6/9/92

Chet -

Attached are the responses to the piping audit concerns. The attached specification addresses one of the concerns.

Jack Fox

52-001

Chet:

Per your request, I made this copy for the docket.

Shou Hou
6/17

D050
1/1

NRC Audit of GE on
ABWR PIPING DESIGN CRITERIA AND SAMPLE ANALYSES
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Item No.: 1 By: ____________

DESCRIPTION OF CONCERN:

Request a list of procedures for analysis methods / criteria for piping and piping supports. Then, copies of selected procedures can be requested.

RESPONSE BY GE:

The NRC/BNL requested ~~the attached~~ a list of documents/information during the audit. GE has agreed to provide all items except the Design Record Files and the detailed internal design procedures. These 2 "excepted" items are available for audit/review/discussion in GE-San Jose and will be made available in GE-Bethesda, but the material may not be copied nor removed. Copies of the other requested items will be forwarded to the NRC.

STAFF EVALUATION:

CONCLUSION:

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Item No.: 2 By: ____________

DESCRIPTION OF CONCERN:

Request 1) Response Spectra for seismic and other loads
2) References in Criteria Doc.
3) SSAR 3.7, 3.9, & applicable figures (e.g. reactor bldg. cross section)
4) Model input data including floppy disk of load cycle/range dwg. for all 3 sample piping systems.

RESPONSE BY GE:

This item is addressed in Item No. 1.

STAFF EVALUATION:

CONCLUSION:

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Item No.: 3 By: ____________

DESCRIPTION OF CONCERN:

A discrepancy exists in SSAR Table 3.2-1 for the SRV piping regarding piping classification of 2/3 versus Class 3 specified elsewhere in the SSAR.

RESPONSE BY GE:

GE concurs with NRC/BNL's finding. This discrepancy was also identified by GE in a recent engineering review of the SSAR. GE will ~~revise~~ modify sections 3.9.3.1.13 and note h of Table 3.2-1 of the SSAR to properly reflect the classification of the SRVDL piping and to be consistent within these applicable sections

STAFF EVALUATION:

CONCLUSION:

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ITEM NO: A-4

DESCRIPTION OF CONCERN:

1. What is the ASME classification of the SRV quencher?

2. What analysis and design method was used relative to its design specification?

RESPONSE BY G.E.:

1. Response prepared by JB Knepp

2. The quencher is analyzed to the rules of ASME-III, Class 3. The quencher is treated as a fabricated assembly of piping components and is analyzed to the rules of ND-3600. The analytical methods are described in the summary stress report and in supporting documents such as:

Containment Loads Report, Specification No. A21-2040;
386HA579, Dynamic Load Methods and Criteria;
Computer Manual for PYSIS.

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Item No.: 4 By: ______________

DESCRIPTION OF CONCERN:

What is the ASME classification of the SRV quencher and what analysis and design method was used relative to its design classification?

RESPONSE BY GE:

Consistent with BWRs, the ABWR quencher will be classified as ASME Class 3.

STAFF EVALUATION:

CONCLUSION:

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Item No.: 5 By: ____________

DESCRIPTION OF CONCERN:

"Why are both ASTM and ASME designation presented in Criteria Document? - Implies could be bought to ASTM.

RESPONSE BY GE:

The ASTM designation will be removed from the Criteria Document, therein invoking the ASME material requirements

STAFF EVALUATION:

CONCLUSION:

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ITEM NO: A-6

DESCRIPTION OF CONCERN:

1. Need to see criteria for all supports - analysis/design.
2. SSAR needs to include description/requirements for guides.

RESPONSE BY G.E.:

1. There is no single GE document that sets forth all the criteria for the design/analysis of supports. The SSAR covers all pipe supports in considerable detail, with the possible exception of the Main Steam/Feedwater guides and structural frame supports such as those in the wetwell. The most important documents defining design/analysis criteria are the G.E. pipe suspension purchase specifications and the pipe suspension drawings. These documents: (1) Provide a complete basis for design, manufacture, qualification, examination and installation of pipe supports for all ASME III piping; Require the design and analysis of supports for nuclear piping to be in conformance with NF Subsection of ASME III and suports for non-nuclear piping to be in conformance with ANSI B31.1; and (3) Provide design loads obtained from the piping analysis and specify the minimum support stiffness, allowable materials, installation tolerances.

Examples of recent documents prepared for the K6/K7 plants are:

- 23A6061 - Main Steam, Feedwater & Safety/Relief Valve Discharge Pipe Suspension.
- 103E1512 - Main Steam Pipe Suspension
- 103E1437 - Feedwater Pipe Suspension
- 103E1525 - SRV D/W Pipe Suspension
- 103E1526 - SRV W/W Pipe Suspension

2. G.E. is now considering adding additional requirements to the SSAR to provide more detail on the main steam and feedwater guides inside containment.

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Item No.: 6 By: ________________

<u>DESCRIPTION OF CONCERN</u>:

1) Need to see criteria for all support - analysis/design.
2) SSAR needs to include description/requirements for guides

<u>RESPONSE BY GE</u>:

2) GE concurs with this comment and will include the requested information in a future amendment of the SSAR. Additionally, information on "other" supports (e.g. energy absorbers) will be added to the SSAR so that use of these "other" support is not precluded.

<u>STAFF EVALUATION</u>:

<u>CONCLUSION</u>:

NRC AUDIT OF GE ON
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ITEM NO: A-7

DESCRIPTION OF CONCERN:

Why does the Piping Criteria document utilize only Reference 6.0-c and not all applicable NRC R.G.'s and S.R.P's ?

RESPONSE BY G.E.:

All applicable NRC R.G's and S.R.P's will be referenced in the Piping Criteria document.

ITEM NO: A-8

DESCRIPTION OF CONCERN:

The 1/3 pipe size criteria is not sufficient, additional piping decoupling/interaction criteria(e.g. SSAR 3.7.2.3.1) are needed. The effect of branch line supports close to the main line should be considered.

RESPONSE BY G.E.:

The criteria specified in Section 3.7.2.3.1 of the SSAR are used to determine whether a piping or equipment subsystem can be decoupled from the Building or primary system model. If the diameter of the branch line is less than 1/3 the diameter of the main line, it can be decoupled from the main line.

For a decoupled branch line, no dynamic supports will be located close to the main line. Otherwise the adjacent support would be loaded by the main line during dynamic events.

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ITEM NO: A-9

DESCRIPTION OF CONCERN:

Request criteria document(s) discussing dynamic analysis criteria in more detail (e.g. basis for highest frequency of interest, damping, delta t for time history analyses, ISM method of analysis, modal analysis method, how is the "effective/weighted" modal damping determined.

RESPONSE BY GE:

Document 386HA579, Dynamic Load Methods and Criteria, by DK Henrie, provides the best available details on the dynamic methods and criteria used by GE in the dynamic analysis of piping. A copy of this document was provided during the March meetings. Based on verbal comments, it is GE's understanding that the 386HA579 document was satisfactory response to this item.

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Item No.: A10 By:______________

DESCRIPTION OF CONCERN:

Are forcing function variations considered for direct integration analysis due to hydrodynamic loads. This variation (expansion and contraction) of the forcing function is the equivalent of response spectra peak broadening.

RESPONSE BY GE:

The wetwell loading input has been defined to cover all frequency ranges (similar purpose of expansion and contraction). Some time history loads are impulse type loads, such as safety relief valve discharge loads, expansion of the time history is equivalent to increasing the load. It is not necessary to add extra conservatism to this type of load. Similarly, it is not appropriate to contract the load (equivalent to reducing the load).

STAFF EVALUATION:

CONCLUSION:

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ITEM NO: A-11

DESCRIPTION OF CONCERN:

Clarify definition of components vs. damping values (snubber&strut) in damping table presented in the Piping Criteria document.

RESPONSE BY G.E.:

The following note will be added to Table 1 : (in the Piping Criteria doc.)

Snubbers and Struts are connected to the piping and to the supporting structure with pin connections, therefore the R.G. 1.61 damping values for bolted steel structures are used. Piping test data results show that the damping values for struts are at least equal to those for bolted structures, and the damping values for snubbers are greater than those for bolted structures.

ITEM NO.: A-12

DESCRIPTION OF CONCERN:

1. Provide the basis for application of all displacements in the same direction.

2. Provide justification for SRSS combination of inertia and displacement effects.

3. Provide criteria for order of combination for inertia and displacement loading events.

RESPONSE BY G.E.:

1. An additional seismic displacement case will be evaluated in which it is assumed that the biological shield wall moves in a direction opposite to the reactor pressure vessel and the drywell wall. Because the seismic inertia loads are so high there will be no significant change in the calculated piping stresses or support loads.
2. "The inertia(primary) and displacement(secondary) stresses are dynamic in nature and their peak values are not expected to occur at the same time. Hence combination of the peak values of inertia stress and anchor displacement stress is quite conservative. In addition, the anchor movement effects are computed from static analyses in which the displacements are applied to produce the most conservative loads on the components. In view of this, the combination of primary and secondary stresses shall be by SRSS."

Referenced from GE doc. no. 386HA579, Rev. 0

ITEM NO: A-12(continued)

RESPONSE BY G.E.:

3. Since all dynamic loads are combined by the SRSS method, the order of combination of inertia and displacement loads does not effect the results. The calculated dynamic loads are then combined with thermal and weight loads either by algebraic summation or by the absolute sum method.

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ITEM NO: A-13

DESCRIPTION OF CONCERN:

1. Interaction concern: flexibility of building local structure affecting/amplifying floor response spectra
   How is this addressed? (e.g. floor flexibility)

2. Piping amplified spectra for branch line analysis,How is this addressed?

3. Provide justification for the 1.2 factor for hydrodynamic amplification to account for local flexibilities

RESPONSE BY G.E.:

1. Flexibility of building local structures, such as steel platforms used for supporting piping and other equipment, are accounted for in the piping analysis. For the sample problem it was assumed that the steel platform has a fundamental frequency greater than or equal to 33 hz. Therefore, there is no amplification of the seismic loads. For hydrodynamic loads, a dynamic amplification factor of 1.2 was used. This factor is necessary to account for amplification at frequencies greater than 33 hz.

2. For branch lines decoupled from the main line, amplified spectra are applied at the attachments to the main line. The ERSIN computer program is used to generate the amplified response spectra.

3. The 1.2 factor was calculated and used in the analysis of the ABWR's under construction in Japan.

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ITEM NO: A-14

DESCRIPTION OF CONCERN:

1. How many cycles will be used for seismic and other loads?
2. What is the basis for using ½ SSE floor spectra for OBE floor spectra?
3. Were building rocking effects added to the vertical spectra?

RESPONSE BY C.E.:

1. The SSAR and the Piping Criteria document will be revised to specify the correct number of cycles. In Table 3.9-1 of the SSAR, the number of events or cycles will be increased by 50 % for the following events: Events 1- 9 and Events 14&15.
2. There is no basis for using ½ sse floor spectra for OBE floor spectra. This was done because the OBE floor spectra were not available. The Piping Design Criteria document will state that for future analysis of ABWR piping, the appropriate OBE floor response spectra shall be used in the analysis.
3. Building rocking effects were not added to the vertical spectra. This was determined to be unnecessary since there was adequate conservatism in the structural analysis.

ITEM NO: A-16

DESCRIPTION OF CONCERN:

How and why is the flooded load included in the analysis?
How many cycles are considered?

RESPONSE BY G.E.:

Two hydrostatic test cycles are considered for each boltup cycle. Therefore 135 events are considered to occur during the 60 year design life. During the hydrostatic test event, the main steam line and the SRV discharge lines are filled with water. Therefore for these lines a dead weight analysis is done for these lines filled with water.

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ITEM NO: A-15

DESCRIPTION OF CONCERN:

1. How do you insure SRV valve to be purchased will have a rise time greater than 20 msec?

2. Same applies to TSV.

RESPONSE BY GE:

1. GE has not placed any restrictions on how fast the safety-relief valves may open or on how rapidly the turbine stop valves may close. The specification for the Safety-Relief Valve requires the "Total elapsed time from start of main disk motion to full stroke of the SRV (i.e., lift to full rated capacity position) shall not exceed 0.15 seconds." GE calculates the forcing function for RV-1 based on a 20 millisecond rise time. Rise time is defined as the period of time from start of flow through the valve until essentially full flow. G.E. has established the 20 milliseconds as a conservative valve based on evaluation of available data from valve manufacturers.

The results of the overall analytical process includes many important variables, including: analytical model of pipe and supports (stiffness, wall thickness, diameters), the analytical assumptions in the computer program RVFOR, out-put time step, steam line pressure, total FL/D and inside diameter of discharge pipe, analytical definition of quencher, code method for calculating stresses at branches and elbows.

G.E. does not feel is necessary, nor desirable, to upper bound all the variables in the analytical process. It is important the overall analytical process give results that are in satisfactory agreement with actual test results. G.E. has performed numerous in-plant tests which have shown the overall analytical procedure for calculating stresses gives reasonable results compared with stress measured.** There is no data to indicace the stress valves calculated by G.E. analytical methods are nonconservative.

In addition, the Start-Up testing program for each BWR requires strain gauge instrumentation be install on typical SRVD lines and SRV inlet piping to confirm, on a plant by plant bases, the analysis gives results in satisfactory agreement with measured results.

2. The philosophy described above also applies to the TSV load.

**

Note: (1) Special in-plant tests performed at Duane Arnold, Monticello, Kuosheng and Coarso.

(2) Special SRV test at Wiley Laboratories facilities at Huntsville, Alabama under direction of H.L. Hwang.

(3) NEDE-23751, BWR/6 Mark III Safety/Relief Discharge Piping Transient Force Parametric Study, Dec. 1977. "Based on test data, the shortest opening time is 0.02 second. It is conservative to assume a short opening time."

(4) HL Hwang Studies:
Letter to E.O. Swain, February 14, 1978, SRV Opening Time.
Letter to H.Chang, dated November 9, 1976, Preliminary Monticello SRV Discharge Test Results, SRV Piping.

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ITEM NO: A-17

DESCRIPTION OF CONCERN:

1. Will GE consider/perform fatigue evaluation for thermal effects when piping involves hot and cold thermal mixing?

2. Provide thermal stratification criteria/methodology for piping analysis.

RESPONSE BY GE:

1. It is GE practice to evaluate the thermal stresses in piping at locations where hot and cold liquid streams are mixing. The normal procedure is to assume the temperature of points in the piping in the vicinity where the mixing occurs will fluctuate rapidly between the hot temperature and cold temperature of the two mixing streams. It is further assumed a large number of thermal cycles between the hot and cold temperatures will occur in a short period of time. Therefore the thermal stresses must be will below the endurance limit of the material. If calculations show the thermal stresses approach or exceed endurance limit values, GE requires a thermal sleeve be designed and installed to protect the pressure boundary from fatigue damage.

2. By KFF

ABWR PIPING DESIGN CRITERIA AND SAMPLE ANALYSIS
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Item No.: A17 By: ______________

DESCRIPTION OF CONCERN:

1. Will GE consider/perform fatigue evaluation for thermal effects when piping involves hot and cold thermal mixing? See p. 3.9-45 of SSAR - should systems requiring this evaluation be specified now?

2. Provide thermal stratification criteria/methodology for piping analysis.

RESPONSE BY GE:

1. By EOS

2. The thermal stratification load is caused by different temperatures at the top and bottom of a horizontal pipe. The loads and stresses caused by thermal stratification are similar to those caused by thermal expansion. Therefore, the stresses and load criteria for thermal stratification should be combined with concurrent thermal expansion stresses and loads by algebraic summation. The combined results should meet the thermal expansion limits specified by ASME Code. The analysis method is described in an internal GE document (ABWR-88027).

STAFF EVALUATION:

CONCLUSION:

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Item No.: 18 By: ________________

DESCRIPTION OF CONCERN:
Provide criteria and basis for considering environmental effects for fatigue evaluation.

RESPONSE BY GE:

GE will provide the three items addressed by Dr. Ranganath during the audit:
(1) Appendix 50 of 22A7014, "Materials and Processes Controls", "Fatigue Crack Orientation Design Rules for Carbon Steel"; (2) PVRC Presentation slides "Fatigue Tests of CS in High Temp. Oxygenated Water"; (3) W.E. Cooper paper: "The Initial Scope & Intent of Section III Fatigue Design Procedures".

STAFF EVALUATION:

CONCLUSION:

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ITEM NO: A -19

DESCRIPTION OF CONCERN:

How is the damping value determined for piping systems which include small and large diameter piping?

Provide procedures to determine damping for both ISM and USM methods of analysis. Provide justification for methodology.

RESPONSE BY G.E.:

Independent Support Motion (ISM) Damping Values:

For each response spectrum used, the damping value corresponds to the pipe size at the support. Therefore, in an ISM response spectra analysis more than one damping value can be used.

Uniform Support Motion (USM) Damping Values:

For each response spectrum used to generate the enveloped response spectrum, the accelerations correspond to a damping value dependent on the pipe size at that support. Once the enveloped response spectrum is generated, the smallest damping is then used in the dynamic analysis.

These are the typical industry practices. For the USM method the use of the smaller damping values in the dynamic analysis is conservative.

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ITEM NO: A-20

DESCRIPTION OF CONCERN:

1. In the Criteria document, clarify the description of the RV2 load and specify any factors used in the RV2 analysis.

   Does SRV all valve bound all RV2 loads?

2. Functional/Operability requirements per S.R.P. 3.9.3 are not in the GE Criteria document.

3. Load combinations for Equation 10 & 11 are not in the Criteria Doc.

4. What revisions will be made to the Tables in the Criteria document?

RESPONSE BY G.E.:

1. The description of all RV2 loads and all applicable factors will be included in the Criteria document. SRV all valves does bound all RV2 loads.

2. & 3. These items will be included in the Criteria document.

4. Tables 3 & 4 will include primary and secondary load combinations. Table 3 will specify that the lesser of two acceptance criteria shall be used, a note will be added on functional capability criteria.

   Tables 3,8,9,11,12,13&14: Individual loads will be separated by commas instead of +'s.

   Table 12: Allowable moments will be deleted, acceptance criteria will specify the applicable ASME Code paragraph.

   Table 9: The acceptance criteria will be specified.

   Table 13: Acceptance criteria will be deleted.

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ITEM NO: A-21

DESCRIPTION OF CONCERN:

Provide BWR 6 Load Combination definitions

RESPONSE BY G.E.:

G.E. Document No. 386HA931, Rev. 2, Event Combinations and Acceptance Criteria, provides the BWR 6 LOad combinations.

ITEM NO: A-23

DESCRIPTION OF CONCERN:

Provide description and bases of spectra interpolation/extrapolation procedure (for different elevations/locations).

RESPONSE BY G.E.:

GE internal procedures provide guidelines on response spectra selection. The RINEX computer program is used to interpolate and extrapolate response spectra.

ABWR PIPING DESIGN CRITERIA AND SAMPLE ANALYSIS
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Item No.: A22 By: ____________

DESCRIPTION OF CONCERN:

Does GE intend to use ASME Section 3200 related to plastic analysis method. If so, provide criteria since the Code lacks requirements in certain areas.

RESPONSE BY GE:

It is not GE's intent to use ASME NB-3200 plastic analysis as a generic method, such as limit analysis, to meet the primary stress allowables. There are two possible applications: (a) calculate the plastic strain for fatigue usage evaluation, and (b) pipe whip restraint analysis due to a postulated pipe break. The present Code requirements are adequate for these two applications.

STAFF EVALUATION:

CONCLUSION:

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ITEM NO: A-24

DESCRIPTION OF CONCERN:

1. What is the method of seismic analysis for the main steam piping beyond isolation valve outside containment to turbine building.

2. If dynamic analysis will be used, then what document provides the seismic spectra input.

RESPONSE BY GE:

1. Main steam piping between containment and the turbine building will be analyzed for seismic loads using response spectra methods and code allowables equivalent to that applied to ASME Class 3, piping.

2. The seismic spectra input has not yet been defined. This subject is still under study by GE and under negotiation with the NRC.

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ITEM NO: A -25

DESCRIPTION OF CONCERN:

Why does piping analysis use ZPA for high frequency effects, rather than the acceleration at the highest frequency at which the modal analysis ends?

RESPONSE BY G.E.:

The acceleration at the analysis cut-off frequency should be used to calculate the high frequency effects.

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ITEM NO: A-26

DESCRIPTION OF CONCERN:

1. What are the analysis/methodology and acceptance criteria for buried piping analysis (beyond short descriptions in SSAR)?

2. What provisions are provided for protection from external events (e.g. wind, tornado, missiles? If no protection is provided for some of the events, what are the analyses/methodology and acceptance criteria?

RESPONSE BY GE:

1. GE ~~will~~ has not yet determined if the SSAR should be revised to provide more definition of analysis methods to be applied to buried piping. At present ASME III Class 2 or 3 piping must meet the requirements of NC/ND 3600. These rules do not distinguish between above ground and underground piping. The Class 2/3 rules may be overly conservative when applied to underground pipe. If the decision is made to provide additional requirements for buried piping, GE will evaluate the most recent actions by piping code committees and determined if code approaches need to be supplemented when applied to ABWR. Examples of Code actions are:

(1) Proposed B31.1 Non-mandatory Appendix VII, Recommended Procedures for the Design of Restrained Underground Piping. (2)

(2) ASME III - DRAFT - General Requirements for ASME Section III Class 2 & 3 Underground Piping.

(3) ASCE Publication - Seismic Response of Buried Pipes and Structural Components - Report by the Seismic Analysis Committee of the ASCE Nuclear Structures and Materials Committee.

2. GE will has not yet determined if the SSAR should be revised to provide more definition of analysis methods to be used for evaluating the effects of external events such as wind, tornados, and missiles. At present, the rules for ASME III Class 2 or 3 piping apply for loads from external events the same as they do for seismic and other dynamic and static loads. If GE determines additional information in the SAR is needed to define magnitude of loads from external events or define Service Limit stress values for these events, the SAR will be revised.

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Item No.: A27 By: ______________

DESCRIPTION OF CONCERN:

Hydrodynamic building filtered loads are based on the Japanese K6/K7 plant design and soil conditions provide justification for applicability of those loads to the ABWR considering the variation in soil properties and their effects on the building response.

RESPONSE BY GE:

Based on past BWR plant experience, the trend indicates that the floor response spectra (FRS) increases as the foundation soil becomes softer. Since K6/K7 is a soft soil site, the resulting FRS for hydrodynamic loads are considered applicable for other site conditions and can be used for the standardized design.

STAFF EVALUATION:

CONCLUSION:

ABWR PIPING DESIGN CRITERIA AND SAMPLE ANALYSIS
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Item No.: A28 By: ______

DESCRIPTION OF CONCERN:

a) Provide additional information to justify the feedwater thermal stratification load definition. Identify test programs and plant measurements which support the model.
b) Justify the application of a linear temperature profile (versus a hot to cold step change) on the pipe cross-section.
c) Thermal striping is not considered in the analysis. Provide evidence to support neglecting the thermal striping phenomenon in the fatigue analysis.

RESPONSE BY GE:

a) Test programs and plant measurements were obtained at the following plants: Leibstadt, Hanford Unit 2 and Nine Mile Point Unit 2. Additionally, an extensive finite element analysis of the Shoreham feedwater piping system was performed to obtain a better understanding of thermal stratification. See also the Response to Item No. A17.

b) Using a hot to cold step change at the center of the pipe will be overly conservative. The reasons are given below:

1. The analysis assumes the same thermal stratification for the entire length of horizontal pipe, but thermal mixing occurs along the pipe due to flow which would reduce the stratification.
2. A step change at the center creates the maximum bending moment. In the actual flow, the hot and cold fluid does not have a step change due to axial flow.
3. The probability for the change from hot to cold fluid occurring at the center of the pipe is small since the amount of flow required for stratification is less than 3% flow. If the dividing line is not at the center, then the bending moment due to stratification is reduced.

c) Temperature stratification between the top and bottom of the feedwater piping and nozzles has caused pipe bowing with pipe support damage and flange leakage, but no pipe failures. The temperature stratifications which have been measured have shown that stratification occurs for only short time durations following reactor scram as the hot piping is filled with cold water, and again during startups as feedwater heating begins, filling the cold piping with hot water. So far, operation of BWR feedwater piping systems have avoided fatigue failure due to prolonged operation with a fluctuating cold water-hot water interface, due to the fact that feedwater velocities are high enough to maintain the piping at constant temperature throughout during most of its operating time.

STAFF EVALUATION:

CONCLUSION:

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Item No.: B1 By: S.J. Lin

DESCRIPTION OF CONCERN:

Currently a criteria document for the determination of break locations and dynamic effects associated with the postulated rupture of piping for the ABWR does not exist. GE should create such a document.

RESPONSE BY GE:

GE will incorporate the current SRP 3.6.2 criteria and postulated locations in the SAR. A separate criteria document is not required for determination of break locations.

STAFF EVALUATION:

CONCLUSION:

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Item No.: B2 By: S.J. Lin

DESCRIPTION OF CONCERN:

The sample analysis of the effects of high energy line breaks in the main steam line was not complete at the time of the audit. Complete the analysis for NRC review. The analysis should be in accordance with revised Section 3.6.2.2 of the SAR.

RESPONSE BY GE:

Sample analyses of main steam line A with two typical break locations have been studied. The first location is at the safe end nozzle break and the second location is at the break of sweepolet to the inlet SRV A. Both breaks have been restrained by the pipe whip restraints and by the pipe stopper (bumper). Assessment of the penetration loads will be submitted in the final report. It is evaluated based on the current SRP 3.6.2 criteria.

STAFF EVALUATION:

CONCLUSION:

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Item No.: B3 By: S.J. Lin

DESCRIPTION OF CONCERN:

The procedures and criteria specified in Section 3.6.2.2 of the SAR relating to analytic methods to define blowdown forcing functions and response models for postulated ruptures of piping are inconsistent with procedures and criteria to be used for the ABWR plant as described during the audit. Revise Section 3.6.2.2 of the SAR to be consistent with current SRP 3.6.2 requirements and current GE procedure and criteria.

RESPONSE BY GE:

Blowdown forcing functions are determined by the method specified in Appendix B of ANSI/ANS-58.2-1988.

In addition, the forcing functions due to the postulated pipe breaks near the reactor or the branch connection is calculated by the solution of one-dimensional, compressible unsteady steam flow in the gas system. The numerical analysis is performed by the method of characteristics. The flow starts with steady flow from RPV to turbine. A pipe break boundary conditon is applied at the break location for the pipe to reverse its flow direction. The pipe segment force time histories are calculated by the momentum change in the pipe segments of a close system. The broken pipe segment force time history is calculated by ANSI/ANS-58.2-1988.

The pipe displacement due to blowdown reaction load is modeled and analyzed using computation program available in the market, i.e. ANSYS. The stresses at the penetration and at other location will be able to analyze by the nonlinear program. The pipe whip restraint capacity is determined by the GE U-rod design and PDA program for selection.

STAFF EVALUATION:

CONCLUSION:

NRC Audit of GE on
ABWR PIPING DESIGN CRITERIA AND SAMPLE ANALYSES
March 23-27, 1992

Item No.: B4 ~~24~~ By: ______________

DESCRIPTION OF CONCERN:

In Section 3E.2.1 of the SSAR, GE proposed the use of a modified J-Integral and associated modified tearing modulus for beyond J-controlled crack growth characterization. Justify the proposed J_{mod}-T_{mod} characterization.

RESPONSE BY GE:

Section 3E.2.1 is revised to identify the approach as an illustrative one which, if adopted, should be justified based on its acceptability by the technical literature. A J_D-approach is identified as a potential more justifiable approach.

STAFF EVALUATION:

CONCLUSION:

NRC Audit of GE on
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March 23-27, 1992

Item No.: 25 (handwritten: 85)   By: ________

DESCRIPTION OF CONCERN:

Section 3E.2.21 describes the carbon steel fracture toughness test program. GE should indicate that the extent of the program indicated in Table 3E.2-4 may not be repesentative for the actual test program required for approval of an application of LBB qualification of selected piping systems.

RESPONSE BY GE:

The following is added at the end of the paragraph leading into Section 3E.2.21. "The purpose of the test program is to generate the necessary data for application in Section 3E.6 and to illustrate a general procedure of conducting the tests per requirements of Item (10) in Section 3E.1.2. The extent of the test program for NRC's approval of an application will depend upon the identified requirements."

STAFF EVALUATION:

CONCLUSION:

NRC Audit of GE on
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Item No.: 86 26 By: ________________

DESCRIPTION OF CONCERN:

Section 3.6.3 of the SSAR does not contain procedures and criteria for LBB evaluations of bimetallic welds. Provide these procedures and criteria.

RESPONSE BY GE:

Section 3E.3.4 is added to address the bimetallic welds of austenitic steel to ferritic steel as follows: "For joining austenitic steel to ferritic steel, the Ni-Cr-Fe Alloys 82 or 182 are generally used for weld metals. The procedures recommended in Section 3E.3.3 for the austenitic welds are applicable to these weld metals. This is justified based on the common~~ality of the~~ procedures, adopted for flaw acceptance in the ASME Code Section XI, Article IWB-3600 and Appendix C, for both types of the welds. If other types of bimetallic weld metals are used, proper procedures should be used with generally acceptable justification."

STAFF EVALUATION:

CONCLUSION:

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Item No.: ~~27~~ 87 By: ______________

DESCRIPTION OF CONCERN:

In Section 3E.3.1.3 of the SSAR, GE Proposed a linear interaction criterion for tearing instability evaluations for combinations of applied tension and bending stresses. Justify the proposed criterion.

RESPONSE BY GE:

The second paragraph of Section 3E.3.1.3 is expanded as follows: "The applicabilty of this proposed rule should be justified by providing a comparison of the predictions by the proposed approach (or an alternate approach) with those available for cases where the combination is treated together."

STAFF EVALUATION:

CONCLUSION:

NRC Audit of GE on
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Item No.: 68 ~~28~~ By: ______

DESCRIPTION OF CONCERN:

In Section 3E.4 of the SSAR, GE proposed a procedure for estimation of leak rates during blowdown of saturated steam. Justify the proposed procedure.

RESPONSE BY GE:

The following is added to the fourth paragraph of Section 3E.4.1.1 after the first lead-in sentence: "However, a justification should be provided by comparing the predictions of the proposed method with the available experimental data, or a generally acceptable method, if available, should be used."

STAFF EVALUATION:

CONCLUSION:

NRC Audit of GE on
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Item No.: 29 By: ________________

DESCRIPTION OF CONCERN:

Clarify the Gudas data in Figure 3E.2-8 of the SSAR.

RESPONSE BY GE:

The Gudas data in Figure 3E.2-8 are for carbon steel SA106 Gr. B base metal (with L-C orientation). A clarification is included on the figure.

STAFF EVALUATION:

CONCLUSION:

displacement),

a_0, a are the initial and current crack lengths respectively.

For the particular case of the compact tension specimen geometry, the preceding Equation and the corresponding rate take the form

$$J_{mod} = J + \int_{a_0}^{a} \gamma \frac{J_{pl}}{b} da \qquad (E.2\text{-}4)$$

where J_{pl} is the nonlinear part of the deformation theory J, b is the remaining ligament and γ is

$$\gamma = (1+0.76\, b/W) \qquad (E.2\text{-}5)$$

Consequently the modified material tearing modulus T_{mod} can be defined as:

$$T_{mod} = T_{mat} + \frac{E}{\sigma_f^2} \frac{\gamma}{b} J_{pl} \qquad (E.2\text{-}6)$$

Since in most of the test J-R curves the $\omega > 10$ limit was violated, all of the material J-T data were recalculated in the J_{mod}, T_{mod} format. The J_{mod}, T_{mod} calculations were performed up to crack extension of $\Delta a = 10\%$ of the original ligament in the test specimen. The J-T curves were then extrapolated to larger J values using the method recommended in NUREG 1061, Vol. 3 [9].

3E.2.2 Carbon Steels and Associated Welds

The carbon steels used in the ABWR reactor coolant pressure boundary piping are: SA 106 Gr B, SA 333 Gr. 6 and SA 672, Gr. C70. The first specification covers seamless pipe and the second one pertains to both seamless and seam-welded pipe. The last one pertains to seam-welded pipe for which plate stock is specified as SA 516. Gr. 70. The corresponding material specifications used for carbon steel flanges, fittings and forgings are ~~given by a GE specification [10]~~ equivalent to the piping specifications.

While the chemical composition requirements for a pipe per SA 106 Gr. B and SA 333 Gr. 6 are identical, the latter is subjected to two additional requirements: (1) a normalizing heat treatment which refines the grain structure and, (2) a charpy test at -50°F with a specified minimum absorbed energy of 13 ft-lbs.

The electrodes and filler metal requirements for welding carbon steel to carbon or low alloy steel are as specified in Table 3E.2-1. A comprehensive test program was undertaken to characterize the carbon steel base and weld material toughness properties. The next section describes the scope and the results of this program.

3E.2.2.1 Fracture Toughness Test Program

The test program consisted of generating true stress-true strain curves, J-Resistance curves and the charpy V-notch tests. Two materials were selected : (1) SA333 Gr. 6, 16 inch diameter Schedule 80 pipe and (2) SA516, Gr. 70, 1 1/4 inch thickness plate. Table 3E.2-2 shows the chemical composition and mechanical property test information provided by the material supplier. The materials were purchased to the same specifications as those to be used in the ABWR applications.

To produce a circumferential butt weld, the pipe was cut in two pieces along a circumferential plane and welded back using the shielded metal arc process. The weld prep was of single V design with a backing ring. The preheat temperature was 200°F.

The plate material was cut along the longitudinal axis and welded back using the SAW process. The weld prep was of a single V type with one side as vertical and the other side at 45°. A backing plate was used during the welding with a clearance of 1/4 inch at the bottom of the V. The interpass temperature was maintained at less than 500°F.

Both the plate and the pipe welds were X-rayed according to Code [11] requirements and were found to be satisfactory.

It is well-known that carbon steel base materials show considerable anisotropy in fracture toughness properties. The toughness depends on the orientation and direction of propagation of the crack in relation to the principal direction of mechanical working or

¶ The Jmod - Tmod approach is used in this appendix for illustrative purposes. It should be adopted if justified based on its acceptability by the technical literature. A JD-approach is another more justifiable approach

Insert A For Page 3E.3-4

3E.3.3 Modified Limit Load Methodology for Austenitic Stainless Steel Piping

Reference 16 describes a modified limit load methodology that may be used to calculate the critical flaw lengths and instability loads for austenitic stainless steel piping and associated welds. If appropriate, this or an equivalent methodology may be used in lieu of the (J/T) methodology described in 3E.3.1.

3E.3.4 Methodology for Bimetallic Welds

Insert from Response 26

3E.3.5 References

See Page 3E.3-4 Revised Page No

the J-integral for a pipe with a through-wall circumferential flaw subjected to pure tension or pure bending are as follows

Tension

$$J = f_1\left(a_e, \frac{R}{t}\right)\frac{P^2}{E} + \alpha\sigma_0\epsilon_0 c\left(\frac{a}{b}\right) b_1\left(\frac{a}{b}, n, \frac{R}{t}\right)\left[\frac{P}{P_0}\right]^{n+1} \qquad (3E.3\text{-}6)$$

where,

$$f_1\left(\frac{a}{b}, n, \frac{R}{t}\right) = \frac{a F^2\left(\frac{a}{b}, n, \frac{R}{t}\right)}{4\pi R^2 t^2}$$

$$P_0 = 2\sigma_0 Rt\left[\pi - \gamma - 2 \arcsin\left(\frac{1}{2}\sin\gamma\right)\right]$$

Bending

$$J = f_1\left(a_e, \frac{R}{t}\right)\frac{M^2}{E} + \alpha\sigma_0\epsilon_0 c\left(\frac{a}{b}\right) h_1\left(\frac{a}{b}, n, \frac{R}{t}\right)\left[\frac{M}{M_0}\right]^{n+1} \qquad (3E.3\text{-}7)$$

where,

$$f_1\left(\frac{a}{b}, n, \frac{R}{t}\right) = \pi a\left(\frac{R}{I}\right)^2 F^2\left(\frac{a}{b}, n, \frac{R}{t}\right)$$

$$M_0 = M_0\left[\cos\left(\frac{\gamma}{2}\right) - \frac{1}{2}\sin(\gamma)\right]$$

The nondimensional functions F and h are given in Reference 6

While the calculation of J for given α, n, σ_0 and load type is reasonably straightforward, one issue that needs to be addressed is the tearing instability evaluation when the loading includes both the membrane and the bending stresses. The estimation scheme is capable of evaluating only one type of stress at a time. This aspect is addressed next.

3E.3.1.3 Tearing Instability Evaluation Considering Both the Membrane and Bending Stresses

Based on the estimation scheme formulas and the tearing instability methodology just outlined, the instability bending and tension stresses can be calculated for various through-wall circumferential flaw lengths. Figure 3E.3-2 shows a schematic plot of the instability stresses as a function of flaw length. For the same stress level, the allowable flaw length for the bending is expected to be larger than the tension case.

When the applied stress is a combination of the tension and bending, a linear interaction rule is used to determine the instability stress or conversely the critical flaw length. The application of linear interaction rule is certainly conservative when the instability load is close to the limit load.

The interaction formulas are following: (See Figure 3E.3-2)

Critical Flaw Length

$$a_c = \left(\frac{\sigma_t}{\sigma_t + \sigma_b}\right) a_{c,t} + \left(\frac{\sigma_b}{\sigma_t + \sigma_b}\right) a_{c,t} \qquad (3E.3\text{-}8)$$

where:

σ_t = applied membrane stress

σ_b = applied bending stress

$a_{c,t}$ = critical flaw length for a tension stress of $(\sigma_t + \sigma_b)$

$a_{c,b}$ = critical flaw length for a bending stress of $(\sigma_t + \sigma_b)$

Instability Bending Stress

$$S_b = \left(1 - \frac{\sigma'_t}{\sigma_t}\right)\sigma'_b \qquad (3E.3\text{-}9a)$$

3E.4 LEAK RATE CALCULATION METHODS

Leak rates of high pressure fluids through cracks in pipes are a complex function of crack geometry, crack surface roughness, applied stresses, and inlet fluid thermodynamic state. Analytical predictions of leak rates essentially consist of two separate tasks: calculation of the crack opening area, and the estimation of the fluid flow rate per unit area. The first task requires the fracture mechanics evaluations based on the piping system stress state. The second task involves the fluid mechanics considerations in addition to the crack geometry and its surface roughness information. Each of these tasks are now discussed separately considering the type of fluid state in BWR piping.

3E.4.1 Leak Rate Estimation for Pipes Carrying Water

EPRI-developed computer code PICEP [1] ~~was~~ may be used in the leak rate calculations. The basis for this code and comparison of its leak rate predictions with the experimental data is described in References 2 and 3. This code ~~was also recently~~ was used in the successful application of LBB to primary piping system of a PWR. The basis for flow rate and crack opening area calculations in PICEP is briefly described first. A comparison with experimental data is shown next.

3E.4.1.1 Description of Basis for Flow Rate Calculation

The thermodynamic model implemented in PICEP computer program assumes the leakage flow through pipe cracks to be isenthalpic and homogeneous, but it accounts for non-equilibrium "flashing" transfer process between the liquid and vapor phases.

Fluid friction due to surface roughness of the walls and curved flow paths has been incorporated in the model. Flows through both parallel and convergent cracks can be treated. Due to the complicated geometry within the flow path, the model uses some approximations and empirical factors which were confirmed by comparison against test data

For given stagnation conditions and crack geometries, the leak rate and exit pressure are calculated using an iterative search for the exit pressure starting from the saturation pressure corresponding to the upstream temperature and allowing for friction, gravitational, acceleration and area change pressure drops.. The inertial flow calculation is performed when the critical pressure is lowered to the back pressure without finding a solution for the critical mass flux.

A conservative methodology was developed to handle the flow of two-phase mixture or superheated steam through a crack. To make the model continuous, a correction factor was applied to adjust the mass flow rate of a saturated mixture to be equal to that of a slightly subcooled liquid. Similarly, a correction factor was developed to ensure continuity as the steam became superheated. The superheated model was developed by applying thermodynamic principles to an isentropic expansion of the single phase steam.

The code can calculate flow rates through fatigue or IGSCC cracks and has been verified against data from both types. The crack surface roughness and the number of bends account for the difference in geometry of the two types of cracks. The guideline for predicting leak rates through IGSCCs when using this model was based on obtaining the number of turns that give the best agreement for Battelle Phase II test data of Collier et al. [~~4~~ 5]. For fatigue cracks, it is assumed that the crack path has no bends.

3E.4.1.2 Basis for Crack Opening Area Calculation

The crack opening area in PICEP code is calculated using the estimation scheme formulas. The plastic contribution to the displacent is computed by summing the contributions of bending and tension alone, a procedure that underestimates the displacent from combined tension and bending. However, the plastic contribution is expected to be insignificant because the applied stresses at normal operation are generally such that they do not produce significant plasticity at the cracked location.

¶ Other methods (e.g., Reference 4) may be used for leak rate estimation at the descretion of the applicant.

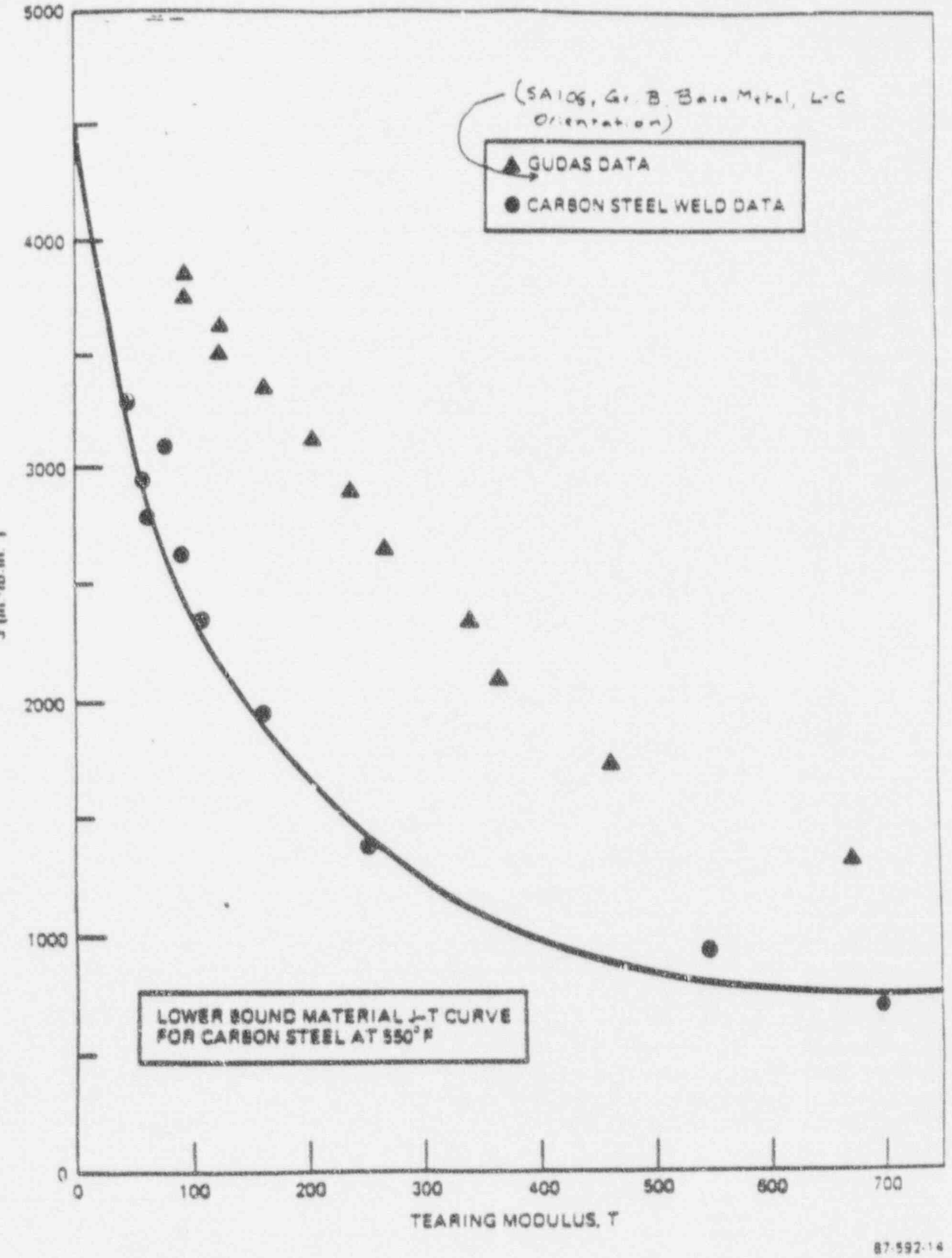

Figure 3E.2-8 PLOT OF 550° F J_{mod}, T_{mod} DATA FROM TEST J–R CURVE

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Item No.: B10   By: ________________

DESCRIPTION OF CONCERN:

THE MATERIALS SPECIFIED IN SECTIONS 3E.2.2, 3E.6.1.3 AND 3E.6.2.4 FOR THE REACTOR COOLANT PRESSURE BOUNDARY PIPING ARE INCONSISTENT. CORRECT THE INCONSISTENCY TO SPECIFY THE MATERIALS TO BE USED.

RESPONSE BY GE:

The inconsistencies in the SSAR will be corrected.

STAFF EVALUATION:

CONCLUSION: