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LOFT PRESSURIZER SURGE AND SPRAY
LINE PIPING THERMAL ANNALYSIS
CLASS I REVIEW

T. L. Kinnaman/R. L. Chapman

EG&G Idaho, Inc.

IDAHO NATIONAL ENGINEERING LABORATORY

DEPARTMENT OF ENERGY

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RESEARCH, ENGINEERING AND CONSTRUCTION REPORT ENGINEERING ANALYSIS DIVISION

THERMAL ANALYSIS

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R. L. Chapman

T. L. Kinnaman

AUTHORS

T. L. Kinnaman, R. L. Chapman

CHECKED BY:

N. E. Pace

N. E. Pace

APPROVED BY:

N. E. Pace

N. E. Pace

11/22/77

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LOFT TECHNICAL REPORT
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Class I Review		
AUTHOR R. L. Chapman T. L. Kinnaman <i>T. L. Kinnaman</i>		GWA NO. 52151-500-510
PERFORMING ORGANIZATION Thermal Analysis Branch		DATE MARCH 31, 1978
LOFT APPROVAL <i>[Signature]</i> PSE <i>[Signature]</i> SPE <i>[Signature]</i> RSB Mgr. <i>[Signature]</i> RSB Mgr. <i>[Signature]</i> P&CSB Mgr.		

LOFT PRESSURIZER SURGE AND SPRAY
LINE PIPING THERMAL ANALYSIS
CLASS I REVIEW

I certify that the LOFT Pressurizer Surge and Spray Line Piping thermal analyses (References 1 through 3) have been reviewed and that these analyses meet the ASME Code, Section III thermal analysis requirements for Class I components for the thermal transients and conditions found in the LOFT Class I Nuclear Piping Specification, ANC-60139⁽⁴⁾, and the LOFT Pressurizer Specification, ANC-60044⁽⁵⁾ with the following exceptions:

- (1) Table C-III of Reference 4 for the "low and high number of cycles" category lists transients which appear to be more severe than used in the analysis documented by Reference 1. The use of less severe transients needs to be justified or re-analysis using the transients from Table C-III of Reference 4 needs to be performed.
- (2) In Reference 1, grid line 9 on Model G (a 4in.x4in.x2-1/2in. reducing tee on the pressurizer spray nozzle) was used to represent the weld line on the spray nozzle weld neck flange (Model H). This representation needs further explanation or analysis of the weld line on model H needs to be done
- (3) The 450°F step transient⁽³⁾ was not applied to the most severe stress location on the surge and spray line piping. The step transient was applied to straight sections of pipe. Application of this step transient to discontinuities in the surge and spray line piping would be more conservative.

The above stated exceptions have been approved by the Thermal Analysis Branch and specific recommendations for resolution. These exceptions are included in Appendix B.

DISCUSSION

Thermal analyses, documented by References 1 through 3, were performed on the LOFT Pressurizer Surge and Spray Line Piping. The first analysis⁽¹⁾ computed the temperature response of selected components in the surge and spray line piping for the following transients: (1) LOCE, (2) Heatup, (3) Low number of cycles grouping, and (4) High number of cycles grouping. The second analysis⁽²⁾ computed the temperature response of the pressurizer surge and spray nozzles for steady state conditions and the following transients:

- (1) Opening of Valve V-4031-IVE after it has been closed during pressurizer heat-up. This causes injection of a cooled ($\sim 70^{\circ}\text{F}$) slug of stagnant fluid into the hot ($\sim 650^{\circ}\text{F}$) spray nozzle at 1/2 gpm.
- (2) Initiation of Purification Injection flow, bringing a cooled slug of stagnant fluid, initially at 70°F , through the 540°F spray line to the 650°F spray nozzle at 20 gpm during plant cooldown.
- (3) Step temperature change of 450°F in the fluid flowing through both nozzles at design flowrates. This transient arises when the pressurizer is maintained up to 450°F above the temperature of the rest of the Primary Coolant System (PCS), and flow is initiated into the pressurizer.

The last analysis⁽³⁾ computed the temperature response of the LOFT pressurizer surge and spray line piping for a 450°F step transient.

In accordance with ASME Code requirements, all analyses of Class I components and systems must be independently reviewed. Since the LOFT pressurizer surge and spray piping is a Class I system, the thermal analyses were reviewed as presented in Appendix A. Appendix B contains the Thermal Analysis Branch comments and recommendations to this review. It is the opinion of the Thermal Analysis Branch that the analyses, as reviewed, meet the requirements of the

ASME Code, Class I piping specification (ANC-60139), and the LOFT pressurizer specification (ANC-60044) with the following exceptions:

- (1) Table C-III of Reference 4 for the "low and high number of cycles" category lists the following two transients which appear to be more severe than used in the analysis⁽¹⁾: (a) 650°F to 470°F step change and hold for at least 38 seconds for 1950 cycles. Reference 1 used a 590°F to 655°F temperature change in 2 seconds for 1500 cycles, and (b) 548°F to 660°F step change for 12010 cycles, Reference 1 used a 655°F to 540°F in 2 seconds for 12470 cycles.
- (2) In Reference 1, grid line 9 on Model G (a 4in.x4in.x2-1/2in. reducing tee on the pressurizer spray nozzle) was used to represent the weld line on the spray nozzle weld neck flange (Model H). This representation needs further explanation or analysis of the weld line on Model H needs to be done.
- (3) The 450°F step transient⁽³⁾ was not applied to the most severely stressed location on the surge and spray line piping. This step transient was applied to straight sections of pipe near the pressurizer surge and spray line nozzles. Application of this step transient to discontinuities in the spray and surge line piping would be more conservative.

The above stated exceptions have been reviewed by the Thermal Analysis Branch and specific recommendations for resolution of these exceptions are included in Appendix B. The Thermal Analysis Branch response to the reviewers' recommendations is also included in Appendix B.

REFERENCES

1. R. A. Lindley, LOFT Pressurizer Surge and Spray Line Thermal Analysis, LTR 1144-15, Aerojet Nuclear Company (November 2, 1973).
2. D. H. VanHaften, Steady State and Transient Thermal Analysis of the LOFT Pressurizer Surge and Spray Nozzles, LTR 1144-29, EG&G Idaho, Inc., (May 2, 1977).
3. B. J. Tolan, 450°F Step Transient Thermal Analysis of the LOFT Pressurizer Surge and Spray Line Piping, LTR 1144-30, EG&G Idaho, Inc. (July 7, 1977).
4. LOFT Class I Nuclear Piping System, ANC-60139, Aerojet Nuclear Company (January 15, 1973).
5. LOFT Pressurizer Specification, ANC-60044, Rev. A, Aerojet Nuclear Company (January 6, 1972).

APPENDIX A

LOFT PRESSURIZER NOZZLES AND PIPING

THERMAL ANALYSIS - CLASS I REVIEW

SUMMARY

A Class 1 review was performed for the thermal analysis of the LOFT pressurizer surge and spray line piping and nozzle temperature transients. The basic assumptions were checked for compliance with the applicable specifications and for good analytical practice. The transients used in the analysis were generally more severe than the ones identified in the specifications. Heat transfer coefficients and fluid flow rates were conservative on the high side. Less conservatism could be used in most cases since the stress analysis indicates a marginal inability to meet specification life cycle requirements. Additional analysis requirements are identified and recommended.

RESULTS

The thermal analysis of the pressurizer nozzle and steam piping is presented in three reports, viz:

1. LTR 1144-15⁽⁴⁾
2. LTR 1144-29⁽⁵⁾
3. LTR 1144-30⁽⁶⁾.

The first of these reports contains the analysis of the transients identified in Reference 1. Subsequently, a more severe transient was identified in which service water can be introduced into the surge line and nozzle. The last two reports contain an evaluation of the effects of this transient on the surge nozzle and surge line respectively. The thermal analysis contained in these three reports was found to conservatively meet the requirements of the LOFT Technical Specifications⁽²⁾ and the LOFT Pressurizer Specification⁽¹⁾ with the following exceptions:

1. The copy of Reference 1 provided, and an additional copy obtained from LOFT files, do not identify the temperature excursions of the fluid in the pressurizer lines resulting from the $\pm 3^\circ\text{F}$ temperature fluctuations in the reactor. Consequently, no evaluation of the transients used for this case was made.
2. Table C-III (p. 75) of Reference 3 identifies a more severe transient in the low number of cycles category (1950 cycles) than was used in the analysis. The table mentioned above shows a 650°F to 470°F step change in temperature that holds for at least 38 seconds. The transient used in the thermal analysis⁽⁴⁾ was an outflow transient going from 590°F to 650°F in two seconds, with a total of 1500 cycles. The same source shows a $548^\circ\text{--}660^\circ\text{F}$ step change for 12,010 cycles, which appears to be more severe than the worst case inflow selected ($655^\circ\text{--}590^\circ\text{F}$ in 2 seconds for 12,470 cycles).

3. Table X⁽⁴⁾ indicates that line 9 of Model G (Figure 5) was used to represent the weld line on the spray nozzle weld neck flange (Model H of Appendix D). The picture edit (p. A-16) shows the location of line 9. The use of a reducing tee thermal model to represent the weld neck flange should be explained in the report.
4. The 450°F step transient⁽⁶⁾ was not applied to the most severe stress location. Although the transient is less severe at the location of the fittings, it intuitively appears that the elbow fittings or the sweepolet connection to the 14" primary pipe might have more severe stress concentrations.

It should be noted that in some cases the conservatism used in the analysis is excessive. A specific example of this is as follows:

The events during blowdown would appear to consist of rapid depressurization with attendant bulk boiling and slug flow out of the pressurizer piping. The alternately flowing bubbles of steam and slugs of water hardly seem compatible with an assumption of nucleate boiling heat transfer for the first six seconds of the accident. A heat transfer coefficient of 12,900 for high velocity steam flow to 13.5 seconds also seems ultraconservative (Table V of Reference 4). Since marginally sufficient cycle life is indicated⁽⁷⁾, a more realistic analysis need not be done.

RECOMMENDATIONS

1. Include the pressurizer surge line connection and a typical elbow in the analysis of a step reduction in temperature due to the introduction of service water into the pressurizer piping.
2. Verify the transients used for the $\pm 3^\circ$ temperature fluctuations and get them placed in Reference 1.

3. Verify that the transients identified in Table C-III of Reference 3 for cases more severe than those used in the analysis do not apply to the pressurizer piping, or analyze for the more severe transients identified therein.
4. Identify how many cycles of 450°F step reductions the system should have to be capable of sustaining. This may negate Item 3 above since the 450°F step is a more severe transient.
5. Verify that the pressurizer piping stress analysis showed a capability to undergo 280 blowdown transients. If this was not shown, repeat the analysis using less conservative heat transfer coefficients. The EB report does not specifically state the number of blowdown cycles used. They state that the two-inch short radius elbow in the surge line failed to pass the cumulative usage factor limit of 1.0 with a usage factor of 1.0264. One of the primary contributors to the high stress level in this component is the thermal stress. How much blowdown transients contribute to the cumulative usage factor is not stated.

REFERENCES

1. LOFT Pressurizer Specification - ANC-60044, Rev. A, Aerojet Nuclear Co., Inc., January, 1972.
2. LOFT Technical Specifications, Aerojet Nuclear Co., Inc., January, 1976.
3. LOFT Class 1 Nuclear Piping System - ANC-60139, Aerojet Nuclear Co., Inc., January, 1973.
4. LOFT Pressurizer Surge and Spray Line Thermal Analysis, R. A. Lindley, LTR-1144-15, Aerojet Nuclear Company, November, 1973.
5. Steady State and Transient Thermal Analysis of the LOFT Pressurizer Surge and Spray Nozzles, D. H. Van Haaften, LTR-1144-29, Aerojet Nuclear Co., May, 1977.
6. 450°F Step Transient Thermal Analysis of the LOFT Pressurizer Surge and Apray Line Piping, B. J. Tolan, LTR-1144-30, Aerojet Nuclear Company, July, 1977.
7. LOFT Primary Coolant Pressurizer System Class 1 Analysis, R. J. McCarter, General Dynamics - Electric Boat Division, December, 1973.

APPENDIX B

RESOLUTION OF REVIEWERS COMMENTS
TO THE LOFT PRESSURIZER SURGE
AND SPRAY LINE PIPING
THERMAL ANALYSES

RESOLUTION OF REVIEWERS' COMMENTS

Resolution of the reviewers' comments to the LOFT pressurizer surge and spray line piping thermal analyses will be addressed on a comment by comment basis. The reviewers' comment will be given first followed by the Thermal Analysis Branch Resolution to that comment. The Thermal Analysis Branch response to the reviewers' recommendations are also included in this appendix.

(1) Comment:

The copy of Reference 5 provided, and an additional copy obtained from LOFT files, do not identify the temperature excursions of the fluid in the pressurizer lines resulting from the $\pm 3^{\circ}\text{F}$ temperature fluctuations in the reactor. Consequently, no evaluation of the transients used for this case was made.

Resolution:

The temperature versus time data used for the $\pm 3^{\circ}\text{F}$ primary system transient⁽⁴⁾ were obtained from an analog simulator. Reference 1 states that this data is given in Figure 6a of the pressurizer specification⁽⁵⁾ where in fact Figure 6a does not exist. The Thermal Analysis Branch was unable to locate this data. The Thermal Analysis Branch recommends the cognizant LOFT organization locate this data and incorporate into the pressurizer specification.

(2) Comment:

Table C-III (p. 75) of Reference 4 identifies a more severe transient in the low number of cycles category (1950 cycles) than was used in the analysis. The table mentioned above shows a 650°F to 470°F step change in temperature that holds for at least 38 seconds. The transient used in the thermal analysis⁽¹⁾ was an outflow transient going from 590°F to 655°F in two seconds, with a total of 1500 cycles. The same source shows a 548°F - 660°F step change for 12,010

cycles, which appears to be more severe than the worst case inflow selected (655°-590°F in 2 seconds for 12,470 cycles).

Resolution:

The Thermal Analysis Branch has reviewed and compared the transients given in Table C-III of Reference 4 with those used in the analysis⁽¹⁾ and agree that considerable differences exist between the two. These differences cannot be explained at the present time. The transients used in the analysis⁽¹⁾ may be nonconservative. To better evaluate the conservativeness of the transients for worst case pressurizer inflow-outflow, the Thermal Analysis Branch recommends the following:

- (1) Review the most recent analog data for the surge line temperature response;
- (2) Re-evaluate the transients specified for the worst case inflow and outflow;
- (3) Evaluate plant operating procedures and their effects on the surge line. A recommendation for re-analysis of the surge line using more severe inflow and outflow transients is contingent upon followup of the above recommendations.

(3) Comment:

Table X⁽¹⁾ indicates that line 9 of Model G (Figure 5) was used to represent the weld line on the spray nozzle weld neck flange (Model H of Appendix D). The picture edit (p. A-16) shows the location of line 9. The use of a reducing tee thermal model to represent the weld neck flange should be explained in the report.

Resolution:

The use of grid line 9 on thermal Model G (a 4in.x4in.x2-1/2in. reducing tee) was used to represent the weld line on Model H (a 4 inch Sch. 160 weld

neck flange) because the wall thicknesses, diameters and fluid conditions or transients are the same. The effects of the wall thickness transitions have been found in other analyses to be relatively insignificant. Also, the thermal transients in this area are not so severe as to make a more accurate analysis necessary.

(4) Comment:

The 450°F step transient was not applied to the most severe stress location. Although the transient is less severe at the location of the fittings, it intuitively appears that the elbow fittings or the sweepolet connection to the 14" primary pipe might have more severe stress concentrations.

Resolution:

The 450°F step transient was applied to the pressurizer surge and spray nozzles⁽²⁾ and piping⁽³⁾. Since an elbow will respond to a transient in the same manner as a straight section of pipe, an elbow need not be analyzed for the 450°F step transient. The 3 inch surge line sweepolet connection was analyzed⁽¹⁾ to four different transients all of which are substantially less severe than the 450°F step transient. Therefore, the Thermal Analysis Branch recommends that the sweepolet connection be analyzed for the 450°F step transient.

RESPONSE TO REVIEWER'S RECOMMENDATIONS(1) Recommendation:

Include the pressurizer surge line connection and a typical elbow in the analysis of a step reduction in temperature due to the introduction of service water into the pressurizer piping.

Response:

See resolution to comment 4 above.

(2) Recommendation:

Verify the transients used for the $\pm 3^\circ$ temperature fluctuations and get them placed in Reference 5.

Response:

See resolution to comment 1 above.

(3) Recommendation:

Verify that the transients identified in Table C-III of Reference 3 for cases more severe than those used in the analysis do not apply to the pressurizer piping, or analyze for the more severe transients identified therein.

Response:

See resolution to comment 2 above.

(4) Recommendation:

Identify how many cycles of 450°F step reductions the system should have to be capable of sustaining. This may negate Item 3 above since the 450°F step is a more severe transient.

Response:

This recommendation should be addressed to LOFT operations as it pertains to the operation of the LOFT facility. The Thermal Analysis Branch recommends that LOFT address this question.

(5) Recommendation:

Verify that the pressurizer piping stress analysis showed a capability to undergo 280 blowdown transients. If this was not shown, repeat the analysis using less conservative heat transfer coefficients. The EB report does not specifically state the number of blowdown cycles used. They state that the two-inch short radius elbow in the surge line failed to pass the cumulative usage factor limit of 1.0 with a usage factor of 1.0264. One of the primary contributors to the high stress level in this component is the thermal stress. How much blowdown transients contribute to the cumulative usage factor is not stated.

Response:

The Thermal Analysis Branch has reviewed the boundary conditions, i.e., fluid temperatures vs time and heat transfer coefficients used for the LOCE transient, and are of the opinion that the boundary conditions used are not that conservative. Use of a less conservative heat transfer coefficient would result in thermal gradients of only a few degrees less which would not increase the number of cycles that much. Therefore, the Thermal Analysis Branch is of the opinion that re-analysis of the pressurizer piping for the LOCE transient is not required.