LOFT TECHNICAL REPORT LTR 113-48
RE & C NUMBER RE-A-77-123
FEBRUARY 3, 1978

LOFT EMERGENCY CORE COOLANT
THERMAL ANALYSIS CLASS I REVIEW

T. L. Kinnaman

EG&G Idaho, Inc.

IDAHO NATIONAL ENGINEERING LABORATORY

DEPARTMENT OF ENERGY

IDAHO OPERATIONS OFFICE UNDER CONTRACT EY-76-C-07-1570

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DATE February 3, 1978

WORK REQUEST NO. 52153-300-510

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

RESEARCH, ENGINEERING AND CONSTRUCTION REPORT ENGINEERING ANALYSIS DIVISION

THERMAL ANALYSIS

LOFT EMERGENCY CORE COOLANT

THERMAL ANALYSIS CLASS I REVIEW

T. L. Kinnaman

AUTHOR
T. L. Kinnaman

CHECKED BY:

N. E. Pace
N. E. Pace

APPROVED BY:

N. F. Pace
N. F. Pace

THIS DOCUMENT HAS NOT RECEIVED PATENT CLEARANCE AND IS NOT TO BE TRANSMITTED TO THE PUBLIC DOMAIN.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

IDAHO NATIONAL ENGINEERING LABORATORY
LOFT TECHNICAL REPORT
LOFT PROGRAM

TITLE LOFT Emergency Core Coolant Thermal Analysis Class I Review		REPORT NO. 113-48
AUTHOR T. L. Kinnaman <i>T. L. Kinnaman</i>		GWA NO. 52153-300-510
PERFORMING ORGANIZATION Thermal Analysis Branch		DATE February 3, 1978
LOFT APPROVAL <i>B W Warner</i> <i>for Hunter</i> <i>11/29/77</i> <i>all</i> <i>RRM</i>		

Distribution

J. G. Arendts
E. S. Brown
H. M. Burton
C. O. Doucette
B. L. Freed (original + 7)
S. Gardner (3)
J. A. Hunter

J. P. Kester

J. R. Jones
T. L. Kinnaman
J. L. Liebenthal
C. A. Moore
N. E. Pace
N. B. Smith
R. R. Stiger
W. C. Townsend
R. A. Wells

LOFT EMERGENCY CORE COOLANT
THERMAL ANALYSIS CLASS I REVIEW

I certify that the LOFT Emergency Core Coolant System thermal analysis (Reference 1) has been reviewed and that this analysis meets 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.

DISCUSSION

A thermal analysis was performed on the LOFT Emergency Core Coolant System (ECCS) by the Thermal Analysis Branch. The results of this analysis is documented by Reference 1. This analysis calculated the temperature response of the following areas on the Class I portion of the ECCS: (1) the junction of the 4-inch Sch. 160 pipe with the check valve, (2) the junction of the 5-inch Sch. 160 pipe with the ECC nozzle on the reactor instrument head, and (3) the junction of 4-inch Sch. 160 pipe with the ECC nozzle on the side of the reactor vessel. The above areas were analyzed for the heatup (70°F to 527°F @ 100°F/hr) and LOCE transients. These transients are as defined in Reference 2.

In accordance with the ASME Code⁽³⁾ requirements, all analyses of Class I components must be independently reviewed. Since the LOFT ECCS up through the second isolation valve is a Class I system, the thermal analysis was reviewed as presented in Appendix A. Appendix B contains the Thermal Analysis Branch comments to this review. It is the opinion of the Thermal Analysis Branch that these comments satisfy all of the reviewer's questions and that the analysis should stand as is, without additional considerations in meeting the ASME Code⁽³⁾ requirements and ANC Specification 60139⁽²⁾.

REFERENCES

1. I. J. Ingvarsson, LOFT Emergency Core Coolant Piping Thermal Transient Analysis, LTR 113-17, Aerojet Nuclear Company, Engineering Division, Idaho Falls, Idaho (September 20, 1974).
2. Aerojet Nuclear Company Specification ANC 60139 Revision 0, LOFT Class I Nuclear Piping System (January 15, 1973).
3. ASME Boiler and Pressure Vessel Code, Section III, Subsection NA, American Society of Mechanical Engineers (July 1, 1974).
4. R. A. Lindley, LOFT Primary Coolant Loop Thermal Transient Analysis, LTR 114-32, Aerojet Nuclear Company, Idaho Falls, Idaho (January 10, 1972).
5. Private communication with the Applied Mechanics Branch regarding ECCS Class I stress analysis (November 1977).
6. H. G. Kraus, SIMIR/6 - A Two-Dimensional Steady State and Transient Heat Conduction Code For Use On An IBM 360/75 Computer, A User's Guide, Technical Report RE-E-76-058, Engineering Division, EG&G Idaho, Inc. (September 23, 1976).

APPENDIX A

REVIEW OF LOFT EMERGENCY
CORE COOLANT SYSTEM THERMAL
ANALYSIS
(WELLS-7-77)

EG&G

Idaho

FORM EG&G-954
(Rev. 9-76)

INTEROFFICE CORRESPONDENCE

date November 16, 1977
to R. R. Stiger
from R. A. Wells *RAW*
subject REVIEW OF LOFT CORE COOLING PIPING THERMAL TRANSIENT
ANALYSIS - Wells-7-77

Attached is a report of the review of the "LOFT Core Cooling Piping Thermal Transient Analysis". The conclusions state that the analysis has not been shown to be conservative for LOFT operating conditions. It has been determined that the boundary condition for the first 7.0 seconds should be re-examined and the analysis re-performed if required.

klh

Attachment

cc: T. L. Kinnaman
N. E. Pace
L. H. Sullivan *LH*
Central File
R. A. Wells File

Summary

The LOFT Emergency Core Coolant Piping Thermal Analysis was checked to insure that the calculations made would conservatively satisfy the requirements in the LOFT technical specifications.

Some of the boundary conditions used have not been shown to be conservative and require review and possible re-analysis. One of the thermal models used could not be clearly related to a specific part of the piping geometry and requires further explanation.

The remainder of the models, the use of the SIMIR code and the other boundary conditions appear conservative and reflect normal thermal analysis methodology and practice. However, the use of constant, rather than temperature varying, thermal properties for some materials may introduce a slight error in these analyses.

Introduction

The "LOFT Emergency Core Coolant Piping Thermal Transient Analysis"⁽¹⁾ was checked to insure that the thermal analyses contained therein conservatively satisfied the requirements contained in the LOFT Technical Specifications and included any thermal transients or conditions that the ECCS piping might see while in service at the LOFT facility. This check included a review of the basic assumptions in the analysis, a check for compliance with applicable specifications and a check of the applicability of the codes, models and boundary conditions that were used.

Discussion

The "LOFT Emergency Core Coolant Piping Thermal Transient Analyses" document contains thermal analyses made with two different boundary conditions on each of three pipe weldment models using the SIMIR⁽²⁾ heat conduction code. Comments about the analyses are listed below and are divided into sections each dealing with a particular aspect of the work.

a) Selection of areas requiring thermal analysis: Three geometries were analyzed in the report. The first geometry is shown on Figure 1 of the report and called "Model A". From the information supplied, it was not possible to accurately match this to a specific part of the ECCS piping. There are some similarities to the area where the 4" ECCS line is connected to the thermal sleeve (DWG 204564) on the hot leg of the primary piping, but also some differences.

This model should be reviewed and if it does not represent this weld joint on the hot leg, an analysis should be made of this area.

No analysis was made of the connection area between the hot leg pipe, the sweep-o-let and this thermal sleeve. It is presumed that this has been done as part of the primary piping thermal analysis - if not, it should be done.

The second, designated "Model B", is a representation of the weld joint area where the upper plenum injection piping connects to the ECCS flange assembly and will represent the most critical area of this piping. The third, "Model C", represents the area of the weld joint between the ECCS piping and either the downcomer or the lower plenum injection nozzle and also represents the most critical area of these pipes.

b) Material thermal properties: Table 1-4.0 of Section III of the ASME code⁽³⁾ indicates that for a typical austenitic stainless steel the thermal conductivity varies by about 20% over the temperature range of 70°F to 600°F. The specific heat varies by 12% over this same range. The thermal analyses used a constant average value for these properties which would produce some error in the thermal gradients calculated. The same general comments also apply to the constant properties assumed for the inconel. Either variable properties or a conservative constant value should be used.

c) Selection of boundary conditions: Two transient conditions were analyzed. The first was a blowdown, based on a RELAP analysis, which reached 600 PSIA in 7.0 seconds. The accumulator flow starts at this time and the assumption was made that 1.5 seconds was required for the accumulators to completely flush the hot water out of the ECCS piping. A

linear change of temperature and film coefficient over this 1.5 second period was assumed. No justification was provided for this assumption, and it may not be conservative. A very high heat transfer coefficient was assumed for the period up to the start of ECC water flow. In some sections of the pipe it may be possible for steam to partially void a section of pipe during the first few seconds which would result in very low heat transfer and little cooling of the pipe. The cold water front would then suddenly pass this point resulting in a step change in temperature somewhat worse than that assumed by the analysis.

The second transient was a heatup from 70°F to 527°F at 100°F per hour. The LOFT Specification ANC-60139⁽⁴⁾ indicates that the proper range is from 70°F to 540°F. Also shown is a startup and shutdown transient with a temperature range of 540°F to 610°F in 600 seconds; a change of 420°F per hour. This may be worse than the transient selected in the analysis and should be checked.

d) Heat transfer coefficients used: As mentioned in the previous section, the boiling heat transfer coefficient of 10,000 BTU/HR FT²-°F may be non-conservative if steam accumulation can void some sections of the pipe. A low heat transfer coefficient over this time period would be conservative. Once ECC flow has started a high heat transfer coefficient would be conservative. The value of 2000 BTU/HR FT²-°F used is conservative for flow rates less than about 1500 gpm through the pipe leg and should be acceptable for this analysis.

e) Code selection and models used: The use of SIMIR appears appropriate for this task. The use of the models, choice of grid sizes, etc.

is consistent with normal thermal analysis practices. The following errors were found in the input: For "Model A", the 11th through 14th X-mesh intervals are shown as .0335 but should be .0235 to be consistent with the sketch. The ρC_p product is shown in Table II to be the same for stainless steel and inconel but is input as different values for cases "B" and "C".

f) Output and data reduction: There is an error in the MOGELT listing in Appendix A, Engineering Report A-71. The 35th card should read:

$$TOUT = TAVE - D$$

This has been corrected in the listing included as a part of the SIMIR report⁽⁴⁾. The status at the time the analysis was made should be checked.

Conclusions

Because of the considerations described above, it is felt that the analysis has not been shown to be conservative for LOFT operating conditions. Particularly important are the assumptions made concerning the boundary conditions in the first 7.0 seconds of the blowdown transient which resulted in the use of very high heat transfer coefficients. These boundary conditions should be reexamined and, if required, the analyses redone.

References

1. I. J. Inguarsson, LOFT Emergency Core Coolant Piping Thermal Transient Analysis, LTR 113-17, Aerojet Nuclear Co., Engineering Division, Idaho Falls, Id (September 20, 1976).
2. H. G. Kraus, SIMIR/6 - A Two Dimensional Steady State and Transient Heat Conduction Code for Use on an IBM 360/R5 Computer, A User's Guide, Technical Report RE-E-76-058, Engineering Division, EG&G Idaho, Inc. (September 23, 1976).
3. ASME Boiler and Pressure Vessel Code, Section III, Subsection NA, American Society of Mechanical Engineers, New York, New York (July 1, 1974).
4. LOFT Class 1 Nuclear Piping System, Specification ANC 60139, Revision 0, Aerojet Nuclear Co., Idaho Falls, Id (January 15, 1973).

APPENDIX B

RESOLUTION OF REVIEWERS
COMMENTS TO THE
EMERGENCY CORE COOLANT
SYSTEM THERMAL ANALYSIS

RESOLUTION OF REVIEWERS' COMMENTS

Resolution of the reviewers' comments to the LOFT Emergency Core Coolant System (ECCS) 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.

(1) Comment:

Selection of areas requiring thermal analysis: Three geometries were analyzed in the report. The first geometry is shown on Figure 1 of the report and called "Model A". From the information supplied, it was not possible to accurately match this to a specific part of the ECCS piping. There are some similarities to the area where the 4" ECCS line is connected to the thermal sleeve (DWG 204564) on the hot leg of the primary piping, but also some differences.

This model should be reviewed and if it does not represent this weld joint on the hot leg, an analysis should be made of this area.

No analysis was made of the connection area between the hot leg pipe, the sweep-o-let and this thermal sleeve. It is presumed that this has been done as part of the primary piping thermal analysis - if not, it should be done.

Resolution:

The geometry depicted by Model A is the junction of the 4-inch Sch. 160 ECC piping with the first check valve upstream of the injection point. The analysis of the connection area between the hot leg piping, the sweep-o-let and the thermal sleeve has been performed as part of Primary Coolant System thermal analysis⁽⁴⁾.

(2) Comment:

Material thermal properties; Table 1-4.0 of Section III of the ASME code⁽³⁾ indicates that for a typical austenitic stainless steel the thermal conductivity varies by about 20% over the temperature range. The thermal analyses used a constant average value for these properties which would produce some error in the thermal gradients calculated. The specific heat varies by 12% over this same range. The same general comments also apply to the constant properties assumed for the inconel. Either variable properties or a conservative constant value should be used.

Resolution:

It is the opinion of the Thermal Analysis Branch that the use of constant average values for thermal conductivity and specific heat in the subject analysis is adequate for the intended purpose of this thermal analysis. Other conservatisms in the analysis techniques, material properties, etc., are adequate to compensate for any small amount of non-conservatism in using constant thermal properties in the thermal models.

(3) Comment:

- (a) Selection of boundary conditions: Two transient conditions were analyzed. The first was a blowdown, based on a RELAP analysis, which reached 600 PSIA in 7.0 seconds. The accumulator flow starts at this time and the assumption was made that 1.5 seconds was required for the accumulators to completely flush the hot water out of the ECCS piping. A linear change of temperature and film coefficient over this 1.5 second period was assumed. No justification was provided for this assumption, and it may not be conservative. A very high heat transfer coefficient was assumed for the period up to the start of ECC water flow. In some sections of the pipe it may

be possible for steam to partially void a section of pipe during the first few seconds which would result in very low heat transfer and little cooling of the pipe. The cold water front would then suddenly pass this point resulting in a step change in temperature somewhat worse than that assumed by the analysis.

- (b) The second transient was a heatup from 70°F to 527°F at 100°F per hour. The LOFT Specification ANC-60139⁽²⁾ indicates that the proper range is from 70°F to 540°F. Also shown is a startup and shutdown transient with a temperature range of 540°F to 610°F in 600 seconds; a change of 420°F per hour. This may be worse than the transient selected in the analysis and should be checked.

Resolution:

- (a) The Thermal Analysis Branch agrees that the use of the high "h" in the stagnant leg of the ECC line may be non-conservative. Also, if the pipe wall stays too hot, film boiling will result with initial ECC flow. However, in accordance with Reference (5), the cycle and stress requirements specified in References (2) and (3) respectively are conservatively met. Therefore, it is the opinion of the Thermal Analysis Branch that the analysis should stand as is. The 1.5 second decrease to 70° is based on ECC initial flow, engineering experimentation, and past analyses of heat conduction along a pipe filled with water and is deemed acceptable.
- (b) The use of the 70°F to 527°F in the heatup transient rather than 70°F to 540°F does not noticeably affect the computed thermal gradients. The maximum DT's occur early in the transient and heating to 540°F would only change the resulting DT's by less than 0.1 °F. The sweep-o-lets at the ECC injection points were analyzed for all transients (Reference 4). All other locations in the ECC piping will not see the same

transients but less severe ones because there is no flow in the ECC line during normal operation. Therefore, the components covered by the subject analysis were not analyzed for the 540°F to 610°F transient. It is slightly non-conservative to ignore this transient but the effect is judged to be small since the transient will be much less severe.

(4) Comment:

Heat transfer coefficients used: As mentioned in the previous section, the boiling heat transfer coefficient of 10,000 Btu/hr-ft²-°F may be non-conservative if steam accumulation can void some sections of the pipe. A low heat transfer coefficient over this time period would be conservative. Once ECC flow has started a high heat transfer coefficient would be conservative. The value of 2000 Btu/hr-ft²-°F used is conservative for flow rates less than about 1500 gpm through the pipe leg and should be acceptable for this analysis.

Resolution:

As discussed in the resolution to comment 3(a) above, the use of a high "h" (10,000 Btu/hr-ft²-°F) resulted in computed DT's, which when analyzed for stresses conservatively met code⁽³⁾ and specification⁽²⁾ requirements. Studies have also been done for the PBF in-pile tube where the h during blowdown was assumed to be 7920 and 720 Btu/hr-ft²-°F for two cases and then quenched with 200°F water. These two cases showed a 600°F and 580°F overall wall $\Delta T_{\max}$ occurring at different times. With the 1.5 second ramp to 70°F, the skin stress should not be increased significantly for either case in LOFT. Therefore, the analysis done is felt to be adequately representative and if non-conservative, it should be only slightly so (less than 10%).

(5) Comment:

Code selection and models used: The use of SIMIR appears appropriate for this task. The use of the models, choice of grid sizes, etc. is consistent with normal thermal analysis practices. The following errors were found in the input: For "Model A", the 11th through 14th X-mesh intervals are shown as .0335 but should be .0235 to be consistent with the sketch. The ρC_p product is shown in Table II to be the same for stainless steel and inconel but is input as different values for cases "B" and "C".

Resolution:

The Thermal Analysis Branch agrees. The use of the larger X-mesh interval i.e., 0.0335 in., results in a thicker section below the weld. Evidently, Model A was incorrectly drawn. To be compatible with the input, the wall section below the weld should be dimensioned 0.665 inches rather than the 0.625 inches shown. Since this discrepancy was of a typographical nature and the correct X-mesh interval was input into the analysis, no effect on the computed thermal gradients was seen. The volumetric heat capacity (ρC_p) for Inconel 600 should be slightly less than that for stainless steel. The correct ρC_p values for stainless steel and Inconel 600 were input into the analysis.

(6) Comment:

Output and data reduction: There is an error in the MOGELT listing in Appendix A, Engineering Report A-71. The 35th card should read:

TOUT = TAVE-D

This has been corrected in the listing included as a part of the SIMIR report⁽⁶⁾. The status at the time the analysis was made should be checked.

Resolution:

The error in MOGELT had been corrected prior to performing the subject analysis.