LOFT TECHNICAL REPORT LTR 1141-29

EG&G REPORT NUMBER RE-A-77-033

JULY 11, 1977

CLASS I REVIEW OF LOFT STEAM GENERATOR
STRESS AND FATIGUE LIFE ANALYSIS REPORT

R. M. Fors, S. Silverman

EG&G Idaho, Inc.

IDAHO NATIONAL ENGINEERING LABORATORY

DEPARTMENT OF ENERGY

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

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The following activities will be performed under WBS 521515:

1. Class I reanalysis and revision of the steam generator stress report, LTR 1141-20, as required to correct deficiencies found during the Class I review, LTR 1141-29.
2. Class I review of revisions to LTR 1141-20.
3. Steam generator specification, ANC 60057, as required to correct deficiencies identified in the Class I review, LTR 1141-29.

Above activities will be continued until the Class I review document LTR 1141-29, certifies that the steam generator stress report, LTR 1141-20, substantiates the acceptability of the steam generator design in accordance with specification ANC-60057 and Section III of the ASME Code for Class I Pressure Vessels.

RE&C Report # RE-A-77-033

DATE July 11, 1977

WORK REQUEST NO. 52151-544-393

LTR 1141-29 *JK*

Date Published by CDCS Jan. 6, 1978

RESEARCH, ENGINEERING AND CONSTRUCTION REPORT ENGINEERING ANALYSIS DIVISION

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CLASS 1 REVIEW OF LOFT STEAM GENERATOR

STRESS AND FATIGUE LIFE ANALYSIS REPORT

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R. M. Fors S. Silverman

R. M. Fors, S. Silverman

AUTHOR

CHECKED BY:

H. L. Magleby

APPROVED BY:

Ed Moore

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(Rev. 12-76)

TITLE		REPORT NO.
Class 1 Review of LOFT Steam Generator Stress and Fatigue		LTR 1141-29
Life Analysis Report		RE-E-77-033
AUTHOR	GWA NO.	
R. M. Fors, S. Silverman		
PERFORMING ORGANIZATION	DATE	
Applied Mechanics Branch <i>Moore 7/15/77</i>	Published by CDCS Jan. 6, 1978	
LOFT APPROVAL <i>7/27/77</i> <i>DH Stevenson</i> <i>for ECA</i>	<i>8/1/77</i> <i>for ECA</i> July 11, 1977	
<u>ABSTRACT</u>		

This report covers the Class 1 review of the LOFT Steam Generator Stress and Fatigue Life Analysis Report. Deficiencies were found which will require evaluation and in some areas reanalysis. The effects of these deficiencies upon the steam generator will include:

1. To further reduce the allowable ΔP across the tubesheet for the Abnormal Design Case of pressure on primary.
2. To reduce the allowable number of LOCE transients at some locations of the steam generator from the numbers listed in the stress report and to increase them at other locations.

TABLE OF CONTENTS

Abstract -----	ii
1.0 Summary -----	1
2.0 Discussion -----	1
3.0 Results -----	2
4.0 References -----	5
APPENDIX A - Stress and Fatigue Analysis of LOFT Steam Generator	
Basic Primary Pressure Boundary -----	A-i
APPENDIX B - Stress and Fatigue Analysis of LOFT Steam Generator	
Basic Secondary Pressure Boundary -----	B-i
APPENDIX C - Stress and Fatigue Analysis of Primary Inlet Nozzle	
APPENDIX D - Stress and Fatigue Analysis of LOFT Steam Generator	
Primary Side Handhole -----	D-i
APPENDIX E - Stress and Fatigue Analysis of Secondary Side Six-	
teen-Inch Manway -----	E-i
APPENDIX F - Stress and Fatigue Analysis of LOFT Steam Generator	
Secondary Side Main Feed Inlet Nozzle -----	F-i
APPENDIX G - Stress and Fatigue Analysis of LOFT Steam Generator	
Secondary Side 4-Inch Inspection Port -----	G-i
APPENDIX H - Design Stress Analysis of LOFT Steam Generator Sec-	
ondary Side Small Nozzles -----	H-i
APPENDIX I - Stress and Fatigue Analysis of LOFT Steam Generator	
Tubesheet Tubes -----	I-i
APPENDIX J - Stress and Fatigue Analysis of LOFT Steam Generator	
Orifice Plate Assembly -----	J-i
APPENDIX K - Stress and Fatigue Analysis of LOFT Steam Generator	
Divider Plate -----	K-i

1.0 Summary

A review has been made of the LOFT Steam Generator Stress and Fatigue Life Analysis Report⁽¹⁾. The review covers:

1. The content of the stress report with respect to the requirements of the design specification, ANC-60057, "LOFT Steam Generator"⁽²⁾.

A primary requirement of the specification is that both primary and secondary sides of the steam generator satisfy the Class 1 requirements of the ASME Section III Code⁽³⁾.

2. Consideration of the adequacy of the analysis procedures and models.
3. Review of details of computer analysis including procedures for evaluation to Code requirements and numerical content. Thermal analysis was also examined to confirm that thermal transient stresses were peaked at the times designated.

A summary of the results of the review are presented in Section 3 and the detailed comments in Appendices A through K. The organization of the appendices is such that a one to one relationship exists between the appendix designation in the stress report and the review.

2.0 Discussion

The basis for the analysis of the steam generator is contained in specification ANC-60057. Consideration was given in the review to certain areas of analysis for which the specification inadequately defines known operational requirements or loadings. Evaluation of the specification for completeness or for consistency with other design documents was, however, not considered to be in the scope of the review.

The analysis was conducted in accordance with the 1971 Edition of Section III of the Boiler and Pressure Vessel Code. Both primary and secondary boundaries are to comply with the requirements for a Class 1 vessel. Review of the secondary pressure boundary, Appendix B, was performed by S. Silverman and the remaining sections (Appendices) by the report co-author, R. M. Fors.

During the review, while deficiencies were found which are the subjects of the remainder of this report, it was also noted that the stress report was of excellent quality in respect to organization, clarity of content, and completeness. Stress summaries were included in each appendix and in the main report. The areas of the steam generator for which full compliance with the Code could not be shown were also clearly stated and summarized in the main report.

3.0 Results

Section 5.0 of the stress report presents a summary of the results of the analyses. Where the stated results refer to areas of analysis in which deficiencies were found during the review, the effects of correcting the deficiencies will be discussed.

Section 5.1 of the stress report indicates that the primary membrane plus bending stress ($P_L + P_B \leq 1.5S_m$) on the tubesheet is 30455 psi which is in excess of the $1.5 S_m$ limit for the Abnormal Design Case having a ΔP of 2500 psi across the tubesheet. Due to an error in evaluation to $\frac{P}{h}$ ratio of the tubesheet, the stress for this Abnormal Design Case should be increased to 36560 psi. The allowable ΔP across the tubesheet will correspondingly be decreased from the 2000 psi shown to 1780 psi.

The initial paragraph of Section 5.2 states that the primary plus secondary stress limit ($P_L + P_B + Q \leq 3 S_m$), was satisfied everywhere except at the primary side handhole seal plate ring. This statement is incorrect as primary plus secondary stresses also exceed the allowable limit in the tubesheet. The latter result, not determined in the stress report, follows from the effect of the error in evaluating the $\frac{P}{h}$ ratio on the primary plus secondary stress calculation.

At the tubesheet location, primary plus secondary stress excluding thermal bending stress also exceeds the $3 S_m$ stress limit. The latter condition must be satisfied as a precondition for performing a simplified elastic-plastic analysis per Code paragraph NB-3228.3.

Primary plus secondary stresses for several locations were not calculated. Obviously the conclusion of Section 5.2 is unproved for these locations which are identified in the appendices to this report. It is also unproved for certain other locations where primary plus secondary stress range was not calculated for some load pairs in particular those including a test condition.

The number of LOCE transients allowable at the tubesheet-primary head junction must be reduced from 180 to about 95 to correct for the error in $\frac{P}{h}$ evaluation of the tubesheet.

The 185 operational startup transients found permissible for the feed inlet nozzle was confirmed by the review.

The results of all bolted flange analysis is questioned due to the cumulative effect of one or more of several factors on each analysis. These are:

1. Incorrectly evaluated material properties and thickness for the equivalent annular ring.

2. Procedural errors in determining bolt bending stress from stress in the annular ring.
3. Incorrect load case elimination in the fatigue analysis.

Conclusions in regard to the divider plate are questioned for the following reasons:

1. The applicability of the pressure data used is questionable.
2. A dynamic load factor should be determined for each section of the divider plate to substantiate use of a static analysis.

Section 5.3 gives results of analysis for testing conditions. The fatigue analysis performed for testing conditions should be evaluated with Normal and Upset Operating Conditions rather than as separate entities. This applies also to the primary plus secondary stress calculation as a precondition for a fatigue analysis even though not explicitly mentioned in part (d) of Code paragraph NB 3226 on Testing Conditions.

Section 5.5 contains a discussion of the faulted condition analysis. The faulted condition given in the specification is the combination of LOCA with ECC injection and design basis accident. The addition of a statement in this section that "ECC injection produces only thermal stress which do not require analysis for faulted conditions" is recommended. Otherwise ~~conclusions~~ conclusions are unchanged.

As noted throughout the Appendices, instantaneous values of thermal expansion were used in performing the stress analyses of the steam generator. As a conservative approach, this is only objectional at locations where thermal stresses and fatigue life fails to satisfy the Code requirements. Mean values are however, the correct and preferred values.

Detailed comments, discussion and enumeration of deficiencies including those noted above are given in Appendices A through K. References to section and page numbers in the appendices refer to those in the stress report.

4.0 References

1. LTR-1141-20, LOFT Steam Generator Stress and Fatigue Life Analysis Report, F. J. Canders, April 23, 1976.
2. LOFT Steam Generator Specifications ANC-60057, Revision A, July 27, 1973.
3. Section III of ASME Boiler and Pressure Vessel Code 1971, including Winter 1971 Addenda.
4. Drawings - Aerojet Nuclear Company (ANC)
Drawing No. 206161 through 206170.
5. M. H. Robinson, Stress Analysis and Redesign of the LOFT Steam Generator Foundation, LOFT Technical Report LTR-1141, Revision 1 (TR-450, Rev. 1, AM-22(, Aerojet Nuclear Company, August 13, 1974.
6. E. C. Lemon, LOFT Steam Generator Thermal Analysis, LOFT Technical Report 1141-26 (RE-E-76-013), Aerojet Nuclear Company, July 27, 1976.
7. K. R. Wichman, et. al., Local Stresses in Spherical and Cylindrical Shells Due to External Loadings, Welding Research Council Bulletin 107, August 1965, Revision April 1972.
8. LOFT Reactor Vessel Specifications, MS-201 Revision 7, June 22, 1972.
9. LTR-20-4, WHAM Code Applications on the LOFT Primary Coolant System, October 2, 1973, by V. T. Berta.

APPENDIX A
STRESS AND FATIGUE ANALYSIS OF LOFT STEAM
GENERATOR PRIMARY PRESSURE BOUNDARY

The analysis of the primary pressure boundary contains several significant deficiencies that will affect the reported results. In summary:

1. The pitch to ligament ratio, $\frac{P}{h}$, used in the analysis included a modified value of h which took credit for the stiffening effect of the tube bundle. While not stated or justified in the report the $\frac{P}{h}$ ratio used represents 50% stiffening. The tubesheet analysis literature and in particular that part reporting investigations by B. F. Langer and others support that choice.

The modified $\frac{P}{h}$ ratio should have been used only to obtain modified values of elastic constants for the equivalent solid plate, E^* and r^* , but was also used in stress calculations. To make this point clear, the actual value of $\frac{P}{h}$ must be used in applying the various equations of the Code-Appendix-8000 to convert from stress in the equivalent solid plate to those in the perforated plate ligament.

2. The procedure used to model the manhole cover plate bolts in this analysis is incorrect. The dimensions (ring thicknesses) and material properties used for the computer analysis and the method of bolt stress evaluation are in error. Procedural errors occur in all appendices where bolting is evaluated. A corrected procedure and a general explanation of the problem is given in the review and comments on Appendix D.
3. Instantaneous values of coefficients of expansion were used in all analyses. As a result, the computed thermal stresses in all thermal runs are overestimated.

4. An incorrect distinction was made between testing conditions and other conditions in performing the primary plus secondary stress calculations. That part of Paragraph NB-3226 of the Code pertaining to fatigue evaluation should be interpreted to imply the prior satisfaction of primary plus secondary stress and/or the requirements for simplified elastic-plastic fatigue evaluation.
5. Certain load case pairs were missed because of not considering the null-point an end-point of both the heatup-cooldown and testing conditions.
6. Several numerical errors in calculations of stress differences from component stresses were noted. Cumulative usage results based on the above stresses will be affected.

Detailed comments relating the specific analysis section to the above general comments follow. For convenience, and due to the size of the appendix, comments are designated by report section number and page number.

1.0 INTRODUCTION

No comment.

2.0 ANALYSIS SUMMARY AND DISCUSSION

Section is subject to revision due to deficiencies and errors in analysis.

3.0 ANALYSIS

3.1 ANALYSIS CRITERIA

No comment.

3.2 STRUCTURAL MODEL AND METHOD OF ANALYSIS

A comment on the model not included in the general comments is the observation that the axisymmetric ring used to model the

ribbed support structure fails to bring out the local bending effects of the real structure on the spherical head or shell. Also, examination of the stresses in the contact material (no. 10) showed the stresses to be oscillating from positive to negative in an unreal manner. This effect occurs in both pressure and thermal runs. This shows an instability which raises further questions concerning this aspect of the analysis.

3.3 MATERIAL PROPERTIES

See general comment relating to coefficients of expansion.

3.3.4 MATERIAL NO. 3

See general comments on bolting analysis.

3.3.10 MATERIAL NO. 10

pg. A-43 Line 5

Title Table A-17

References to material No. 9 should be to material No. 10.

3.4 LOADING CONDITIONS

No comment.

3.5 BOLT PRELOAD ANALYSIS

No comment.

3.6 DESIGN CONDITION ANALYSIS

3.6.2 Analysis to Satisfy $P_m \leq S_m$ Condition

3.6.2.5 Tubesheet

pg. A-79, pg A-80, pg. A-81

See general comment pertaining to use of ligament width in stress equations.

3.6.3 Analysis to satisfy $P_L + P_B \leq 1.5 S_m$ condition.

3.6.3.3 Tubesheet

pg. A-89, A-92, A-97.

See general comment pertaining to use of ligament width in stress equations.

3.6.3.5 Primary Head-Tubesheet Junction

Pg. A-104 through A-106

The calculations on these pages are for local membrane stresses for which the $1.5 S_m$ allowable applies. However, since the stresses are less than S_m it would be preferable to categorize the stresses as general membrane. The requirement for local membrane stresses to be below $1.1 S_m$ within a calculated distance can then be eliminated (it is presently missing).

Pg. A-106 through A-108

This section should include calculations of primary plus secondary stress for the abnormal design case. The statement referring to this case at bottom of pg. A-107 is insufficient by itself.

3.6.3.6 Secondary Shell-Tubesheet Junction

Pg. A-110 through A-112

See first comment on previous section. Also, primary plus secondary stress calculations for mechanical loads are missing.

3.7 NORMAL AND UPSET OPERATING TRANSIENT ANALYSIS

3.7.2 Point in the Primary Shell at Tubesheet-Primary Shell Junction

(EL. No. 349)

a) Calculations to Satisfy $P_L + P_B + Q \leq 3 S_m$ Condition

See General comment on treatment of testing conditions.

b) Fatigue Life Analysis for Element No. 349

The results of this section may or may not be correct depending on results of section a) which are incomplete.

3.7.3 Point in Tubesheet (Perforations)

Pgs. A-149 through A-153 and pg A-159

See general comment pertaining to $\frac{P}{h}$ ratio.

3.7.4 Point in Fillet-Primary Side

Pgs. A-181, A-182, and A-183

The calculated stress differences for pairs 6-8 and 0-7 are incorrect.

3.7.5 Point at Tubesheet-Secondary Shell Junction (Element No. 572)

See general note pertaining to primary plus secondary stress calculations for leak test conditions.

3.7.6 Point in Fillet at Tubesheet Secondary Shell Junction (Element No. 261)

See general note pertaining to primary plus secondary stress calculations for leak test conditions.

Pgs. A-207, A-208, and A-209

The calculated stress differences for pairs 4-3, 5-2, 8-3, 3-9, 3-5, 0-2, and 3-NOFP are incorrect.

3.7.7 through 3.10

No comment.

3.7.7 See general comments on bolt analysis.

APPENDIX B
STRESS AND FATIGUE ANALYSIS OF LOFT STEAM
GENERATOR BASIC SECONDARY PRESSURE BOUNDARY

The results of the review of Appendix B of the stress report are presented below in the order of decreasing significance.

- A. The design specification (Ref. 2) does not consider the possibility of failure of the primary tubes. Such a failure would allow primary coolant at perhaps 2500 psia into the secondary shell which is designed for 1100 psia. An earthquake might cause internal hardware to break loose and rupture the primary tubes.
- B. The nozzle region must satisfy the ASME Code requirements of NB-3227.5. Within the limits of reinforcing, the pressure and external loads which cause P_m stresses, must satisfy the S_m limit. This has not been checked and from the magnitude of the stresses at the weld line (see Section 3.5.3.4), the limit may not be met.
- C. The drawing of the steam generator (Ref. 4) indicates that the minimum thickness of the steam generator spherical head is 1.5" and the nominal thickness is 1.75". The analysis correctly employed the minimum thickness to verify the ASME Code design requirements for the basic spherical head. The nominal thickness was employed to investigate the steam outlet nozzle. Because of the larger-than-normal difference between those two values, it is felt that the "true" nominal thickness should have been used in the computer model of the spherical head nozzles. That is, the thickness should have been experimentally determined and then employed in the computer model.
- D. The support bolt preload employed in the calculations (see pp B-28, B-42) has been changed to a larger value (Ref. 5, Appendix IV). The consequences have not been evaluated.

- E. The effect of the primary nozzle loads on the support bolts has not been investigated. Significant stresses may be induced.
- F. There is no detailed discussion either in the design specification (Ref. 2) or the stress report or the thermal analysis (Ref. 6) of the secondary side transients. It is felt that each possible transient should be considered and discussed as to its significance. When necessary, preliminary calculations should be made to confirm that the effects of the transient are negligible. Comments about the secondary transients may be found on p B-21.-
- G. It is not clear what criteria should be satisfied for the support bolts. Should the bolts be stressed up to 94% of yield ($= \frac{89.2}{95.4}$) and should fatigue be considered? See page B-45 for calculations.
- H. The local stresses in the nozzle region due to mechanical nozzle loads were evaluated by an early Bijlaard paper (see pp B-36 and B-63 for calculations). Preliminary calculations using more recent data (Ref. 7) indicate rather large differences between the two references, with the more recent reference yielding higher stresses. In addition, the data of Reference 5 has never been investigated by EG&G stressors to ascertain that the results are accurate or conservative.
- I. In Section 3.6.4, it is stated that the highest stressed chamber shell element 785 (see p B-54). An investigation of the other elements indicates that the stresses in element 778 are greater than those of element 785.
- J. The skirt shell is considered in Section 3.6.2. It is not clear what criteria the skirt must satisfy since it is not a pressure boundary. The design specification does not clarify this point. Class 1 allowables were employed.

- K. The steam generator drawings indicate that the steam outlet nozzle is fabricated from forged carbon steel without further material designation. The analysis employed properties for SA-105 Gr. II. Therefore, the actual material is not known to conform to ASME requirements. An investigation of the ASME Code materials indicates that SA-181 Gr 1 has the minimum allowable values for carbon steel forgings. At 400° for example, $S_m = 20.6$ ksi for SA 105 Gr II and $S_m = 17.2$ ksi for SA-181 Gr 1.
- L. For operating conditions, the skirt chamber junction was not checked to verify that the $3 S_m$ limit of the ASME Code is satisfied (see p B-51). However, even with peak stresses included, the $3 S_m$ limit is satisfied.
- M. The main steam nozzle loads employed in the analysis (see p B-20) have been superseded. The latest values are as follows (report to be issued, authored by Mike Nitzel):

<u>PX</u>	<u>VY</u>	<u>VZ</u>	<u>TX</u>	<u>MY</u>	<u>MZ</u>	<u>RUN</u>
501	1967	1788	0	0	0	LOCE MEN3 SNU92661 5/10/77
180	293	692	0	0	0	SSE MEN3 SNU93401 5/11/77
732	2282	2298	0	0	0	LOCA MEN2 SNU92558 5/11/77
574	-38	62	0	0	0	Dead Wt. } MEN2
665	1050	-118	0	0	0	Therm. Exp. } SNU9C396 5/12/77

These can be resolved into stress resultants as shown. Also shown are the values employed in the analysis. It is seen that except for PX, the values employed in the analysis are larger. The component PX induces very small stresses so that the analysis is conservative.

- N. The requirements of the ASME Code, NB-3227.4 for triaxial stresses, has not been shown to be satisfied.
- O. In the computer input for the submodel region of the skirt/shell junction there was an error in a boundary pressure card for the design condition run (JJCXROGA). The boundary is shown below:

The boundary pressure card listed the nodes as 151 and 97, while two cards should have been used with nodes 151 and 115, and 115 and 97. An examination of the run indicates that the result is that the program excludes from node 115 the force due to pressure. The net effect of the error is insignificant (verify by examining computer output).

- P. The temperature differences were examined between several points along the support bolts and skirt and points of equal height along the shell. Typical results may be seen in the following figure. It is seen that although the maximum average temperature difference between the shell and skirt/bolting may occur at 15,000 seconds or later. The value of 16,200 sec employed in the analysis is as good an estimate as any.

Q. The bolt area employed to calculate the stresses should correspond to the minimum diameter at the root of the thread. Thus

$$A_{\min} = \frac{\pi}{4} (1.1118)^2 = .9708 \text{ in}^2$$

instead of .9940 which was employed. The stress is then 91,920 psi instead of 89,775 psi. See also comment (G).

APPENDIX C
STRESS AND FATIGUE ANALYSIS OF PRIMARY
INLET NOZZLE

NB-3112.3 Design Mechanical Loads

A discrepancy exists between Design Loads in the stress report and those in the Specification⁽²⁾. This violates the following code procedures:

"The specific combinations and values of mechanical loadings which must be considered in conjunction with the design pressure and design temperature in evaluating the requirements of NB-3221.1, NB-3221.2, and NB-3221.3 shall be those identified in the Design Specification (NA-3250) and designated as the Design Mechanical Loads. The actual mechanical loads at the appropriate time shall be used in the computations made to show compliance with the stress intensity limits of NB-3222.2 and NB-3222.4
(b) . . . ---

(b) The effects of earthquake . . . ---

The loadings, movements, and number of cycles to be used in the analysis shall be part of the Design Specifications."

Inasmuch as the Design Specification, ANC 60057, has not been updated to show the actual mechanical loads acting on the nozzles, sections of the stress report pertaining to those areas of analysis fail to comply with Article NB-3000 of the Code. The above also applies to the value of the leak test pressure which is incorrectly listed as 2750 psi.

Modeling Considerations

The SAAS-3 Finite Element Model as shown on page C-11 includes a cylindrical pipe extension which represents a 45° elbow in the real structure. The elbow is shown as an integral part of the steam generator on the ANC drawings. Accordingly, analysis of the elbows should be included or justification for the exclusion should be given.

The analysis performed was modeled with incorrect material properties. A nickel-chrome-iron (Inconel) designation was given to elements 1 through 269, whereas elements 115 through 269, part 3-3 is a forged carbon steel. Paragraph 3.3.2 of Appendix C lists an A-105 Grade II forging material which was not used in the SAAS III input. Whether this material was to be used for part 3-3, shown on the drawing (206163) only by a proprietary MIL specification, is not clear.

Also, with reference to material properties it is noted that the use of instantaneous values of the thermal coefficients is conservative but incorrect. Mean values should be used with a 70°F reference or stress free temperature.

A final point with respect to the model is that the requirements of NB-3122.3 (cladding) Secondary and Peak Stresses are not satisfied. This paragraph requires consideration of the cladding in both thermal and stress analysis except provided it is both integrally bonded and 10% or less of the total thickness of the component. The 10% limitation is satisfied in the spherical shell but not in the nozzle.

Paragraph 3.5

The analysis on these pages does not take into consideration the special requirement for nozzle analysis within the limits of reinforcement as stated in NB-3227.5 Nozzle Piping Transition. This section requires that stresses in nozzles resulting from pressure, external loads, and moments (including those due to thermal expansion) be given a P_m classification. Hence, in general, separate calculations on each side of the limit of reinforcement are required.

As to the calculation of the above stress, it is incorrect to categorize the shear stress, T_{rz} , per NB-3227.2 since it is not a pure shear. This stress shown in part d must be included with those in part c.

3.6.4

It is stated in this section that, because of the irregular section, that standard methods of stress linearization did not apply well and were omitted for that reason as well as the judgement that the primary plus secondary stress is not critical. The reviewer does not agree with these conclusions. Linearization, while not straightforward because the centroids of elements involved are not coplanar, can be accomplished by interpolation of stresses to the desired plane. As to the second point, the primary plus secondary stress must be evaluated to substantiate the use of $K_e = 1$ in the fatigue calculation.

APPENDIX D
STRESS AND FATIGUE ANALYSIS OF LOFT STEAM
GENERATOR PRIMARY SIDE HANDHOLE

One of the results of this analysis was a calculated cumulative usage factor of .95 which is close to the limit, 1.0. Some of the procedural details used to establish the bolt ring geometry and material properties and ultimately bolt stress and fatigue are considered to be incorrect. A correct procedure is as given.

1. The maximum stress and cumulative usage factor in the bolt will usually occur at the reduced section at the base of the threaded section. Thus stresses will properly be based on the minimum bolt radius, r_b .
2. The thickness of the equivalent bolt ring, t , and the elastic moduli, E_{ZR} , E_{RR} , and $G_{RZ,R}$ should be based on the bolt diameter most representative of the stiffness of the bolt. Usually, this will be the nominal bolt diameter.
3. Stresses in the equivalent bolt ring should be used to obtain the forces and moments acting on each bolt at the critical section.
4. The axial and bending stress in the bolt are calculated from the forces and moments acting on the bolt.
5. Residual stresses due to tightening are added, the factor of 4 for the thread concentration is applied and fatigue calculations performed.

Steps 2, 3, and 4 of the LOFT Steam Generator Analysis differed from the above as follows:

Step 2 - the thickness and elastic moduli were based on the minimum bolt diameter. This underestimated the ring stiffness which is considered unconservative.

Step 3 - stresses in the equivalent bolt ring were extrapolated to the surface and linearized.

Step 4 - stresses in the bolt were calculated as the product of the above stress and the ratio of the bolt ring area to the minimum bolt area.

The objection to the latter two steps are: (1) the extrapolated surface stress includes a large percentage of fictitious stress introduced by the boundary conditions of the model but not existing in the bolt, and (2) bending stresses are not related by the area ratio.

In the primary side handhole analysis, the stress linearization step was omitted but this does not negate the objection to the procedure.

One other point on this section was that in reviewing the computer output, it was noticed the two of the gap elements No. 77 and 78 were in tension on the Control Rod Drop and the LOCE Transients due to equilibrium requirements it follows that part of the compressive stresses on the remaining elements is not genuine.

Page D-43

1. The calculation

$$T = \frac{346650}{4.25} = 8153 \text{ in. lbs.}$$

should be

$$T = \frac{34650}{4.25} = 8153 \text{ in. lbs.}$$

2. Paragraph 2 at the bottom of page D-43 should be revised to fit reported results in Table D-19.

3.7.4 SEAL PLATE (SUPPORT) RING

Inclusion of the flexitallic gasket as a structural element would significantly reduce the indicated overstress.

APPENDIX E
STRESS AND FATIGUE ANALYSIS OF SECONDARY
SIDE-SIXTEEN-INCH MANWAY

It is concluded in this analysis that the manway bolts fail to meet the Code requirement for fatigue. The bolt analysis deficiencies discussed in the general comments would suggest that the S_a values of TABLE-E-16 should be revised. However, given the correctness of the S_a values, the stated conclusion is incorrect due to a conservative but unnecessary procedure used in the cumulative damage analysis. A correct procedure is illustrated which reduced the cumulative usage factor to 0.704.

TRANSIENT COMB.	SPECIFIED TRANS. n	RING STRESS RANGE	BOLT THREAD STRESS	S_a	ALLOW TRANS. N	$\frac{n_i}{N_i} = U_i$
1-5	65	31800	456126	228063	160	.406
PL-5	195	7600	109011	54506	2000	.098
PL-3	1500	3800	3800	27253	7500	.200

$$\sum \frac{n}{N} = 0.704$$

APPENDIX F
STRESS AND FATIGUE ANALYSIS OF LOFT STEAM
GENERATOR SECONDARY SIDE MAIN FEED INLET NOZZLE

The results of this analysis show that the main feed inlet nozzle is inadequate in fatigue for the "operational startup transient." No errors were found that modify this conclusion. The allowable number of cycles could be extended somewhat by using mean values of coefficient of expansion rather than instantaneous values but not enough to eliminate the problem.

Paragraph 3.4.3, item 2, states that the "operational startup transient" is a new condition not given in the steam generator specifications. Documentation of the origin and source of the transient was not included and should be supplied.

APPENDIX G

STRESS AND FATIGUE ANALYSIS OF LOFT STEAM
GENERATOR SECONDARY SIDE 4-INCH INSPECTION PORT

See general comments on bolting analysis deficiencies.

Pg. G-38

See comment of APPENDIX E concerning cumulative damage analysis.

APPENDIX H
DESIGN STRESS ANALYSIS OF LOFT STEAM GENERATOR
SECONDARY SIDE SMALL NOZZLES

The only deficiency noted in this analysis was an error of transposition of negligible effect. The error: on bottom line of page H-11, change values to read $.469 + .5 (.973) = .9555$ in.

APPENDIX I
STRESS AND FATIGUE ANALYSIS OF LOFT STEAM
GENERATOR TUBESHEET TUBE

Pg. I-4

In Table I-1

part a stress requirements

3 S_m on left should be $P_L + P_B + Q$

Pg. I-6

Instantaneous values of coefficients of expansion used are conservative.

Pg. I-23

The Code contains three curves for separate grades of nickel-chrome-iron. The value of $B \approx 14600$ was apparently taken from Fig. VII-1100-4-1 rather than Fig. VII-1100-4. For the latter find $B \approx 13400$ and $P_a = 1734$ psi.

APPENDIX J
STRESS AND FATIGUE ANALYSIS OF LOFT STEAM
GENERATOR ORIFICE PLATE ASSEMBLY

No significant deficiencies were noted in this analysis. As in other sections, instantaneous values of coefficients of expansion were used, but since the usage factor is low, the extraconservatism does not matter.

The assembly is a bolted structure but comments on deficiencies of bolted structures do not apply for two reasons:

1. The thickness of the equivalent bolt ring was set equal to the minimum bolt radius rather than $r_b \sqrt{3}$. The magnitude of the minimum bolt radius is approximately equal to the proper value based on the nominal diameter. Hence the elastic properties are approximately correct.
2. Calculation of bolt stresses or fatigue analysis was not required.

APPENDIX K
STRESS AND FATIGUE ANALYSIS OF LOFT
STEAM GENERATOR DIVIDER PLATE

As discussed in Section 3.2 of the report, the LOFT Steam Generator Specifications⁽²⁾ does not define the loading across the divider plate. This loading exists due to the depressurization wave passing from inlet to outlet of the steam generator in a finite period of time.

In lieu of direction regarding the depressurization load in the steam generator specification, information given in the LOFT Reactor Specifications (MS-201)⁽⁸⁾ was used. Accordingly, it was assumed that the differential load across the divider plate was 650 psi. Further, since a static analysis was performed, it was also assumed that the 650 psi load was applied statically.

We find some problems with this procedure. First, the LOFT Reactor Vessel Specification is not the best source for loads on the divider plate. The preferred source is the WHAM blowdown analysis performed by V. T. Berta and reported in LTR 20-4⁽⁹⁾. Second, consideration should be given to the dynamic load factor as determined from the duration of the load and the natural frequency of the divider plate as well as to the amplitude of the load.