Commonwealth Edison
One First National Plaza, Chicago, Illinois
Address Reply to: Post Office Box 767
Chicago, Illinois 60690 - 0767

August 20, 1987

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

Subject: LaSalle County Station Units 1 and 2
Operability Assessment Criteria for
Piping Systems: Supplemental Response
NRC Docket Nos. 50-373 and 50-374

References (a): Letter dated October 8, 1986 transmitting "Topical Report on Operability Assessment of ASME Section III, Piping and Supports after Unanticipated Loadings."

(b): Letter dated November 20, 1986 from E.G. Adensam requesting additional information on Operability Assessment Criteria.

Dear Sir:

Attached are the responses to the NRC questions transmitted in Reference (b). These questions were in regard to the "Topical Report on Operability Assessment of ASME Section III Piping and Supports After Unanticipated Loadings" transmitted in reference (a). The operability assessment criteria in the original report was modified to include responses to NRC questions.

During the preparation of this response, tests conducted by General Electric (GE) reported in GE document NEDC-31364, indicated that requirements in another GE report No. NEDO-21985 are no longer necessary. Those tests were performed by GE under contract to the NRC and EPRI. Based on this data, the operability criteria in the original report (Reference (a)) have been changed to reflect this new information.

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Please direct any questions you may have regarding this matter to this office.

Very truly yours,

C. M. Allen
Nuclear Licensing Administrator

lm

Enclosure with 2 attachments

cc: P. Shemanski (NRR)
Resident Inspector - LSCS
Regional Administrator - RIII
J. Gavula - RIII

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QUESTIONS ON OPERABILITY ASSESSMENT CRITERIA

	QUESTIONS	COMMENTS
1.0	GENERAL QUESTIONS REGARDING THE APPLICABILITY OF THE PROPOSED OPERABILITY CRITERIA	
1.1	The last sentence of the first paragraph under Section 2.0, "Background", seems to imply that any evaluation for unanticipated loadings would be limited to only the subsystem in which the loading or support component failure occurs. What evaluations would be performed on branch line systems if, on the run subsystem, an unanticipated loading occurs?	Based on the observed failure, a loading mechanism will be postulated. All piping subject to the above load will be evaluated. The above evaluation will include branch piping provided the load on the branch is significant and/or the displacement of the header at the branch location is significant.
1.2	Are proposed operability criteria intended to be used to assess the functional adequacy of valves, pumps, turbines, or other mechanical/electrical equipment?	The proposed criteria is intended for piping. Valves, pumps, turbines and other mechanical components will be evaluated on a case by case basis.
1.3	Will analysis techniques to determine piping system responses and support loads be the same as those used for the original design calculations? Would independent support motion, ASME Code Case N-411 damping, or response spectra peak shifting (ASME Code Case N-397) be utilized in the calculations involving unanticipated dynamic loads?	The analysis technique that is best suited for the postulated load will be used. An attempt will be made to predict the stresses and loads as accurately as feasible. Independent support motion, Code Case N-411 damping and response spectra peak shifting will be used where appropriate.
1.4	What course of action is planned if evaluations indicate concern at locations where excessive deformations (i.e. large strains) are not acceptable (e.g. flange leakage, piping components or equipment nozzles deform such that the flow area reduces beyond that required by system performance, etc.)?	Visual inspection will be performed. Based on the nature and extent of the observed deformation, if any, NDE, repair or replacement of the component will be recommended.
1.5	Are over pressurization loadings or temperatures beyond design limits included in the definition of unanticipated loadings for the proposed operability criteria?	Yes

QUESTIONS ON OPERABILITY ASSESSMENT CRITERIA

	QUESTIONS	COMMENTS
1.6	Will "as-built" piping system data per I&E Bulletin 79-14 requirements be utilized for the reanalysis effort?	The piping system data from the latest piping analysis will be used. The latest piping analysis includes all reconciliation for as-built (I&E Bulletin 79-14) dimensions outside tolerances.
1.7	Please discuss the accuracy of linear elastic techniques in predicting large strains, stresses significantly beyond the material yield strength, equipment responses, and support loads which may be evaluated under the proposed operability criteria.	Linear elastic methods are not adequate for accurately predicting large deformations or stresses that are significantly beyond yield. However, they are adequate for predicting fatigue damage provided they are interpreted using consistent test data. The proposed approach is consistent with the Code.
1.8	After the discovery of an unanticipated loading, what course of action will be followed? The response should include when the discovery is made during operation and during an outage, whether or not examination or component replacement would be made, in what time frame, monitoring programs, etc. What corrective actions would be taken to prevent the recurrence of unanticipated loads?	See the attached flow chart for the course of action to be taken after an unanticipated loading. Whether the discovery is made during operation or during an outage, the course of action is the same. If a component does not pass the operability criteria, the component will immediately be declared inoperable and be taken out of service. The component will not be declared operable and returned to service until it passes visual examination or NDE, or the component is repaired or replaced. Corrective actions will be developed on a case-by-case basis after analyzing the source of the unanticipated loading. Examples of corrective actions already implemented included: 1) removing snubbers which were highly susceptible to failure by redesigning the piping support arrangement, and 2) installing new vents on the RHR system where the inability to vent some sections of the system was identified as the problem. Monitoring programs will be considered if the unanticipated load cannot be quickly identified and eliminated.

QUESTIONS ON OPERABILITY ASSESSMENT CRITERIA

	QUESTIONS	COMMENTS
1.9	Would postulated line break locations per SRP 3.6.2 criteria, in-service inspection (ISI) requirements per ASME Section XI, or any other operational requirements change as a result of recalculated stresses or cumulative fatigue values evaluated due to unanticipated loadings? Would line break locations be postulated for Class 1 and Class 2/3 piping if the evaluated cumulative usage factor exceeds 0.1? Discuss the intended course of action and the impact on operability if the stress limit of 0.8 $(1.2S_h + S_a)$ for Class 2/3 piping or the stress limit of $2.4S_m$ for Class 1 piping is exceeded one or more times?	Unanticipated loads are not design basis loads and are expected to happen much less than 2% of the life of the plant. Therefore, if an unanticipated load causes the piping stress to exceed the limit of 2.4 S_m for Class 1 piping or the limit of 0.8 $(1.2\ S_h + S_a)$ for Class 2/3 piping, one or more times, or causes the cumulative fatigue usage factor to exceed 0.1, no new line break locations will be postulated nor will any new locations be added to the ISI program. However, if the unanticipated load causes piping stresses to exceed ASME Service Level D limits, the overstressed locations will be visually inspected. Furthermore, NDE will be performed at locations where the cumulative fatigue usage factor has exceeded 1.0. If deformation or indications are found, either by visual inspection or NDE, and repair or replacement is not necessary according to Section XI requirements, these locations will be added to the ISI program. Corrective actions to prevent the unanticipated load from reoccurring will be developed. If the unanticipated load cannot be prevented, it will then become a design basis load. The piping subsystems affected by the new design basis load will be reanalyzed and redesigned, if necessary. The stress reports will be revised to incorporate the new design basis load.
1.10	What edition and addenda of the ASME Code would be utilized in the proposed evaluations?	The Code of Record and sections of later editions and addenda maybe used if the differences in the later editions and addenda can be satisfactorily reconciled with the Code of Record in accordance with Section XI.

QUESTIONS ON OPERABILITY ASSESSMENT CRITERIA

QUESTIONS	COMMENTS
2.0 SPECIFIC QUESTIONS REGARDING CLASS 1 PIPING SYSTEMS AND WELDED ATTACHMENTS OPERABILITY CRITERIA	
2.1 Does the first sentence under Section 3.1, "Piping and Welded Attachments," imply that the effects of unanticipated loadings must satisfy all the requirements of NB-3600, including stress limits? If this is not the proper interpretation, are alternate stress limits (if applicable, please specify and discuss) proposed for the evaluation of Class 1 piping and welded attachments subjected to unanticipated thermal loadings? What course of action (visual examinations, NDE, component replacement, etc.) would be followed if either of these stress limits are exceeded? If just an evaluation of fatigue life is proposed and no stress limits are implied in the proposed operability criteria for unanticipated thermal loads, please discuss the impact on operability of Class 1 piping and welded attachments subjected to potentially excessive and repetitive thermal gradients, thermal ratchet loadings, elastic fatigue loadings, and elastic-plastic fatigue loadings.	To justify operability, only the requirements of NB-3600 for Service level D Units shall be satisfied for sustained plus mechanical loads. This requirement is shown in detail in Attachment "A", for piping and pipe supports with stress limits. See flow chart for course of action upon exceeding these stress limits. If the criteria in Attachment "A" is not satisfied, then the system still can be shown to be operable, if one of the following is satisfied: a. Cumulative usage factor (due to potentially excessive and repetitive thermal gradients, thermal ratchet loadings, elastic fatigue loadings, and elastic-plastic fatigue loadings) is less than 1, and visual inspection shows no visible deformation. b. If the cumulative usage factor (due to potentially excessive and repetitive thermal gradients, thermal ratchet loadings, elastic fatigue loadings, and elastic-plastic fatigue loadings) is more than 1, then NDE will be performed. If the NDE results show no damage, then the system will be classified operable.
2.2 What is the impact on operability if the recalculated stresses due to an unanticipated thermal loading exceed $3S_m$, potentially preventing elastic-plastic shakedown from occurring.	The proposed visual inspection along with NDE is intended to address operability concerns due to stresses exceeding $3\ S_m$.

	QUESTIONS	COMMENTS
2.3	Will the GE Topical Report NEDO-21985 be utilized for evaluating unanticipated mechanical loadings? What is the intended course of action (visual examination, NDE, component replacement, etc.) if the stress limits specified in that document are exceeded? Will fatigue effects from unanticipated mechanical loadings be incorporated into the cumulative fatigue life? If so, explain the methodology to be utilized.	The GE Topical Report NEDO-21985 will not be utilized for evaluating unanticipated mechanical loadings. This is because of tests performed by GE (NEDC-31364) and EPRI for the NRC has shown that piping components do not experience plastic collapse under dynamic loading up to 24 times the load required to achieve Level D stress limits (linear response spectrum analysis with 2% damping) and that this multiple becomes 12 instead of 24 if Code Case N-411 damping is used in the analysis. Also with regard to functionality, the tests show that the failure mode for elbows and tees (most critical fittings) is fatigue ratcheting, rather than ductile collapse or hinge formation. Tests results also show that functionality may not be a limiting concern since the component's diameter, and hence flow area, appear to be increasing as plastic ratcheting occurs. For the above reasons, GE Topical Report NEDO-21985 need not be met. The unanticipated loads will be classified as faulted load. They are included in the fatigue evaluation. The fatigue evaluation will be per ASME Code Section III NB.
2.4	Per the requirements of the proposed operability criteria, under what circumstances and when would visual examinations of Class 1 piping systems or welded attachments be performed after unanticipated loadings? Explain for both mechanical and thermal loadings.	See flow chart and answer to Question 2.1.
2.5	Per the requirements of the proposed operability criteria, under what circumstances and when would NDE examinations of Class 1 piping systems or welded attachments be performed after unanticipated loadings? Explain for both mechanical and thermal loadings.	See flow chart and answer to Question 2.1.

QUESTIONS ON OPERABILITY ASSESSMENT CRITERIA

	QUESTIONS	COMMENTS
2.6	Per the requirements of the proposed operability criteria, under what circumstances and when would replacement of Class 1 piping system components or welded attachments be performed after unanticipated loadings? Explain for both mechanical and thermal loadings.	The Class 1 component will be repaired or replaced if it does not meet ASME Code Section XI requirements (also see flow chart).
2.7	How are welded attachments to be analytically evaluated under the proposed operability criteria? Would WRC Bulletin 107, ASME Code Cases N-318, N-391 and N-393, or other methodology (please specify) be utilized?	WRC Bulletin 198, ASME Code Cases N-318, N-391 and N-392 and "Stress Concentration in Tubular Joints" by J. S. Kuang, A. B. Potvin and R. D. Leick, Offshore Technology Conference Paper, Number 2205, 1975, will be used.
2.8	How do ASME Section XI requirements correlate with the proposed operability criteria for Class 1 piping systems? Do the inspection requirements of 4 and 5 above satisfy Section XI requirements?	The inspection procedures satisfy all requirements of ASME Section XI.
2.9	Tests have indicated that the fatigue life of material is dependent upon the order and magnitude of cyclic loadings imposed. What effects do unanticipated loadings have on the predicted fatigue life of piping components, especially if the unanticipated loading results in large imposed strains? Is the cumulative usage factor of 1.0 for both design and unanticipated loadings technically adequate? Should the cumulative usage factor due to unanticipated loadings alone be limited to a value less than 1.0 to minimize potential reductions in the predicted fatigue life?	Unanticipated loadings may decrease the fatigue life of piping components and this is considered in the proposed operability criteria. Fatigue damage from unanticipated loading is calculated using an approach that is consistent with the intent of the Code. Cumulative usage factors from both unanticipated and design basis loads are combined and the total usage factor is limited to 1.0.

QUESTIONS	COMMENTS
3.0 SPECIFIC QUESTIONS REGARDING CLASS 2 AND 3 PIPING SYSTEMS AND WELDED ATTACHMENTS OPERABILITY CRITERIA	
3.1 Regarding the last sentence under Section 3.1, "Piping and Welding Attachments", please define for clarity the term "highly stressed areas"?	Highly stressed areas are the piping locations that exceed Code allowables.
3.2 No ASME Code stress limits are implied in the proposed operability criteria for unanticipated thermal loads. Are alternate stress limits (if applicable, please specify and discuss) proposed for the evaluation of Class 2 and 3 piping and welded attachments subjected to unanticipated thermal loadings? What course of action (visual examination, NDE, component replacement, etc.) would be followed if these stress limits are exceeded? If just an evaluation of fatigue life is proposed and no stress limits are implied in the proposed operability criteria for unanticipated thermal loads, please discuss the impact on operability of Class 2 and 3 piping and welded attachments subjected to potentially excessive and repetitive thermal gradients, thermal ratchet loadings, elastic fatigue loadings, and elastic-plastic fatigue loadings.	See answer to Question 2.1.
3.3 What is the impact on operability if the recalculated stresses due to an unanticipated thermal loading exceed $2S_y$ (taken at operating temperature of the transient), potentially preventing elastic-plastic shakedown from occurring?	The proposed visual inspection along with NDE is intended to address operability concerns due to stresses exceeding $2\ S_y$ (See flow chart).
3.4 Will fatigue effects from unanticipated mechanical loadings be incorporated into the cumulative fatigue life? If so, explain the methodology to be utilized?	Yes, fatigue effects from unanticipated mechanical and thermal loadings will be added to the other design basis loads and incorporated into the fatigue life calculations using the method outlined in Attachment B.

QUESTIONS ON OPERABILITY ASSESSMENT CRITERIA

	QUESTIONS	COMMENTS
3.5	Per the requirements of the proposed operability criteria, under what circumstances and when would visual examinations of Class 2 and 3 piping systems or welded attachments be performed after unanticipated loadings? Explain for both mechanical and thermal loadings.	See flow chart and answer to Question 3.2.
3.6	Per the requirements of the proposed operability criteria, under what circumstances and when would NDE examinations of Class 2 and 3 piping systems or welded attachments be performed after unanticipated loadings? Explain for both mechanical and thermal loadings.	See flow chart and answer to Question 3.2.
3.7	Per the requirements of the proposed operability criteria, under what circumstances and when would replacement of Class 2 and 3 piping system components or welded attachments be performed after unanticipated loadings? Explain for both mechanical and thermal loadings.	Repair or replacement will be performed if ASME Section XI inspection requirements are not met (also see flowchart).
3.8	How are welded attachments to be analytically evaluated under the proposed operability criteria? Would WRC Bulletin 107, ASME Code Cases N-318, N-391 and N-392, or other methodology (please specify) be utilized.	WRC Bulletin 198, ASME Code Cases N-318, N-391 and N-392 and "Stress Concentration in Tubular Joints," by J. S. Kuang, A. B. Potvin and R. D. Leick Offshore Technology Conference Paper, Number 2205, 1975, will be used.
3.9	How do ASME Section XI requirements correlate with the proposed operability criteria for Class 2 and 3 piping systems? Do the inspection requirements of 5 and 6 above satisfy Section XI requirements?	The inspection procedures satisfy all the requirements of the ASME Code Section XI.
3.10	What is the intended course of action if the ratio of n/N exceeds 1.0?	Visual examination will be performed. If deformation is observed, then the component will be nondestructively (NDE) examined. Further, it will be included in ISI Program.
3.11	What material limitations are implied in the use of the fatigue equation $N = (245000/IS)^5$ cycles.	The curve $N = (245000/IS)^5$ cycles was originally developed for low carbon steel (SA-106). It can be used for all Low Carbon and Stainless Steels.

QUESTIONS	COMMENTS
3.12 Tests have indicated that the fatigue life of material is dependent upon the order and magnitude of cyclic loadings imposed. What effects do unanticipated loadings have on the predicted fatigue life of piping components, especially if the unanticipated loading results in large imposed strains? Is the cumulative usage factor of 1.0 for both design and unanticipated loadings technically adequate? Should the cumulative usage factor due to unanticipated loadings alone be limited to a value less than 1.0 to minimize potential reductions in the predicted fatigue life?	Unanticipated loadings may decrease tha fatigue life of piping components and this is considered in the proposed operability criteria. Fatigue damage from unanticipated loading is calculated using an approach that is consistent with the intent of the Code. Cumulative usage factors from both unanticipated and design basis loads are combined and the total usage factor is limited to 1.0.

	QUESTIONS	COMMENTS
4.0	SPECIFIC QUESTIONS REGARDING PIPING SUPPORT COMPONENTS AND STRUCTURES OPERABILITY CRITERIA	
4.1	Please define "faulted allowables" in terms of stress levels, load combinations, and the applicable criteria document.	Faulted condition is the same as Service Level D. The stress allowables, load combination and the applicable criteria as defined in the FSAR.
4.2	The proposed operability criteria states that, if faulted allowables are exceeded, visual examinations will be performed. Are these visual examinations adequate to ensure the continued functionality of the support or structure? What about subsurface cracks resulting from the potential overloadings? With regards to fatigue considerations, how many times would piping support components or structures be allowed to exceed their initial design stress allowables (normal, upset, emergency, and faulted)?	Yes, visual inspection in accordance with Section XI is adequate to ensure continued functionality. Subsurface cracks are not expected if there are no visible indications. If the component does not pass Section XI inspection requirements, the component will be repaired or replaced in accordance with Section XI. There is no limit to the number of times the piping support components or structures exceed their initial faulted design stress allowables. However, each time faulted allowables are exceeded, the pipe support component or structure must undergo and pass visual inspection in accordance with Section XI requirements. As mentioned before, unanticipated loads are expected to happen much less than 2% of the life of the plant. The emphasis is put on corrective actions to prevent unanticipated loads from reoccurring.
4.3	Per the requirements of the proposed operability criteria, under what circumstances and when would visual examinations of piping support components or structures be performed after unanticipated loadings? Explain for both mechanical and thermal loadings.	For both mechanical and thermal loads, the procedure is the same. If loads exceed faulted allowables, a visual examination will be performed. Please see the attached flowchart.

QUESTIONS ON OPERABILITY ASSESSMENT CRITERIA

	QUESTIONS	COMMENTS
4.4	Per the requirements of the proposed operability criteria, under what circumstances and when would NDE examinations of piping support components or structures be performed after unanticipated loadings? Explain for both mechanical and thermal loadings.	For both mechanical and thermal loads, the procedure is the same. If loads exceed faulted allowables, a visual examination will be performed. Please see the attached flowchart.
4.5	Per the requirements of the proposed operability criteria, under what circumstances and when would replacement of piping support components or structures be performed after unanticipated loadings? Explain for both mechanical and thermal loadings.	Piping support components or structures will be visually inspected and the decision to repair or replace any component will be per ASME Section XI requirements.
4.6	How would the modeling of pipe supports be reflected in the piping system reanalysis if the pipe support component or structure was sufficiently overloaded to cause plastic yielding, brittle fracturing, or buckling and result in a significant drop of the restraining capability of the support in question?	Bounding piping/support model or models will be developed on a case-by-case basis.
4.7	How do ASME Section XI requirements correlate with the proposed operability criteria for piping component supports? Do the inspection requirements of 4.3 and 4.4 above satisfy Section XI requirements.	Inspection requirements of 4.3 and 4.4 satisfy all the requirements of ASME Section XI.
4.8	How would containment penetrations be evaluated when subjected to unanticipated loads?	Containment penetrations will be evaluated per applicable ASME Code using faulted condition allowables.
4.9	How will standard pipe support components (catalog items) be evaluated?	If standard component support manufacturers' allowables are exceeded, the support will be evaluated per Subsection NF of ASME Code. If NF allowables are exceeded, visual inspection will be performed and the component supports will be replaced or repaired, if necessary.

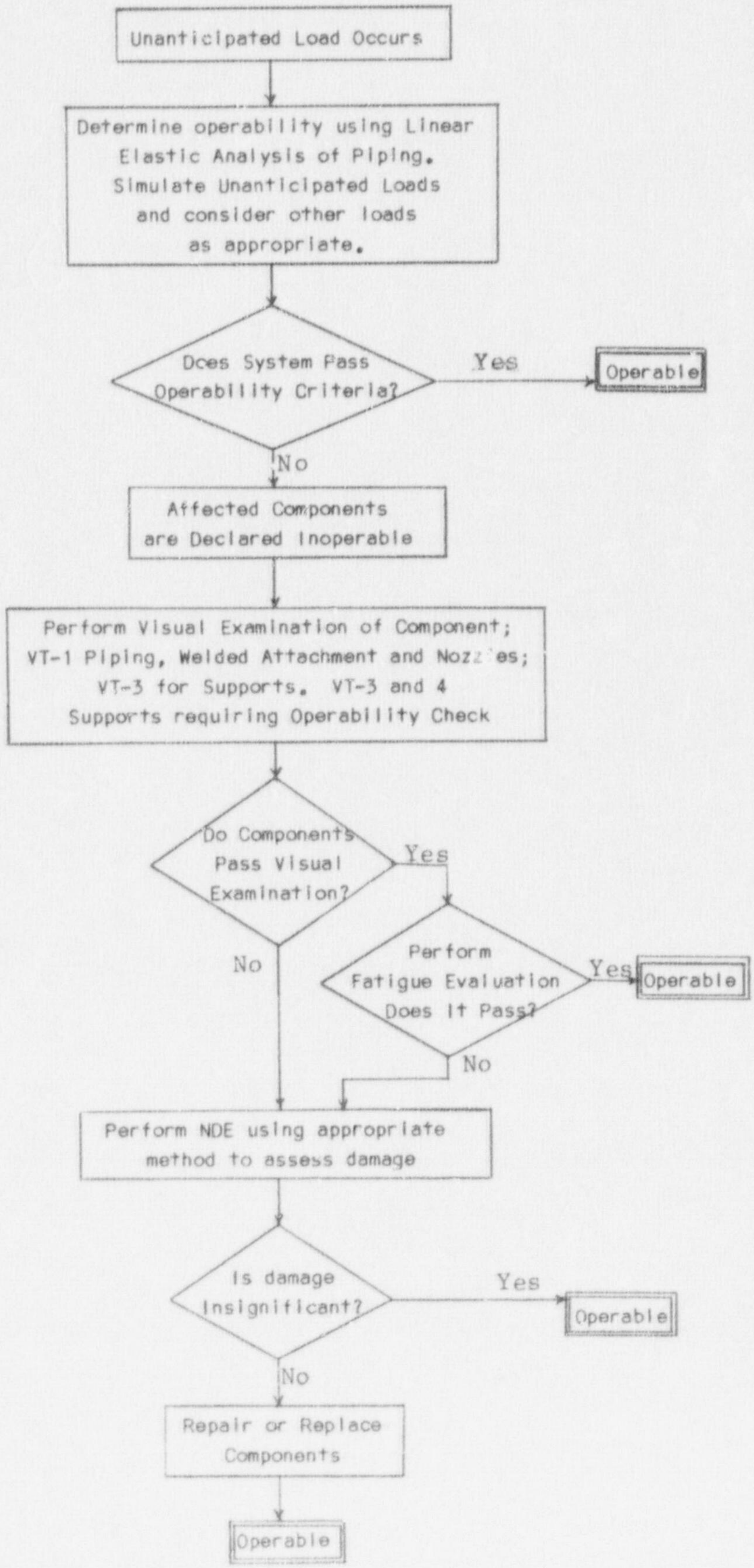
QUESTIONS ON OPERABILITY ASSESSMENT CRITERIA

QUESTIONS	COMMENTS
4.10 How will concrete expansion bolts for embedments be evaluated under the proposed operability criteria and the requirements of I&E Bulletin 79-02? Include commentary on load type combinations, load component (axial force, shear force, bending moments, and torsion) combinations, and planned evaluations if the concrete is locally cracked around the concrete expansion bolt(s) or embedments.	See Attachment A for safety factors. If concrete is locally cracked around the concrete expansion bolt(s) or embedments, then the support will be considered ineffective for operability assessment which is consistent with the I&E Bulletin 79-02.

QUESTIONS ON OPERABILITY ASSESSMENT CRITERIA

QUESTIONS	COMMENTS
5.0 SPECIFIC QUESTION REGARDING THE SARGENT AND LUNDY ATTACHMENT	
5.1 In order to clearly understand the intended use of the proposed operability criteria, please explain the terms "transient stresses" and "IE Bulletin No. 79-14 allowables" found in the last sentence of the second paragraph of Section 1.0, "Introduction". A similar comment regarding I&E Bulletin 79-14 allowables also appears in Section 7.0, "Conclusions".	The word transient stresses is intended to mean dynamic piping stresses due to mechanical transient loads such as hydraulic transient. The 79-14 allowables are conservatively defined as Service Level D (Faulted) piping allowables.

FLOWCHART


Unanticipated Load Occurs
Determine operability using Linear Elastic Analysis of Piping. Simulate Unanticipated Loads and consider other loads as appropriate.
Does System Pass Operability Criteria?
Yes
Operable
No
Affected Components are Declared Inoperable
Perform Visual Examination of Component; VT-1 Piping, Welded Attachment and Nozzles; VT-3 for Supports. VT-3 and 4 Supports requiring Operability Check
Do Components Pass Visual Examination?
Yes
Perform Fatigue Evaluation Does It Pass?
Yes
Operable
No
No
Perform NDE using appropriate method to assess damage
Is damage insignificant?
Yes
Operable
No
Repair or Replace Components
Operable

PIPING AND PIPE SUPPORT OPERABILITY CRITERIA

1.0 PURPOSE:

To establish a piping system assessment/acceptance criteria to verify that a safety related piping system will remain operable and perform its intended safety function while the plant is in the operating mode. This criteria will be implemented when it is verified that any of the following situations exist and it is determined that the situation results in a condition which exceed FSAR committments:

1. There is discrepancy between documented design basis condition and actual field condition (examples are; missing or broken weld, hanger, installation deviation greater than acceptable tolerance...etc.).

2. An unanticipated loading condition (example: hydraulic transient due to improper venting, snubber with high drag,...etc.).

2.0 SCOPE:

This procedure applies to safety related piping systems and pipe supports.

3.0 DEFINITIONS:

3.1 Operable:

A condition in which piping components and its supporting structure will continue to perform their intended safety function. This can only be a temporary condition and the design basis requirements shall be met during the next plant outage.

4.0 OPERABILITY CRITERIA

4.1 Piping Operability Criteria

Under maximum loading, the pipe stress shall meet the following.

a. Weight + pressure $\leq$ Sy

b. Weight + pressure + all other experienced occasional mechanical [(1)] loads $\leq$ 2Sy (ASME Level D Allowables).

c. If the thermal stresses exceeds code requirements, then perform fatigue evaluation as per Attachment "B", using operation history to date and postulated load till next outage.

Where Sy = Minimum Specified/Inplace Yield Strength at operating temperature.

(1) This includes but not limited to seismic load, fluid transient loads and SRV loads.

4.2 Standard Pipe Support Components (Catalog Items)

Under maximum loading, ASME level 'D' (Faulted) allowables shall be used.

4.3 Pipe Support Steel Operability Criteria

For situations discussed in Section 1.0 above, the loads under operating conditions shall not exceed 95% of the plastic capacity of the pipe support system.

For bolted/welded connections, the loads shall not exceed 95% of the ultimate capacity of the connections.

4.4 Concrete Expansion Anchor Assemblies:

Factor of Safety = 2

4.5 Supplemental Analytical Techniques:

To assess the operability of pipe systems, the following techniques may be implemented:

1. Redistribution of loading within the pipe system.
2. Detailed dynamic analysis for dynamic loads.
3. Utilization of latest research data.
4. Use of actual material strength.

Piping and Welded Attachments

Class 1 piping will be evaluated per the fatigue evaluation requirements in ASME Code Section III, Subsection NB. The code does not provide any low cycle fatigue methodology for Class 2 and 3 piping. The following approach to fatigue evaluation of Class 2 and 3 piping is a logical extension of Code rules in the low cycle range using the same test data and the factor of safety that form the basis of ASME Code Section III Subsection NC/ND 3650 fatigue evaluation requirements for load cycles greater than 7000.

The fatigue requirement is satisfied using the following equations:

$$N = (245000/iS)^5 \text{ Cycles}$$

$$n/N \leq 1$$

where

n = Actual number of load cycles

N = Allowable number of load cycles

iS = Intensified pipe stress range. Code intensification factors are used.

If the piping is subjected to stress cycles with more than one stress level, then the cumulative fatigue damage is calculated using the Miner's rule as defined below:

$$\sum_{j=1}^{k} n_j/N_j \leq 1.0$$

where

n_j = Actual cycles associated with iS_j ($j = 1, 2, \ldots\ldots, k$)

N_j = Allowable cycles for stress level iS_j

iS_j = Stress level associated with loading event j

Further, the above approach could be used to evaluate mechanical loads.