air connection has been bored and retapped to 3/8 inch NPT. The full ported 1 inch solenoid valve is wall mounted as close to the valve as possible, connected with 1/2 inch I.D. Synflex hose. This assembly is directly connected to a 1 inch NPT pressure regulator, fed directly from a 1 inch supply header. The supply pressure to the valve is at least 55 psig, which allows the maximum pressure to the actuator without exceeding the actuator housing rating.

This combination of high pressure, short tubing run, and large line size allows for very fast operation. Static, no-load tested response times have been less than 2 seconds from full closed to full open, and 1 second from full open to full closed.

Question 9

Two valve opening sequences were considered in the piping submittal; the three SRVs opening simultaneously and discharging without PORV flow and the three PORVs opening simultaneously and discharging without PORV flow. These sequences, however, may not bound the forces for all possible valve opening sequences. The experience of EG&G Idaho indicates that maximum forces would be expected when the sequence of opening is such that the initial pressure waves from the SRVs opening reach a common junction simultaneously. Additional justification should be provided to demonstrate that the sequences considered in the submittal are adequate.

Response

Two valve opening cases were addressed in "the submittal"*, 1) the three safety valves opening simultaneously and discharging without PORV flow and 2) the three PORV's opening simultaneously without safety valve flow. The three safety valves are identical and have the same set pressure (± 1 percent). It was, therefore, assumed for the analysis that all three safety valves open simultaneously without PORV flow. Because of similarity, all three PORV's were also assumed to open simultaneously without safety valve flow.

Maximum common header (area of piping common to both safety and relief valve discharge piping) forces theoretically could be expected when valve sequencing is such that the initial pressure waves from valve opening reach a common downstream junction simultaneously. Based upon engineering judgment:

1. The simultaneous opening of the safety valves results in practically simultaneous peak loads at the safety valves common branch point. The peak forces occur within approximately .02 seconds of each other. As a result, no significant impact in the common header region, due to safety valve discharge, is expected, if the valve sequencing is adjusted such that the peaks of the initial pressure waves reach a common downstream header point simultaneously.

2. The total lengths of effective piping between each valve outlet and the common junction point are not exactly the same. The likelihood of the valve phasing being such to compensate for the different lengths is very small; therefore, the peaks of the initial pressure waves from valve opening, either safety or relief, would not reach a common downstream junction at exactly the same time.

3. There is a significant amount of piping and dynamic supports between the valve outlets and the common point. In the unlikely event that increased loadings from this common point to the relief tank were to occur, the effects would be limited primarily from near the common point to the relief tank. Significant isolation of the common region from the upstream region because of the support configuration exists. Therefore, the operability and integrity of the valves, the inlet lines to the valves, or the nozzles on the pressurizer would not be jeopardized.

Considerable margin exists between the conservatively calculated maximum stresses and the allowable stresses for the safety valve discharge event. Tables 6-4 and 6-11 of "the submittal" report illustrate this for the upstream piping and Tables 6-8 and 6-15 demonstrate this for the downstream piping.

*Westinghouse report dated November 1982 transmitted by PGandE letter to H. R. Denton dated December 13, 1983.

Question 10

The submittal does not discuss the nozzle loads at the inlet or outlet flanges of the SRVs and the PORVs or stress analyses of other sections of the valves. Sufficient information should be provided so that the acceptability of the loads can be verified or appropriate references cited.

Response

The valve inlet and outlet flanges and butt welds are qualified as part of the Diablo Canyon piping stress analysis according to the applicable B16.5, 1968 and B31.1, 1967 Code requirements.

Question 11

The submittal identifies the initial conditions for the SRV and PORV analyses. However, the method of handling the valve resistances is not described and the valve opening times and the corresponding flows are not reported. Since the ASME code requires derating the SRVs to 90 percent of predicted flow, actual flows of 111 percent of rated are likely. Additional information should be provided describing considerations of SRV derating and describing methods used to predict the flows for the SRVs and PORVs. The submittal states that the water in the loop seal remains upstream of the SRV until the valve is opened fully; is this conservative since the valve will simmer and not open fully until the loop seal water has passed through it?

Response

The piping analysis does not state that the water in the loop seal remains upstream until the valve is fully open. Modeling of the water in the thermal-hydraulic analysis was conducted with the water seal upstream of the valve prior to transient initiation. At time =0+ the transient was initiated and the slug position was analytically calculated during and subsequent to valve opening. This approach is consistent with the technique used for comparison with EPRI tests 908 and 917.

Safety and relief valves are modeled as two-way junctions. The pressure drop across the valve, provided the system is sub-cooled is given by:

$$\Delta P = \rho C_D v^2$$

Where: ΔP = pressure drop

C_D = discharge coefficient = f(Cv)

ρ = fluid density

v = velocity through the valve

In the case of choking at the valve, the velocity at the valve orifice area is set at the sonic velocity. Upstream and downstream boundary conditions are iteratively set to conserve mass and energy. Choked flow is internally checked to ensure the proper formulation is applied.

The maximum expected steam flow rate through the Masoneilan PORV's, the valves utilized at Diablo Canyon, is 210,000 lb/hr at approximately 2350 psia. Values of 228,600 and 230,400 lb/hr, respectively at 2745 and 2780 psia (both tests conducted at pressures above the valve set pressure) were observed in EPRI/Wyle Tests (EPRI Report NP-2670-LD, Volume 6, "EPRI/Wyle Power Operated Relief Valve Phase III Test Report Volume 6: Summary of Phase III testing of the Masoneilan Relief Valve", October, 1982). To account for all uncertainties and tolerances in the valve flow rate, the valve flow area was adjusted accordingly. The minimum analytically calculated steam flow of each of the three PORV's is greater than 275,000 lb/hr. This is a flow of 131 percent of rated. The analysis assumed a 100 percent linear PORV valve opening in 1.00 seconds. Full open times, based upon tests, averaged 2.77 seconds with a minimum value of 1.64 seconds for opening on steam.

The nominal steam flow rating for the Crosby Safety Valves at 2500 psia +3 percent accumulation is 420,000 lb/hr. A value of 460,000 lb/hr was observed in both EPRI tests 908 and 917. This flow, however, was based upon upstream conditions of 2700 psia. As with the PORV's, to ensure that adequate margin existed in the valve flow rate to account for all uncertainties and tolerances, the analytically calculated steam flow was checked prior to finalizing this phase of the overall effort. The flow used in the analysis was 119 percent of rated. The safety valves were presumed to open fully in 0.040 seconds. This is based upon an effective linear opening time. This valve opening time, as illustrated by test 908 and 917 comparisons, results in a very good data match.

Question 12

The adequacy of the thermal-hydraulic analyses could not be verified since sufficient detail is not provided in the submittal. To provide for a more complete evaluation, additional discussion should be provided for the rationale used in selecting key parameters such as node spacing, time-steps, valve flow area and choked flow junctions. Computer printouts of input and output for the limiting transient should also be provided.

Response

The adequacy of the thermal-hydraulic analyses can be verified by the comparison of analytical and test results for thermal-hydraulic loadings in safety valve discharge piping for EPRI tests 908 and 917 presented in "the submittal". In that evaluation, node spacing and time-step size were selected on the basis of stable solutions of the characteristic equations and matching of test data. The safety valve full open flow area of 0.022 ft^2 was used in the model. This area is slightly smaller than the Crosby M-orifice area of 0.025 ft^2 for the tested valve, but results in a good analytical match of the tested fully open valve flow rate. Appropriate water temperatures were used. All pertinent data, including friction factors, loss factors and flow areas were based upon representative calculations and the system layout. Modeling of the water was conducted with the water seal upstream of the valves prior to transient initiation. At time =0+, the transient was initiated and the slug position was analytically calculated during and subsequent to valve opening.

The Diablo Canyon Plant Specific thermal-hydraulic analysis was conducted based upon the same approach as used for the comparison to test data. Node spacing and time-step size were utilized consistent with values utilized in the comparison. Valve flow areas were selected based upon actual valve data with appropriate margins applied to account for flow rate uncertainties. All pertinent data, including friction factors, loss factors and flow areas were based upon representative calculations and the system layout. Modeling of the water slug from a temperature profile, considering initial location and movement of post-transient initiation, was consistent with the comparison study. Choked flow is checked internally and automatically every time-step to ensure the proper formulation is applied at every flow path.

Because of the proprietary nature of the computer program, input and output data are not supplied at this time. However, if so desired, this information could be reviewed at a later date.

Question 13

The analysis did not compute the temperature distribution of the loop seal water for the proposed case with the loop seal pipe insulated but used a temperature distribution roughly consistent with that observed during the Electric Power Research Institute (EPRI) Test 917. The assumed temperature distribution needs to be verified by analysis or measurement before the piping thermal-hydraulic analysis can be considered satisfactory.

Response

An analysis was performed in designing the loop seal insulation to assure that the minimum temperature at the end of the loop seal was consistent with that used in the analysis. Measurement of the temperature at the end of the loop seal will be made prior to criticality.

Question 14

The submittal states that the SRV and PORV connections to the pressurizer were modeled as anchors. Was it verified that the vessel possesses no flexibility that could affect the piping response? The submittal does not mention the large displacement of the connection due to the thermal expansion of the pressurizer when heated to operating conditions. Verification should be provided that the displacements were considered in the stress analyses of the piping, pressurizer nozzles, and the valves.

Response

The pressurizer model and the corresponding temperature distribution and displacement of the pressurizer are included in the Westinghouse thermal analysis of the SRV and PORV lines*.

*Westinghouse report dated November 1982, transmitted by PGandE letter to H. R. Denton dated December 13, 1983.

Question 15

Insufficient information is available to assess the structural analyses. A more complete assessment requires description of the key parameters used in the analyses such as damping, lumped mass spacing, details of support models, and the integration time-step. The submittal infers that only the net unbalanced forces for the ITCHVALVE elements were used as input to the structural analysis. A discussion should be provided that describes how the axial extension from the balancing forces on each end of the elements was treated. Computer printouts of input and output for the limiting transient should be provided.

Response

As noted in the "submittal", the structural analysis programs utilized in the static and dynamic analyses were described in the Westinghouse report WCAP-8252. This was reviewed and approved by the NRC Staff (letter dated April 7, 1981 from R. L. Tedesco to T. M. Anderson). Following is a discussion of key parameters used in the structural analyses of the thermal-hydraulic events:

1. Damping - A conservative system damping of 2 percent, consistent with the value used for HOSGRI, was utilized. This is much lower than the actual expected value and is below the 10 percent damping used in the structural comparison to EPRI Tests 908 and 917.

2. Lumping - Lumped mass spacing was determined to ensure that all appropriate mode shapes were accurately represented.

3. Supports - The structural supports were modeled in sufficient detail to analytically represent the system. The shock suppressors and struts were modeled by inputting a stiffness in series with the piping. Minimum rigid stiffness values were utilized. All supports were linear and a linear overall system analysis was conducted.

4. Time-Step - The integration time step is internally determined within the structural program and is based upon convergence criteria that results in stable solutions. The largest time-step which could be selected is 0.0001 second. The time-step is automatically adjusted such that the relative error of each modal coefficient is at least less than 10^{-2}.

The axial extension from the balancing forces on each end of the structural segment was considered in the evaluation. However, this effect for this particular application was found to be negligible relative to the net unbalanced forces. Referring to structural analyses comparisons to test results for tests 908 and 917, maximum support and pipe loads compared well with test results. Good comparisons of the maximum displacement values downstream of the safety valve were also seen.

Because of the proprietary nature of the computer program, input and output data are not supplied at this time. However, if so desired, this information could be reviewed at a later date.

Question 16

The submittal does not discuss how the safety valve bonnet assemblies and the relief valve actuators were modeled. They should be modeled as masses displaced from the pipe centerline and if the natural frequency of the bonnets or actuators could potentially be excited by piping or support motion then elements connecting the masses to the pipe should represent the flexibility of these structures. A discussion of the modeling of these items should be included. Also, the statement made concerning modeling of the piping supports in the structural model is questionable. The submittal states that all supports with natural frequencies of 20 Hz or greater were modeled as rigid. A frequency this low, however, does not imply rigidity. Details as to how supports were actually modeled should be provided.

Response

The valve bonnet assemblies and the relief valve actuators are modeled as extended masses, displaced from the pipe centerline. Each valve's weight and center of gravity are selected from the valve drawings. The stem properties (diameter and thickness) are then selected to represent the valve frequency. Supports with a natural frequency of 20 Hz or greater are modeled as rigid in accordance with Diablo Canyon licensing commitments.

Question 17

Solving the acceleration term of the momentum balance equation was used to develop a forcing function for the structural code. The experience of EG&G Idaho with this technique is that spurious data spikes will occur during water discharge transients if every computational time-step is used. However, if a finite time-step is used, the technique may not include the peak load. Additional discussion of the solution techniques should be provided which demonstrates the accuracy and applicability of results for water discharge transients.

Response

A finite time-step that resulted in stable results was utilized for both the data comparison and the plant specific thermal-hydraulic evaluation. A discussion of the method of characteristics solution technique is presented in the following articles:

1. A. C. Spencer and S. Nakamura, "Implicit Characteristic Method for One-Dimensional Fluid Flow", ANS Transaction, Volume 17, P. 247, November, 1973.

2. S. Nakamura, M. A. Berger and A. C. Spencer, "Implicit Characteristic Method for One-Dimensional Fluid Flow", Proceedings of the Conference on Computational Methods in Nuclear Engineering, Conf.-75040, National Technical Information Service, Springfield, VA. 1975.

A. C. Spencer is a permanent Westinghouse employee who was and is directly involved in the development of the ITCHVALVE Computer Program.

Modifying the time-steps could change the results; however, the time-step was selected on the basis of stable results and showed good comparison to test results.

Question 18

The Design Earthquake (DE) and Double Design Earthquake (DDE) response spectra used in the analysis has been identified as preliminary. The results of the comparison between the preliminary and final response spectra should be documented and if necessary, a revised report demonstrating the adequacy of the as-built pressurizer safety and relief valve piping should be submitted.

Response

The DE and DDE response spectra used in the analysis were based on preliminary response spectra for the pressurizer compartment available at the time of the analysis. These spectra envelope the final DE and DDE response spectra curves.

Question 19

The method of handling the valve opening while the loop seal water is being passed through the valve and the valve popping open after the water discharge was not discussed. Additional information should be provided discussing the technique used and to demonstrate that the technique is conservative.

Response

For water slug discharge through each safety valve (as discussed in response to Question No. 11), the water seal is passing through the valve as the valve is opening. Before the slug is completely through the valve (0.040 seconds), the valve is fully open. Consequently, the safety valve is fully open when the tail of the seal water reaches the valve outlet. This results in the maximum driving force for the water seal in the downstream piping. This approach, as previously noted, resulted in a good comparison to test data.

Question 20

Was the piping upstream of the safety valves analyzed as a Class 1 system?

Response

The piping upstream of the safety valves was analyzed as Class 1 system. SER Section 3.2.2 accepted the classifications of this system as given on Table 3.3-4, Sheet 25 of 38 of the FSAR.