CORRECTED PAGES

Attached are corrected pages to be inserted in the GIP.

CONTENTS

CONTENTS (Continued)

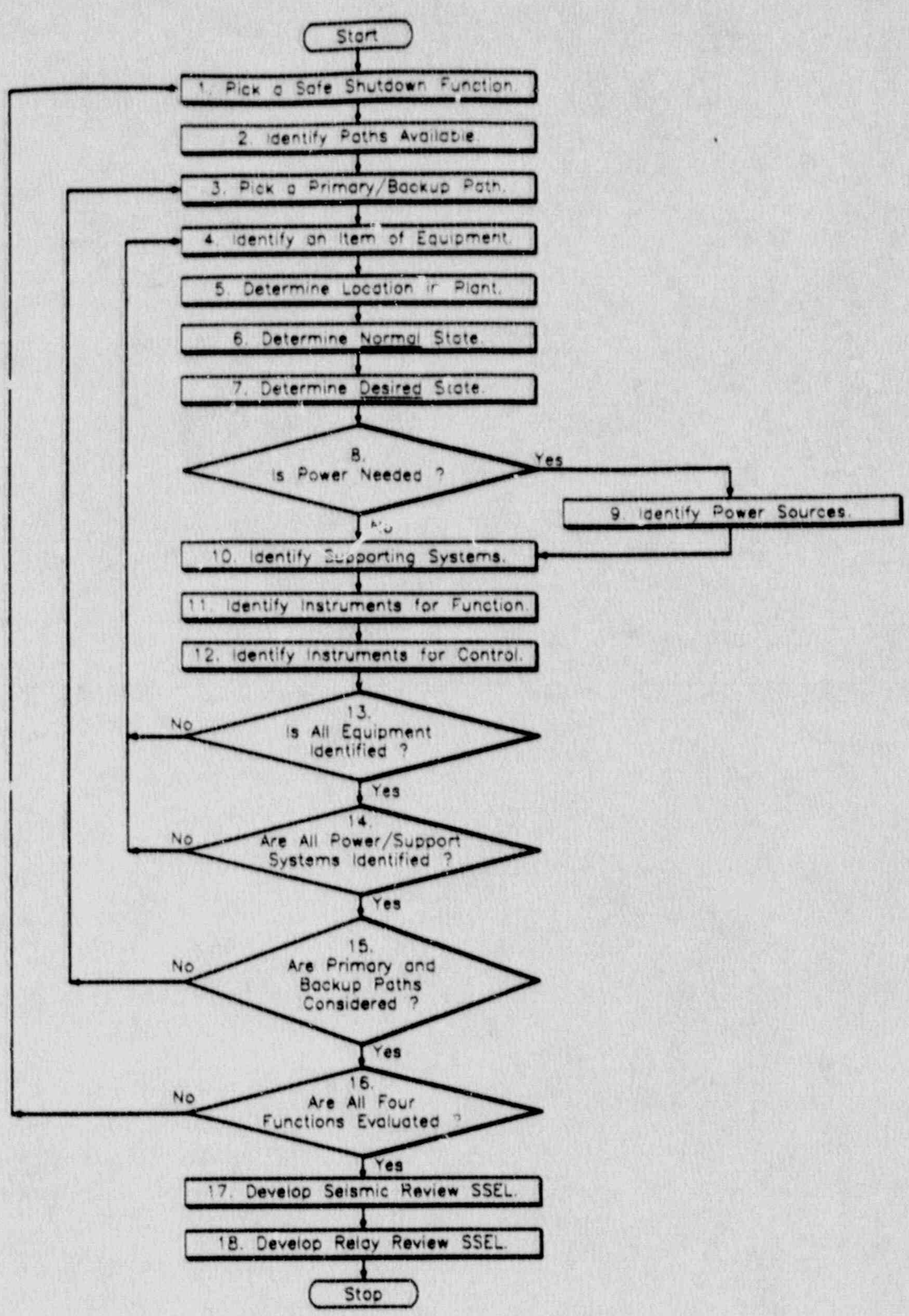

Figure A-10. Steps for Identifying Safe Shutdown Equipment.

Exhibit A-1

Page No. ___
Report Date/Time ________

SAFE SHUTDOWN EQUIPMENT LIST (SSEL)

FUNCTION ________________

ALTERNATIVE ________________

Line No. (1)	Train (2)	Eq. Cl. (3)	Equipment ID Number (4)	System/Equipment Description (5)	Drawing No. /Rev./Zone (6)	Bldg. (7)	Floor Elev. (8)	Room or Row/Col (9)	Eval Type (10)	Notes (11)	Normal State (12)	Desired State (13)	Power Req'd? (14)	Supporting Sys. Dwg. No./Rev. (15)	Required Supporting Systems or Components (16)

Certification

The information identifying the equipment required to bring the plant to a safe shutdown condition on this Safe Shutdown Equipment List (SSEL) is, to the best of our knowledge and belief, correct and accurate. **(One or more signatures of Systems or Operations Engineers)**

________________	________________	________
Print or Type **Name/Title**	Signature	**Date**
________________	________________	________
Print or Type **Name/Title**	Signature	**Date**

C.2.2 Check for Anchor Type

The specific manufacturers and product names of expansion anchors covered by this procedure are listed in Table C.2-2 below. This table also lists capacity reduction factors (RT_p for pullout and RT_s for shear) which should be multiplied by the nominal pullout and shear capacities (P_{nom}, V_{nom}) given in Table C.2-1 to obtain the allowable pullout and shear capacities (P_{all}, V_{all}) as follows:

$$P_{all} = P_{nom} \, RT_p$$
$$V_{all} = V_{nom} \, RT_s$$

Note that, generally, expansion anchors should not be used for securing vibratory equipment such as pumps and air compressors. If such equipment is secured with expansion anchors, then there should be a large margin between the pullout loads and the pullout capacities; i.e., the loads on these expansion anchors should be primarily shear.

The principal differences between shell- and nonshell-type expansion anchors are explained below.

Shell-type expansion anchors are expanded into the concrete by application of a setting force independent of the load later applied to the bolt or nut by the equipment being anchored. The key feature of this type of expansion anchor is that it relies upon its initial preset for holding it in place. Figure C.2-1 shows the features of several types of shell-type expansion anchors.

Figure C.2-1a shows a "Self-Drilling Type" of shell-type expansion anchor. This type of anchor is set in place by driving the shell down over the cone expander which is resting against the bottom of the hole.

Table C.2-2

TYPE OF EXPANSION ANCHORS
COVERED BY THIS PROCEDURE AND
ASSOCIATED CAPACITY REDUCTION FACTORS

Manufacturer	Product Name	Type	Capacity Reduction Factors (RT_p, RT_s)
Hilti	Kwik-Bolt	Nonshell	1.0
	HDI	Shell	1.0
	Sleeve	Nonshell	0.6
ITW/Ramset	Dynaset	Shell	1.0
	Dynabolt	Nonshell	0.75
	Trubolt	Nonshell	0.75
ITW/Ramset/ Redhead	Multiset Drop-In	Shell	1.0
	Self Drilling	Shell	1.0
	Dynabolt Sleeve	Nonshell	1.0
	Nondrill	Shell	1.0
	Stud	Shell	0.75
	TRUBOLT	Nonshell	0.75
Molly	Parasleeve	Nonshell	1.0
	MDI	Shell	1.0
	Parabolt	Nonshell	0.75
Phillips	Self-Drilling	Shell	1.0
	Wedge	Nonshell	1.0
	Sleeve	Nonshell	1.0
	Multi-Set	Shell	1.0
	Stud	Shell	1.0
	Non-Drilling	Shell	1.0
Rawl	Drop-In	Shell	1.0
	Stud	Shell	0.75
	Saber-Tooth	Shell	0.75
	Bolt	Nonshell	0.75
Star	Selfdrill	Shell	0.75
	Steel	Shell	0.6
	Stud	Shell	0.6
USE Diamond	Sup-R-Drop	Shell	1.0
	Sup-R-Stud	Shell	1.0
	Sup-R-Sleeve	Nonshell	1.0
	Sup-R-Drill	Shell	0.75
WEJ-IT	Drop-In	Shell	1.0
	Sleeve	Nonshell	1.0
	Wedge	Nonshell	0.75
	Stud	Shell	0.6

SQUG

Enclosure 1 to
SQUG Letter Dated
September 21, 1990

SIGNIFICANT CHANGES AND ADDITIONS
INCORPORATED IN REVISION 2 OF THE GIP

Numerous changes and additions are included in Revision 2 of the GIP compared to Revision 1. The significant ones are summarized below and grouped by the part and section of the GIP.

PART I.

Licensing and Implementation Guidelines, has been modified to more clearly address licensing issues covered in the NRC's Safety Evaluation Report (SER) on Revision 0 of the GIP and the Supplementary Safety Evaluation Report (SSER) No. 1 on Revision 1 of the GIP. The wording used in this part has also been revised to be as consistent as possible with the wording used in SSER No. 1. Since the format of this part of the GIP has changed, a "Road Map" has been prepared and included as an enclosure to the forwarding letter. Because of the narrative style of Part I Revision 2, the "Road Map" cross references the location of the issues and positions from Revision 1 to Revision 2.

PART II.

Section 1, Introduction, has been expanded to include a summary of the guidelines for the Cable and Conduit Raceway Review. Revisions to other parts of the Introduction also have been made to clarify the material.

Section 2, Seismic Evaluation Personnel, has been expanded to include the responsibility of the Seismic Capability Engineer (formerly called Seismic Capability "Member" Engineer) to establish in-cabinet amplification factors for the relay review. A section has been added which describes the two training courses SQUG is developing; Part III of the GIP (Requirements for SQUG Training Course) has been deleted. Section 2 also has been reorganized and the material revised to clarify the roles and responsibilities of the individuals involved in the USI A-46 review.

Section 3, [illegible]tification of Safe Shutdown Equipment, has been revised to incorporate agreements reached with the NRC Staff on several issues. Additions to Section 3 include a discussion of (1) the scope of the Cable and Conduit Raceway Review, (2) the suggested methods for performing the Operations Department review of the Safe Shutdown Equipment List (SSEL), and (3) the type of documentation which should be generated. This section also has been re-organized and the material revised to be consistent with the lessons learned during the three SQUG training courses.

Section 4, Screening Verification and Walkdown, has been revised to more clearly describe how to compare the seismic capacity of equipment to the seismic demand imposed upon it when using the Bounding Spectrum and Generic Equipment Ruggedness Spectra (GERS). The subsection on anchorage has been rewritten and expanded (1) to incorporate agreements reached with SSRAP and the NRC staff on numerous issues, (2) to include anchorage evaluations for J-bolts, and (3) to include all the information required to perform anchorage evaluation; Appendix C (Anchorage Data) also was updated to be consistent with these changes to Section 4. The remainder of Section 4 is revised for clarity and consistency with the remainder of the GIP.

Section 5, Outlier Identification and Resolution, has been expanded to address outliers for all aspects of the GIP evaluations, including relay evaluations, and the cable and conduit raceway review. This section also contains a number of editorial clarifications.

Section 6, Relay Functionality Review, has been revised to include a multi-level screening approach for comparing relay seismic capacity to seismic demand. This section also contains a number of editorial clarifications.

Section 7, Tanks and Heat Exchangers Review, has been revised to reflect resolution of numerous NRC and SSRAP comments. It now also allows evaluations of vertical tanks made of material other than steel and containing fluids other than water.

Section 8 Cable and Conduit Raceway Review, is a new section. It includes all the requirements for seismic review of cable tray and conduit raceway systems.

Section 9, Documentation, is revised to cover documentation requirements for all portions of the USI A-46 seismic review.

Section 10, References, includes the list of the latest available reference documents. Several EPRI and EQE documents are being finalized at this time; the final versions of these documents will be referenced in the next revision of the GIP.

Appendix A, Procedure for Identification of Safe Shutdown Equipment, includes a revised step-by-step procedure and flow diagram based on the lessons learned during the SQUG training courses.

Appendix B, Summary of Equipment Class Descriptions and Caveats, is a new appendix which includes a summary description of each of the equipment classes in the earthquake experience data base and the GERS testing data base. This appendix also includes, in one place, a listing of all the caveats and restrictions associated with the use of these data bases. The Seismic Evaluation Work Sheets (SEWS) which had been in Appendix B in Revision 1 of the GIP are now included in Appendix G.

Appendix C, Anchorage Data, is rewritten to cover the details of the various types of anchors now covered by the GIP. It is consistent with the anchorage evaluation methodology contained in Section 4.

Appendices D, E, and F, contain a number of editorial clarifications.

Appendix G, Screening and Evaluation Work Sheets (SEWS), contains the SEWS which had been included in Appendix B in Revision 1 of the GIP. The SEWS in Appendix G have been revised to be consistent with changes and additions made to the other sections of the GIP. In Revision 1 of the GIP, Appendix G had been reserved for guidance in obtaining additional data for use in the Seismic Margins Program. It has been decided that it is not appropriate to include such guidance in the GIP.

PART III

Requirements for SQUG Training Course, has been deleted from the GIP. A discussion of the requirements of the two SQUG training courses is included in Section 2 of Part II.

Enclosure 2 to
SQUG Letter Dated
September 21, 1990

ROAD MAP TO CHANGES IN PART I OF GIP, REVISION 2

Following issuance of the GIP, Revision 1, SQUG revised the format of Part I of the GIP to be more descriptive and useful to utility engineers implementing the procedure. Rather than providing SQUG positions and resolutions of issues in an abbreviated form, Part I was revised to be a narrative with instructive examples. Further, in this revision of Part I, SQUG attempts to incorporate information contained in the Staff's Supplemental Safety Evaluation Report (SSER) No. 1 on the GIP, dated June 29, 1990, with appropriate clarification.

To facilitate NRC Staff review of this revision to Part I, SQUG provides this "Road Map" which, in Section I, below, cross-references the positions and issues (called topics) in Part I of the GIP, Revision 1, to the location in Part I, Revision 2, where the same topics are addressed. Section II of this "Road Map" cross-references topics in the SSER No. 1 to the paragraphs in Part I, Revision 2, addressing those topics. It should be emphasized that this "Road Map" is provided to facilitate Staff review of the GIP and is not part of the GIP which, along with its references, stands alone.

Section I - Cross-Reference Between GIP Revision 1 and Revision 2

Listed below are topics from Part I, Revision 1, in order of page and paragraph number, along with the number of the paragraph in Revision 2 that addresses the same topic. Some topics were moved from Part I to Part II of the GIP in Revision 2 because of their technical nature; this is noted where appropriate. In many cases, the Revision 2 discussions of Revision 1 topics are clarified and expanded. Where appropriate, comments below point out the nature of the clarifications.

1. **The Generic Letter as Guidance**

   Revision 1: Page 2, numbered paragraph 1.

   Revision 2: The GIP provides guidance and commitments that fully incorporate the guidance in the Generic Letter. See paragraph 1.2. This concept is applied throughout Part I. The difference between GIP commitments and guidance is addressed in more detail in paragraph 1.3.

2. **The Role of SSRAP**

   Revision 1: Page 2, numbered paragraph 2, and page 12, numbered paragraph 1.

   Revision 2: Paragraph 2.2.2.

3. **Reportability and JCOs**

Revision 1: Page 3, numbered paragraph 3, page 7, numbered paragraph 2, and page 12, numbered paragraph 3.

Revision 2: Paragraph 2.2.5.

4. **Summary Reports**

Revision 1: Page 3, numbered paragraph 4.

Revision 2: Paragraph 2.2.4.

5. **Completion Reports**

Revision 1: Page 3, numbered paragraph 5.

Revision 2: Paragraph 2.2.4.

6. **Plant-Specific SERs**

Revision 1: Pages 3 and 12, numbered paragraphs 5.

Revision 2: Paragraph 2.2.10.

7. **Backfitting Analysis for Modifications**

Revision 1: Page 4, numbered paragraph 6.

Revision 2: Paragraph 2.3.1. SQUG's position on this topic has been explained in more detail.

8. **Compliance with GDC-2**

Revision 1: Page 5; page 13, numbered paragraph I.b.

Revision 2: Paragraph 2.3.2. SQUG has clarified this issue to address compliance with the seismic aspects of GDC-2.

9. **Revision of Plant Design Basis**

Revision 1: Page 5.

Revision 2: Paragraph 2.3.3. The discussion addresses revision of the licensing basis rather than the design basis. Examples are provided.

10. **USI A-17 and A-40**

Revision 1: Page 5.

Revision 2: Paragraph 2.3.5.

11. **Assumptions**

Revision 1: Page 6, numbered paragraph 1.

Revision 2: Paragraph 2.2.3.

12. **Scope of Safe Shutdown Equipment**

Revision 1: Page 6, numbered paragraph 2.

Revision 2: Part II, Section 3.3.

13. **Regulatory Guide 1.97 Equipment**

Revision 1: Page 6, numbered paragraph 2.

Revision 2: Paragraph 2.4.2.

14. **Seismic Interaction**

Revision 1: Page 6, numbered paragraph 3.

Revision 2: Part II, Section 4.5 and Appendix D.

15. **Instrument Air Lines**

Revision 1: Page 7, numbered paragraph 4.

Revision 2: Part II, Section 4.5 and Appendix D.

16. **72-Hour Hot Shutdown Criterion**

Revision 1: Page 7, numbered paragraph 5(a).

Revision 2: Paragraph 2.2.11.

17. **Safe Shutdown Equipment Redundancy**

Revision 1: Page 7, numbered paragraph 5(b).

Revision 2: Paragraph 2.4.1.

18. **Instrumentation and Controls**

Revision 1: Page 7, numbered paragraph 6.

Revision 2: Paragraph 2.4.3.

19. **Selecting Review Team Members**

Revision 1: Page 8, numbered paragraph 1.

Revision 2: Part II, Section 2.

20. **Multipliers**

Revision 1: Page 9, numbered paragraph 3.

Revision 2: Paragraph 2.2.6.

21. **Spectral Acceleration for Anchorage Verification**

Revision 1: Page 9, numbered paragraph 4.

Revision 2: Part II, Section 4.2.

22. **Relay Review**

Revision 1: Page 10, numbered paragraph 5.

Revision 2: Part II, Section 6.

23. **Flexibility in Considering Safety Function**

Revision 1: Page 11, numbered paragraph 6(1)

Revision 2: Paragraph 2.3.4, at end of paragraph.

24. **New and Replacement Equipment**

Revision 1: Page 11, numbered paragraphs 6(2) and (3), and page 14, numbered paragraph II.D.1.3.

Revision 2: Paragraphs 2.3.4, 2.3.3 and 1.2. This position is now explained in much greater detail, and includes specific criteria.

25. **Maintenance Programs**

Revision 1: Page 11, numbered paragraph 1.

Revision 2: Paragraph 2.2.7.

26. **Implementation Schedule**

Revision 1: Page 12, numbered paragraph 2.

Revision 2: Paragraphs 2.2.8 and 2.2.4.

27. **Third Party Audits**

Revision 1: Page 12, numbered paragraph 4.

Revision 2: Paragraph 2.2.9.

28. **Adequacy of Seismic Capacity of Equipment in Older Plants**

Revision 1: Page 13, numbered paragraph I.a.

Revision 2: Paragraph 1.1. SQUG has clarified that adequate margins of seismic capacity exist for properly anchored equipment.

29. **Operability of Equipment**

Revision 1: Page 13, numbered paragraph II.A.1.

Revision 2: Paragraph 2.4.1. This paragraph has been expanded to address single failure concerns and administrative controls for safe shutdown equipment removed from service.

30. **General Agreement vs. Full Concurrence**

Revision 1: Page 13, numbered paragraph II.D.1.1.1.

Revision 2: Paragraph 2.2.1. SQUG has clarified this position to indicate that full concurrence will be assumed unless specific concerns are identified.

31. **Postponement**

Revision 1: Page 14, numbered paragraphs II.D.1.1.a.2 and II.D.1.1.c.1.c.

Revision 2: Paragraph 2.2.8.

32. **New, Modified and Repaired Anchorages**

Revision 1: Page 14, numbered paragraph II.D.1.5.

Revision 2: Paragraph 2.3.4, near end.

33. **Recognizing, Documenting and Reporting Deficiencies**

Revision 1: Page 14, numbered paragraphs III.C.2.1.a and b.

Revision 2: Paragraph 2.2.5.

Section II - SQUG Responses to the NRC SSER No. 1 on the GIP, Revision 1

Part I of the GIP attempts to resolve all open issues in the Staff's SSER No. 1 on Part I, Revision 1, and incorporates the SSER No. 1 language, with clarification, wherever possible. Listed below are the SSER No. 1 topics cross-referenced to Part I, Revision 2.

1. **Differences Between GIP and Generic Letter**

   Staff SSER: Page 2, numbered paragraph 1.0.

   Revision 2: Paragraphs 1.2 and 2.2.8. Since implementation will not proceed until all open issues are resolved, problems with plant-specific open issues resulting from differences between the GIP and the Generic Letter should not occur.

2. **Reporting and the Need for JCOs**

   Staff SSER: Page 3, numbered paragraph 3, page 13, numbered paragraph 2, and page 17, numbered paragraph 3.

   Revision 2: Paragraph 2.2.5.

3. **Summary Reports**

   Staff SSER: Page 4, numbered paragraph 4.

   Revision 2: Paragraph 2.2.4. Section 9 of Part II clarifies that the information requested for "all the relays identified for safe shutdown" applies only to <u>essential</u> relays.

4. **Completion Reports**

   Staff SSER. Pages 4 and 5, numbered paragraphs 5.

   Revision 2: Paragraphs 2.2.4 (completion letter) and 2.3.1 (backfitting and modifications).

5. **Plant-Specific SERs**

   Staff SSER: Pages 5 and 18, numbered paragraphs 5.

   Revision 2: Paragraph 2.2.10.

6. **Correction of Deficiencies**

   Staff SSER: Page 5, numbered paragraph 6.

   Revision 2: Paragraph 2.3.1.

7. **Compliance with GDC-2**

Staff SSER: Page 7, numbered paragraph (1), and page 19, numbered paragraph I.B.

Revision 2: Paragraph 2.3.2.

8. **Specific Seismic Qualification Commitments**

Staff SSER: Page 7, numbered paragraph (2).

Revision 2: Paragraph 2.3.3.

9. **Revision of the Plant Design Basis**

Staff SSER: Page 7, numbered paragraph (3).

Revision 2: Paragraph 2.3.3. SQUG has clarified Part I to indicate that licensees will revise their commitments to a methodology for verifying/qualifying seismic equipment. These are licensing commitments, i.e., the licensing bases, not the design bases.

10. **Extending the A-46 Criteria to All Seismic Equipment**

Staff SSER: Pages 8 to 10, numbered paragraph (2).

Revision 2: Paragraph 2.3.4. Part I incorporates language directly from the SSER.

11. **72-Hour Hot Shutdown Requirement**

Staff SSER: Page 11, numbered paragraph 5.

Revision 2: Paragraph 2.2.11.

12. **Review Team Qualifications**

Staff SSER: Page 12, numbered paragraph 1.

Revision 2: Part II, Section 2. SQUG interprets the Staff discussion not to preclude use of one individual for two areas of expertise or use of individuals without specific degrees for key review team positions.

13. **Categories of Relays**

Staff SSER: Page 15, numbered paragraph 6, NRC comment (1).

Revision 2: Part II, Section 6. SQUG assumes the three categories in the SSER are examples of relay categories and not a definitive statement restricting the categories of relays which can be used.

14. **Relay Chatter**

Staff SSER: Page 16, numbered paragraph 6(1)(c).

Revision 2: Part II, Section 6.3. SQUG interprets this paragraph in the SSER to mean essential relays that must function properly following the earthquake but may chatter during strong motion shaking.

15. **Role of SSRAP**

Staff SSER: Page 17, numbered paragraph 1.

Revision 2: Paragraph 2.2.2.

16. **Third-Party Audits**

Staff SSER: Page 18, numbered paragraph 4.

Revision 2: Paragraph 2.2.9.

17. **Adequacy of Seismic Capacity of Equipment in Older Plants**

Staff SSER: Pages 18 and 19, numbered paragraph I.A.

Revision 2: Paragraph 1.1. SQUG has clarified that adequate margins of seismic capacity exist for properly anchored equipment.

18. **Operability of Equipment**

Staff SSER: Page 19, numbered paragraph II.A.1.

Revision 2: Paragraph 2.4.1. This paragraph has been expanded to address single failure concerns and administrative controls for safe shutdown equipment removed from service.

19. **General Agreement vs. Full Concurrence**

Staff SSER: Page 20, numbered paragraph II.D.1.1.1.

Revision 2: Paragraph 2.2.1. SQUG has clarified this position to indicate that full concurrence will be assumed unless specific concerns are identified.

20. **Postponement**

Staff SSER: Page 20 and 21, numbered paragraphs II.D.1.1.a.2 and II.D.1.1.c.1.c.

Revision 2: Paragraph 2.2.8.

21. **New Installations**

Staff SSER: Page 21, numbered paragraph II.D.1.3.

Revision 2: Paragraph 2.3.4.

22. **New, Modified and Repaired Anchorages**

Staff SSER: Page 21, numbered paragraph II.D.1.5.

Revision 2: Paragraph 2.3.4, near end.

23. **Recognizing, Documenting and Reporting Deficiencies**

Staff SSER: Page 21, numbered paragraphs III.C.2.1.a and b.

Revision 2: Paragraph 2.2.5.

Enclosure 3 to
SQUG Letter Dated
September 21, 1990

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM

INTRODUCTION

This "Checklist" summarizes the resolution of numerous open/unresolved issues in the USI A-46 program. There are five sections to this "Checklist" which are described below.

- Introduction is given here and describes the contents of this "Checklist."

- Summary of Results describes the changes made to this "Checklist" since the last version was published.

- Status Table categorizes the status of all open/unresolved issues into seven categories.

- History Table summarizes the historical positions taken by NRC, SSRAP, and SQUG on each of the open/unresolved issues. This History Table also includes a column showing the "Status" of each issue. To assist reviewers of the GIP, Revision 2, the "Status" column of this version of the checklist includes a reference to the section(s) in the GIP, Rev. 2, where the issue is addressed. This reference is included only for those issues which were resolved in the GIP, Rev. 2; the issues resolved in the GIP, Rev. 1, do not include the reference.

  Note that in some cases, the issues are being resolved by revising the reference document, not the GIP. This occurs when the issue relates to clarifying the basis for the USI A-46 criteria; the GIP only provides the procedure for applying the USI A-46 criteria.

  Note that the positions taken by NRC, SSRAP, and SQUG include a reference to a document (underlined reference numbers). The titles of these documents are listed in the "Reference" section of this checklist, described below.

- References lists the titles of the various documents (mostly reports of Technical Review Meetings) where positions were taken by NRC, SSRAP, and SQUG.

Note that wherever there is a change in the "Checklist" between the previous version and this one, a single vertical line is added in the left-hand margin of the affected column to identify where the change or addition has been made.

SUMMARY OF RESULTS

The previous version of this "Checklist" was published on 10/10/89. Since that time there have been numerous meetings held and several position papers published which have closed out nearly all the open/unresolved issues that have resulted from the development of generic guidelines for resolution of USI A-46. These changes are summarized below.

Three (3) new issues have been added as follows.

- C.4 Westinghouse test data in potential conflict with GERS
- D.24 Expansion anchor types with limited backup test data or low test data
- E.7 Switchgear GERS cover relay chatter

Except for Issue C.4, these new issues have been resolved and the results included in Revision 2 of the GIP. Resolution of Issue C.4 is in progress; Revision 2 of the GIP incorporates resolution of all the GERS issues short of the potential conflicts with Westinghouse test data.

Nine (9) issues changed from "Open" to "Resolved" status category as follows.

- A.5 Basis for excluding NSSS equipment
- A.6 Boundary of CRD mechanism
- D.17 Factors of safety and cracks in concrete
- D.22 Expansion anchor strength criteria for $f'_c < 3500$ psi
- D.23 J-hook concrete fastener strength criteria
- E.6 Similarity criteria for determining ruggedness of untested relays
- J.1 Approval of training program
- K.2 Applicability of USI A-46 criteria to any equipment in plant
- K.4 Equipment operability

The resolution of all the above issues are incorporated into Revision 2 of the GIP except for Issue E.6 for which SQUG has deferred finalization and implementation of the similarity criteria for determining ruggedness of untested relays.

One (1) issue changed from "Resolved" to "No" status category as follows.

G.1 Cable and conduit raceway evaluation criteria

This issue was changed to a "No" (i.e., SQUG disagrees with the NRC position and no change made to GIP, Rev. 2). SQUG does not consider it to be necessary for a 3 X Dead Load evaluation to be performed for non-ductile cable and conduit raceway supports since suitable horizontal load checks are performed on these types of supports to demonstrate their seismic adequacy. SSRAP concurs in SQUG's position.

Two (2) issues remain "Open" at this time as follows.

C.4 Westinghouse test data in potential conflict with GERS

E.2a GERS for all types of relays

Both these issues remain open pending resolution of potential conflicts between Westinghouse test data and the GERS (relay and non-relay). SQUG and Westinghouse are currently attempting to resolve these apparent conflicts.

The overall status of the open/unresolved issues is a follows.

"Resolved"		88	(Was 78)
"No"		1	(Was 0)
"Open"		2	(Was 10)
	Total	91	(Was 88)

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM

STATUS TABLE

No.	Status Categories
1.	Resolved per GIP, Rev.1.
2.	Resolved in GIP, Rev. 2.
3.	Resolved in GIP, Rev. 2 with disagreement. SQUG disagrees but will not generically contest the NRC position.
4.	SQUG disagrees and does not accept with NRC position; no change made to GIP, Rev. 2.
5.	Open issue. SQUG developing criteria or justification for review by NRC/SSRAP.
6.	Open issue. NRC evaluating criteria or justification.
7.	Open issue. SQUG evaluating NRC position.

Note that if both the NRC and SQUG are taking action to resolve an open issue, the symbol "1/2" will appear in both columns 6 and 7 of the Status Category below.

Issues	Status Category: Resolved 1	2	3	No 4	Open 5	6	7
A. Safe Shutdown Equipment List (SSEL)							
1. Use of TMI Action Plan Item II.F.2 equipment		X					
2. Selection of preferred safe shutdown path	X						
3. Training/procedures for shutting down after earthquake	X						
4a. Compatibility of plant operating procedures with SSEL	X						
4b. Documentation of review of plant operating procedures		X					
5. Basis for excluding NSSS equipment		X					

Issues	Status Category: Resolved 1	Resolved 2	Resolved 3	No 4	Open 5	Open 6	Open 7
A. Safe Shutdown Equipment List (SSEL) (Continued)							
6. Boundary of CRD mechanism		X					
7. Cast iron valves, fittings, etc.		X					
8. Definition of hot shutdown		X					
B. Earthquake Experience Data Base							
1. New equipment added to generic seismic experience data base	X						
2. SSRAP bounding spectrum	X						
C. Test Experience Data Base							
1. GERS levels		X					
2. GERS vintage		X					
3. GERS for distribution panel boards and switchboards		X					
4. Westinghouse test data in potential conflict with GERS					X		
D. Anchorage Guidelines							
1a. Visual inspection of expansion anchor bolts		X					
1b. Seismic load reversals for expansion anchors		X					
2. Sampling rate for tightness checks of expansion anchor bolts		X					
3. Torque to be used for tightness checks of expansion anchor bolts		X					

Issues	Status Category: Resolved 1	Resolved 2	Resolved 3	No 4	Open 5	Open 6	Open 7
D. Anchorage Guidelines (Continued)							
4. Shear-tension interaction formulation for cast-in-place bolts and headed studs	X						
5. Modified, replaced or new anchorages		X					
6. Damping values for determining spectral acceleration	X						
7. Wall-mounted cabinets and panels		X					
8. Computer codes		X					
9. Adequacy of cabinet anchorage stiffness		X					
10. Embedment length for expansion anchor bolts		X					
11. Embedment length for cast-in-place bolts		X					
12. Tables in GIP for grouted-in-place bolts, interaction equations, and weld allowables		X					
13a. Edge distance and bolt spacing for adjacent equipment		X					
13b. Edge distance and bolt spacing in general		X					
14. German anchorage test data		X					
15. PCI handbook	X						
16. "Direct method" of generating in-structure response spectra		X					

Issues	Resolved 1	Resolved 2	Resolved 3	No 4	Open 5	Open 6	Open 7
D. Anchorage Guidelines (Continued)							
17. Factors of safety and cracks in concrete		X					
18. Effect of concrete strength on tensile strength of expansion anchors	X						
19. Missing bolt sizes in GIP Appendix C tables		X					
20. Effect of bending on anchorage		X					
21. Discrepancy between GIP and anchorage report		X					
22. Expansion anchor strength criteria for $f_c' < 3500$ psi		X					
23. J-hook concrete fastener strength criteria		X					
24. Expansion anchor types with limited backup test data or low test data		X					
E. Relay Review Guidelines							
1. Operator response to spurious alarms	X						
2a. GERS for all types of relays					X		
2b. GERS for older relays		X					
3a. In-cabinet amplification factors for MCCs and SWGR			X				
3b. In-cabinet amplification factors for control panels and bench boards using S&A approach	X						

Issues	Status Category: Resolved 1	2	3	No 4	Open 5	6	7
E. Relay Review Guidelines (Continued)							
3c. Inclusion rules for cabinets with high and low in-cabinet amplification factors	X						
4. Relay mounting		X					
5. Relays subject to impact chatter		X					
6. Similarity criteria for determining ruggedness of untested relays		X					
7. Switchgear GERS cover relay chatter		X					
F. Seismic Interaction							
1. Effects of fire, flooding, and exposure to fluids, and seismic interaction affecting distri-bution lines beyond first anchorage point	X						
G. Cable & Conduit Raceway Systems							
1. Evaluation criteria				X			
H. Tanks and Heat Exchangers							
1. Evaluation criteria contained in GIP, Rev. 1	X						
2. Structural integrity and buckling of tanks		X					
3. Refueling water storage tanks (RWST) in PWRs	X						
4. Tanks supported on legs and skirts		X					
5. Cracks in concrete near tank anchor bolts		X					

	Status Category						
	Resolved			No	Open		
Issues	1	2	3	4	5	6	7
H. Tanks and Heat Exchangers (Continued)							
6. Margin of safety over wide range of parameters	X						
7. Damping values for determining spectral acceleration		X					
8. Concrete saddles		X					
9. Shell buckling for horizontal tanks		X					
10. Foundation/soil properties		X					
11. Sample response spectrum	X						
12. Coefficient of friction beneath tank	X						
13. Location of slotted anchor bolt holes in horizontal tanks		X					
14. Height of fluid in horizontal tanks		X					
15. Bibliography		X					
16. Pad mounted equipment		X					
17. Shear load on anchorage bolts			X				
18. Effect of shear load on tank wall buckling		X					
19. Effect of 2 directions of seismic motion		X					
20. Use of AISC factors of 1.7 and 33%		X					
21. Soil-structure interaction (SSI) effect		X					
22. Frequency shifts due to partially filled tank		X					

Issues	Status Category						
	Resolved			No	Open		
	1	2	3	4	5	6	7
H. Tanks and Heat Exchangers (Continued)							
23. Buckling at top of tank		X					
24. Penetrations and attachments		X					
25. Anchorage arrangements other than chairs		X					
26. Hoop stress due to vertical excitation		X					
27. Slosh heights from low frequency excitation		X					
I. Miscellaneous GIP Topics							
1. Systems engineer qualification			X				
2a. Qualifications for seismic capability member engineers			X				
2b. Qualifications for cable tray evaluation personnel		X					
3. Method for estimating fundamental frequency of equipment		X					
4. Audits of plant-specific implementation	X						
J. Training Course							
1. Approval of training program		X					
2. Type of personnnel to take training course	X						

Issues	Status Category: Resolved 1	2	3	No 4	Open 5	6	7
K. <u>Generic Letter 87-02 and Licensing Issues</u>							
1. Plant-specific SERs	X						
2. Applicability of USI A-46 criteria to any equipment in plant		X					
3. Equipment required for Reg. Guide 1.97 but not for USI A-46			X				
4. Equipment operability		X					
Totals	19	64	5	1	2	0	0
	88			1	2		
	91						

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
A. Safe Shutdown Equipment List (SSEL)				
1. Use of TMI Action Plan Item II.F.2 equipment	Reactor vessel level instrumentation is needed following an overcooling transient in which the reactor coolant level drops below the lowest pressurizer level instrument (1:II.A.2.2)	No comment (14)	Need for specific instrumentation will be determined on plant-specific basis. GIP changed to list instruments as examples (3:II.3.4)	NRC to document acceptance of SQUG position; approve Rev. 1 of GIP
	4/28/89 - The staff believes that more use should be made to the TMI Action Plan Item II.F.2 requirement for instrumentation and the reactor coolant inventory measurement in particular. Those items common to all A-46 plants should be listed in Table 3-2, GIP Revision 1. Delete the footnote (3) of the Table 3-2 and include those items in Item 3 of Table 3-2 (17)		5/3/89 - Disagree and cannot accept NRC position which is out of scope of USI A-46 and not required for safe shutdown	5/3/89 - Disagree
	5/3/89 - The Staff clarified that reactor vessel level instruments should be included in the list of safe shutdown equipment, but not all II.F.2 instruments need to be included			
	6/15/89 - Need only consider subcooling margin instrumentation, core exit thermocouple instrumentation, and reactor vessel level instrumentation (21)		6/15/89 - The GIP will not require the use of TMI Action Plan II.F.2 instruments but will list reactor vessel level, core exit temperature, and subcooling margin as examples of measurement variables to be considered for PWRs (21)	6/15/89 - Resolved in principle. GIP to be revised per SQUG position 9/21/90 - Resolution in Sec. 3.3.7 of GIP, Rev. 2

* The position/comment taken by NRC, SSRAP and SQUG are briefly summarized in this checklist. The full statement of the position or comment is contained in the document referenced in parentheses. Changes made in this checklist from the previous issue (dated 10/10/89) are denoted by a single vertical line in the left-hand side of the affected column.

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
A. Safe Shutdown Equipment List (SSEL) (Continued)				
2. Selection of preferred safe shutdown path	Ease of performing walkdown should not be given high priority (1:II.A.2.3) 4/28/89 - Staff agrees with the statement in GIP Revision 1 (17)	Agree with the NRC comment and consider GIP change acceptable (14)	GIP changed (3:3.0)	NRC to document acceptance of SQUG position; approve Rev. 1 of GIP 5/3/89 - Resolved per GIP, Rev. 1
3. Training procedures for shutting down after earthquake	Should train operators to use USI A-46 safe shutdown equipment during/after earthquake (1:II.A.2.3)	Operators should be aware of which equipment was qualified (10:S.12, 14)	Event-based procedures are not now used at plants. Symptom-based procedures are in use and provide adequate assurance that operable equipment is used (2:II.A.2.3 and 10:S.12). GIP revised per (3:3.3.8 and 7) to require: · Utilities to have procedures written for operation of safe shutdown equipment, and · These procedures to be available to the operator if he uses the plant emergency operating procedures, and · The shutdown procedures to be reviewed by the plant Operations Department to confirm that only USI A-46 equipment is needed to safely shut down	NRC to document acceptance of SQUG position; approve Rev. 1 of GIP

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
A. Safe Shutdown Equipment List (SSEL) (Continued)				
3. Training procedures for shutting down after earthquake (Continued)	4/28/89 & 5/12/89 - Operator training for recognizing the availability of A-46 equipment is required for each licensee for the implementation of USI A-46 resolution (17, 18)		5/3/89 - Disagree and cannot accept NRC position since operator training for earthquakes is not possible; for example, training for use of EQ equipment is not now required	5/3/89 - Disagree
	6/15/89 - Staff will take SQUG position under advisement and reevaluate whether NRC position would require A-46 plants to go beyond requirements for new plants (21)		6/15/89 - Same position as above plus it is noted that operator training for specific events such as earthquakes is not required for new nuclear plants (21)	6/15/89 - Open issue. NRC to reevaluate their position and report results at July meeting
	7/26/89 - The NRC Staff accepts SQUG's position (25)			7/26/89 - Resolved per GIP, Rev. 1 (25)
4a. Compatibility of plant operating procedures with SSEL	Should perform control room walkdown without relying on any equipment not on the SSEL (1:II.A.2.4)	No comment (14)	GIP changed to require Operations Department of plant to review SSEL against operating procedures. Control room walkdown is one method of review but others can be used (3:II.3.3.8)	NRC to document acceptance of SQUG position; approve Rev. 1 of GIP
	4/28/89 - The Staff agrees that each licensee may use its own approach to verify that the procedures are compatible with the methods used for safe shutdown of its plant. However, the staff expects to perform selective audits of operating procedures by witnessing limited control room walkdowns to assure that existing procedures, assuming that only equipment on the safe shutdown equipment list remains operable and available for shutdown, will permit the recognition of failed systems and direction to the safe shutdown path (17)			5/3/89 - Resolved per GIP, Rev. 1

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
A. Safe Shutdown Equipment List (SSEL) (Continued)				
4b. Documentation of review of plant operating procedures	Results of plant review should be submitted to NRC (19:G.2)	Agree with NRC comment (14)	GIP, Rev. 2 will be changed to require submittal to include a statement that review was done by Operations Department of plant	SQUG to address GIP, Rev. 2
	4/28/89 - Results should be submitted for NRC review and/or audit (17)		5/3/89 - GIP will be expanded to include guidelines for documenting procedure review	5/3/89 - Resolved in principle. GIP to be revised
				9/21/90 - Resolution in Sec. 3.7 of GIP, Rev. 2
5. Basis for excluding NSSS equipment	Justification for excluding NSSS equipment from scope of USI A-46 not provided in GIP (14)	No comment (14)	Major NSSS equipment is out of scope of USI A-46 (2:II.A.2.5 and 3:3.2.1). No change to GIP is necessary	NRC to provide basis for safety concern in excluding major NSSS equipment from scope of USI A-46
	4/28/89 - Not addressed at this time (17)		5/3/89 - GIP to be revised to provide basis for excluding NSSS equipment	5/3/89 - Open issue. Criteria to be developed by SQUG
			12/5/89 - Forwarded position paper to NRC providing basis for exclusion of NSSS equipment from scope of USI A-46 (29)	12/5/89 - Open issue pending NRC review and acceptance of SQUG position paper.
	12/12/90 - Several preliminary comments provided but overall there was no major concern with SQUG's position (30)		12/12/89 - GIP, Rev. 2 to be revised to clarify boundary of NSSS equipment (30)	12/12/89 - Resolved in principle. GIP, Rev. 2 to be revised to incorporate SQUG's position (30)
				9/21/90 - Basis for excluding NSSS provided in Reference 29. Resolution included in Sec. 3.3.2 of GIP, Rev. 2.

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
A. Safe Shutdown Equipment List (SSEL) (Continued)				
6. Boundary of CRD mechanism	Not all portions of CRD mechanisms should be excluded from scope of USI A-46 (14)	No comment (14)	Those portions of the CRD mechanism attached to the outside and inside of the reactor vessel are excluded from scope (14)	SQUG to revise GIP to clearly define boundary of CRD mechanism to exclude from scope
	4/28/89 - Not addressed at this time (17)		5/3/89 - GIP to be revised to clarify boundary of NSSS equipment	5/3/89 - Open issue. Criteria to be developed by SQUG
				9/21/90 - Basis for excluding major items of NSSS equipment provided in Reference 29. Resolution included in Sec. 3.3.2 of GIP, Rev. 2
7. Cast iron valves, fittings, etc.		Should look for cast iron equipment in the safe shutdown systems (10:0.3 and 10:S.9). Agree that such cast iron equipment is not likely to be in plant but if it is found, then action should be taken to address it (14)	Not considered likely to be in safe shutdown systems (10:0.3 and 10:S.9). No change to GIP is necessary	None
	4/28/89 - If the cast iron equipment is found in the A-46 scope, it should be specifically evaluated for seismic adequacy (7)		5/3/89 - GIP will be revised to clarify that it is not necessary to specifically look for cast iron equipment, but that SRTs should not ignore obvious use of it and if found should evaluate its seismic adequacy	5/3/89 - Resolved in principle. GIP to be revised
				9/21/90 - Resolution in App. B.7.1, B.7.2, and B.8.1 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
A. Safe Shutdown Equipment List (SSEL) (Continued)				
8. Definition of hot shutdown	GIP allows PWRs to be brought to hot standby whereas intent of NUREG-1211 is for plant to be brought to hot shutdown, i.e., below about 300°F (15) 4/28/89 & 5/12/89 - Replace the definition described in Section 3.3 of GIP Revision 1 by the following: "Hot shutdown is defined in the Technical Specification of each plant, and typically for PWR, it requires the reactor to be subcritical (i.e., reactivity condition K_{eff} less than 0.99) and average reactor coolant temperature above 200°F and less than 350°F". (17, 18) 5/3/89 - Staff identified their position to be that the safe shutdown equipment list does not have to include long-term residual heat removal (RHR equipment).	No comment (14)	Based on discussions with the NRC staff who wrote NUREG-1211, use of the term "hot shutdown" was meant to allow plants to be brought to a subcritical shutdown condition above cold shutdown temperatures, i.e., above 200°F. No change to GIP is considered necessary. 5/3/89 - Disagree and cannot accept NRC position which is inconsistent with SER on Rev. 0 and with intent of GL 87-02	NRC staff to discuss intent of NUREG-1211 and reach consensus. 5/3/89 - Disagree

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
A. Safe Shutdown Equipment List (SSEL) (Continued)				
8. Definition of hot shutdown (Continued)	6/15/89 - Intent of staff is to have PWRs lower their temperature and pressure within 72 hours to the point where RHR equipment could be used but not require RHR equipment to be included on the SSEL. It is not the intent to require plants to cool down faster than their original design capability but those plants which cannot cool down to hot shutdown within 72 hours should discuss this with the staff. Tentatively agree with Compromise Resolution.		6/15/89 - There is a wide variation in the A-46 plant's Tech. Spec. definitions of hot shutdown. Use the Tech. Spec. definition of hot shutdown but allow plants to cool down further if desired. Some plants may not be able to cool down to hot shutdown within 72 hours because they were not originally designed to do so without offsite power. Tentatively agree with the Compromise Resolution	6/15/89 - Resolved in principle with the following: Compromise Resolution: Require the plants to cool down to their Tech. Spec. definition of Hot Shutdown within 72 hours. Can cool down to a lower temperature if desired. RHR equipment need not be included on the SSEL. It is not the intent to require plants to cool down faster than their original design capability. If plants can not achieve hot shutdown within 72 hours, report to NRC as a part of the A-46 implementation report.
	7/26/89 - The NRC staff accepts the Compromise Resolution (25)			7/25/89 - Resolved in principle. (25) 9/21/90 - Resolution in Sec. 3.2.3 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
B. Earthquake Experience Data Base				
1. New equipment added to generic seismic experience data base	"Newly manufactured" equipment not a part of data base unless reviewed by NRC (1:II.B.1.1)	Judgment of SRT can be used to include new equipment if it clearly has the same features as the equipment in the experience data base. If there is any question, the NRC must review the question (14)	New equipment with design features similar to equipment in data base can be considered a part of the data base based on judgment of SRT (2:II.B.1.1). No change to GIP is necessary	NRC to document acceptance of SQUG position; approve Rev. 1 of GIP
	4/28/89 - Judgment of SRT may be used. However, the NRC will audit plant specific implementation of USI A-46 and may evaluate this specific aspect (17)		5/3/89 - Accept NRC position	5/3/89 - Resolved per GIP, Rev. 1
2. SSRAP bounding spectrum	Open issue pending NRC staff review and acceptance (1:II.B.2)	The SSRAP bounding spectrum is acceptable to SSRAP (14)	SSRAP bounding spectrum is acceptable	NRC to complete review of SSRAP report (12) and either document acceptance of SSRAP bounding spectrum or provide comments
	4/28/89 - Not addressed at this time (17)			5/3/89 - Open issue. Criteria being evaluated by NRC. NRC to provide their position to SQUG/SSRAP by 5/18/89 meeting
	5/18/89 & 6/8/89 - Bounding Spectrum is considered adequate except for use with MOVs. Basis for using 60% of SSRAP reference spectrum for MOVs not established (19, 22)	6/14/89 - SSRAP provided basis for use of Bounding Spectrum for MOVs (21)		6/14/89 - Open issue. NRC evaluating basis and will provide position at 7/26/89 meeting
	7/26/89 - Use of 0.6 factor with Bounding Spectrum for MOVs is not justified from a strict comparison to seismological data. Request pipe stress data for valves with operators (25)	7/26/89 - It is SSRAP's strong technical judgment that further reduction of spectrum for MOVs is inappropriate (25)	7/26/89 - Concur in SSRAP's position (25)	7/26/89 - Open issue. NRC to reconsider SSRAP/SQUG position including technical bases for judgment in addition to use of seismological data. SSRAP to provide pipe stress data for valves with operators for NRC review (25)
	9/13/89 - NRC Staff accepts SQUG/SSRAP position (26)			9/13/89 - Resolved per GIP, Rev. 1 (26)

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
C. Test Experience Data Base				
1. GERS levels	BNL has proprietary test data which indicates GERS for some classes of equipment may be too low (1:II.C.2.1)	Will review any BNL data in conflict	All known conflicts have been addressed and resolved (4)	NRC to obtain BNL data to complete review of GERS and either document acceptance of SQUG position or provide comments
	4/28/89 - The criteria for determining GERS screening levels should be based on "HCLPF" value corresponding to a high (95%) confidence of a low (5%) probability of failure from the available data base (17)	5/3/89 - HCLPF and GERS should give equivalent results when each is done properly. If there are differences, then the reason for the differences should be determined and resolved		5/3/89 - Resolved in principle. GIP and GERS reports to be revised to state that the approach used to generate HCLPF and GERS should give equivalent results. NRC agreed to provide any additional BNL data for consideration in GERS within 3 months (7/31/89) so that the GERS work can be finalized
	5/18/89 - BNL comments on GERS Supplement No. 1 and BNL report with SWGR data provided to SQUG/SSRAP (1[illegible]			
	6/13/89 - Meeting between BNL, NRC, ANCO, MPR, SG is needed to compare BNL test data to GERS (21)			6/13/89 - Open issue. NRC/SQUG to evaluate BNL data for applicability during 7/11 - 7/13/89 meeting
	7/26/89 - Accept Compromise Resolution incorporating BNL data (25)	7/26/89 - Accept Compromise Resolution incorporating BNL data (25)	7/26/89 - Accept Compromise Resolution incorporating BNL data (25)	7/26/89 - Resolved in principle in accordance with Compromise Resolution below (25)

Compromise Resolution:
- MCCs with integral, welded base channels: GERS = 3.5g
- MCCs with external base channels attached with 3/8" diameter or larger bolts: GERS = 2.5g
- LV SWGR to have caveat identifying acceptable manufacturers
- MV SWGR to have caveat requiring breaker position mechanism
- MV SWGR without internal inspections: GERS = 2.5g
- MV SWGR with inspection showing no problem with support of internal devices: GERS = 3.0g

9/21/90 - Resolution in App. B.1.2, B.2.2, and B.3.2 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
C. Test Experience Data Base (Continued)				
2. GERS vintage	Test data used for GERS is based on recent models of equipment which may be more rugged than earlier models used in A-46 plants (1:II.C.2.2)	Resolved per (4) subject to confirmation that BNL does not have any data which contradicts the 4G spectral levels for MCCs given in this report	Resolved per (4)NRC to obtain BNL data to complete review of GERS and either document acceptance of SQUG position or provide comments	
	4/28/89 - With the staff position stated in C.1 above, the staff will assume the GERS vintage issue is not a problem (17)			5/3/89 - Resolved in principle. GIP and GERS reports to be revised to include any data made available in the next 3 months as agreed in Issue C.1 above
				9/21/90 - Resolution in App. B of GIP, Rev. 2
3. GERS for distribution panel boards and switchboards	There should be different GERS for these items (1:II.A.2.1 and 1:II.C.2.3)	Resolved per (4)	Resolved per (4)	NRC to complete review of GERS (4) and either document acceptance of SQUG position or provide comments
	4/28/89 - The GERS for these items should be determined based on the staff position described in C.1 above (17)			5/3/89 - Resolved in principle. GIP and GERS reports to be revised to include any data made available in the next 3 months as agreed in Issue C.1 above
	7/26/89 - Accept Compromise Resolution (25)	7/26/89 - Accept Compromise Resolution (25)	7/26/89 - Accept Compromise Resolution (25)	7/26/89 - Resolved in principle as follows: Compromise Resolution: Switchboard GERS to be reduced from 5.0g to 3.5g. Pannelboard GERS to remain at 2.5g (25)
				9/21/90 - Resolution in App. B.14.2 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
C. Test Experience Data Base (Continued)				
4. Westinghouse test data in potential conflict with GERS	12/5/88 - W letter to NRC objecting to Staff use of GERS as summary data containing proprietary Westinghouse information (32)		2/2/90 - Use of the GERS is an integral part of the SQUG approach for resolution of USI A-46 (33)	2/2/90 - Open issue. NRC and SQUG to seek ways to resolve issue (33)
	4/11/90 - Westinghouse withdrew objection with the understanding the W could work with SQUG, SSRAP, and NRC to resolve apparent conflicts between W test data and GERS (34)			4/[illegible]0 - Open issue pending detail comparison of W test data and GERS
	7/10/90 - EPRI/ANCO non-relay GERS report is acceptable subject to inclusion of editorial comments and resolution of apparent conflicts with W test data (35)	7/10/90 - EPRI/ANCO non-relay GERS report is acceptable subject to inclusion of editorial comments and resolution of apparent conflicts with W test data (35)	7/10/90 - EPRI/ANCO non-relay GERS report dated 4/90 sent for review. Editorial comments will be included in report. SQUG/EPRI/ANCO to work with W to sort through W test data and resolve apparent conflicts with GERS (35)	7/10/90 - Open issue pending W/SQUG review and resolution of apparent conflicts with GERS. All other issues resolved (35)
				9/21/90 - Open issue pending W/SQUG review and resolution of apparent conflicts with GERS

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
D. Anchorage Guidelines				
1a. Visual inspection of expansion anchor bolts	"All" expansion anchor bolts should be visually inspected (1:II.D.1.1.a). Concur with SQUG, subject to the SRT considering seismic load reversals. See Issue D.1.b (13)	Concur with SQUG (13)	The word "all" refers to only those bolts required for adequate anchorage (2:II.D.1.1.a.1).	NRC to document acceptance of SQUG position
	4/28/89 - All expansion anchors should be visually inspected except when there is an accessibility problem (See NRC Generic SER dated July 29, 1988, page 22) (17)			5/2/89 - Resolved in principle with use of the following words: "All accessible anchorages will be visually inspected. Inaccessible anchorages not required for strength/distribution need not be inspected. Inaccessible/obstructed anchorages required for strength/distribution will be inspected by the SRT on a best effort basis without resorting to equipment disassembly, removal, etc."
				9/21/90 - Resolution in Sec. 4.4.1 of GIP, Rev. 2
1b. Seismic load reversals for expansion anchors	Seismic load reversals should be considered when evaluating adequacy of expansion anchors (13)		GIP will be changed to require the SRT to consider the effect of seismic load reversals (13)	SQUG to revise GIP, Rev. 2
	4/28/89 - Staff concurs (17)			5/2/89 - Resolved in principle. GIP to be revised
				9/21/90 - Resolution in Sec. 4.4.1, Checks 6 and 11 and in App. C.1 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
D. Anchorage Guidelines (Continued)				
2. Sampling rate for tightness checks of expansion anchor bolts	100% of expansion anchor bolts should be tightness checked for cabinets with essential relays and for anchorages using a safety factor of 2. Sampling of tightness can be used for all other expansion anchors based on 95% confidence of no more than 5% non-conforming bolts (1:D.1.1.c, 1:D.2.1.a, and 8). Concur with SQUG (13)	Concur with SQUG to accept inaccessible anchorages if sample of accessible anchorages are consistently tight (13)	For inaccessible anchorages, engineering judgment can be used to assess adequacy based on the accessible sample tested for tightness (3:4.4.2 and 3:4.4.2.2). GIP will be changed to require the SRT to first try to use the conservative anchorage criteria or perform tightness checks during a refueling outage before relying on engineering judgment. Basis for engineering judgment should be documented (13)	SQUG to revise GIP, Rev. 2. NRC to document acceptance of SQUG position
	4/28/89 - The staff agrees with the SQUG if it is a last resort and the sample of accessible anchorages indicates consistent tightness and basis for engineering judgment should be documented (17)			5/2/89 - Resolved in principle. GIP to be revised
				9/21/90 - Resolution in Sec. 4.4.1, Check 4 and App. C.2.3 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
D. Anchorage Guidelines (Continued)				
3. Torque to be used for tightness checks of expansion anchor bolts	Should use manufacturers' recommended torque for setting bolts to assure that the bolts have been properly set (9)	Concur with SQUG (13)	A "wrench-tight" torque check (i.e., about 20% of installation torque) is considered adequate to provide reasonable assurance that the expansion anchor is not loose in the hole. Capacity test not intended (3:4.4.2.2)	EPRI/URS/Blume to contact manufacturers and ask for recommendations (13)
	4/28/89 - The staff agrees with SQUG approach (17)			5/3/89 - Open issue. SQUG to consider sampling of older, installed bolts. SSRAP to investigate ICBO and other information on this topic
	5/3/89 - Staff changed position out of concern that manufacturers recommend use of 100% installation torque for checking tightness			
	5/18/89 & 6/8/89 - Staff accepts use of "wrench tight" torque if bolt does not turn more than 1/4 turn (19) (22)		5/18/89 - SQUG re-evaluation concludes 20% torque is appropriate (19)	6/14/89 - Resolved in principle. GIP and EPRI report to address issue
				9/21/90 - Resolution in Sec. 4.4.1, Check 11 and App. C.2.3 of GIP, Rev. 2
4. Shear-tension interaction formulation for cast-in-place bolts and headed studs	Use straight line shear-tension interaction equation (1:D.1.2.b)	Concur with SQUG (13)	Bilinear shear-tension interaction formulation has adequate conservatism (2:II.D.1.2.b). No change to GIP is necessary.	NRC to document acceptance of SQUG position; approve Rev. 1 of GIP
	4/28/89 - The staff agrees. To provide uniformity, the bilinear relationship can be applied to all anchorages (17)			5/2/89 - Resolved per GIP, Rev. 1

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
D. Anchorage Guidelines (Continued)				
5. Modified, replaced or new anchorages	Should use current licensing criteria and procedures for design of new equipment anchorage, i.e. reduced factors of safety in GIP can not be used (1:D.1.3 and 1:D.1.5 and 7)	Concur with NRC (14)	NRC position is inconsistent with GL 87-02. Licensee should have option of using USI A-46 criteria for new installations (2:II.D.1.3 and (2:II.D.1.5)	NRC to document acceptance of SQUG position
	4/28/89 - Current licensing criteria and procedures should be used for modified, replaced, or new anchorages, i.e., reduced factors of safety in GIP cannot be used (17)		5/2/89 - Agree that factor of safety of 4 should be used for new and modified anchorages, but cannot agree to more general revision that plants use "current licensing criteria"	5/2/89 - Resolved in principle. GIP to be clarified as given in SQUG's position
				9/21/90 - Resolution in Part I, Sec. 2.3.4 of GIP, Rev. 2
6. Damping values for determining spectral acceleration	GIP not consistent with SSRAP report (1:D.2.1.b). Resolved (8)	Position is stated in SSRAP report (13)	GIP changed per (3:C.3)	NRC to document acceptance of SQUG position; approve Rev. 1 of GIP
	4/28/89 - The Staff agrees with those described in GIP, Revision 1 (17)			5/2/89 - Resolved per GIP, Rev. 1

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
D. Anchorage Guidelines (Continued)				
7. Wall-mounted cabinets and panels	Provide guidelines for anchorage (1:D.2.2). Resolved (8 and 13) 4/28/89 - The staff agrees with the SQUG approach (17)	No comment (13)	GIP changed per (3:4.4.1). GIP, Rev. 2 to include an example (13)	SQUG to revise GIP, Rev. 2. NRC to document acceptance of SQUG position 5/2/89 - Resolved in principle. GIP to be revised 9/21/90 - Resolution in Sec. 4.4.3 under "Seismic Inertial Anchor Loads" and in Sec. 4.4.1, Check 4 of GIP, Rev. 2. Note that Appendix C no longer includes example calculations of cabinet loads on anchors.
8. Computer codes	Open pending NRC staff review and acceptance as validated and verified codes (1:D.2.3 and 8) 4/28/89 - Not addressed at this time (17) 5/18/89 - For EPRI/Blume Anchorage Code (EBAC), guidance should be provided on selection of neutral axis location. For S&A code (ANCHOR), Revision 1, there are no significant comments. Staff is reviewing Revision 2 (19) 6/8/89 - ANCHOR 2.0 is less conservative than ANCHOR 1.0 and EPRI anchorage criteria. (22) 6/13/89 - SWRI considers ANCHOR 2.0 to be technically correct (24)	No comment (13)	Computer Codes considered as implementation tools for SRT 5/18/89 - Neutral axis to be at the centroid of the base when using EBAC unless SRT provides justification for a different location (19)	NRC to complete review of codes and either document acceptance of them or provide comments 5/2/89 - Open issue. Criteria given to NRC just prior to meeting are being evaluated by NRC 5/18/89 - Use of EBAC resolved in principle. EBAC manual and GIP to reflect SQUG position. Use of ANCHOR is an open issue subject to NRC review of Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
D. Anchorage Guidelines (Continued)				
8. Computer codes ontinued)	7/27/89 - Request confirmation that EPRI shear-tension interaction is used in ANCHOR 2.0 (25)		7/27/89 - ANCHOR 2.0 uses EPRI bi-linear shear-tension interaction equation as the default value (25)	7/27/89 - Use of EBAC resolved in principle. EBAC manual and GIP to recommend centroid as neutral axis. Use of ANCHOR 2.0 resolved per ANCHOR users manual (25)
				9/21/90 - Resolution of centroid issue in Sec. 4.4.1, Check 1 and in Sec. 4.4.3 under "Seismic Inertial Anchor Loads" of GIP, Rev. 2
9. Adequacy of cabinet anchorage stiffness	More guidance is needed in the GIP (1:D.2.4 and 8)	No comment (13)	GIP was changed to include guidelines contained in SSRAP report (3:4.4.2.3)	NRC to document acceptance of SQUG position; approve Rev. 1 of GIP
	4/28/89 - The staff finds the information provided in GIP Revision 1 for typical size cabinet adequate. However, a simplified and practical method of estimating the impact of anchorage stiffness on the fundamental frequency of heavy equipment (e.g., vertical pumps) should be developed for use in the USI A-46 implementation (17)			5/2/89 - Resolved in principle. GIP to be revised to estimate effect of anchorage stiffness on natural frequency of heavy equipment
				9/21/90 - Resolution in App. C.1 of GIP, Rev. 2
10. Embedment length for expansion anchor bolts	Some brands of expansion anchors for certain diameters come in different lengths. The GIP should address this (1:D.2.5 and 8)	Concur with NRC (13)	GIP to include lengths of acceptable expansion anchors	SQUG to revise in GIP, Rev. 2
	4/28/89 - Not addressed at this time (17)			5/2/89 - Resolved in principle. GIP to be revised
				9/21/90 - Resolution in Sec. 4.4.1, Check 5 and in App. C.2.4 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
D. Anchorage Guidelines (Continued)				
11. Embedment length for cast-in-place bolts	GIP should require that the minimum embedment length be verified as a part of the anchorage evaluation (9)	Concur with NRC (13)	GIP changed per (3:C.2.9)	NRC to document acceptance of SQUG position; approve Rev. 1 of GIP
	4/28/89 - The embedment depth should be checked by reference to drawings or by ultra-sonic testing (17)			5/2/89 - Resolved in principle. GIP to be revised to require check of embedment length from drawing, UT, or other means
				9/21/90 - Resolution in Sec. 4.4.1, Check 5 and in App. C.3.2 of GIP, Rev. 2
12. Tables in GIP for grouted-in-place bolts, interaction equations, and weld allowables	Not included in EPRI Anchorage Report. This is an open issue pending NRC staff review and acceptance (1:II.D.2.6 and 8)	Will complete review when EPRI anchorage report is revised (13, 14)	Material presented to NRC/SSRAP per (13)	NRC and SSRAP to complete review of the GIP Rev. 1 (3) and the material from (13) and either document acceptance of SQUG position or provide comments
	4/28/89 - Not addressed at this time (17)			5/2/89 - Resolved in principle. URS to justify 10% tensile strength
			9/21/90 - Judgment and experience used to select a capacity reduction factor of 10 for grouted-in-place bolts without special installation procedures	9/21/90 - EPRI/URS anchorage report to document SQUG position in next revision. Factor of 10 incorporated into App. C.5.1 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

	Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
D. Anchorage Guidelines (Continued)					
13a.	Edge distance and bolt spacing for adjacent equipment	Open pending NRC staff review and acceptance (1:II.D.2.7 and 8)	No comment (14)	No comment (14)	NRC to complete review of GIP Rev. 1 (3) and either document acceptance of SQUG position in GIP or provide comments
		Eligehausen test data indicates the bolt spacing and the distance to an edge affect tensile capacity (9)	Concur with SQUG (13)	Eligehausen test data was for shallow embedments. When embedment effects are accounted for, EPRI criteria are still valid (9). No change to GIP is necessary. See Topic 14 for discussion of re-analysis of German data	NRC to complete review of material and either document acceptance of SQUG position or provide comments
		Proximity of other anchorages (e.g., pipe supports) could lower strength of equipment anchorage (9)	Concur with NRC (13)	GIP to include guidance for checking proximity of other anchorages (9)	
		4/28/89 - See comment in Item D.13b			5/2/89 - Resolved in principle. GIP to be revised per SQUG position
					9/21/90 - Resolution in App. C of GIP, Rev. 2 for all types of anchors covered by GIP
13b.	Edge distance and bolt spacing in general	4/28/89 - Staff endorses the 30° cone concept for assessing the spacing and edge distance effects on the tensile strength reduction of multi-anchors (17)		5/3/89 - The 30° failure cone applies only to shallow embedments. This concern is resolved by SQUG adopting a minimum embedment length for cast-in-place bolts of 4 times the bolt diameter or 3 inches, whichever is greater. Embedment length is defined as the distance from the concrete surface to the surface of the bolt head closest to the concrete surface	5/2/89 - Resolved in principle. GIP and anchorage report to be revised as described by SQUG position. URS to send basis for reduction factor equations by 5/11/89
					9/21/90 - Resolution described in EPRI/URS anchorage report and incorporated in edge distance criteria in App. C of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
D. Anchorage Guidelines (Continued)				
14. German anchorage test data	SQUG should review this test data and modify GIP wh e necessary (1:II.D.2.8). Ope pending NRC review and acceptance (8)	Concur with SQUG (5 and 13)	Re-analyzed data shows there is 98% non-failure probability for various embedments (5 and 13). No change to GIP is necessary	NRC to complete review of material in (5 or 13) and either document acceptance of SQUG position or provide comments
	4/28/89 - Same as D.13 (17)			5/2/89 - Resolved in principle. GIP and anchorage report to be revised as appropriate in conjunction with Issues D.13a and D.13b
				9/21/90 - See resolutions associated with Issues D.13a and D.13b
15. PCI handbook	Some SQUG plants may have used this handbook (1:II.D.2.9). Open pending NRC staff review and acceptance (8)	No comment (13)	GIP guidelines do not rely on this handbook (2:II.D.2.9). No change to GIP is necessary	NRC to complete review of GIP Rev. 1 (3) and either document acceptance of SQUG position in GIP or provide comments
	4/28/89 - Since the PCI criteria are not used, this issue is moot (17)			5/2/89 - Resolved per GIP, Rev. 1
16. "Direct method" of generating in-structure response spectra	Open issue pending NRC staff review and acceptance for generic use (1:II.D.2.10 and 8). Resolved (13)	No comment (13)	GIP to note that generic use of "direct method" has not been accepted by NRC but may be accepted on a plant-specific basis (13)	SQUG to revise GIP, Rev. 2. NRC to document acceptance of SQUG position
	4/28/89 - Its use must be reviewed on a case-by-case basis (17)			5/2/89 - Resolved in principle. GIP to be revised per SQUG position
				9/21/90 - Resolved by deleting reference to Direct Generation Method in Sec. 4 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
D. Anchorage Guidelines (Continued)				
17. Factors of safety and cracks in concrete	Crack widths of 0.01 in. to 0.02 in. can cause up to 50% reduction of tensile capacity (9)	Same concern as NRC (9 and 5). To cover crack issue for widths up to about 0.02 inches and to cover a number of other minor issues, increase FS to 3 for non-shell expansion anchors without use of 1.25 factor of conservatism (13)	Increase FS to 4 for non-shell expansion anchors for crack widths greater than 0.02 inches (13)	EPRI/URS/Blume to further evaluate cracked concrete test data. SQUG and NRC to evaluate SSRAP suggested revision to FS for non-shell expansion anchors
	4/28/89 - Staff accepts a Factor of Safety of 3 but rejects deletion of the 1.25 load factor to account for the effects of cracks (≤0.02 inch) in concrete for non-shell expansion anchors. For cracks greater than 0.02 inches, a separate evaluation should be made (17)			5/2/89 - Open issue. Criteria given below being evaluated by NRC. Note two items of disagreement with SQUG (Factor of Safety for shell expansion anchors near hairline cracks and Factor of Safety for cabinets with relays)

Factor of Safety for Expansion Anchors Near Cracks

	Shell	Non-Shell
˚ Hairline cracks (< ~ 20 mils)	4 (NRC) 3 (SQUG)	3
˚ Cracks ~ 20 mils	4	4
˚ Cracks > ~ 20 mils	outlier	outlier

Demand Factor (Multiplier on demand applied to all anchorages)

˚ Medium Centered Spectra	1.25
˚ Conservative (SRP) Spectra	1.0

Tensile Strength — Per EPRI/URS Report; GIP, Rev. 1

Inspections - Sample — Per Issue D.2 resolution
- Torque — Wrench tight per Issue D.3 resolution

Relay Cabinets:
- SQUG Position: No special checks or different factors of safety.
- NRC Position: Minimum factor of safety of 4 for cabinets with relays.

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
D. Anchorage Guidelines (Continued)				
17. Factors of safety and cracks in concrete (Continued)	5/18/89 & 6/8/89 - Same NRC position as above except use FS=3 for shell and non-shell expansion anchors in concrete with cracks <= 0.010 inches near fewer than 50% of bolts. Use FS=4 when cracks <=0.010 inches are near more than 50% of bolts or when cracks are 0.010 to 0.020 inches wide (19)(22)		5/18/89 - Same SQUG position as above except use Demand Factor of 1.0 for all spectra (19)	
			6/14/89 - Disagree but will accept NRC position (21)	6/14/89 - Resolved with disagreement for expansion anchors. GIP and EPRI report to be revised per NRC position. SQUG to also develop similar criteria for cracks near cast-in-place anchorages
	7/27/89 - Draft EPRI anchorage report is acceptable subject to editorial changes and resolution of strength criteria for cast-in-place anchorages with concrete cracks up to 0.020 inches (25)	7/27/89 - Draft EPRI anchorage report is acceptable subject to editorial changes (25)	7/27/89 - Accept suggested editorial changes. (25)	7/27/89 - Open issue. NRC to consider whether existing capacity reduction factor adequately accounts for concrete cracks up to 0.020 inches wide for cast-in-place anchorages (25)

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
D. Anchorage Guidelines (Continued)				
17. Factors of safety and cracks in concrete (Continued)	10/5/89 - Do not agree with SQUG positi[illegible] on crack width for cast-in-pla[illegible] [illegible]chorages. Also F.S. of 1.7 do[illegible] appear to be included in SQUG approach.	10/5/89 - Evaluating SQUG position	10/5/89 - Use the following strength reduction factors for cast-in-place anchorages with cracks: Crack Width — Reduction Factor < 0.020" — 1.0 0.020" - 0.060" — 0.75 > 0.060 — Outlier	10/5/89 - Open issue. Discussions between URS/SSRAP/NRC are planned to resolve this issue
	12/12/89 - Concur with cast-in-place criteria for cracked concrete contained in 12/5/89 URS transmittal (30)	12/12/89 - Concur with cast-in-place criteria for cracked concrete contained in 12/5/89 URS transmittal (30)	12/12/89 - EPRI/URS anchorage report and GIP to incorporate material in 12/5/89 URS transmittal	12/12/89 - Resolved in principle. EPRI/URS report and GIP to be revised per SQUG position
	2/1/90 - Concur with SSRAP position (31)	2/1/90 - Concur with criteria for factors of safety for cast-in-place anchors in cracked concrete in 1/25/90 URS transmittal except that reduction factor to be used starting at 0.010 inches (31)	2/1/90 - EPRI/URS anchorage report and GIP to incorporate material in 1/25/90 URS transmittal including the 0.010 inch starting point for use of a reduction factor (31)	2/1/90 - Resolved in principle. EPRI/URS report and GIP to be revised per SQUG position
				9/21/90 - Resolution in App. C of GIP, Rev. 2 for each type of applicable anchor
18. Effect of concrete strength on tensile strength of expansion anchors	Ultimate expansion anchor strength of Phillips and Hilti catalog data for 4000 psi concrete is less than EPRI ultimate expansion anchor strengths for all concrete strengths greater than 3500 psi (9)	Concur with SQUG (5). Effect covered in revised FS=3 for non-shell expansion anchors (13)	Tensile strength test data for concrete strengths from 3500 psi to 4500 psi compared to test data for concrete strengths greater than 3500 psi shows that the results are about the same (5). No change to GIP is necessary	NRC to complete review of material from (5 and 13) and either document acceptance of SQUG/SSRAP position or provide comments

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
D. Anchorage Guidelines (Continued)				
18. Effect of concrete strength on tensile strength of expansion anchors (Continued)	4/28/89 - Staff's position is to use the manufacturer's catalog tensile strength rather than the EPRI values (17)			5/2/89 - Open issue. Criteria being evaluated by NRC. See Issue D.17 above
	5/18/89 & 6/8/89 - Staff accepts EPRI values of strength in GIP, Rev. 1 (19)(22)		5/18/89 - Use EPRI values for expansion anchorage bolt allowables (19)	6/8/89 - Resolved per GIP, Rev. 1
19. Missing bolt sizes in GIP Appendix [illegible] tables	Provide data in various tables for missing anchor bolt diameters (8)	No comment (13)	Missing bolt sizes [illegible] added to GIP	SQUG to revise GIP, Rev. 2
	4/28/89 - Not addressed at this time (17)			5/2/89 - Resolved in principle. GIP to be revised
				9/21/90 - Resolution in App. C of GIP, Rev. 2
20. Effect of bending on anchorage		Use of anchorage strength reduction factor of 50% for significant bending is not acceptable (5)	GIP will be changed to require separate evaluation of effects of bending (5, 13)	SQUG to revise GIP, Rev. 2
	4/28/89 - Not addressed at this time (17)			5/2/89 - Resolved in principle. GIP to be revised to indicate bending should be evaluated
				9/21/90 - Resolution in Sec. 4.4.1, Check 12 of GIP, Rev. 2
21. Discrepancy between GIP and anchorage report	5/2/89 - Table C-3 of GIP is not consistent with EPRI/URS report page 2-40			5/2/89 - Resolved in principle. Discrepancy to be corrected in GIP
				9/21/90 - Resolution in App. C.3.1 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
D. Anchorage Guidelines (Continued)				
22. Expansion anchor strength criteria for $f_c' < 3500$ psi	6/14/89 - No problem with proposed criteria but question whether criteria are needed for $f_c' <$ 3000 psi (21)	6/14/89 - Considerable effort required to review and reach agreement on guidelines (21)	6/14/89 - Proposed approach for anchorage strength data with 2000 psi $\le f_c' \le$ 3500 psi (21)	6/14/89 - Open issue. SQUG to poll utility members to determine if criteria below f_c' = 3500 psi is needed
			6/27/89 - Poll of SQUG utilities shows that about 12 plants have lower strength concrete (25)	6/27/89 - Open issue. URS/Blume to prepare a proposal to develop anchorage strength values for 2500 psi and 3000 psi concrete (25)
		11/15/89 - Concerned with extrapolating down to 2500 psi. Asked to see test data deaggregated into 2000 to 2500 psi range and 3000 to 3500 psi range (28)	11/15/89 - URS to address SSRAP concern in a future meeting (28)	11/15/89 - Open issue pending URS resolution of SSRAP concern (28)
	12/12/89 - Concur with criteria for lower strength concrete in URS 12/5/89 transmittal except for SSRAP concern (30)	12/12/89 - Concur with criteria for lower strength concrete in URS 12/5/89 transmittal except for concern that tensile capacity of expansion anchors appears to be reduced in the 3500 to 4000 psi range (30)	12/12/89 - URS to address SSRAP concern in a future meeting (30)	12/12/89 - Open issue pending URS resolution of SSRAP concern (30)
	2/1/90 - Concur with criteria for expansion anchor tensile strength in concrete below 4000 psi as described in 1/25/90 URS transmittal (31)	2/1/90 - Concur with criteria for expansion anchor tensile strength in concrete below 4000 psi as described in 1/25/90 URS transmittal (31)	2/1/90 - EPRI/URS anchorage report and GIP to incorporate material from 1/25/90 URS transmittal	2/1/90 - Resolved in principle. EPRI/URS report and GIP to be revised per SQUG's position.
				9/21/90 - Resolution in App. C.2.1 and C.2.7 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
D. Anchorage Guidelines (Continued)				
23. J-hook concrete fastener strength criteria		7/27/89 - More data is needed to support a strength criteria for J-hook concrete fasteners (25)	7/27/89 - Limited information was provided (25)	7/27/89 - Open issue. URS to provide additional justification for strength criteria of J-hook concrete fasteners and include results in supplemental report (25)
	11/15/89 - Concur with SSRAP comments (28)	11/15/89 - A minimum factor of safety of 1.5 should be met. Increase minimum spacing to 3 bolt diameters. Calculate smooth bar capacities using pre-1983 ACI code and British standard and compare to URS criteria. Concrete cracking not an issue if J-bolt is not near an edge or rebar is present. Deaggregate concrete strength data into 2000 to 2500 psi range and 3000 to 3500 psi range (28)	11/15/89 - URS to address SSRAP concerns in a future meeting (28)	11/15/89 - Open issue pending URS resolution of SSRAP concerns (28)
	12/12/89 - Concur with J-bolt criteria contained in URS 12/5/89 transmittal (30)	12/12/89 - Concur with J-bolt criteria contained in URS 12/5/89 transmittal (30)	12/12/89 - EPRI/URS anchorage report and GIP to incorporate material included in 12/5/89 URS transmittal	12/12/89 - Resolved in principle. EPRI/URS report and GIP to be revised per SQUG position
	2/1/90 - Concur with J-bolt criteria in 1/25/90 URS transmittal subject to changes noted in SSRAP's position (31)	2/1/90 - Concur with J-bolt criteria in 1/25/90 URS transmittal subject to correction of strength reduction formula, clarification of figure showing minimum embedment length, and editorial changes (31)	2/1/90 - EPRI/URS anchorage report and GIP to incorporate material from 1/25/90 URS transmittal and changes suggested in SSRAP position	2/1/90 - Resolved in principle. EPRI/URS report and GIP to be revised per SQUG's position
				9/21/90 - Resolution in App. C.4 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
D. Anchorage Guidelines (Continued)				
24. Expansion anchor types with limited backup test data or low test data		11/15/89 - Some makes and models of expansion anchors included in EPRI/URS anchorage report have not been included in test data or have questionable tensile capacity (e.g., WEJ-IT) (28)	11/15/89 - URS to address SSRAP concern in a future meeting (28)	11/15/89 - Open issue pending URS resolution of SSRAP concern (28)
		2/1/90 - Same concern as above. Certain makes and models of expansion anchors should be deleted since there is insufficient data available (31)	2/1/90 - List of acceptable makes and models of expansion anchors to include only those with adequate test data. URS to separately develop criteria for commonly used makes and models for which test data are not available (31)	21/1/90 - Open issue. SQUG to develop criteria for questionable makes and model of expansion anchors
		7/10/90 - Certain types of expansion anchors in EPRI/URS anchorage report had lower catalog failure test data than the mean used in anchorage report. Several other anchor types had few reported tests. Basis for including these should be included in anchorage report. Expansion anchor data is not applicable to masonry block wall (35)	7/10/90 - URS to develop a basis for using expansion anchors which have low catalog failure test data and limited test data. Anchorage report and GIP to be revised to exclude use of anchorage data in masonry block wall (35)	7/10/90 - Open issue. URS to develop criteria for expansion anchors with low or limited test data. Other issues resolved.
		8/24/90 - Agreement was reached with EPRI and URS/Blume on criteria for including expansion anchor makes and models not included in the EPRI/URS test data base (36)	8/24/90 - URS presented basis for including the makes and models of expansion anchors which have low or limited test data or no test data at all except for manufacturers data. Agreement was reached on seismic capacity criteria (36)	8/24/90 - Resolved in principle. EPRI/URS anchorage report and GIP to be revised per agreement at meeting (36)
				9/21/90 - Resolution in App. C.2.1 and C.2.2 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
E. Relay Review Guidelines				
1. Operator response to spurious alarms	Cannot rely upon normal operator response to clear alarms since operators are not trained to respond to spurious alarms arising from a seismic event (1:II.E.2.1)	No comment (14)	Operators are trained to respond to alarms whether spurious or real. Resolved per (11). No change to GIP is necessary	NRC to document acceptance of SQUG position; approve Rev. 1 of GIP
	4/28/89 - The staff concurs with the SQUG position that the reactor operators are trained to respond to alarms regardless of whether they are spurious or real. Other NRC programs (and A-46 Selection of Safe Shutdown Path) to verify adequate operator training and procedures preclude any need for a separate requirement as part of the A-46 implementation (17)			5/3/89 - Resolved per GIP, Rev. 1
2a. GERS for all types of relays	Testing of some types of relays, including older vintage relays, is needed (1:II.E.2.2)	Resolved per (5) subject to review of final report and confirmation that BNL does not have any data which contradicts this report	Resolved per (5)	NRC to complete review of material in (5) and either document acceptance of SQUG position or provide comments
	4/28/89 - The lack of GERS or other qualific?tion data for some relays is a problem encountered during the pilot plant reviews. The staff position is that for any relay which needs to be qualified under A-46 guidelines (chatter is unacceptable) a GERS or other qualification data must be provided (17)		5/3/89 - Guidelines based on qualification data for classes of equipment can be used	5/3/89 - Open issue. Criteria under development by SQUG
		6/13/89 - A reduction factor of 1/1.1 should be applied to seismic capacity of relays based on GERS (21)	6/13/89 - GIP to be revised to include 1/1.1 factor (21)	6/13/89 - Open issue. GERS report under development. GIP to be revised by SQUG

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
E. Relay Review Guidelines (Continued)				
2a. GERS for all types of relays (continued)	7/26/89 - BNL relay test data (900 pages) made available for review (24)		7/26/89 - Relay GERS report made available for review (25)	7/26/89 - Open issue. NRC (BNL) to review and comment on relay GERS report by end of August '89. SQUG to review and comment on BNL relay test data (25)
	9/13/89 - The IEEE standards for relay testing may not be adequate; however, this should be addressed separately from the USI A-46 program. If data exists which is lower than the current relay GERS, then these lower values should be used until proven to be invalid (26)	9/13/89 - Single relay tests may not be adequate since there appears to be variability in the BNL test data; however, this is not an A-46 issue since IEEE-344 allows single tests. Can not accept relay GERS when test data is in conflict with it (26)	9/13/89 - ANCO to complete relay GERS report and list specific relays for which BNL data are in conflict (26)	9/13/89 - Open issue. SQUG (ANCO) to complete relay GERS report. SQUG/NRC/SSRAP to resolve differences between individual GERS and BNL test data in conflict during October meeting (26)
	2/1/90 - Set of 13 comments sent from BNL on 1/10/90. Agree with resolution of these comments reached during meeting (31)	2/1/90 - No comments on relay GERS report. Concur with resolution of NRC's 13 comments (31)	2/1/90 - EPRI/ANCO report or relay GERS transmitted on 12/14/89. Resolutions of NRC's 13 comments to be incorporated into relay GERS report (31)	2/1/90 - Open issue pending review of final report
	7/10/90 - Relay GERS report is accepted subject to incorporation of editorial comments and resolution of any conflicts with W test data (35)	7/10/90 - Relay GERS report is acceptable subject to incorporation of editorial comments, clarification of GERS bases, and resolution of any conflicts with W test data (35)	7/10/90 - EPRI/ANCO relay GERS report dated 5/90 sent for review. Report will be revised to incorporate resolution of comments (35)	7/10/90 - Open issue pending review of revised report
				9/21/90 - Open issue pending final review of relay GERS report. Reference to latest version of relay GERS report included in Sec. 6 and 10 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
E. Relay Review Guidelines (Continued)				
2b. GERS for older relays	4/28/89 - The staff has reviewed recent testing report prepared for SQUG which compared older relays to the post 1975 relays. The staff agrees with the conclusion derived from the vintage testing that, for relays sampled, the vintage issue is not of a concern. Based on this testing and the experience data, the staff agrees that the GERS generated from newer relay data may be applied for older relays. If future testing identifies any specific relays for which the older vintage are significantly less rugged, an appropriate notification by the NRC will then be issued (17)			5/3/89 - Resolved in principle. GIP and GERS report to be revised 9/21/90 - Reference to latest version of relay GERS report included in Section 10 of GIP, Rev. 2
3a. In-cabinet amplification factors for MCCs and SWGR	Should provide a method to determine seismic demand at the location where relays are mounted in cabinets (1:II.E.2.3) 4/28/89 - Not addressed at this time (17) 5/12/89 - In-cabinet amplification factor should be: MCC 4.0 SWGR 9.0 Other (To Be Determined) (Ref. 18)	Factor of 3 for MCC type cabinets, 6 for switchgear type cabinets approved. Approach being used for developing factors for other panels is judged appropriate (5, 14)	Same as SSRAP position. Work is underway to develop additional amplification factors based on in-situ testing and other available test data (5)	NRC to document acceptance of SQUG/SSRAP position 5/3/89 - Open issue. Criteria under development by SQUG

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
E. Relay Review Guidelines (Continued)				
3a. In-cabinet amplification factor for MCCs and SWGR (continued)	5/18/89 - Can use 3 and 6 for relays mounted near frame members or mounted below half-height. Use 4 and 9 for remaining locations (19)	5/18/89 - Still support 3 and 6 for MCCs and SWGR panels (19)	5/18/89 - Same as SSRAP position (19)	5/18/89 - Open issue. Criteria under development by SQUG
	6/13/89 - Reconsidering position and leaning toward acceptance of MCC = 3 SWGR = 7 (Ref. 21)	6/13/89 - Dr. Kennedy evaluation of in-cabinet amplification shows: MCC = 3 SWGR = 5 - 7 (Ref. 21)	6/13/89 - Should use in-cabinet amplification factors of: MCC = 3 SWGR = 6 (Ref. 21)	6/13/89 - Open issue. NRC to consider position, based on Dr. Kennedy's evaluation for in-cabinet amplification (21)
			9/13/89 - Disagree with NRC position but will accept the following in-cabinet amplification factors: MCC = 3 SWGR = 7 (Ref. 26)	9/13/89 - Resolved with disagreement. GIP to be revised (26)
				9/21/90 - Resolution in Sec. 6.4.2, Screening Level 2, Table 6-2 of GIP, Rev. 2
3b. In-cabinet amplification factors for control panels and bench boards using S&A approach		5/18/89 - Concur in overall approach subject to detail comments contained in Reference 19	5/18/89 - Presentation of approach by S&A (19)	
	6/8/89 - Use of S&A approach cannot be accepted on a generic basis because of use of "direct method" of generating in-structure response spectra. (Same position as in Issue D.16.) Will review on a case-by-case basis, however (22)			

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
E. Relay Review Guidelines (Continued)				
3b. In-cabinet amplification factors for control panels and bench boards using S&A approach (continued)	6/13/89 - Convergence criteria for "direct spectra generation method" is needed. Participation factor should be in range from 2 to 2.5. Strengthen geometric inclusion rules for class of equipment covered (21)	6/13/89 - Participation factor of 1.5 appears to be too low. Strengthen geometric inclusion rules for class of equipment covered (21)	6/13/89 - Participation factor of 1.5 is appropriate (21)	6/13/89 - Open issue. SQUG developing criteria/basis for: - Basis for using generic AF = 3 for control panels and bench boards - Convergence criteria for use in "direct spectra generation method" - Participation factor of 1.5 - Geometric inclusion rules for class of equipment covered
	7/26/89 - May not allow use of "direct method" for all types of ground motion spectra. NRC structural branch to review S&A approach and comment at next SG meeting. NRC contractor (SWRI) agrees with 11 Hz lower bound subject to review of Humbolt Bay test data (25)	7/26/89 - Use of 11 Hz lower bound acceptable subject to review of Humbolt Bay test data. Use of high damping, 3 different type input spectra, clipping of narrow response spectral peaks, and revised inclusion rules suggested (25)	7/26/89 - S&A to revise approach based on SSRAP suggestions (25)	7/26/89 - Open issue. NRC to review and comment on "direct method". SQUG to revise approach to address SSRAP suggestions and to evaluate Humbolt Bay test data (25)
	9/13/89 - Agree with Overall Resolution (26)	9/13/89 - Agree with Overall Resolution (26)	9/13/89 - S&A methodology revised to incorporate SSRAP suggestions (26)	9/13/89 - Resolved in principle according to the following (26): Overall Resolution: - S&A methodology acceptable - Generic amplification factor of 4.5 for control panels and benchboards - Humbolt Bay test data is not in conflict with S&A approach and caveats - Direct generation method is an industry generic issue which will be addressed outside of USI A-46

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
E. Relay Review Guidelines (Continued)				
3b. In-cabinet amplification factors for control panels and bench boards using S&A approach (continued)	12/12/89 - Agree with S&A final draft report of 10/30/89 provided: · Peak amplification reduction factor of 0.6 applies only to highly amplified, narrow spectra · Restrictions are placed on the use of the Direct Generation Method (DGM) (30)	12/12/89 - Agree with S&A final draft report of 10/30/89 subject to review of seismic capacity vs. demand portion of the relay screening report. Concur with SQUG's position on DGM that this is an industry concern, not a USI A-46 issue (30)	12/12/89 - S&A to prepare restrictions to the use of the 0.6 reduction factor and include in EPRI/S&A in-cabinet amplification report. Disagree with NRC position on limitations to use of DGM. Appropriate application of DGM is an industry concern, not a USI A-46 issue and should not be addressed as a part of the USI A-46 resolution methodology (30)	12/12/89 - Open issue. S&A to develop specific restrictions on the use of the 0.6 factor for NRC and SSRAP review. Open issue. NRC to reconsider position on use of DGM.
	2/1/90 - Accept limitations on use of 0.6 peak reduction factor provided by S&A. Continue to require restrictions on the use of DGM (31)	2/1/90 - Accept limitations on use of 0.6 peak reduction factor provided by S&A (31)	2/1/90 - Limitations provided on use of 0.6 peak reduction factor. Disagree with NRC position regarding restrictions on use of DGM but will include them in EPRI/S&A in-cabinet amplification report (31)	2/1/90 - Open issue pending NRC/SSRAP review of revised report
	7/10/90 - EPRI/S&A report acceptable subject to inclusion of editorial comments, validation of computer code, and inclusion of additional restrictions providing parameters to computer code (35)	7/10/90 - EPRI/S&A report acceptable subject to inclusion of editorial comments and justification of basis for welding every 6 feet on center along the front and rear edges of a cabinet (35)	7/10/90 - S&A provided copies of latest in-cabinet amplification report dated 6/5/90 for review. S&A to revise report per NRC and SSRAP comments and to prepare a letter describing resolution of the issues raised during the meeting (35)	7/10/90 - Resolved in principle. EPRI/URS report to be revised per SQUG position. NRC to complete their validation of the S&A computer program

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
E. Relay Review Guidelines (Continued)				
3b. In-cabinet amplification factors for control panels and bench boards using S&A approach (continued)				9/21/90 - Resolved in principal pending receipt and review of final EPRI/S&A report. Resolution incorporated into Sec. 6.4.2, Screening Level 2 of GIP, Rev. 2
3c. Inclusion rules for cabinets with high and low in-cabinet amplification factors			6/13/89 - Inclusion rules being developed as part of the integrated approach for relay evaluation (21)6/13/89 - Open issue. Criteria under development by SQUG	
	7/26/89 - NRC consultant (SWRI) considers overall proposed approach reasonable but inclusion rules should be based on fundamental parameters affecting dynamic response (freq., mode shape, damping) (25)	7/26/89 - Have no problem with overall proposed approach but need to review the data to support the inclusion rules and the proposed amplification factors for each category (25)	7/26/89 - Justification for the inclusion rules and amplification factors being developed (25)	7/26/89 - Open issue. Justification for criteria, under development by S&A, to be reviewed during September SG meeting (25)
	9/13/89 - Agree with the inclusion rules subject to clarification of some of the rules (26)	9/13/89 - Agree with the inclusion rules subject to clarification of some of the rules (26)	9/13/89 - Revised inclusion rules were presented (26)	9/13/89 - Resolved in principle (26)
				9/21/90 - Resolution in Sec. 6.4.2, Screening Level 2 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
E. Relay Review Guidelines (Continued)				
4. Relay mounting	Should check all relay mountings, not just spot check, during the relay walkdown (1:II.E.2.5)	Agree with SQUG position (14)	Spot check is adequate to confirm that plant construction methods were consistent with manufacturers' recommendations (2:II.E.2.5). No change to GIP is necessary	NRC to document acceptance of SQUG position; approve Rev. 1 of GIP
	4/28/89 - The staff concurs with the SQUG that a 100% walkdown is not required. The sample size will be developed by the SQUG/SSRAP and approved by the staff (17)			5/3/89 - Resolved in principle. GIP to be revised to define known vulnerable types of relays to be looked for during sampling walkdown
				9/21/90 - Resolution in Sec. 6.5 of GIP, Rev. 2
5. Relays subject to impact chatter	Some relays are subject to chatter due to high frequency input (e.g., impact). GERS do not adequately address this issue. NRC Relay Review Group has reviewed and concurred in SQUG approach (11)	SQUG approach is acceptable (5)A list of relays vulnerable to high frequency input has been developed and will be used for screening out these relays (5)NRC staff should document acceptance of SQUG position or provide comments		
	4/28/89 - The staff and SQUG have reached agreement on a list of known relays that appears vulnerable to high frequency excitation. As with the vintage issue, any future problems identified could result in a separate NRC notification after the completion of the A-46 program (17)			5/3/89 - Resolved in principle. GIP to be revised to include list of vulnerable relays
	6/13/89 - Meeting between BNL, NRC, ANCO, MPR, and SG is needed to compare BNL relay test data to GERS (21)			6/13/89 - Open issue. NRC/SQUG evaluating BNL data for applicability

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
E. Relay Review Guidelines (Continued)				
5. Relays subjet to impact chatter (continued)	7/26/89 - Vulnerable relays from BNL tests of SWGR to be included on low ruggedness relay list (25)	7/26/89 - Vulnerable relays from BNL tests of SWGR to be included on low ruggedness relay list (25)	7/26/89 - Vulnerable relays from BNL tests of SWGR to be included on low ruggedness relay list (25)	7/27/89 - Resolved in principle. Low ruggedness relay list to be revised by SQUG (25)
				9/21/90 - Resolution in App. E of latest version of EPRI/MPR relay evaluation report. Reference to this report included in Sec. 6 and 10 of GIP, Rev. 2
6. Similarity criteria for determining ruggedness of untested relays			6/13/89 - Ground rules for comparing similarity of untested relays to tested ones being developed as part of the integrated approach for relay evaluation (21)	6/13/89 - Open issue. Criteria to be developed by SQUG with a working level review and comment by NRC
				7/26/89 - Draft rules for judging similarity to be sent by SQUG to SSRAP and NRC for review prior to next series of relay tests (25)
	9/13/89 - Rules appear reasonable but not convinced until after they have been validated by comparison to results of ANCO relay tests. Should have a team of recognized relay experts make this comparison (26)	9/13/89 - Similarity judgments should be made by a limited group of very knowledgeable and experienced relay experts (26)	9/13/89 - Similarity rules presented. Validity of rules to be determined by comparison to test results to be run by ANCO in the fall (26)	9/13/89 - Open issue. ANCO to run relay tests in Fall of 1989 and compare results to similarity rules (26)
			10/26/89 - SQUG will discontinue developing guidelines in this area until a need for them is established and funds are available (27)	10/26/89 - Resolved. Criteria development put on hold per SQUG position. GIP will not include guidelines in this area (27)
				9/21/90 - Criteria omitted from GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
E. Relay Review Guidelines (Continued)				
7. Switchgear GERS cover relay chatter	12/12/89 - Separate evaluation of switchgear relays needed; switchgear GERS not sufficient (30)	12/12/89 - Concur with SQUG's position (30)	12/12/89 - Switchgear GERS also demonstrate relay functionality provided the following conditions are met: · GERS capacity should exceed demand · Relays which affect breaker operation should not be on Low Ruggedness Relay List · Any relays added to switchgear should be evaluated for seismic adequacy using Relay evaluation methods (30)	12/12/89 - Open issue. NRC to evaluate SQUG's position and reconsider their position (30)
	2/1/90 - Separate evaluation of switchgear relays which control essential switchgear breaker operation is not necessary if: · Switchgear capacity (GERS or Bounding Spectrum) exceed demand, · Relays in these switchgear circuits are identified and documented in the Relay Evaluation Report, and · The identified relays are determined not to be on the Low Ruggedness Relay list. NRC noted that they may, in the future ask SQUG to address these identified relays after completion of the USI A-46 program (31)	2/1/90 - Accept NRC's position (31)	2/1/90 - Accept NRC's position (31)	2/1/90 - Resolved in principle. EPRI/MPR relay evaluation report and GIP to be revised per NRC's position
				9/21/90 - Resolution at end of Sec. 6.4.2 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
F. Seismic Interaction				
1. Effects of fire, flooding, and exposure to fluids, and seismic interaction affecting distribution lines beyond first anchorage point	Utilities should be encouraged to evaluate these concerns even though they are not within the scope of the USI A-46 review (1:II.F.1.a)	Should look for vulnerabilities to "utility" lines (10.0.20)	These seismic interactions are outside the scope of USI A-46 as defined in GL 87-02 (2:II.F.1.a and 10:0.20). Revision 1 to the GIP mentions that the utility may add these additional seismic interaction concerns to the scope of their review if they desire (3:0.5). The GIP also recommends that areas of concern observed during the walkdown should be evaluated (3:4.3). No other changes to GIP are necessary	NRC to document acceptance of SQUG position; approve Rev. 1 of GIP
	4/3/89 - The staff agrees with the SQUG approach (17)			5/3/89 - Resolved per GIP, Rev. 1

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
G. Cable & Conduit Raceway Systems				
1. Evaluation criteria	Topic to be addressed in future SER (1:II.G.2)	Overall approach being proposed appears acceptable subject to review of (1) revised cable/conduit raceway report and (2) report describing fatigue analysis approach and (3) alternative to 3x deadweight vertical load check (5)	Criteria under development. To be included in GIP, Rev. 2. Preliminary criteria being revised to incorporate lessons learned during tria se and alternative to 3x deadweight vertical load check (5)	NRC provide review/comment on cable tray criteria (9/88) and concur in resolution of issue
	4/26/89 - SQUG should choose one of the following two options: 1. Use the criteria already accepted by the staff. a. plant walkdown review b. limited analysis (15-20 cases) i Dead load (DL) design check ii Vertical capacity check (3xDL) iii Horizontal capacity check if the support connection is not ductile (2g horizontal load) c. Rod-hung type -- fatigue check 2. Take it out of the USI A-46 scope (17)		5/3/89 - Include cable trays in scope of USI A-46. Criteria under development	5/3/89 - Open issue. Criteria under development by SQUG. SSRAP to meet with EQE to revise report and EQE to issue report by 5/30/89 for discussion in mid-June meeting

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
G. Cable & Conduit Raceway Systems (Continued)				
1. Evaluation criteria (Continued)	6/14/89 - Accept revised cable tray evaluation criteria subject to clarifications in final report (21)	6/14/89 - Accept revised cable tray evaluation criteria (21)	6/14/89 - Presentation of revised EQE cable tray report dated 6/19/89 (21)	6/14/89 - Resolved in principle. EQE report and GIP to be revised to include agreed upon criteria
	6/27/89 - Must use 3xDL check for non-ductile lateral support systems since all cable trays in data base passed this criterion (23)	6/27/89 - Do not consider it necessary to use 3xDL for non-ductile supports since suitable horizontal load checks are required (23)	6/27/89 - Disagree and cannot accept NRC position on use of 3 x DL check for non-ductile supports (23)	6/27/89 - Disagree. EQE report and GIP will not require 3 x DL for non-ductile supports
			9/13/89 - Disagree with use of 3 x DL check for non-ductile supports	9/13/89 - Disagree. No change to the GIP on use of 3 x DL
				9/21/90 - Cable and conduit evaluation criteria included in Sec. 8 of GIP, Rev. 2. Use of 3 x DL check limited to ductile supports

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
H. Tanks and Heat Exchangers				
1. Evaluation criteria contained in GIP, Rev. 1		No significant comments (5)	Criteria to be supplemented in GIP, Rev. 2 to include expanded scope of applicable tanks (5)	SQUG to address in GIP, Rev. 2
	4/28/89 - Not addressed at this time (17)			5/2/89 - Resolved per GIP, Rev. 1
2. Structural integrity and buckling of tanks	GIP should address this (1:II.H.1)	SQUG's response is acceptable (14)	GIP revised per (3:II.7)	NRC to document acceptance of SQUG position; approve Rev. 1 of GIP
	4/28/89 - The staff considers this issue to be resolved since SQUG has agreed to specifically address these issues. Concerns relate to the criteria and methods are addressed elsewhere (17)			5/2/89 - Resolved per GIP, Rev. 1
			6/14/89 - Factored into draft URS/EPRI tanks and heat exchangers report Ref. 20 (21)	6/14/89 - Resolved in principle GIP and EPRI report to address issue
				9/21/90 - Resolution in Sec. 7 of GIP, Rev. 2
3. Refueling water storage tanks (RWST) in PWRs	GIP should include RWST in scope (1:II.H.1)	SQUG's response is acceptable (14)	GIP revised per (3:II.7.0)	NRC to document acceptance of SQUG position; approve Rev. 1 of GIP
	4/28/89 - The staff considers this issue to be resolved (17)			5/2/89 - Resolved per GIP, Rev. 1
				9/21/90 - Resolution in Part I, Sec. 2.3.5 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
H. Tanks and Heat Exchangers (Continued)				
4. Tanks supported on legs and skirts	GIP should address this (1:II.H.1)	SQUG's preliminary response to this is too general (14)	GIP, Rev. 2 will include guidelines for evaluating this (5)	SQUG to address in GIP, Rev. 2
	4/28/89 - Not addressed at this time (17)			5/2/89 - Resolved in principle. GIP to be revised
		6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Factored into draft URS/EPRI tanks and heat exchangers report Ref. 20 (21)	6/14/89 - Resolved in principle. GIP and EPRI report to address issue
				9/21/90 - Resolution in Sec. 7.2.1 of GIP, Rev. 2
5. Cracks in concrete near tank anchor bolts	Guidelines should be provided for assessing reduction of tank capacity (6)	Effect of non-ductile anchorage failure should be addressed (14)	Effect of cracks in concrete covered in anchorage work (14)	SQUG to develop guidelines to address ductile vs. non-ductile failure mode
	4/28/89 - Not addressed at this time (17)			5/2/89 - Resolved in principle. GIP to be revised to address non-ductile anchorage failure
	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Non-ductile anchorage failure covered in Ref. 20. Effects of cracks in concrete to be addressed in URS/EPRI anchorage report and referenced in tanks and heat exchangers report (21)	6/14/89 - Resolved in principle. GIP and EPRI report to address issue
				9/21/90 - Resolution in Sec. 7.3.3, Step 12 and Sec. 7.4.2, Step 2 of GIP, Rev. 2
6. Margin of safety over wide range of parameters	Perform sensitivity study to resolve uncertainty in proper use of guidelines (6)	Agree with SQUG (14)	Sensitivity study not needed. See references by Haroun and Veletsos (14)	SQUG to send NRC copies of references. NRC to review and approve GIP, Rev. 1
	4/28/89 - The staff considers this issue to be resolved (17)			5/2/89 - Resolved per GIP, Rev. 1

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
H. Tanks and Heat Exchangers (Continued)				
7. Damping values for determining spectral acceleration	Value of 4% appears too high for adequately anchored tank at rock site (6)	Agree with SQUG (14)	4% damping is realistic yet conservative for the analysis technique used (14)	NRC to document acceptance of SQUG position; approve Rev. 1 of GIP
	4/28/89 - The staff agrees that a total damping value of 4% should be used for tank evaluations (17)			5/2/89 - Resolved per GIP, Rev. 1
	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Factored into draft URS/EPRI tanks and heat exchangers report Ref. 20 (21)	6/14/89 - Resolved in principle. GIP and EPRI report to address issue
				9/21/90 - Resolution in Sec. 7.2.2 of GIP, Rev. 2
8. Concrete saddles	Expand guidelines to address this (6)	Provide guidelines for checking connectivity between tank, saddle, and floor	Concrete saddles in safety systems are not common. Criteria for their evaluation is same as for steel saddles. No change to GIP at this time (14)	SQUG to revise GIP to address connectivity between tank, saddle, and floor
	4/28/89 - Guidelines should be expanded to included tanks on concrete saddles. The staff will review the guidelines for checking connectivity between tank saddle and the floor (17)			5/2/89 - Resolved in principle. GIP to be revised
	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Factored into draft URS/EPRI tanks and heat exchangers report Ref. 20 (21)	6/14/89 - Resolved in principle. GIP and EPRI report to address issue
				9/21/90 - GIP, Rev. 2 does not specifically include criteria for concrete saddles but instead in Sec. 7.2.1 of GIP, Rev 2 references EPRI/URS tank and heat exchanger report for guidance on tank configurations not included in the GIP screening guidelines

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
H. Tanks a.. Heat Exchangers (Continued)				
9. Shell buckling for horizontal tanks	Expand guidelines to address this (6)	Not an issue since buckling under normal dead weight loading is controlling (14)	Seismic experience data does not show this to be a concern (14)	SQUG to develop an example showing dead weight loading controls design of shell
	4/28/89 - Not addressed at this time (17)			5/2/89 - Open issue. URS to provide example calculation showing that this is not a concern; to be provided by 5/30/89
	6/14/89 - Agree with approach i.. Ref. 20 but need additional words stating this failure mode is not credible and need not be evaluated (21)	6/14/89 - Agree with approach in Ref. 20. Experience data shows this failure mode is not a problem (21)	6/14/89 - URS/EPRI report to address issue including a statement that shell buckling of horizontal tanks is not a credible failure mode and need not be evaluated (21)	6/14/89 - Resolved in principle. GIP and EPRI report to address issue
				9/21/90 - Resolution in Sec. 7.4.2 of GIP, Rev. 2
10. Foundation/Soil properties	Provide guidelines on the acceptable foundation and soil media characteristics (8)	Revise GIP to specifically address .hift in frequency due to soil structure interaction (14)	Procedure provides for variation of impulsive frequency which covers frequency shift due to soil structure interaction (14)	SQUG to clarify guidelines to address effect of frequency shift due to SSI
	4/28/89 - Not addressed at this time (17)			5/2/89 - Resolved in principle. URS resolution 3-5 of 4/7/89 letter to use word "should" for "may". GIP to be revised
	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Factored into draft URS/EPRI tanks and heat exchangers report Ref. 20 (21)	6/14/89 - Resolved in principle. GIP and EPRI report to address issue
				9/21/90 - Resolution in Sec. 7.3.2, Step 4 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
H. Tanks and Heat Exchangers (Continued)				
11. Sample response spectrum	Provide sample response spectrum or reference one (8)	Sample spectra could be included but is not considered necessary (14)	SRT is familiar with concept of response spectra. No change in GIP is considered necessary (14)	NRC to document acceptance of SQUG position; approve GIP, Rev. 1
	4/28/89 - The staff considers this issue to be resolved (17)			5/2/89 - Resolved per GIP, Rev. 1
12. Coefficient of friction beneath tank	Describe results of using coefficients of friction greater or less than 0.55 (8)	Agree with SQUG position (14)	Coefficient of 0.55 is considered low for flat bottom tanks. Experience data shows that tanks do not slide (14). No change to GIP is necessary	NRC to document acceptance of SQUG position; approve GIP, Rev. 1
	4/28/89 - The staff considers coefficient of 0.55 adequate for flat bottom tanks (17)			5/2/89 - Resolved per GIP, Rev. 1
13. Location of slotted anchor bolt holes in horizontal tanks	Text of GIP Section 7.2.2.1 and Figure 7-12 are not consistent (8)	Agree with NRC comment (14)	Figure to be corrected in GIP, Rev. 2 (14)	SQUG to revise GIP, Rev. 2
	4/28/89 - Not addressed at this time (17)			5/2/89 - Resolved in principle. GIP to be revised
	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Factored into draft URS/EPRI tanks and heat exchangers report Ref. 20 (21)	6/14/89 - Resolved in principle. GIP and EPRI report to address issue
				9/21/90 - Resolution in Sec. 7, Figure 7-13 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
H. Tanks and Heat Exchangers (Continued)				
14. Height of fluid in horizontal tanks	Explain why fluid height in horizontal tanks is not a significant parameter (8)	Agree with SQUG position (14)	Procedure assumes tank is filled with water. GIP will be revised to clarify (14)	SQUG to revise GIP, Rev. 2
	4/28/89 - Since tanks are not always completely filled, the effects of partially filled tanks should be examined (17)			5/2/89 - Resolved in principle. GIP and final report to include caution to check for sharp increase in spectra (more than proportion with frequency)
	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Factored into draft URS/EPRI tanks and heat exchangers report Ref. 20 (21)	6/14/89 - Resolved in principle. GIP and EPRI report to address issue
				9/21/90 - Resolution in Sec. 7.4.2, Step 10, footnote of GIP, Rev. 2
15. B 'iography	Provide a listing of all papers used and referenced in developing the evaluation guidelines (8)	Agree with NRC position (14)		SQUG to develop a response
	4/28/89 - Not addressed at this time (17)			5/2/89 - Resolved in principle. Report to be revised
	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Factored into draft URS/EPRI tanks and heat exchangers report Ref. 20 (21)	6/14/89 - Resolved in principle. GIP and EPRı report to address issue
				9/21/90 - Latest version of EPRI/URS tank and heat exchanger report referenced in Sec. 10 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
H. Tanks and Heat Exchangers (Continued)				
16. Pad mounted equipment		Guidelines are needed to determine whether pad is competent to withstand uplift loads (5)		SQUG to develop a response
	4/28/89 - Not addressed at this time (17)			5/2/89 - Resolved in principle. GIP to be revised consistent with URS 2/10/89 response on anchorage
			6/14/89 - Evaluation of pad mounted equipment to be addressed in EPRI anchorage report not in tanks and heat exchangers report	6/14/89 - Resolved in principle per SQUG position
				9/21/90 - Resolution in Sec. 4.4.1, Check 14 of GIP, Rev. 2
17. Shear load on anchorage bolts	Explain why shear load is not considered for anchor bolts (16)	Anchor bolts do not resist shear load, friction on tank bottom does (14)		SQUG to develop a response
	4/28/89 - Not addressed at this time (17)			
	[illegible]89 & 5/12/89 - Staff requests the[illegible] to be a check of clearances or shear load capacity under some circumstances (18)	5/2/89 - Shear is not a significant issue and need not be addressed	5/2/89 - Disagree and cannot accept NRC position. Shear is not a significant issue and need not be addressed	5/2/89 - Disagree
	6/14/89 - [illegible]ree with approach in Ref. 20 (21)	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Disagree but EPRI report (20) revised to warn against shear loads in anchorage (21)	6/14/89 - Resolved with disagreement. GIP and EPRI report to address issue
				9/21/90 - Resolution in Sec. 7.3.4, Step 16 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
H. Tanks and Heat Exchangers (Continued)				
18. Effect of shear load on tank wall buckling	Explain how shear and buckling loads in shell are considered in guidelines (16)	Same answer as above (14)		SQUG to develop a response
	4/28/89 - Not addressed at this time (17)			5/2/89 - Resolved in principle. Report to be revised per response 3-2 of 4/7/89 URS memo
	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Factored into draft URS/EPRI tanks and heat exchangers report Ref. 20 (21)	6/14/89 - Resolved in principle. GIP and EPRI report to address issue
				9/21/90 - Effect of shear load on tank wall addressed in latest EPRI/URS tank and heat exchanger report. Procedure from this report included in Sec. 7.3 of GIP, Rev. 2
19. Effect of 2 directions of seismic motion	Explain why two horizontal components of earthquake motion are not considered (16)	For symmetric structures, two horizontal components can be resolved into one direction of motion (14)		SQUG to develop a response
	4/28/89 - Not addressed at this time (17)			5/2/89 - Resolved in principle. Report to be revised consistent with URS memo of 4/7/89, Comment 3-3
	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Factored into draft URS/EPRI tanks and heat exchangers report Ref. 20 (21)	6/14/89 - Resolved in principle. GIP and EPRI report to address issue
				9/21/90 - Effect of seismic motion in 2 directions addressed in latest EPRI/URS tanks and heat exchanger report. Sec. 7.3.2, Step 4 and Sec. 7.4.2, Step 10 uses maximum horizontal component

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
H. Tanks and Heat Exchangers (Continued)				
20. Use of AISC factors of 1.7 and 33%	Clarify GIP to prevent use of 33% increase of an allowable strength when used in conjunction with 1.7 load factor (16)	Agree with NRC comment (14)		SQUG to develop a response
	4/28/89 - Not addressed at this time (17)			5/2/89 - Resolved in principle. GIP to be revised to clarify use of 33%
	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Factored into draft URS/EPRI tanks and heat exchangers report Ref. 20 (21)	6/14/89 - Resolved in principle. GIP and EPRI report to address issue
				9/21/90 - Use of factors addressed in latest EPRI/URS tank and heat exchanger report. Sec. 7 of GIP, Rev. 2 used procedure from this report.
21. Soil-structure interaction (SSI) effect	Address SSI effect in GIP (16)	Agree with NRC comment (14)		SQUG to develop a response
	4/28/89 - Not addressed at this time (17)			5/2/89 - Resolved in principle. GIP to be revised as described under Issue H.10
	6/14/89 - Agree with approach in Ref. 20 except criteria for soil competency should be 3500 ft/sec (21)	6/14/89 - Agree with approach in Ref. 20 except criteria for soil competency should be 3500 ft/sec (21)	6/14/89 - SSI effect factored into URS/EPRI tanks and heat exchangers report [illegible] Will change criteria for soil competency to [illegible] ft/sec (21)	6/14/89 - Resolved in principle. G[illegible] and E[illegible]RI report to address issue
				[illegible]/90 - Resolution in Sec. 7.3.2, Step 4 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
H. Tanks and Heat Exchangers (Continued)				
22. Frequency shifts due to partially filled tank	Since the fluid level in the tank influences the natural frequency of the tank, effect on selecting acceleration from response spectra should be addressed (16)	For practical response spectra, the change in acceleration with respect to frequency is not significant compared to the reduction in moment loading with a reduction in tank level (14)		SQUG to develop a response
	4/28/89 - Not addressed at this time (17)			5/2/89 - Resolved in principle. GIP to be revised as described in Issue H.14
	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Factored into draft URS/EPRI tanks and heat exchangers report Ref. 20 (21)	6/14/89 - Resolved in principle. GIP and EPRI report to address issue
				9/21/90 - Resolution for vertical tanks uses maximum tank fill level with maximum spectral acceleration over range of frequencies ± 20% of fluid-structure modal frequency; included in Sec. 7.3.2, Step 4 of GIP, Rev. 2. Resolution for horizontal tanks has a check for effect of partially filled tank in Sec. 7.4.2, Step 10, Footnote of GIP, Rev. 2.
23. Buckling at top of tank	Explain why buckling at top of tank is not addressed in guidelines (16)	Buckling at top of tanks is out-of-scope of USI A-46 program. Experience data does not show this to be a real safety concern (14)		SQUG to develop a response
	4/28/89 - Not addressed at this time (17)			5/2/89 - Resolved in principle. Report to be revised per response 3-7 of URS 4/7/89 memo

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
H. Tanks and Heat Exchangers (Continued)				
23. Buckling at top of tank (continued)	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Agree with approach in Ref. 20 (21)	6/1 /89 - Factored into draft URS/EPRI tanks and heat exchangers report Ref. 20 (21)	6/14/89 - Resolved in principle. GIP and EPRI report to address issue
				9/21/90 - Effect of tank top buckling addressed in latest EPRI/URS tank and heat exchanger report. Procedure from this report included in Sec. 7.3.5 of GIP, Rev. 2
24. Penetrations and attachments	Provide basis for ignoring response to effect of appurtenances on tank (16)	GIP already addresses attachments and penetrations (14)		SQUG to develop a response
	4/28/89 - Not addressed at this time (17)			5/2/89 - Resolved in principle. Report to be revised per response 3-8 of URS 4/7/89 memo. GIP to be revised to add caution relative to flexibility of attached piping
	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Agree with approach in Ref. 20 (21)	6/14/89 - Factored into draft URS/EPRI tanks and heat exchangers report Ref. 20 (21)	6/14/89- Resolved in principle. GIP and EPRI report to address issue
				9/21/90 - Resolution in Sec. 7.3.7 of GIP, Rev. 2
25. Anchorage arrangements other than chairs	Explain why explicit guidelines for anchorage arrangements other than chairs are not needed (16)	Guidelines for other arrangements are covered with words in the GIP (14)		SQUG to develop a response
	4/28/89 - Not addressed at this time (17)			5/2/89 - Resolved in principle. GIP will be revised per response 3-9 of URS 4/7/89 memo. GIP will clarify that all chairs must be checked

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
H. Tanks and Heat Exchangers (Continued)				
25. Anchorage arrangements other than chairs (continued)	6/14/89 - Agree with approach in Ref. 20 except other types of chair details "need to be" checked (21)	6/14/89 - Agree with approach in Ref. 20 except other types of chair details "need to be" checked (21)	6/14/89 - Draft URS/EPRI tanks and heat exchangers report (Ref. 20) discusses use of other types of chair details. Report will be changed to say checks of other types of chairs "needs to be" performed (21)	6/14/89 - Resolved in principle. GIP and EPRI report to address issue
				9/21/90 - Resolution in Sec. 7.3.6 of GIP, Rev. 2
26. Hoop stress due to vertical excitation	GIP should address hoop stresses due to vertical excitation (16)	Experience data does not indicate this to be a failure mode (14)		SQUG to develop a response
	4/28/89 - Not addressed at this time (17)			5/2/89 - Resolved in principle. Report to be revised to include discussion in response 3-10 of URS 4/7/89 memo
	6/14/89 - Agree with approach in Ref. 20 except report should note that there have not been seismically-induced failures from hoop stress (21)	6/14/89 - Agree with approach in Ref. 20 except report should note that there have not been seismically-induced failures from hoop stress (21)	6/14/89 - Draft URS/EPRI tanks and heat exchangers report (Ref. 20) addresses hoop stress. Report will be changed to note that there have not been seismically-induced failures in welded tanks from hoop stresses (21)	6/14/89 - Resolved in principle. GIP and EPRI report to address issue
				9/21/90 - Hoop stress effect addressed in latest EPRI/URS tank and heat exchanger report. Procedure from this report included in Sec. 7.3 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
H. Tanks and Heat Exchangers (Continued)				
27. Slosh heights from low frequency excitation	Response spectra can be in error at low frequencies so that calculated slosh heights will also be questionable (16)	Each plant can use design FSAR response spectra which are valid at low frequencies (14)		SQUG to develop a response
	4/28/89 - Not addressed at this time (17)			5/2/89 - Resolved in principle. Report to be revised to include discussion in response 3-11 of URS 4/7/89 memo
	6/14/89 - Agree with approach in Ref. 20 except that report should state that slosh height limits are based on judgement (21)	6/14/89 - Agree with approach in Ref. 20 except that report should state that slosh height limits are based on judgment (21)	6/14/89 - Draft URS/EPRI tanks and heat exchangers report (Ref. 20) addresses slosh height and freeboard clearance. Report will be changed to note that slosh height limits are based on judgment but believed to be conservative (21)	6/14/89 - Resolved in principle. GIP and EPRI report to address issue
				9/21/90 - Slosh heights and freeboard clearance are addressed in latest EPRI/URS tank and heat exchanger report. Procedure from this report included in Sec. 7.3.5 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
I. Miscellaneous GIP Topics				
1. Systems engineer qualification	Should require extensive experience and broad understanding (1:III.A.2.1)	Agree with SQUG position (14)	While extensive experience and broad understanding are desirable, they are not considered necessary since engineering judgment is not a key feature in selection of safe shutdown equipment. List is documented and can easily be reviewed (2:III.B.2.1). No change to GIP is necessary.	NRC to document acceptance of SQUG position; approve Rev. 1 of GIP
	4/28/89 - The staff does not agree. The staff believes that the qualification of system engineer for the implementation of A-46 should include extensive experience and broad understanding of the nuclear power plant systems (17)		5/3/89 - Disagree but will accept NRC position	5/3/89 - Resolved with disagreement. GIP to be revised
				9/21/90 - Resolution in Sec. 2.2 of GIP, Rev. 2
2a. Qualifications for seismic capability member engineers	Should include a structural, a mechanical, and an electrical engineer (1:App., Section 2.1 and 7)	Should have experience in nuclear plant earthquake engineering and have experience in structural or mechanical engineering. Not necessary to require minimum years of experience (5, 14)	GIP Rev. 2 will be revised as agreed with SSRAP (2:App., Section 2.1) (5)	SQUG to address in GIP, Rev. 2
	4/28/89 - The qualifications as described in GIP Revision 1 are acceptable to the staff and should not be revised (i.e., five years experience requirements should stay) (17)		5/3/89 - Disagree but will accept NRC position	5/3/89 - Resolved with disagreement. GIP to be revised
				9/21/90 - Resolution in Sec. 2.4 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
I. Miscellaneous GIP Topics (Continued)				
2b. Qualifications for cable tray evaluation personnel	4/28/89 - The tasks of Chapter 8 (Cable Tray) should also be performed by the seismic capability member engineer (17)			5/3/89 - Resolved in principle. GIP to be revised
				9/21/90 - Resolution in Sec. 2.4 of GIP, Rev. 2
3. Method for estimating fundamental frequency of equipment	GIP should provide guidance on how to do this (1:III.B.2.1)	Would like to review guidelines when complete. Elaborate guidelines not considered necessary to judge whether frequency is greater or less than about 8 Hz (14)	Guidelines being developed and will be included in GIP, Rev. 2 (2:III.B.2.1)	SQUG to address in GIP, Rev. 2
	4/28/89 - Not addressed at this time (17)			5/3/89 - Open issue. Criteria under development. GIP to be revised
	9/13/89 - Agree with resolution in status column (26)	9/13/89 - Agree with resolution in status column (26)	9/13/89 - Agree with resolution in status column (26)	9/26/89 - Resolved in principle. Method for estimating fundamental frequency of equipment not to be covered in GIP but covered in SQUG training course (20)
				9/21/90 - Guidance for estimating natural frequency of equipment to be covered in training course; GIP will not include this guidance.

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
I. Miscellaneous GIP Topics (Continued)				
4. Audits of plant-specific implementation		An independent audit should be done because seismic evaluation requires considerable engineering judgment (10:S.1)	NRC plans to conduct such audits (10:S.1). No change to GIP is necessary	None
	4/28/89 - The staff plans to conduct detailed audits of some plants to fulfill its regulatory responsibility. The staff agrees with the SSRAP recommendation that independent audits to be conducted by the industry are an excellent means of checking the engineering judgments by the SRTs	5/3/89 - SSRAP still believes an audit is needed for all plants		5/3/89 - Resolved per GIP, Rev. 1

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
J. Training Course				
1. Approval of training program	NRC approval of training seminar/workshop is required (1:V.A.a)	No comment (14)	NRC approval is considered necessary only for Part III of GIP. SQUG does not consider it necessary to obtain formal NRC approval of each detail of course (2:V.A.a)	NRC to document acceptance of SQUG position; approve Rev. 1 of GIP
	4/28/89 - Not addressed at this time (17)			5/3/89 - Open issue. Criteria under development
	5/3/89 - NRC may not write an SER on training			
				9/21/90 - Description of training courses covered in Sec. 2.6 of GIP, Rev. 2
2. Type of personnel to take training course	All personnel involved in A-46 review, walkdown, and audit should take course (1:V.A.b)	Lead relay reviewer should be trained (10:S.6)	Only seismic capability member engineers, NRC auditors, and lead relay reviewers need to receive formal training (2:V.A.b and 10:S.b). No change to GIP is necessary	NRC to document acceptance of SQUG position; approve Rev. 1 of GIP
	4/28/89 - The staff agrees (17)			5/3/89 - Resolved per GIP, Rev. 1

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
K. Generic Letter 87-02 and Licensing Issues				
1. Plant-specific SERs	Plant-specific SERs will be issued for each USI A-46 plant based on the walkdown summary report from the utility. The utility should also send a letter to the NRC when all corrective actions are complete (2:App., Gen. Comment 5, and 2:App., Specific Comment, and 7)	No comment (14)	SQUG accepts NRC position (7)	NRC to document their position
	4/28/89 - The staff considers this issue to be resolved (17)			5/3/89 - Resolved per GIP, Rev. 1. Plant-specific SERs to be issued
2. Applicability of USI A-46 criteria to any equipment in plant	USI A-46 rules can be used for all electrical and mechanical equipment in plant provided: • Equipment reviewed/walkdown in accordance with GIP, and • Equipment changes, modifications, and replacements are performed in accordance with GIP, and • The GIP is maintained in a usable form in the future with NRC approval of significant changes. with the exception that the A-46 rules will not supersede other specific commitments made by licensee to meet other more limiting seismic qualification criteria (e.g., Reg. Guide 1.97, TMI Action Plan, etc.) (2:App., Specific Comment, and 2:App., Section 2.6.3 and 7)	Out of scope of SSRAP's area of responsibility (14)	After issuance of the plant-specific SER resolving A-46, a licensee may revise the plant design bases relating to seismic requirements for mechanical and electrical equipment to reflect the A-46 resolution (3:I.3.0)	NRC to document their stated position in SER and document acceptance of SQUG position; approve Rev. 1 of GIP

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
K. Generic Letter 87-02 and Licensing Issues (Continued)				
2. Applicability of USI A-46 criteria to any equipment in plant (continued)	4/28/89 - Not addressed at this time (17)			5/3/89 - Open issue. Criteria being evaluated by NRC
				9/21/90 - Resolution in Part I, Sec. 2.3.4 of GIP, Rev. 2
3. Equipment required for Reg. Guide 1.97 but not for USI A-46	Open pending NRC staff review and acceptance (1-App., Section 1.2 and 7)	No comment (14)	Equipment in scope of Reg. Guide 1.97 is not required to be seismically qualified unless it is also required to achieve and maintain safe shutdown for up to 72 hours, i.e., it is on the USI A-46 SSEL (2-App., Section 1.2)	NRC to document acceptance of SQUG position; approve Rev. 1 of GIP
	4/28/89 - The A-46 criteria would not apply to electrical and mechanical equipment for which other seismic licensing criteria have been imposed/committed to by the licensee. This restriction is interpreted to mean that the A-46 criteria would not supersede any plant-specific license commitments to utilize other seismic qualification criteria (e.g., for Reg. Guide 1.97 and TMI Items II.F.2 equipment)		5/3/89 - Disagree but will accept NRC position. GIP to be revised	5/3/89 - Resolved with disagreement. GIP to be revised
				9/21/90 - Resolution in Part I, Sec. 2.3.3 and 2.4.2 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM
HISTORY TABLE

Issue	NRC Position/Comment*	SSRAP Position/Comment*	SQUG Position/Comment*	Status
K. Generic Letter 87-02 and Licensing Issues (Continued)				
4. Equipment Operability	NRC accepts SQUG's position (7)	No comment (14)	Equipment operability, as related to equipment out-of-service, is beyond the scope of USI A-46 (7). Deleted from GIP (2:II.A.1)	NRC to document acceptanc. of SQUG position; approve Rev. 1 of GIP
	4/28/89 - The staff has some concern in deleting Sections 3.1.2.4 and 3.3.7 of GIP Revision 0. The staff agrees that it is unlikely that an earthquake will occur concurrently with having redundant components out of service provided that the allowable outage time is appropriately limited or strictly controlled by plant technical specifications. However, the staff believes that the statement in paragraph 3.1.2.4 of GIP Revision 0 is important and its should be put back in the GIP. In addition, the staff believes that the second sentence of second paragraph in Section 3.3.6 of GIP Revision 1 should be modified as follows: "If an item of equipment is taken out of service for maintenance and the allowable outage time is controlled by technical specification or appropriately limited, then that item of equipment is considered the single failure equipment for the purpose of this procedure". With these changes, the deletion of Section 3.3.7 of GIP Revision 0 is acceptable.		5/3/89 - NRC position represents a change in design basis of plant. Will agree to this position if NRC will agree to allow revision of plant design basis per SQUG position in Issue K.2	5/3/89 - Open issue. NRC to evaluate SQUG position 9/21/90 - Resolution in Part I, Sec. 2.4.1 of GIP, Rev. 2

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM

REFERENCES

No.	Document Description
1.	NRC Generic Safety Evaluation Report (GSER) based on GIP, Rev. 0.
2.	SQUG Response to GSER based on GIP, Rev. 0, September 21, 1988.
3.	Generic Implementation Procedure (GIP), Revision 1, December 1988.
4.	ANCO Report 1087.74C, "Supplementary Studies, Generic Seismic Ruggedness of Power Plant Equipment," December 1988.
5.	SQUG Report of Technical Review Meeting held on 1/17-1/19/89, in San Francisco, CA.
6.	NRC (P. Y. Chen) informal comments on tank and heat exchanger evaluation criteria telecopied to Mr. Wm. Schmidt just prior to SQUG Technical Review Meeting on 1/17-1/19/89.
7.	Memorandum to SQUG Utilities dated 9/23/88 from Wm. R. Schmidt, documenting tentative agreements reached with the NRC staff on significant licensing issues during a meeting on 9/20/88.
8.	NRC (Structural Branch) informal comments on GIP, Rev. 1, telecopied to Mr. R. Starck on 1/30/89.
9.	NRC Memo (G. Bagchi) dated 1/24/89 with enclosed report of meeting held on 12/1/88 between NRC, SQUG, and SSRAP to address anchor bolt issues.
10.	SSRAP comments on GIP, Rev. 0 and SQUG's response to them, dated 11/16/88.
11.	MPR (J. Betlack) meeting report dated 8/5/88 documenting agreements reached between SQUG and NRC on relay evaluation criteria.
12.	SSRAP Report dated 8/26/88, "Use of Seismic Experience and Test Data to Show Ruggedness of Equipment in Nuclear Power Plants."
13.	MPR (R. Starck) meeting report dated 2/24/89, documenting agreements reached between SQUG, SSRAP and the NRC staff on anchorage criteria during a meeting in Rockville, MD, on 2/16/89.
14.	NRC's and SSRAP's position/comment on the checklist of open/unresolved issues in the USI A-46 program were provided to SQUG during the SQUG/SSRAP/NRC meeting on 3/17/89. Also see report of this meeting.

REFERENCES (Continued)

No.	Document Description
15.	NRC (Reactor Systems Branch) comments on GIP, Rev. 1, telecopied to R. Starck (MPR) on 2/28/89.
16.	NRC (ESGB) additional comments on GIP, Rev. 1, Section 7, "Tanks and Heat Exchangers", dated 3/14/89, given to SQUG and SSRAP during 3/17/89 meeting.
17.	NRC (L. Marsh) letter dated 4/28/89 with enclosure stating NRC position on Checklist of Open/Unresolved Issues in USI A-46.
18.	NRC (L. Marsh) letter dated 5/12/89 and Enclosure 2 clarifying the NRC position on the Checklist of Open/Unresolved Issues in USI A-46.
19.	SQUG (W. Schmidt) report of USI A-46 Technical Review Meeting held in Bethesda, MD, on 5/18 & 5/19/89.
20.	URS/Blume (D. Jhaveri) memo dated 5/30/89 forwarding revised draft Tank & Heat Exchanger Report.
21.	SQUG (W. Schmidt) report of USI A-46 Technical Review Meeting held in Rockville, MD, on 6/13, 6/14, and 6/15/89.
22.	NRC (L. Marsh) letter dated 6/8/89 with enclosures addressing (1) S&A method for developing in-cabinet response spectra, (2) ground motion for MOVs in experience data base, (3) anchorage criteria, and (4) ANCHOR 2.0.
23.	Conference calls between NRC, EQE, SSRAP, KMC, MPR on 6/27 and 6/28/89 to discuss applicability 3xDL check for non-ductile lateral support systems for cable tray systems.
24.	NRC (T. Marsh) letter dated 7/19/89 with enclosures addressing the following topics: (1) SWRI 7/5/89 letter on ANCHOR 2.0 (2) SWRI 7/5/89 letter on Relay Seismic Evaluation Approach (3) BNL 7/21/89 letter on review of SQUG Relay Report (4) BNL 6/12/89 letter on GE HFA Relay Seismic Qualification Data (5) BNL 1/89 draft report on Seismic Fragility of Nuclear Plant Equipment, Vol. II (6) Whlie Labs 3/24/89 report on Seismic Fragility Test Program on Various Relays

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM

REFERENCES (Continued)

No.	Document Description
25.	MPR (W. Schmidt) report of USI A-46 Technical Review Meeting held in Rockville, MD, on 7/26 and 7/27/89.
26.	MPR (W. Schmidt) report of USI A-46 Technical Review Meeting held in San Francisco, CA, on 9/13 and 9/14/89.
27.	MPR (W. Schmidt) report of USI A-46 Technical Review Meeting held in Bethesda, MD, on 10/26 and 10/27/89.
28.	MPR (W. Schmidt) report of USI A-46 Technical Review Meeting held in Washington, DC, on 11/15/89.
29.	SQUG (N. Smith) letter to NRC (L. Marsh) dated 12/5/89 forwarding the following two position papers: • SQUG Position Paper, Seismic Qualification of New and Replacement Equipment in USI A-46 Nuclear Power Plants," dated 11/3/89. • SQUG Position Paper, "Technical Basis for Excluding NSSS Equipment and Supports From the Scope of USI A-46," dated 10/16/89.
30.	MPR (W. Schmidt) report of USI A-46 Technical Review Meeting held in Clearwater Beach, FL, on 12/12 and 12/13/89.
31.	MPR (W. Schmidt) report of USI A-46 Technical Review Meeting held in Rockville, MD, on 2/1 and 2/2/90.
32.	Westinghouse (R. Wiesemann) letter to NRC (T. Murley) dated 12/5/88 objecting to the NRC's use of the GERS for resolution of USI A-46.
33.	MPR (W. Schmidt) report of meeting between representatives of SQUG Steering Group and NRC-NRR management held in White Flint, MD, on 2/2/90.
34.	Westinghouse (R. Wiesemann) letter to NRC (T. Murley) dated 4/11/90 withdrawing Westinghouse's objections to NRC's use of the GERS for resolution of USI A-46.

CHECKLIST OF OPEN/UNRESOLVED ISSUES IN USI A-46 PROGRAM

REFERENCES (Continued)

No.	Document Description
35.	MPR (R. Starck and J. Betlack) report of USI A-46 Technical Review Meeting held in Lake Geneva, WI, on 7/10 and 7/11/90.
36.	URS/Blume (D. Jhaveri) report of meeting between URS/Blume, EPRI, and members of SSRAP held in Palo Alto, CA, on 8/24/90, to discuss inclusion of additional expansion anchors in anchorage report.

Revision 2

CONTROL COPY NO. _____

GENERIC IMPLEMENTATION PROCEDURE

(GIP)

FOR SEISMIC VERIFICATION OF

NUCLEAR PLANT EQUIPMENT

September 1990

SQUG

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

Section Page

PART II - GENERIC PROCEDURE FOR PLANT-SPECIFIC IMPLEMENTATION

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

REVISION STATUS

ACKNOWLEDGEMENTS

This document is the product of a team effort by many different organizations and individuals. Listed below are those which made significant contributions to the development of the guidelines and criteria contained herein.

The Seismic Qualification Utility Group (SQUG) and the Electric Power Research Institute (EPRI) have provided the financial support for the preparation of this document. The utilities that are or have been members of SQUG are listed below. Utilities not currently members of SQUG are denoted by an asterisk (*).

Alabama Power Co.
American Electric Power Co., Inc.
Arkansas Power & Light Co.
Baltimore Gas & Electric Co.
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Central Nuclear de Almaraz (Spain)
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Florida Power Corp.
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GPU Nuclear Corp.
Iowa Electric Light & Power Co.
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Tennessee Valley Authority
Toledo Edison Co.
Tractebel sa (Belgium)
Vermont Yankee Nuclear Power Corp.
Virginia Power
Westinghouse Savannah River Co.
Wisconsin Electric Power Co.
Wisconsin Public Service Corp.
Yankee Atomic Electric Co.

The SQUG Steering Group and the Electric Power Research Institute (EPRI) have provided the overall direction and supervision of the development of the guidelines and criteria contained in this document. The individuals serving in this capacity are listed below:

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ACKNOWLEDGEMENTS (Continued)

The <u>companies under contract</u> to SQUG and EPRI and the individuals currently and previously employed by these organizations who made significant contributions to the development of the guidelines and criteria in this document are listed below. Individuals not currently employed by the company listed are denoted by an asterisk (*).

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- Sam Swan
- Peter Yanev

MPR Associates, Inc.
- Kelley Baker
- Jess Betlack
- William Schmidt
- Richard Starck

Southern Company Services
- Donald Moore

Stevenson & Associates
- Walter Djordjevic
- John Stevenson
- Gary Thomas

URS Corporation/John A. Blume & Associates, Engineers
- Martin Czarnecki
- Dilip Jhaveri

The <u>Senior Seismic Review and Advisory Panel</u> (SSRAP) served as an expert advisory panel to the NRC and SQUG during the development of the guidelines and criteria contained in this document. Their contributions and advice are greatly appreciated. The individuals serving on this panel are listed below:

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Loring Wyllie, H. J. Degenkolb Associates, Engineers

GLOSSARY OF TERMS

AC	-	Alternating Current
ADS	-	Automatic Depressurization System
AFW	-	Auxiliary Feedwater
ARS	-	Amplified Response Spectra
ASME	-	American Society of Mechanical Engineers
B&PV	-	Boiler and Pressure Vessel
BWR	-	Boiling Water Reactor
CCW	-	Component Cooling Water
CRD	-	Control Rod Drive
CST	-	Condensate Storage Tank
CVCS	-	Chemical and Volume Control System
DC	-	Direct Current
DG	-	Diesel Generator
DH	-	Decay Heat
EE	-	Earthquake Experience
EPRI	-	Electric Power Research Institute
ESW	-	Emergency Service Water
FSAR	-	Final Safety Analysis Report
FWCI	-	Feedwater Coolant Injection
GERS	-	Generic Equipment Ruggedness Spectra
GIP	-	Generic Implementation Procedure
GRS	-	Ground Response Spectra
HCLPF	-	High Confidence, Low Probability of Failure
HELB	-	High Energy Line Break
HPCI	-	High Pressure Coolant Injection
HPCS	-	High Pressure Core Spray
HVAC	-	Heating Ventilating and Air Conditioning
HX	-	Heat Exchanger
LOCA	-	Loss of Coolant Accident
LPCI	-	Low Pressure Coolant Injection
LPCS	-	Low Pressure Core Spray
MCC	-	Motor Control Center
MS	-	Main Steam
MSIV	-	Main Steam Isolation Valve
NPSH	-	Net Positive Suction Head
NRC	-	Nuclear Regulatory Commission
NSSS	-	Nuclear Steam Supply System
OSVS	-	Outlier Seismic Verification Sheet
P&ID	-	Piping and Instrumentation Diagram
PORV	-	Power-Operated Relief Valve
PWR	-	Pressurized Water Reactor
RBCCW	-	Reactor Building Closed Cooling Water
RC	-	Reactor Coolant
RCIC	-	Reactor Core Isolation Cooling
RCS	-	Reactor Coolant System
RTD	-	Resistance Temperature Detector
RHR	-	Residual Heat Removal

GLOSSARY OF TERMS (Continued)

RHRS	-	Residual Heat Removal System
RWCU	-	Reactor Water Cleanup
RWST	-	Refueling Water Storage Tank
SAV	-	Specified Acceleration Value
SC	-	Shutdown Cooling
SCE	-	Seismic Capability Engineer
SEWS	-	Screening Evaluation Work Sheets
SLC	-	Standby Liquid Control
SQUG	-	Seismic Qualification Utility Group
SRP	-	Standard Review Plan
SRT	-	Seismic Review Team
SRV	-	Safety Relief Valve
SSE	-	Safe Shutdown Earthquake
SSEL	-	Safe Shutdown Equipment List
SSRAP	-	Senior Seismic Review and Advisory Panel
SVDS	-	Screening Verification Data Sheet
SW	-	Service Water
USI	-	Unresolved Safety Issue
ZPA	-	Zero Period Acceleration
ZPGA	-	Zero Period Ground Acceleration

Part I

LICENSING AND IMPLEMENTATION GUIDELINES

1.0 INTRODUCTION

1.1 Background

In December 1980, the Nuclear Regulatory Commission (NRC) Staff initiated an unresolved safety issue, USI A-46, "Seismic Qualification of Equipment in Operating Plants," related to seismic adequacy of mechanical and electrical equipment in older nuclear plants. After substantial technical research by both the Seismic Qualification Utility Group (SQUG) and the NRC regarding this issue, the Staff published, on February 19, 1987, a detailed approach for resolving USI A-46, in Generic Letter 87-02, "Verification of Seismic Adequacy of Mechanical and Electrical Equipment in Operating Reactors, Unresolved Safety Issue (USI) A-46." Implementation guidance for generic and plant-specific resolution of A-46 was provided in an enclosure to the Generic Letter, entitled "Seismic Adequacy Verification Procedure" (herein referred to as the Generic Letter Procedure).

The resolution methodology for USI A-46 is based, in part, on the belief that there is adequate margin in the seismic capacity of properly anchored equipment in older operating plants. It should be noted that trial plant walkdowns conducted to date support this conclusion. The purpose of USI A-46 is to verify this conclusion.

The Generic Letter Procedure sets forth an approach for verifying seismic adequacy of equipment using earthquake experience data supplemented by test results, as necessary. Utilities subject to USI A-46 are encouraged to participate in a generic program to accomplish seismic verification of equipment. As a result, SQUG developed this "Generic Implementation Procedure (GIP) For Seismic Verification of Nuclear Plant Equipment."

1.2 Purpose of the GIP

The GIP provides the detailed technical approach, generic procedures and documentation guidance which can be used by NRC licensees to verify the seismic adequacy of mechanical and electrical safe shutdown equipment. In this regard, the GIP also contains all of the activities necessary for resolution of USI A-46.

This method is sufficiently rigorous to provide a level of safety comparable to that achieved by the current requirements applicable to nuclear power plants in areas such as testing and qualification methods, for existing equipment as well as new and replacement equipment. The USI A-46 (GIP) methodology is primarily a conservative screening process. However, if safe shutdown equipment should fail to pass the initial screening, i.e., it is classified as an outlier, more detailed methods for verifying its seismic adequacy are provided in Section 5 of Part II of the GIP.

Because the GIP will be approved by the NRC in a safety evaluation report (SER), it provides an NRC-accepted method to verify the seismic adequacy of equipment and to resolve USI A-46 for individual plants. Every aspect of the Generic Letter Procedure has been fully considered in development of the GIP. Therefore, licensees (and the NRC Staff during review) will be guided solely by the GIP without reference to the Generic Letter.

The GIP contains two major Parts. Part I introduces USI A-46 and its resolution and establishes direction on specific licensing and implementation issues. Part II provides direction on how to apply the generic procedure to a plant-specific implementation. Part II also includes direction for selecting seismic evaluation personnel, identifying safe shutdown equipment, performing screening verifications and walkdowns, and resolving outliers.

1.3 GIP Commitments and Guidance

Each section of Part II of the GIP (except Sections 1 and 10) is divided into SQUG commitments (generally the "X.1" paragraph of each section, where "X" is the section number) and implementation guidance in the remaining paragraphs of that section. The commitments are key features of each aspect of the program. For the USI A-46 verification of seismic adequacy of electrical and mechanical equipment in response to the Generic Letter, licensees agree to implement the commitments as stated or to notify the NRC in writing if a GIP commitment is not implemented. The remaining guidance in the GIP comprises suggested methods for implementing the noted commitments. SQUG members may use the suggested methods or may substitute equivalent methods without notifying the NRC. However, SQUG members should be prepared to explain why the substituted method is equivalent.

For purposes of USI A-46 resolution, licensees will be bound by the commitments specifically set forth in their docketed submittals, i.e., the commitment sections of the GIP as modified by any written exceptions. NRC inspections related to USI A-46 will focus solely on whether each licensee's commitments as noted above have been met.

2.0 ISSUES AND POSITIONS

2.1 Introduction

Development of a generic program to resolve USI A-46 has led to a number of licensing and implementation issues, some of which are covered in this Section and some of which are covered in other parts of the GIP. Issues addressed in this Section generally pertain to the licensing aspects of the A-46 program, the impact of related NRC requirements (such as reporting regulations) on the implementation of the generic program, and technical matters which have been the subject of considerable discussion between SQUG and the NRC and have a significant impact on the implementation of the generic program.

Identification and resolution of A-46 issues have been the result of evolutionary processes starting with the Generic Letter and continuing to the present. These processes are documented by the references listed in Section 4 of Part I of the GIP, starting with the SQUG response to the Generic Letter (Reference 2 of Part I). The primary issues contained in these references have been addressed and incorporated into the GIP. Each revision of the GIP, including this revision, contains prior resolutions or positions on unresolved issues. For example, Revision 0 of the GIP included issues identified by SQUG in response to the Generic Letter. The Safety Evaluation Report (SER) prepared by the NRC based on Revision 0 of the GIP resulted in a new set of issues and positions that were subsequently included in Revision 1 of the GIP. SQUG intends to continue the process of revising the GIP to capture resolved issues as well as to reflect current issues and positions.

The SQUG "Checklist of Open/Unresolved Issues in the USI A-46 Program" (contained in Reference 7 of Part I), which is provided regularly to the NRC Staff for review and concurrence, summarizes the resolution history of many of these issues and cross-references supporting documentation containing details of the resolution. SQUG may revise this Checklist from time to time to track issues from identification to resolution. The Checklist may provide valuable information if future questions arise as to the scope and intent of these issues. Documents referenced in this Checklist and in other sections of the GIP should be referred to where more detail is desired or the historical development of an issue is of interest.

The remainder of this Section of Part I documents SQUG's position on some of these issues, and for clarification provides examples of possible licensing issue scenarios. The examples are merely accepted methods to resolve these issues on a plant-specific basis; other methods may also be used.

2.2 Interpretations of Guidelines

2.2.1 NRC Concurrence. Words such as "in general agreement with," when used by the NRC Staff in correspondence and SERs relating to the GIP, mean full concurrence with the relevant GIP section unless the Staff indicates specific areas of disagreement.

2.2.2 The Role of SSRAP During Implementation of A-46. The Senior Seismic Review and Advisory Panel (SSRAP) was established to provide technical review of SQUG efforts in developing a generic program to resolve USI A-46 through the use of experience data on equipment in industrial facilities which had been subjected to strong motion seismic events. SSRAP's functions and responsibilities were defined and agreed upon mutually by SQUG and the NRC Staff. SSRAP's tenure will end as a group at the completion of the development of the GIP. SQUG may reconvene SSRAP from time to time for assistance on generic matters. Use of SSRAP for such generic tasks, however, will be at the discretion of SQUG.

2.2.3 Assumptions. Section 3 of Part II of the GIP sets forth the basic assumptions regarding plant conditions to be used by SQUG members.

2.2.4 Completion Reports. To resolve USI A-46, the Generic Letter Procedure provides for submittal of an inspection report by each licensee upon completion of the plant walkdown. Licensees using the GIP for resolution may satisfy this USI A-46 report provision by referencing the GIP and by providing a plant-specific summary report, including a proposed schedule for future modifications and replacements, where appropriate. Details regarding the contents of the report are contained in Section 9 of Part II of the GIP. Each member utility will also provide a completion letter advising the NRC that any corrective actions identified in the summary report or agreed to with the Staff as a result of other related correspondence have been completed.

2.2.5 Reportability and the Need for JCOs. USI A-46 resolution methodologies do not impose any additional reporting requirements beyond the submittal requirements of Section 2.2.4 above, nor do they require preparation of Justifications for Continued Operation (JCOs) unless necessary to meet existing regulatory requirements applicable to the licensee, including the requirement to operate the facility in a manner that will not endanger the public health and safety. (It should be noted that the JCO referenced above need not necessarily be submitted to the NRC staff.)

Thus, failure of equipment to meet GIP initial screening or outlier resolution guidelines does not, of itself, give rise to a need for the licensee to consider a JCO or reporting under applicable reporting requirements unless the plant has modified its commitments to adopt the USI A-46 (GIP) methodology as its licensing basis for seismic qualification of electrical and mechanical equipment. However, if a determination is made that equipment failing to meet the GIP initial screening or outlier resolution guidelines does not meet the existing plant licensing or design bases, including specific plant commitments and requirements, the licensee must consider reportability and operability implications pursuant to Technical Specifications and 10 C.F.R. §§ 50.72 and 50.73, among others as appropriate, including the need for a JCO. Non-safety grade equipment selected for use in A-46 is not exempt from reporting requirements.

2.2.6 Multiplier for Equipment Above the 40-foot Level. It may be possible to justify seismic demand multipliers based on ground response for equipment above 40 feet. (Note: Section 4 of Part II uses a 1.5 multiplier for equipment below about 40 feet.) If the seismic demand study being undertaken by EPRI establishes multipliers above the 40-foot level, then SQUG may submit this in a GIP revision for approval by the NRC in accordance with Section 3.0 of Part I of the GIP.

2.2.7 Maintenance Programs. Existing preventive maintenance and inspection programs, as required by existing NRC requirements, will suffice to meet the maintenance and inspection guidelines for USI A-46. For example, during individual plant walkdowns, tightness testing of bolts and visual inspection to determine that bolts are not missing or obviously loose are covered in Section 4 of Part II of the GIP. It is not necessary to establish a program to periodically reinspect tightness after the walkdowns.

2.2.8 Implementation Schedule and Postponements. An implementation schedule need not be provided to the NRC staff until the final SER on the GIP is issued and open issues are resolved. Each licensee will commit to a final date (for example, a calendar date, or optionally, a specified number of days after completion of a given refueling outage) for submitting to the Staff a report summarizing the results of the A-46 review (see Paragraph 2.2.4 of Part I). Any delay beyond that date should be justified to the Staff; however, the licensee may organize and conduct its review as necessary to meet the scheduled date.

2.2.9 Third-Party Audits. SQUG will not provide for third-party audits; however, the NRC may require individual licensees to provide such audits after appropriate Staff justification in compliance with NRC Staff procedural requirements.

2.2.10 Plant-Specific SERS. Plant-specific SERs based upon the summary report of walkdown results will be issued by the NRC to close USI A-46 on each docket.

2.2.11 Achieving and Maintaining Hot Shutdown. Licensees are to identify equipment necessary to bring the plant to, and maintain it in, a hot shutdown condition during the first 72 hours following a Safe Shutdown Earthquake (SSE) as described in Section 3 of Part II of the GIP. Achieving hot shutdown within 72 hours may be inconsistent with some aspects of the licensing and design bases of some plants. Therefore, deviations from the 72-hour hot shutdown period will be considered by the Staff on a case-by-case basis with sufficient justification.

2.3 Compliance With Regulations

2.3.1 Backfitting. When a licensee concludes that no further action is necessary for an equipment condition that fails to meet the GIP initial screening or outlier resolution guidelines, but the condition is not a deficiency against the plant's current licensing or design bases, the Staff must comply with backfitting requirements pursuant to 10 C.F.R. § 50.109 before the licensee can be required to take any further action. The licensee must notify the Staff of the condition in the summary report (see Paragraph 2.2.4 of Part I) and provide a justification for not performing corrective modifications or replacements of equipment. Such justification is interpreted to mean that a simple statement will be provided as to the reason for not performing the modifications or replacements. The reason may be, for example, that the cost or safety benefit of performing such a modification or replacement is not considered warranted. Licensees need not provide an analytical justification for not modifying the identified condition.

It is the staff's responsibility under 10 C.F.R. § 50.109 to first justify that the condition must be modified, after which, modifications may be required. However, a backfitting analysis is not needed if the condition is a deficiency against the plant's current licensing or design bases.

2.3.2 Compliance with GDC-2. Equipment, including new and replacement equipment, evaluated and found acceptable using the USI A-46 (GIP) methodology are in full compliance with the seismic requirements (and not solely the intent) of General Design Criterion 2 of 10 C.F.R. Part 50, Appendix A, as related to seismic adequacy. Use of the USI A-46 (GIP) methodology is an NRC-approved alternative method for satisfying the pertinent equipment seismic requirements of GDC-2 (for those plants where GDC-2 applies).

2.3.3 Revision of Plant Licensing Bases. A licensee may, in accordance with 10 C.F.R. § 50.59, revise the plant licensing bases to reflect that the USI A-46 (GIP) methodology may henceforth be used for verifying the seismic adequacy of existing and new or replacement mechanical and electrical equipment within the scope of equipment covered by the GIP. (See Paragraph 2.3.4, below, for extending the scope of plant equipment to which the revised licensing bases apply, and for treatment of new or replacement equipment under the revised licensing bases.)

The USI A-46 (GIP) methodology shall not supersede any seismic qualification requirements imposed or committed to in connection with the resolution of other specific issues (e.g., Regulatory Guide 1.97, TMI Action Item II.F.2, and Individual Plant Examination for External Events) unless these qualification requirements or commitments are also revised according to appropriate regulatory requirements, e.g., Section 50.59, where applicable.

To help clarify the intent of this section for modifying the licensing bases of the plant, the following examples are provided. These examples explore some, but not all, of the possible scenarios that may be encountered by licensees when revising their licensing bases to adopt the USI A-46 (GIP) methodology (or an alternative) as the method for verifying seismic adequacy of electrical and mechanical equipment within the scope of equipment covered by the GIP.

Example 1: Revising the plant licensing bases when the plant is not currently committed to using any specific method to verify seismic adequacy of equipment, and there are no specific commitments to seismic qualification requirements for equipment connected with the resolution of other specific issues.

When a plant has no general commitment to methods or standards for seismic verification or qualification of equipment, i.e., the FSAR is silent, and no specific licensing commitments exist for specific issues (as discussed in Example 2, below), the plant may adopt the USI A-46 (GIP) methodology without specific notification of the NRC. This is neither a license change nor a change to the facility as described in the FSAR. Nevertheless, as with any change in the plant procedures or methodology for evaluation of plant adequacy, the basis for the change should be documented. One option available is a safety evaluation pursuant to 10 C.F.R. § 50.59 together with a formal FSAR change (if appropriate) in accordance with 10 C.F.R. § 50.71(e).

Example 2: Revising the plant licensing bases when the plant is not generally committed to any specific method to verify seismic adequacy, but when specific commitments to seismic qualification requirements exist for equipment connected with the resolution of other specific issues.

(a) For equipment not covered by any specific commitment, a Section 50.59 safety evaluation should be conducted and the FSAR changed (if appropriate) to reflect the new commitment in the manner suggested for Example 1, above.

(b) The USI A-46 (GIP) methodology will not supersede seismic qualification requirements imposed or committed to in connection with the resolution of other specific issues (e.g., Regulatory Guide 1.97, TMI Action Item II.F.2, and Individual Plant Examination for External Events).

To substitute the USI A-46 (GIP) methodology for specific licensing commitments such as these, Section 50.59 must be followed and the NRC notified, as appropriate.

Example 3: Revising the plant licensing bases when the plant is generally committed to using IEEE 344-1971 to verify seismic adequacy of equipment, but has no specific commitments to seismic qualification requirements for equipment connected with the resolution of other specific issues.

Where the plant has a general commitment to IEEE 344-71 and no other specific licensing commitments exist, a Section 50.59 safety evaluation should be performed and documented. In addition, if a change to the FSAR is appropriate, the NRC must be notified pursuant to Section 50.71.

The USI A-46 (GIP) methodology is more conservative than IEEE 344-1971. Accordingly, for plants committed to IEEE 344-1971, unless otherwise provided in the final SER on the GIP or the plant-specific SER following completion of the USI A-46 resolution, the change of commitment to the USI A-46 (GIP) methodology does not involve an unreviewed safety question. This does not relieve plants of the requirement of performing and documenting a Section 50.59 evaluation.

Example 4: Revising the plant licensing bases when the plant is generally committed to using IEEE 344-1971, and in addition, has specific commitments to more conservative guidance for equipment connected with resolution of specific issues.

(a) For equipment not subject to seismic qualification requirements imposed or committed to in connection with the resolution of other specific issues, the plant may modify its commitment to reflect use of the USI A-46 (GIP) methodology as described for Example 3, above.

(b) For equipment subject to seismic qualification requirements imposed or committed to in connection with the resolution of other specific issues, the commitments to the specific requirements may be revised as described in paragraph (b) of Example 2, above.

Example 5: This is a variation of Examples 1-4 that expands the scope of the USI A-46 (GIP) methodology to include new and replacement equipment and equipment outside the scope of A-46, when the equipment is within the scope of equipment covered by the GIP.

The scope of application of the USI A-46 (GIP) methodology may be expanded to include all mechanical and electrical equipment in the plant, provided the licensee also commits to the guidelines presented in Section 2.3.4 of Part I of the GIP, "Future Modifications and New and Replacement Equipment." A Section 50.59 safety evaluation should be performed and documented expanding the application of the USI A-46 (GIP) methodology from A-46 equipment to the new scope of equipment. If a change to the FSAR is appropriate, the NRC must be notified pursuant to Section 50.71.

Subsequent to resolution of USI A-46, if licensees take exception to the GIP criteria and modify those criteria for plant-specific application, this shall be accomplished by modifying the plant licensing bases using the regulatory provision of 10 C.F.R. § 50.59. This will be considered a plant-specific modification of a licensing commitment, not a modification of the GIP.

2.3.4 Future Modifications and New and Replacement Equipment. For any new equipment and replacement of or modifications to equipment having seismic requirements (including equipment not evaluated in response to A-46), licensees shall comply with the plant's licensing bases. Should the licensing bases include use of the USI A-46 (GIP) methodology as an option for verifying seismic adequacy, that methodology may be extended to all mechanical and electrical equipment if and only if the following conditions are satisfied:[1]

1. The equipment is reviewed and/or inspected in accordance with the GIP;

2. Equipment changes and modifications are performed in accordance with the GIP;

3. New or replacement equipment complies with any one of the following:

   a. If it is identical to the equipment originally installed in the plant, the criteria and procedures in the GIP apply,

   b. If it is not identical to the equipment originally installed in the plant, the licensee may, on a case-by-case basis establish the equipment's similarity to the installed equipment. The definition of similarity includes the following elements: (1) excitation, (2) dynamic properties and operability, and (3) dynamic response. After the similarity is established, then the criteria and procedures in the GIP apply, or

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[1] The USI A-46 (GIP) methodology is acceptable and sufficient for verifying the seismic adequacy of commercial grade equipment to be dedicated for safety-related purposes; for other (non-seismic) critical characteristics of equipment to be dedicated, licensees are referred to the guidance/requirements delineated in Generic Letters 89-02 and 89-09 which include applicable criteria of 10 C.F.R. Part 50, Appendix B.

c. If it is not identical to the equipment originally installed in the plant and the similarity is not established, its seismic adequacy may be verified by conducting a plant and equipment-specific evaluation using the approved USI A-46 (GIP) procedures, or at the licensee's option, application of current seismic qualification criteria or other means acceptable to the staff; and

4. The GIP is to be maintained in a usable form in the future, with NRC approval of significant changes, in accordance with Section 3.0 of Part I of the GIP. The USI A-46 (GIP) criteria and methodology do not supersede any seismic qualification requirements imposed or committed to in connection with the resolution of other specific issues (e.g., Regulatory Guide 1.97, Three Mile Island Action Item II.F.2, and Individual Plant Examination for External Events) unless those requirements or commitments are revised according to applicable regulatory requirements.

A-46 (GIP) criteria may be applied to modification or repair of existing anchorages (e.g., anchor bolts or welds) including one-for-one component replacements (e.g., replacing bolts in one-for-one component replacements) and for new anchorage designs. However, allowable anchorage loads, i.e., factors of safety, currently recommended for new nuclear plants, should be met for new anchorage designs.

When verifying the seismic adequacy of replacement equipment, some flexibility will be allowed in considering the safety function of the equipment. For example, as discussed in Section 6 of Part II, a relay may either be shown to be seismically adequate during an SSE or it may be determined that its function is not necessary for safe shutdown, in which case it is not an essential relay and seismic adequacy need not be verified. Similar functional screening is applicable to other parts of replacement equipment.

2.3.5 Resolution of USI A-40 and A-17. Utilities implementing the GIP and successfully completing the A-46 resolution, including tanks, heat exchangers and seismic spatial systems interactions, will have fully addressed, without any other actions, USI A-40 (Seismic Design Basis), as it applies to seismic adequacy of tanks and heat exchangers, and USI A-17

(Systems Interactions), as it applies to spatial interactions. Resolution of A-46 thus closes the remaining seismic issues associated with these USIs.

2.4 Equipment Selection and Verification

2.4.1 Operability and Redundancy. In general, operability and availability of A-46 safe shutdown systems and components will be governed by existing plant Technical Specifications. In all cases, unless in conflict with a Technical Specification or a license condition, the USI A-46 (GIP) methodology may be used to assess operability as related to seismic adequacy.

If an item of equipment is taken out of service for maintenance and the allowable time is controlled by a Technical Specification or is appropriately limited by administrative controls, that item of equipment is considered the single-failure equipment for the purpose of this procedure. Thus, the plant system containing the out-of-service equipment need not withstand a single failure in addition to the equipment taken out of service.

Where a licensee concludes that A-46 safe shutdown equipment not currently covered by Technical Specifications should be available during plant operation and, therefore, controlled, the licensee may develop either administrative controls or additional Technical Specifications, at its option, for that equipment. Administrative controls for A-46 equipment not subject to Technical Specifications should (1) address the operability of redundant components or alternative means for achieving and maintaining safe shutdown prior to removing A-46 equipment from service, and (2) establish a maximum amount of time the A-46 equipment may be out of service, considering the probability of an earthquake during the out-of-service period.

2.4.2 <u>Regulatory Guide 1.97 Equipment</u>. Post-accident monitoring instrumentation as reflected in Regulatory Guide 1.97 shall be verified seismically adequate according to plant-specific commitments agreed to with the NRC Staff, which may involve resolution using the USI A-46 (GIP) criteria. Meeting the seismic commitments agreed to with the NRC Staff regarding Regulatory Guide 1.97 will fully resolve USI A-46 for that equipment.

2.4.3 <u>Instrumentation and Controls</u>. Section 1 of the Generic Letter Procedure suggests that safe shutdown equipment should be selected to, among other things, "[m]aintain control room functions and instrumentation and controls necessary to monitor hot shutdown." In this regard:

- The reference to the control room does not preclude reliance on local instrumentation; and
- This guidance only applies after the period of strong motion from the earthquake.

Details regarding the use of instrumentation and controls to monitor and control the plant shutdown are contained in Section 3 of Part II of the GIP.

3.0 REVISIONS TO THE GIP

It is anticipated that the GIP will be a living document, undergoing revisions from time to time. Revisions to the GIP criteria may be made generically (e.g., by SQUG with NRC approval). Generic changes to the GIP will not apply retroactively to licensees committed to an earlier revision unless the licensees specifically commit to the new revision or, as a result of the safety significance of the issue, the Staff finds the change in position is warranted after following appropriate NRC regulatory controls, e.g., 10 C.F.R. § 50.109.

Where a cognizant industry organization (e.g., SQUG, EPRI or NUMARC) seeks a significant generic revision of the GIP, it must first submit the recommended change to the NRC Staff for review and approval. (A significant change is one that would be on a general level of an unreviewed safety question, as defined in 10 C.F.R. § 50.59.) The Staff will review the recommendation and provide its response in an SER. Changes that are not significant may be made by a cognizant organization and may be provided to licensees without NRC staff approval.

Unless the change is made retroactive by the Staff, as discussed above, licensees have the option of modifying their licensing bases (using the Staff SER as justification) to commit to the new revision. In modifying the licensing bases, licensees will be required to follow the provisions of 10 C.F.R. § 50.59, where appropriate.

In addition to generic changes to the GIP, an individual licensee may modify its licensing bases using the regulatory provision of 10 C.F.R. § 50.59. This may result in plant-specific modifications to the GIP criteria, as discussed in Paragraph 2.3.3 of Part I. This is considered to be modification of a plant commitment, not a change to the GIP.

4.0 REFERENCES FOR PART I

1. NRC Generic Letter 87-02, issued February 19, 1987.
2. SQUG response to Generic Letter 87-02 sent to T. Murley (NRC) by N. Smith (SQUG Chairman) on October 9, 1987.
3. SQUG Generic Implementation Procedure, Revision 0, issued June 1988.
4. NRC Safety Evaluation Report on Revision 0 of the GIP, issued July 29, 1988.
5. SQUG response to NRC Safety Evaluation Report on Revision 0 of the GIP sent to L.C. Shao (NRC) by N. Smith (SQUG Chairman) on September 22, 1988.

6. Generic Implementation Procedure, Revision 1, issued December 23, 1988.

7. "Checklist of Open/Unresolved Issues in USI A-46 Program," dated September 21, 1990.

8. NRC Supplement 1 to the Safety Evaluation Report on Rev. 1 of the GIP, issued June 29, 1990.

9. Letter from N.P. Smith to L.B. Marsh, December 5, 1989, forwarding SQUG Position Paper, "Technical Basis for Excluding NSSS Equipment and Supports from the Scope of USI A-46," October 16, 1989.

10. NUREG-1030, "Seismic Qualification of Equipment in Operating Nuclear Power Plants," February 1987.

11. NUREG-1211, "Regulatory Analysis for Resolution of Unresolved Safety Issue A-46 Seismic Qualification of Equipment in Operating Plants," February 1987.

Part II

GENERIC PROCEDURE FOR PLANT-SPECIFIC IMPLEMENTATION

Section 1

INTRODUCTION

1.1 PURPOSE

The purpose of this procedure is to summarize the technical approach and provide generic procedures and documentation requirements which can be used by owners/operators of operating nuclear power plants to verify the seismic adequacy of the mechanical and electrical equipment needed to bring the plants to a safe shutdown condition following a safe shutdown earthquake (SSE). This procedure can be used to address the NRC Unresolved Safety Issue (USI) A-46, "Seismic Qualification of Equipment in Operating Plants," as required by NRC Generic Letter 87-02 and supporting documents (References 1, 2, and 3).

The scope of equipment covered in this procedure includes active mechanical and electrical equipment such as: motor control centers; switchgear; transformers; distribution panels; pumps; valves; HVAC equipment; batteries and their racks; engine and motor generators; and instrumentation and control panels, cabinets, and racks. Relays are also reviewed in this procedure to determine if plant safe shutdown systems could be adversely affected by relay (contact) chatter as a result of an SSE. In addition, this generic procedure includes guidelines for evaluating the seismic adequacy of tanks, heat exchangers, and cable and conduit raceway systems.

1.2 BACKGROUND

The requirements for seismic design of nuclear power plants from 1960 to the present have evolved from the application of commercial building codes (which use a static load coefficient approach applied primarily to major building structures) to more sophisticated methods today. Current nuclear seismic design requirements for new plants consist of detailed specifications including dynamic analyses or testing of safety-related structures, equipment, instrumentation, controls, and their associated distribution systems (piping, cable trays, conduit, and ducts). Because of the extent of changes in the design requirements which have occurred over the years, the NRC initiated USI A-46, "Seismic Qualification of Equipment in Operating Plants," in December of 1980, to address the concern that a number of older operating nuclear power plants contained equipment which may not have been qualified to meet the newer, more rigorous seismic design criteria. Much of the equipment in these operating plants had been installed when design requirements, seismic analyses, and documentation were less formal than the rigorous practices currently being used to build and license nuclear power plants. However, it was realized that it would not be practical or cost-effective to develop the documentation for seismic qualification or requalification of safety-related equipment using procedures applicable to plants currently under construction. Therefore, the objective of USI A-46 was to develop alternative methods and acceptance criteria which could be used to verify the seismic capability of essential mechanical and electrical equipment in operating nuclear power plants.

In early 1982, the Seismic Qualification Utility Group (SQUG) was formed for the purpose of collecting seismic experience data as a cost-effective means of verifying the seismic capability of equipment in operating plants. One source of experience data is the numerous non-nuclear power plants and industrial facilities which have experienced major earthquakes. These facilities contain industrial grade equipment similar to that used in nuclear power plants. Another source of seismic experience data is shake table tests which have been performed since the mid 1970's to qualify safety-related equipment for licensing of nuclear plants. To use these sources of seismic experience data, SQUG and the Electric Power Research Institute (EPRI) have collected and organized this information and have developed guidelines and criteria for its use. This procedure is the generic means for applying this experience data to verify the seismic adequacy of mechanical and electrical equipment which must be used in a nuclear power plant during and following a safe shutdown earthquake.

1.3 APPROACH

The approach used in this procedure for verifying the seismic adequacy of mechanical and electrical equipment is consistent with the intent of NRC Generic Letter 87-02, "Verification of Seismic Adequacy of Mechanical and Electrical Equipment in Operating Reactors, Unresolved Safety Issue (USI) A-46" (Reference 1), including NUREG-1030 (Reference 2) and NUREG-1211 (Reference 3). The approach is also consistent with the EPRI Seismic Margins Assessment Program (SMA). The four major steps used in this procedure for the majority of the equipment to be evaluated are listed below, along with the section of the procedure where these steps are covered in detail:

- Selection of Seismic Evaluation Personnel (Section 2)
- Identification of Safe Shutdown Equipment (Section 3)
- Screening Verification and Walkdown (Section 4)
- Outlier Identification and Resolution (Section 5)

The seismic adequacy verification of the following types of equipment are covered in separate sections:

- Relay Functionality Review (Section 6)
- Tanks and Heat Exchangers Review (Section 7)
- Cable and Conduit Raceway Review (Section 8)

The documentation requirements for these reviews are included in each of these sections and in Section 9.

Each of the sections of Part II of the GIP (Sections 2 through 9) is divided into SQUG commitments and implementation guidance. The SQUG commitments, which follow the introduction in each of these sections, describe the key features of this procedure which SQUG members agree to implement for resolution of USI A-46; the NRC should be notified of any exceptions which are taken to these commitments. The remainder of each section provides implementation guidance in the form of suggested methods for implementing the commitments. SQUG members may use the suggested methods or substitute equivalent methods without notifying the NRC; however, they should be prepared to explain the justification for the equivalence of the substituted method.

The remainder of this section summarizes the material covered in Sections 2 through 9.

1.3.1 Seismic Evaluation Personnel

Several types of individuals, their qualifications, and their responsibilities for implementing this procedure are described in Section 2. These individuals include: (1) Systems Engineers who identify the methods and the equipment needed for bringing the plant to a safe shutdown condition, (2) Plant Operations Personnel who have a comprehensive understanding of the plant layout and the function and operation of the equipment and systems in the plant and who compare the plant operating procedures to the safe shutdown equipment list for compatibility, (3) Seismic Capability Engineers who perform the Screening Verification and Walkdown of the safe shutdown equipment, and (4) Relay Evaluation Personnel who perform the relay functionality review.

Since the instructions and requirements contained in this procedure are guidelines and not fixed, inflexible rules, the Seismic Capability Engineers must exercise sound engineering judgment during the Screening Verification and Walkdown. Therefore the selection and training of qualified Seismic Capability Engineers for the Seismic Review Teams (SRTs) is an important element in this Generic Implementation Procedure for resolution of USI A-46.

Section 2 also describes the SQUG-developed training course which should be taken by the individuals who perform the seismic review of the plant. These courses provide assurance that there is a minimum level of understanding and consistency in applying the guidelines contained in this procedure.

1.3.2 Identification of Safe Shutdown Equipment

The mechanical and electrical equipment needed to achieve and maintain a safe shutdown condition in a nuclear plant are identified in a two-step approach in Section 3 and Appendix A. The first step is to define the various alternative methods or paths which could be used to accomplish each of the four following safe shutdown functions:

- Reactor Reactivity Control
- Reactor Coolant Pressure Control
- Reactor Coolant Inventory Control
- Decay Heat Removal

One of the alternate methods for accomplishing each of these functions should be selected as the preferred safe shutdown alternative. This selection should also include backup equipment or a backup train of equipment so that the plant can be shut down in the event there is an active failure or unavailability of a single item of equipment. Equipment in other alternate methods can also be identified, if desired.

The second step is to identify the individual items of safe shutdown equipment for the preferred method by tracing out the path of action, fluid, and/or power on system description drawings and by developing a safe shutdown equipment list (SSEL).

The SSEL should be shown to be compatible with the plant operating procedures by the plant's Operations Department.

1.3.3 Screening Verification and Walkdown

The Screening Verification and Walkdown of mechanical and electrical equipment is described in Section 4. Appendices B through G provide supplemental information for performing this seismic adequacy verification. The seismic adequacy verification of relays, tanks and heat exchangers, and cable and conduit raceways are described in Sections 6, 7, and 8, respectively, and are summarized later in this Introduction.

The purpose of the Screening Verification and Walkdown is to screen out from further consideration those items of equipment which pass conservative, yet easy to apply, seismic adequacy criteria. The screening verification is based heavily on the use of seismic experience data. Those items of equipment which do not pass the screening verification are considered "outliers" and should be evaluated further as described in Section 5.

The four areas considered during the Screening Verification and Walkdown of safe shutdown equipment are:

- Comparison of the equipment seismic capacity to the seismic demand imposed upon it.
- Determination that the seismic experience data is applicable to the plant-specific safe shutdown equipment.
- Evaluation of the equipment anchorage adequacy.
- Check for adverse seismic spatial interactions.

1.3.4 Outlier Identification and Resolution

Items of safe shutdown equipment that do not pass the screening criteria contained in the GIP are considered outliers and should be evaluated further as described in Section 5.

Methods of outlier r solution are typically more time consuming and expensive than the screening evaluations. Also, outlier resolution may be somewhat open-ended in that several different options or approaches are available to verify the seismic adequacy of the equipment. The most appropriate method of outlier resolution will depend upon a number of factors such as (1) which of the screening criteria could not be met and by how much, (2) whether the discrepancy lends itself to an analytical evaluation, (3) how extensive the problem is in the plant and in other plants, and (4) how difficult and expensive it would be to modify, test, or replace the subject items of equipment.

1.3.5 Relay Functionality Review

The purpose of the relay functionality review, which is summarized in Section 6, is to verify that plant safe shutdown systems cannot be prevented from performing their safe shutdown functions by relay (contact) chatter as a result of an earthquake.

The first step in the review is to screen out from further consideration all those systems for which relay chatter would not significantly affect the safe shutdown systems or for which operator actions could be taken to reset the system following the earthquake. The second step is to evaluate the seismic adequacy of the individual relays which have not been screened out by comparing the seismic demand imposed on the relays with their seismic capacity. These essential relays are also walked down as part of this evaluation to spot check relay types, mountings, and locations, and, if necessary, to estimate in-cabinet amplification factors.

1.3.6 Tanks and Heat Exchangers Review

The review of tanks and heat exchangers for seismic adequacy is described in Section 7 and includes evaluations for: (1) stability of tank walls to prevent buckling (for large, vertical ground- or floor-mounted tanks only),

(2) anchorage and load path strength, (3) support member strength (e.g., support saddles and legs), and (4) adequate flexibility of attached piping to accommodate the motion of large, flat-bottom, vertical storage tanks. Screening guidelines are provided in the form of charts and calculation formulas that simplify the complex dynamic fluid-structure interaction analyses for large vertical tanks and simplify the equivalent static analysis method for horizontal tanks.

1.3.7 Cable and Conduit Raceway Review

Guidelines for verifying the seismic adequacy of electrical cable and conduit raceway systems are included in Section 8. Seismic adequacy of raceway systems is defined as protecting electrical cable function and maintaining overhead support. The screening guidelines address seismic adequacy by (1) using walkdown guidelines and (2) performing limited analytical reviews.

The walkdown guidelines have two purposes. First, the raceway systems are screened to check that they are representative of the experience data base. The walkdown guidelines also check for certain details that may lead to undesirable seismic performance as shown by past experience. Second, worst-case bounding samples of as-installed raceway system supports are selected for limited analytical review.

A limited analytical review is performed to check that the bounding sample supports are as rugged as those that have been shown to perform well by past earthquake experience. The checks address the raceway support dead load integrity, ductility, vertical capacity, and lateral capacity.

1.3.8 Documentation

The types of documents which should be developed for the USI A-46 evaluation are described in Section 9. The four major types of documents are:

- Safe Shutdown Equipment List (SSEL) Report
- Relay Evaluation Report
- Seismic Evaluation Report
- Completion Letter

1.4 QUALITY ASSURANCE AND QUALITY CONTROL REQUIREMENTS

The USI A-46 program for verification of seismic adequacy of equipment as defined by this procedure is outside the scope of commitments made in plant FSARs and Technical Specifications which form the basis of the operating license for the plant; therefore, there is no requirement to perform the USI A-46 program under the nuclear quality assurance and quality control requirements defined for the safety-related equipment in these plants. Instead, the following quality assurance elements apply to implementation of this procedure for the USI A-46 program:

- SQUG training courses will be provided to train individuals for use of the GIP.
- The safe shutdown alternatives will be reviewed by plant operating personnel.
- The seismic adequacy of equipment will be evaluated by at least two engineers, either of whom may identify the equipment as an outlier.

These training, evaluation, and review guidelines, together with the documentation requirements described in this procedure, are consistent with the requirements of Generic Letter 87-02 (Reference 1).

If modifications are made to any safety-related plant equipment as a result of the USI A-46 program, then the evaluations and designs for the changes in hardware should be performed in accordance with the quality assurance program and quality control requirements as defined in the plant FSAR and Technical Specifications.

The seismic adequacy verifications described in this document are based on the assumption that the equipment being evaluated was constructed and installed in accordance with the design and installation documents used by the utility; therefore, it is not necessary to perform quality control checks of the equipment or their installation for resolution of USI A-46 except as described in this document.

Section 2

SEISMIC EVALUATION PERSONNEL

2.0 INTRODUCTION

The purpose of this section is to define the responsibilities and qualifications of the individuals who will implement this generic procedure. The seismic evaluation personnel include individuals who identify safe shutdown equipment, who perform the plant walkdown and verify the seismic adequacy of equipment and cable/conduit raceway systems, and who perform the relay screening and evaluation. This may involve a number of plant and engineering disciplines including structural, mechanical, electrical, systems, earthquake, and plant operations.

Most utilities may prefer to implement this procedure using a designated team of individuals; i.e., a Seismic Review Team (SRT). However, the functions and responsibilities may be assigned to existing utility departments or groups, without definition of a dedicated team, provided the individuals in these utility departments or groups have the appropriate qualifications and training and that the walkdown teams have the required collective qualifications. Similarly, the individuals who undertake the seismic review may be utility or contractor personnel, provided the qualification and training criteria are met. This flexibility allows for the possibility that the functions may be performed by individuals of different disciplines at different times. Utility management is responsible for evaluating the qualifications of the seismic evaluation personnel for compliance with this procedure.

The remainder of this section is organized as follows:

- The requirements to which SQUG utilities commit when adopting the guidelines for personnel responsibilities and qualifications for resolution of USI A-46 are given in Section 2.1.
- The responsibilities and qualifications of the Systems Engineers who identify the safe shutdown equipment are described in Section 2.2.
- The responsibilities of the Plant Operations Personnel who review the Safe Shutdown Equipment List (SSEL) and assist during the seismic walkdown are described in Section 2.3.
- The responsibilities, qualifications, and training of the Seismic Capability Engineers who conduct the seismic walkdown are described in Section 2.4.
- The responsibilities, qualifications, and training of the Relay Review Engineers who perform the relay screening and evaluation are described in Section 2.5.
- The purpose and content of the SQUG training courses are summarized in Section 2.6.

2.1 SQUG COMMITMENTS

Members of SQUG adopting the Generic Implementation Procedure for USI A-46 resolution commit to the following in regard to the qualifications of individuals responsible for implementing the procedure:

2.1.1 Systems Engineers

The licensee will provide Systems Engineers to develop the list of equipment required for safe shutdown described in Section 3. Individuals selected to perform this function will be degreed engineers, or equivalent, with experience in the systems, equipment, and operating procedures of the plant.

2.1.2 Seismic Capability Engineers

The licensee will provide qualified Seismic Capability Engineers to perform the following tasks described in Sections 4, 6, 7, and 8.

1. Conduct a walkdown of plant equipment on the safe shutdown equipment list and cable/conduit raceway systems in the plant.
2. Assess the seismic adequacy of this equipment and raceway systems based upon experience, analyses, and/or engineering judgment.

These individuals will be degreed engineers, or equivalent, who have completed a SQUG-developed training course on seismic adequacy verification of nuclear power plant equipment, and will have at least five years experience in earthquake engineering applicable to nuclear power plants and in structural or mechanical engineering. At least one engineer on each Seismic Review Team will be a licensed professional engineer.

As a group, the engineers on each Seismic Review Team will possess knowledge in:

1. Performance of equipment, systems, and structures during strong motion earthquakes in industrial process and power plants.
2. Conduct of nuclear plant walkdowns.
3. Nuclear design codes and standards.
4. Seismic design, analysis, and test qualification practices for nuclear power plants.

2.1.3 Lead Relay Reviewer

The licensee will also provide a Lead Relay Reviewer to perform the Relay Functionality Review described in Section 6. This individual will be an experienced, degreed electrical engineer or equivalent who has successfully completed a SQUG-developed training course on the relay screening and evaluation procedure.

2.2 SYSTEMS ENGINEERS

The primary responsibility of the Systems Engineer is to develop the Safe Shutdown Equipment Lists (SSELs) as described in Section 3. This involves first identifying the various alternative paths or trains for bringing the plant to, and maintaining it in, a safe shutdown condition during the first 72 hours following a Safe Shutdown Earthquake (SSE). With help from the plant Operations Department, the Systems Engineer should select the preferred safe shutdown alternative for which seismic adequacy will be verified. All necessary equipment in this selected shutdown path should be identified.

If, after the plant has been walked down, the path selected contains few outliers, further systems evaluation by the Systems Engineer may not be necessary. However, if as a result of the walkdown, numerous outliers are found or outliers which are difficult to resolve are identified, the Systems Engineer may be requested to develop SSELs for an alternative path.

In addition to the primary responsibility of developing the SSEL, the Systems Engineer may be asked to provide background information and guidance to (1) the Seismic Capability Engineers who evaluate the seismic adequacy of the equipment and (2) the Relay Evaluation Personnel who perform the relay functionality review.

The Systems Engineer should be a degreed engineer, or equivalent, and have extensive experience with and broad understanding of the systems, equipment, and procedures of the plant.

2.3 PLANT OPERATIONS PERSONNEL

The plant Operations Personnel have two types of responsibilities during implementation of this procedure. First, they are responsible for reviewing the Safe Shutdown Equipment List (SSEL) (developed in Section 3) as compared to the plant procedures for shutting down the plant, to confirm that the SSEL is compatible with approved normal and emergency operating procedures (EOPs). Note that normal plant shutdown procedures would be used for any deliberate, planned shutdown and EOPs would be used for a plant trip or emergency shutdown following an earthquake. Second, plant Operations Personnel may be asked to assist the Seismic Capability Engineers during the Screening Verification and Walkdown and assist the Relay Review Personnel during the Relay Functionality Review.

To fulfill these responsibilities, the plant Operations Personnel should have knowledge of both steady-state and transient operations and the associated plant-specific operating procedures. They should be able to supply information on the consequences of, and operator recovery from, functional anomalies. It is their responsibility to provide information on the function and operation of individual equipment, instrumentation, and control systems.

Plant Operations Personnel may assist the Seismic Capability Engineers either as staff support or as members of an SRT. Though it is not required that the plant Operations Personnel be part of the seismic walkdown team, it is recommended. The plant Operations Personnel should have experience in the specific plant being seismically verified.

2.4 SEISMIC CAPABILITY ENGINEERS

The Seismic Capability Engineers should fulfill the following responsibilities:

- Become familiar with the SQUG approach as defined in the GIP and reference documents.
- Become familiar with the seismic design basis of the plant being evaluated, especially the equipment on the safe shutdown equipment list and the postulated Safe Shutdown Earthquake (SSE).
- Conduct the seismic evaluations and walkdowns of equipment and systems as described in the following sections:
  - Screening Verification and Walkdown (Section 4)
  - Relay Functionality Review (Section 6)
  - Tanks and Heat Exchangers Review (Section 7)
  - Cable and Conduit Raceway Review (Section 8)
- Use experience and judgment to verify the seismic adequacy of equipment and systems identified as necessary for safe shutdown.
- Perform additional analyses and calculations, when necessary, to verify the seismic adequacy of the safe shutdown equipment and systems.
- Make recommendations for any additional evaluations or physical modifications to equipment or systems which may be necessary to verify the seismic adequacy of equipment identified as outliers as described in Section 5.

The Seismic Capability Engineers may be assisted in fulfilling the above responsibilities by other individuals. For example, others may do background work to obtain information necessary for performing the seismic evaluations; they may also locate and assist in evaluating existing seismic qualification documentation; and they may perform backup calculations where necessary. Another example is that Seismic Capability Engineers may ask the Systems Engineers and the Plant Operations Personnel for information on how an item of equipment operates in a system so they may decide whether a malfunction of certain features of the item of equipment will affect its safe shutdown performance. Regardless of what help the Seismic Capability Engineers receive from others, they should remain fully responsible for all the seismic evaluations, engineering judgments, and documentation, including the details and backup documentation.

The Seismic Capability Engineers should be degreed engineers, or equivalent, who have completed a SQUG-developed training course on seismic adequacy verification of nuclear power plant equipment. These engineers should have experience (at least five years) in earthquake engineering applicable to nuclear power plants and in structural or mechanical engineering.

The Screening Verification and Walkdown should be conducted by one or more Seismic Review Teams (SRTs) consisting of at least two Seismic Capability Engineers on each team. The engineers on each team should collectively possess the following knowledge and experience:

- Knowledge of the performance of equipment, systems, and structures during strong motion earthquakes in industrial process and power plants. This should include active mechanical and electrical equipment and process and control equipment.
- Nuclear plant walkdown experience.
- Knowledge of nuclear design standards.
- Experience in seismic design, seismic analysis and test qualification practices for nuclear power plants. This should include active mechanical and electrical equipment and process and control equipment.

It is not necessary for each Seismic Capability Engineer to possess each of the above qualifications; differing levels of expertise among the SRT engineers is permitted. However, each SRT should collectively possess the above qualifications and each engineer on the team should have the ability to make judgments regarding the seismic adequacy of equipment.

At least one of the Seismic Capability Engineers on each of the Seismic Review Teams should be a licensed professional engineer to ensure that there is a measure of accountability and personal responsibility in making the judgments called for in the GIP.

In general, the individuals who perform the seismic review walkdown may be required to wear protective clothing, wear a respirator, work in radiation areas, climb ladders, move through crawl spaces, climb over obstacles, and work in high temperatures or other difficult situations. Therefore, the SRT members should be in good physical condition and have the capability and willingness to perform these tasks as necessary.

2.5 RELAY EVALUATION PERSONNEL

The Relay Evaluation Personnel include those individuals who will perform the Relay Functionality Review described in Section 6 and Reference 8. This evaluation includes reviewing electrical circuit drawings, documenting the review conclusions, performing the relay walkdowns, and providing associated support activities.

Electrical engineering will be the primary engineering discipline involved in the relay review; however, the evaluation may also use a number of other engineering disciplines; including structural, mechanical, systems and earthquake engineering. Information and assistance from plant personnel regarding plant operations and maintenance may also be required.

The capabilities and responsibilities of the various Relay Evaluation Personnel are listed below:

Lead Relay Reviewer

The Lead Relay Reviewer should be a degreed, or equivalent, electrical engineer with experience who is familiar with the Relay Functionality Review procedure described in Section 6 and Reference 8. The Lead Relay Reviewer should successfully complete the SQUG-developed relay training course. The relay walkdown described in Section 6 is not expected to involve entries into radiation areas nor any special physical demands.

The Lead Relay Reviewer should either perform the review or assist reviewers in interpreting electrical design drawings and in identifying essential relays in the safe shutdown systems. The Lead Relay Reviewer should have a good understanding of circuit design logic and the consequences of relay malfunction in essential circuits.

Assistant Relay Reviewer

An Assistant Relay Reviewer with an electrical engineering background can be used to document the relay review and obtain support documentation such as electrical drawings, technical specifications, operator reference manuals, and procedures. Additional assistant reviewers with other backgrounds could also be used.

Systems Personnel

Systems Engineers and/or plant Operations Personnel who are capable of providing information on the operation of the safe shutdown systems and plant operating procedures should be used in the Relay Functionality Review. Their assistance will be needed to identify safe shutdown equipment and essential control and power circuits which may be tripped as a result of an earthquake. They should also be able to provide information on the instrumentation and controls available to monitor and control the equipment affected by relays.

Plant Maintenance Representative

A plant staff electrical and/or instrumentation and controls maintenance representative should be available to provide assistance during the Relay Functionality Review to help establish the location, mounting, types and characteristics of relays in the safe shutdown circuits.

Seismic Capability Engineers

The Seismic Capability Engineers should perform certain appropriate evaluations in support of the Relay Functionality Review. These evaluations can be performed during the Screening Verification and Walkdown (described in Section 4) and include:

- Identifying potential instances of seismic spatial interaction.
- Giving special consideration to expansion anchor bolts which secure cabinets containing essential relays.
- Establishing in-cabinet amplification factors for cabinets containing essential relays.

2.6 SQUG TRAINING COURSES

Two training courses were developed by SQUG to provide additional guidance on how to implement USI A-46 using the GIP and the referenced documents. These courses include:

- The Walkdown Training Course provides guidance for the Screening Verification and Walkdown (Section 4), the Outlier Identification and Resolution (Section 5), the Tanks and Heat Exchangers Review (Section 7), and the Cable and Conduit Raceway Review (Section 8). Guidance is also provided on estimating in-cabinet amplification factors for electrical cabinets containing essential relays (Section 6) and documenting the USI A-46 evaluation (Section 9).

This course is provided primarily for the Seismic Capability Engineers, however others who may support these engineers may also take this course.

- The Safe Shutdown Equipment Selection and Relay Screening and Evaluation Training Course provides instructions on the Identification of Safe Shutdown Equipment (Section 3) and how to perform the Relay Functionality Review (Section 6).

  This course is provided primarily for the Lead Relay Reviewers. The Systems Engineers and others may also take this course.

The objectives of these SQUG training courses are as follows:

- Provide additional information on the background, philosophy, and general approach developed by SQUG to resolve USI A-46.

- Provide additional guidance in the use of the GIP and applicable references to select safe shutdown equipment and to verify their seismic adequacy.

Section 3

IDENTIFICATION OF SAFE SHUTDOWN EQUIPMENT

3.0 INTRODUCTION

The purpose of this section is to describe the overall method for identifying the mechanical and electrical equipment needed to achieve and maintain safe shutdown conditions in a nuclear plant. Appendix A provides a detailed step-by-step procedure for using this method based on the guidance contained in this section. A description of the contents of the subsections contained herein is given below.

Section 3.1 provides the commitments in regard to identification of safe shutdown equipment. The remaining sub-sections provide implementation guidance. The general criteria and governing assumptions to be used in identifying the equipment are defined in Section 3.2. The scope of equipment to be identified is defined in Section 3.3; it includes mechanical and electrical equipment which should operate to accomplish a safe shutdown function, tanks and heat exchangers, equipment which should not inadvertently operate due to relay (contact) chatter, and cable and conduit raceway systems supporting electrical wire for safe shutdown equipment.

For resolution of USI A-46, it is not necessary to verify the seismic adequacy of all plant equipment defined as Seismic Category I, e.g., in NRC Regulatory Guide 1.29. Instead, only those systems, subsystems, and equipment needed to bring the plant from a normal operation condition to a safe shutdown condition need be identified to ensure safety during and following a Safe Shutdown Earthquake (SSE). The method described in the remainder of this section for identifying safe shutdown equipment has two major steps. The first step is to identify the various alternative methods or paths which could be used to accomplish the following four safe shutdown functions:

- Reactor Reactivity Control
- Reactor Coolant Pressure Control
- Reactor Coolant Inventory Control
- Decay Heat Removal

These four safe shutdown functions are described in Section 3.4. Because of redundancy and diversity in nuclear power plants, there may be several paths or trains which could be used to accomplish these four functions. Only the active equipment in a primary path or train and backup equipment within that path or a backup path need be identified for seismic evaluation as discussed in Section 3.2. The preferred safe shutdown path can be selected based on such considerations as previous systems analyses (e.g., for fire protection), ease of use by operators, compatibility with plant procedures, and status of existing seismic qualification of equipment. There may be other secondary considerations for selecting certain safe shutdown paths such as ease of performing the plant walkdown and seismic adequacy verification. The various alternative paths for accomplishing the safe shutdown functions are summarized in Section 3.5 for pressurized water reactors (PWRs) and for boiling water reactors (BWRs). Appendix A gives a detailed description of these alternative paths.

After identifying the preferred safe shutdown paths, the second major step is to identify the individual items of equipment contained in these preferred safe shutdown paths. The approach for identifying the individual items of safe shutdown equipment is summarized in Section 3.6. Appendix A gives a detailed description of this method including a step-by-step procedure, flow diagram, and documentation forms which can be used to develop a Safe Shutdown Equipment List (SSEL) for seismic adequacy verification and an SSEL for relay evaluation.

Section 3.7 describes several methods which may be used by the plant's Operations Department to review the SSEL for compatibility with the plant operating procedures. Section 3.8 summarizes the documentation which should be generated when identifying safe shutdown equipment.

3.1 SQUG COMMITMENTS

Members of SQUG adopting the Generic Implementation Procedure for USI A-46 resolution commit to the following in regard to identification of safe shutdown equipment:

3.1.1 Identification of Safe Shutdown Path

Relying on the Systems Engineers noted in Section 2, the licensee will identify equipment needed to achieve and maintain a safe shutdown condition following a safe shutdown earthquake (SSE).

To identify this equipment, the licensee will use a two-stage approach:

1. The licensee will select a safe shutdown path which would ensure that the four essential safe shutdown functions listed below can be accomplished following an SSE. The functions are:

    - Reactor reactivity control
    - Reactor coolant pressure control
    - Reactor coolant inventory control
    - Decay heat removal

2. After identifying the safe shutdown path, the licensee will identify the individual items of equipment required to accomplish the four essential safe shutdown functions.

3.1.2 Assumptions Used in Identifying Safe Shutdown Path

In selecting the safe shutdown path and equipment the licensee will be bound by the following conditions:

1. Offsite power may not be available for up to 72 hours following the earthquake.

2. No other extraordinary events or accidents (e.g., LOCAs, HELBs, fires, floods, extreme winds, sabotage) are postulated to occur other than the SSE and loss of offsite power.

3. If achieving and maintaining safe shutdown is dependent on a single item of equipment whose failure to perform its active function, either due to seismic loads or random failure, would prevent accomplishment of any of the four essential safe shutdown functions, an alternative method to safe shutdown by use of a different path or a different item of equipment in the same path will be identified for seismic evaluation which is not dependent on that item of equipment.

4. Where operator actions are relied upon to achieve and maintain safe shutdown, the licensee will ensure that appropriate procedures are available which consider the time within which actions must be taken, and that operators have been trained in the use of these procedures.

5. The equipment to be identified for seismic evaluation will include:

   - Active mechanical and electrical equipment which operates or changes state to accomplish a safe shutdown function.

   - Active equipment in systems which support the operation of identified safe shutdown equipment; e.g., power supplies, control systems, cooling systems, lubrication systems.

   - Instrumentation needed to confirm that the four safe shutdown functions have been achieved and are being maintained.

   - Instrumentation needed to operate the safe shutdown equipment.

   - Tanks and heat exchangers used by or in the identified safe shutdown path.

   - Cable and conduit raceways which support electrical cable for the selected safe shutdown equipment.

6. The following equipment types need not be identified for seismic evaluation:

    - Equipment which could operate but does not need to operate and which, upon loss of power, will fail in the desired position or state. This type of equipment is defined as passive for the purposes of this procedure.

    - Passive equipment such as piping; filters; electrical penetration assemblies; and small, lightweight electrical junction or pull boxes.

    - Self-actuated check valves and manual valves.

    - Major items of equipment in the nuclear steam supply system, their supports, and components mounted on or within this equipment such as the reactor pressure vessel, reactor fuel assemblies, reactor internals, control rods and their drive mechanisms, reactor coolant pumps, steam generators, pressurizer, and reactor coolant piping.

7. The following types of equipment will be identified for use in the relay evaluation procedure described in Section 6:

    - Active, electrically-powered or -controlled equipment.

    - Electrically-powered or -controlled equipment considered passive but whose inadvertent operation due to relay chatter could adversely affect the accomplishment of a safe shutdown function.

3.2 GENERAL CRITERIA AND GOVERNING ASSUMPTIONS

This section defines the criteria, governing assumptions, and general guidelines for identifying the safe shutdown equipment. This includes definition of terms, boundary conditions, and requirements for single equipment failure.

3.2.1 Safe Shutdown Following an SSE

The plant should be capable of being brought from normal operating conditions to a safe shutdown condition following a design basis, safe shutdown earthquake (SSE).

3.2.2 Normal Operating Conditions Defined

Normal operating conditions of the plant are defined as having the reactor coolant system at or near normal operating pressure and temperature.

3.2.3 Safe Shutdown Defined

Safe shutdown is defined as bringing the plant to, and maintaining it in, a hot shutdown condition during the first 72 hours following an SSE. Hot shutdown is defined by the plant's Technical Specifications.

The plant may be quickly cooled to the hot shutdown condition and held there for the 72 hours, or the plant may be slowly cooled so that the hot shutdown condition is reached at the end of the 72 hours.

It is not necessary to include the long-term Residual Heat Removal (RHR) equipment in the Safe Shutdown Equipment List (SSEL); however, some plants may not have sufficient water inventory to stay in the hot shutdown mode for three days. Other plants may prefer to be brought to a cold shutdown condition during this period of time instead of staying in the hot shutdown mode. In these cases it may be necessary to add RHR equipment to the SSEL.

It is not the intent of the USI A-46 program to require plants to cool down faster than their original design capability under a loss of offsite power condition. If a plant takes longer to achieve hot shutdown conditions than the 72 hours, then this should be reported to the NRC as part of the Seismic Evaluation Report described in Section 9.

3.2.4 Loss of Offsite Power

Loss of offsite power may occur as a result of the earthquake. The safe shutdown capability should remain intact while offsite power is not available for a minimum of 72 hours following an SSE. Note that the possibility of not losing offsite power should also be considered.

3.2.5 No Other Accidents

No concurrent or sequential potential events are postulated to occur other than a design basis safe shutdown earthquake (SSE) and a loss of offsite power. For example, no loss of coolant accidents (LOCAs), high energy line breaks (HELBs), fires, flooding, extreme winds and tornados, lightning, sabotage, etc., are postulated to occur.

3.2.6 Single Equipment Failure

Systems selected for accomplishing safe shutdown should not be dependent upon a single item of equipment whose failure, either due to seismic loads or random failure, would preclude safe shutdown. At least one practical alternative should be available for accomplishing safe shutdown, which is not dependent on that item of equipment. This alternative should also be evaluated for seismic adequacy. For example, two motor-operated valves in series may be used to isolate a line and two motor-operated valves in parallel may be used to open a line. As an alternative, a separate, redundant train of equipment may be used as a backup.

An equipment failure is defined as the failure of the active functional capability of the equipment, not its structural integrity. For example, for a motor-operated valve, failure of the valve to open or close with the motor operator is a failure of the valve to perform its active function. It is not necessary to consider rupture or leakage of fluid from the valve as a failure mode.

If an item of equipment is taken out of service for maintenance, then that item of equipment is considered the single equipment failure for the purposes of this procedure.

Manual operation of an item of equipment which is normally power-operated is considered an acceptable means of providing backup operation provided sufficient manpower, time, and procedures are available. For example, the primary mode of closing or opening a valve may be by its motor operator while the backup or redundant means of closure or opening may be manual operation of this same valve or a manual valve in the same line.

Any common systems which are used by more than one unit at a reactor plant site should be redundant only within that common system, not on a per unit basis, provided each redundant path in the common system has the capacity to simultaneously support all the units to which it is common.

When evaluating the equipment selected for a single active failure, any equipment not included on the Safe Shutdown Equipment List (SSEL) should be assumed to be not available for plant shutdown.

3.2.7 Operator Action Permitted

Timely operator action is permitted as a means of achieving and maintaining a safe shutdown condition provided procedures are available and the operators are trained in their use. Typical times for operator action are 10 minutes for control room items and 20 minutes for items outside the control room.

3.2.8 Procedures

Procedures should be in place for operating the equipment selected for safe shutdown and operators should be trained in their use. It is not necessary to develop new procedures specifically for compliance with the USI A-46 program. Existing plant procedures can be used.

If an SSE occurs, it is not necessary to use only the safe shutdown equipment identified for the USI A-46 program. The operator may attempt shutdown using other available systems and equipment provided these other means of shutting down do not prevent later use of the safe shutdown method identified for the USI A-46 program.

The plant procedures for shutting down should be reviewed by the Operations Department of the plant to verify that the procedures are compatible with the identified method of safe shutdown and that they do not preclude the use of the safe shutdown equipment if some other method of shutting down is attempted first. Further, this review should assume that the only equipment which is available for the shutdown is the USI A-46 safe shutdown equipment. See Section 3.7 for suggested methods of performing this review.

The shutdown procedures which are associated with the use of the USI A-46 safe shutdown equipment should be procedures which are available to the operator as a result of his following approved normal and emergency operating procedures (EOPs). Note that normal plant shutdown procedures would be used for any deliberate, planned shutdown; EOPs would be used for a plant trip or emergency shutdown.

3.3 SCOPE OF EQUIPMENT

The purpose of this subsection is to define the equipment which is included within the scope of review for resolution of USI A-46.

3.3.1 Equipment Classes

The 22 classes of equipment listed in Table 3-1 define the major types of mechanical and electrical equipment which are included within the scope of USI A-46. Note that building structures and such passive equipment as piping, penetration assemblies, etc., are not within the scope of USI A-46.

Equipment Classes #1 through #20, along with the sub-categories of equipment listed under these 20 major equipment class names, are the specific types of equipment for which there are seismic experience data. Appendix B provides a summary description of the equipment included in the earthquake experience data base and the generic seismic testing data base. References 4, 5, and 6 provide additional details on the type of equipment included in these data bases. The following symbols are used after each sub-category name in Table 3-1 to note which data base contains data on each sub-category of equipment:

(EE) - <u>E</u>arthquake <u>E</u>xperience data base.

(GERS) - <u>G</u>eneric <u>E</u>quipment <u>R</u>uggedness <u>S</u>pectra testing data base.

Equipment Class #21 is for tanks and heat exchangers, and Equipment Class #22 is for cable and conduit raceways. Selection of this equipment is discussed later in Sections 3.3.9 and 3.3.10 respectively.

Equipment Class #0 (Other) is a catchall category for all other items of mechanical and electrical equipment needed for safe shutdown but which either do not fit into one of the other 22 classes or for which there is insufficient seismic experience data at this time to be included as a sub-category of one of the 22 classes. This type of plant-specific equipment includes certain types of valves, turbine-driven emergency generators, etc. This type of equipment should be placed in Equipment Class #0, classified as an outlier, and evaluated using the methods described in Section 5.

Table 3-1

EQUIPMENT CLASSES
(Including Sub-Categories in
Seismic Experience Data Base) [1]

0 OTHER

1 MOTOR CONTROL CENTERS

Motor control center (EE) (GERS-MCC.7)[1]
Wall- or rack-mounted motor controllers (EE)

2 LOW VOLTAGE SWITCHGEAR

Low voltage draw-out switchgear (typically 600 Volt) (EE) (GERS-MVS/LVS.3)
Low voltage disconnect switches (typically 600 Volt) (EE)
Unit substations (EE)

3 MEDIUM VOLTAGE SWITCHGEAR

Medium voltage draw-out switchgear (typically 4160 Volt) (EE) (GERS-MVS/LVS.3)
Medium voltage disconnect switches (typically 4160 Volt) (EE)
Unit substations (EE)

4 TRANSFORMERS

Liquid-filled medium/low voltage transformers (typically 4160/480 Volt) (EE)
Dry-type medium/low voltage transformers (typically 4160/480 Volt) (EE)
Distribution transformers (typically 480/120 Volt) (EE) (GERS-TR.3)

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1 The sub-categories of equipment listed under the major equipment classes are included in one of the following experience data bases:

(EE) - Earthquake Experience data base summarized in Appendix B and References 4 and 5.

(GERS-XXX) - Generic Equipment Ruggedness Spectra testing data base summarized in Appendix B and Reference 6, where XXX is the GERS identification symbol.

Table 3-1 (continued)

EQUIPMENT CLASSES
(Including Sub-Categories in
Seismic Experience Data Base)[1]

5 HORIZONTAL PUMPS

Motor-driven horizontal centrifugal pumps (EE)
Engine-driven horizontal centrifugal pumps (EE)
Turbine-driven horizontal centrifugal pumps (EE)
Motor-driven reciprocating pumps (EE)

6 VERTICAL PUMPS

Vertical single-stage centrifugal pumps (EE)
Vertical multi-stage deep-well pumps (EE)

7 FLUID-OPERATED VALVES

Diaphragm-operated pneumatic valves (EE) (GERS-AOV.3)
Piston-operated pneumatic valves (EE)
Spring-operated pressure relief valves (EE)

8 MOTOR-OPERATED AND SOLENOID-OPERATED VALVES

Motor-operated valves (EE)
Motor-operators (GERS-MOV.3)

Solenoid-operated valves (EE) (GERS-SV.2)

9 FANS

Blowers (EE)
Axial fans (EE)
Centrifugal fans (EE)

10 AIR HANDLERS

Cooling coils (EE)
Water-cooled air handlers (EE)
Refrigerant-cooled air handlers (including enclosed chiller) (EE)
Heaters (EE)

Table 3-1 (continued)

EQUIPMENT CLASSES
(Including Sub-Categories in Seismic Experience Data Base) [1]

11 CHILLERS

Water chillers (EE)
Refrigerant chillers (EE)

12 AIR COMPRESSORS

Reciprocating-piston compressors (EE)
Centrifugal compressors (EE)

13 MOTOR-GENERATORS

Motor-generators (EE)

14 DISTRIBUTION PANELS

Distribution panelboards (120-480 Volt, AC & DC) (EE) (GERS-DSP.6)
Distribution switchboards (120-480 Volt, AC & DC) (EE) (GERS-DSP.6)

15 BATTERIES ON RACKS

Lead-cadmium flat plate batteries (EE)
Lead-calcium flat plate batteries (EE) (GERS-BAT.4)
Planté (Manchex) batteries (EE)
Battery racks (2 tiers or less) (EE) (GERS-BAT.4)

16 BATTERY CHARGERS & INVERTERS

Solid state battery chargers (EE) (GERS-BC.3)
Solid state static inverters (EE) (GERS-INV.4)

17 ENGINE-GENERATORS

Piston engine-generators (EE)

18 INSTRUMENTS ON RACKS

Transmitters (Pressure, temperature, level, flow) (GERS-PT.4)
Wall-mounted sensors/transmitters (EE)
Rack-mounted sensors/transmitters (EE)
Supporting racks (EE)

Table 3-1 (continued)

EQUIPMENT CLASSES
(Including Sub-Categories in
Seismic Experience Data Base) [1]

19 TEMPERATURE SENSORS

Thermocouples (EE)
RTDs (EE)

20 INSTRUMENTATION AND CONTROL PANELS AND CABINETS

Wall-mounted & rack-mounted instrumentation and control panels (EE)
Wall-mounted & rack-mounted instrumentation and control cabinets (EE)
Dual switchboard instrumentation and control cabinets (EE)
Duplex switchboard & benchboard (walk-in) instrumentation and control boards (EE)

21 TANKS AND HEAT EXCHANGERS

22 CABLE AND CONDUIT RACEWAYS (EE)

All mechanical and electrical equipment needed for bringing a plant to a safe shutdown condition and maintaining it there should be identified for seismic evaluation, even if that item of equipment is not listed in one of the sub-categories of Table 3-1. For example, piston-operated hydraulic valves are not listed as a sub-category of Equipment Class #7 (Fluid-Operated Valves) since they are not in the seismic experience data base. Nevertheless, if a piston-operated hydraulic valve is needed for accomplishing a safe shutdown function (e.g., as a main steam isolation valve), then it should be identified as a safe shutdown item of equipment in Equipment Class #0 (Other), identified as an outlier, and evaluated for seismic adequacy using some means other than by direct comparison to the seismic experience data base.

3.3.2 Exclusion of NSSS Equipment

The major pieces of equipment in the Nuclear Steam Supply System (NSSS) which are located inside the containment are excluded from the scope of the USI A-46 review. Also excluded are the supports for this equipment along with all the components mounted in or on this equipment. Examples of the NSSS equipment and the components mounted on them which are excluded from the scope of USI A-46 are given below.

- Reactor vessel and its supports, reactor fuel assemblies, reactor internals, control rod drive mechanisms[1], in-core instrumentation, and safety relief valves
- Reactor coolant and reactor recirculation pumps and their supports and drive motors
- Steam generators and their supports, tubes, safety relief valves
- Neutron shield tank and its supports and neutron detectors

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1 Note that only the control rod drive mechanisms mounted on or in the reactor vessel are excluded from the scope of the USI A-46 review; BWR control rod drive equipment located outside of the drywell should be included on the Safe Shutdown Equipment List.

- Pressurizer and its supports, heaters, and safety relief valves
- Reactor coolant system piping and recirculation lines

Relays and other types of contactors and switches are also included within the scope of the GIP. They have not been included as an equipment class in Table 3-1 since the seismic evaluation of these components is handled differently, as described in Section 6.

3.3.3 Rule of the Box

One important aspect of identifying the equipment included within the scope of the procedure is explained by the "rule of the box." For equipment included in Classes 1 through 20, all the components mounted on or in this equipment are considered to be part of that equipment and do not have to be evaluated separately. For example, a diesel generator (Equipment Class #17) includes not only the engine block and generator, but also all other items of equipment mounted on the diesel generator or on its skid; such as the lubrication system, fuel supply system, cooling system, heaters, starting systems, and local instrumentation and control systems. Components needed by the diesel generator but not included in the "box" (i.e., not mounted on the diesel generator or on its skid) should be identified and evaluated separately. Typically this would include such items as off-mounted control panels, air-start compressors and tanks, pumps for circulating coolant and lubricant, day tanks, and switchgear cabinets.

The obvious advantage to this "rule of the box" is that only the major items of equipment included in Table 3-1 need be verified for seismic adequacy, i.e., if a major item of equipment is shown to be seismically adequate using the guidelines in this procedure, then all of the parts and components mounted on or in that item of equipment are also considered seismically adequate. However, as noted in Section 4.3, the Seismic Capability Engineers should exercise their judgment and experience to seek out suspicious details or uncommon situations (not specifically covered by the caveats in Appendix B) which may make that item of equipment vulnerable to SSE effects. This evaluation should include any areas of concern within the "box" which could be seismically vulnerable such as added attachments, missing or obviously inadequate anchorage of components, etc.

One exception to this "rule of the box" is relays (and other types of contacts used in control circuitry). Even though relays are mounted on or in another larger item of safe shutdown equipment, they should be identified and evaluated for seismic ruggedness using the procedure described in Section 6 since they may be susceptible to chatter during seismic excitation. The relays to be evaluated are identified by first identifying the major items of safe shutdown equipment which could be affected if the relays malfunctioned. Then, in Section 6, the particular relays used to control these major items of equipment are identified and evaluated for seismic adequacy.

3.3.4 Active Equipment

Active mechanical and electrical equipment which operate or change state to accomplish a safe shutdown function should be identified for seismic evaluation. Electrical equipment without moving parts such as batteries, transformers, battery chargers and inverters are considered active for the purposes of this procedure and are included within the scope of USI A-46.

It is not in the scope of the GIP to verify the seismic adequacy of passive equipment such as piping, filters, and electrical penetration assemblies, nor building structures. Likewise, it is not in the scope of the GIP to verify the seismic adequacy of potentially active equipment which does not need to operate if it is already in the proper state to accomplish its safe shutdown function and it fails in that desired position upon loss of power. For example, if a motor-operated gate valve, which isolates a drain line in the reactor coolant system, is already closed, and it stays closed upon loss of power, then it can be considered a passive item of equipment for the purposes of this procedure. The valve body and its disc are considered to be an extension of the passive piping system. The potential for inadvertent opening of the valve due to relay chatter in its control circuit is evaluated as a part of the Relay Functionality Review described in Section 6; therefore such equipment should be identified for relay evaluation as described in Section 3.3.7 below.

3.3.5 Inherently Rugged Equipment

Certain types of active mechanical and electrical equipment are inherently rugged and need not be evaluated for seismic adequacy in the USI A-46 program. This equipment includes:

- Self-actuating check valves without external actuators. If a check valve has an external actuator, then this actuator and its connection to the check valve should be evaluated for seismic adequacy.
- Manually-operated valves.
- Small, lightweight electrical junction and pull boxes.

While it is not necessary to verify the seismic adequacy of inherently rugged equipment, it is recommended that, when such equipment is active for accomplishing a safe shutdown function, the equipment be included on the Safe Shutdown Equipment List (SSEL) for completeness. It could be labeled as being in equipment class "R" (i.e., inherently rugged). For example, if a manual valve with a handwheel operator is opened or closed by a plant operator (i.e., the valve is performing an active function), then this valve could be added to the SSEL for completeness to show what item of equipment is used to accomplish this active function. However, this manual valve need not be evaluated for seismic adequacy.

On the other hand, if a power-operated valve (e.g., a motor-operated valve), is opened or closed manually by a human operator using the handwheel (rather than using the power drive), then it should be on the SSEL and it should also be evaluated for seismic ruggedness.

3.3.6 Equipment in Supporting Systems

Any active equipment in systems which support the operation of identified safe shutdown equipment should also be identified for seismic evaluation. Supporting systems can include power supplies (e.g., electrical, pneumatic), control systems, cooling systems, lubrication systems, instrumentation, and heating, ventilating, and air conditioning systems. Likewise, if any item of equipment in these supporting systems is dependent upon some other system for support, then the active equipment in this secondary supporting system should also be identified for seismic evaluation.

3.3.7 Equipment Subject to Relay Chatter

If an item of equipment could inadvertently start, stop, or change state due to relay chatter (or other malfunction of a relay or other electrical device with contacts) and thereby prevent a safe shutdown function from being accomplished, then it should be identified and used as an input to the Relay Functionality Review described in Section 6.

The equipment which should be identified as subject to relay chatter includes all the active, electrically-powered, safe shutdown equipment identified for seismic evaluation (as described in Sections 3.3.4 and 3.3.6). In addition, some of the electrically-powered equipment considered passive, and hence, not subject to seismic evaluation, should be identified for relay evaluation. This could include equipment which is already in the proper state to accomplish a safe shutdown function and would fail in this state upon loss of power, but due to relay chatter, could inadvertently change state and thereby result in the safe shutdown function failing to be accomplished. The example used earlier of a closed, motor-operated gate valve which isolates a drain line in the reactor coolant system is a case where the valve would not be identified for seismic evaluation, but should be identified for relay evaluation.

Obviously any electrically-powered equipment whose operation, or the lack thereof, does not affect the accomplishment of any safe shutdown function, need not be identified for relay evaluation. For example, there may be a closed, motor-operated valve which should stay closed; however, if there is a closed manual valve downstream of this motor-operated valve, then it does not make any difference whether the motor-operated valve opens or remains closed.

3.3.8 Instrumentation

The scope of equipment which should be identified for seismic evaluation includes those instruments which measure the primary process variables used to assure that the plant is in a safe shutdown condition. This includes instruments used to measure reactor reactivity, reactor coolant pressure, reactor coolant inventory, and decay heat removal. Tables 3-2 and 3-3 provide examples of the primary process variables which can be measured to monitor these safe shutdown functions for pressurized water reactors (PWRs) and boiling water reactors (BWRs) respectively.

In addition to the instruments needed for measuring the primary process variables, any instruments needed to control the safe shutdown equipment should also be identified. For example, if a modulating valve is being used to control the level of water in a tank, then the level instrumentation for this tank should be identified as instrumentation needed by the modulating valve. Note that the power supply for this level instrumentation should also be identified as a supporting system for the level instrument.

Table 3-2

EXAMPLES OF THE PRIMARY PROCESS VARIABLES[1] WHICH CAN BE MEASURED TO MONITOR SAFE SHUTDOWN FUNCTIONS FOR PWRs

1. <u>Reactor Reactivity Control</u>

   - Core Neutron Flux
   - Position of All Control Rods, Reactor Coolant Boron Concentration[2] and Cold Leg Temperature

2. <u>Reactor Coolant Pressure Control</u>

   - Reactor Coolant Pressure
   - Subcooling Margin or Reactor Coolant Cold Leg Temperature
   - Pressurizer Level[3]

3. <u>Reactor Coolant Inventory Control</u>

   - Pressurizer Level
   - Reactor Vessel Water Level[4]

4. <u>Decay Heat Removal</u>

   - Reactor Coolant Pressure
   - Reactor Coolant Hot Leg or Core Exit Temperature
   - Reactor Coolant Cold Leg Temperature

See notes on next page.

Table 3-2 (continued)

EXAMPLES OF THE PRIMARY PROCESS
VARIABLES[1] WHICH CAN BE MEASURED TO MONITOR
SAFE SHUTDOWN FUNCTIONS FOR PWRs

NOTES:

1 Note that additional process variables may also be needed to control some of the safe shutdown equipment. For example, a tank level measurement might be needed to control the operation of valves which should be opened or closed to permit the use of another tank.

2 It may be possible to eliminate boron concentration measurements on a plant-specific basis if it can be shown that planned actions during the 72-hour safe shutdown period will not result in unacceptable boron dilution in the reactor coolant system.

3 Pressurizer level should be measured for the pressure control function if pressurizer heaters are used to control pressure so that the heaters remain covered.

4 The need to measure reactor vessel level, in addition to pressurizer level, should be considered if the reactor coolant level drops below the lowest pressurizer level instrument reading during a potential overcooling transient.

Table 3-3

EXAMPLES OF THE PRIMARY PROCESS VARIABLES[1] WHICH CAN BE MEASURED TO MONITOR SAFE SHUTDOWN FUNCTIONS FOR BWRs

1. <u>Reactor Reactivity Control</u>
   - Core Neutron Flux
   - Position of All Control Rods

2. <u>Reactor Coolant Pressure Control</u>
   - Reactor Coolant Pressure
   - Reactor Coolant Temperature

3. <u>Reactor Coolant Inventory Control</u>
   - Reactor Vessel Water Level

4. <u>Decay Heat Removal</u>
   - Reactor Coolant Temperature
   - Reactor Coolant Pressure

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1 Note that additional process variables may also be needed to control some of the safe shutdown equipment. For example, a tank level measurement might be needed to control the operation of valves which should be opened or closed to permit the use of another tank.

Note that it is not necessary, in general, to identify instrumentation which simply indicates the status of an item of safe shutdown equipment. For example, it is not necessary to monitor the current (amps) of a motor driving a pump, if the fluid level in the vessel to which the pump is pumping is being monitored (i.e., if the essential process variable is being measured). Likewise it is not necessary, in general, to identify valve position instrumentation.

3.3.9 Non-Safety-Grade Equipment

It is permissible to identify non-safety-grade equipment for accomplishing safe shutdown functions; however, the operation of this equipment should be included in the plant operating procedures used to shut down the plant.

3.3.10 Tanks and Heat Exchangers

Tanks and heat exchangers which are needed by or connected to the safe shutdown systems should also be identified for seismic evaluation. Even though tanks and heat exchangers are passive equipment, they are included within the scope of equipment which should be evaluated for seismic adequacy in Section 7.

There are two types of seismic concerns regarding tanks and heat exchangers. The first is maintaining its structural integrity so that the fluid contained therein can be used by a safe shutdown system. The second concern is ensuring that these large, heavy items of equipment stay in place during an SSE so that attached lines do not rupture from large displacements of the tank or heat exchanger. To protect against this second concern, it may be necessary to evaluate the seismic adequacy of certain tanks or heat exchangers even if they are outside the pressure boundary of the safe shutdown system if a boundary isolation valve is located relatively close to the tank or heat exchanger.

At the option of the utility; large, flat-bottom, metal, refueling water storage tanks (RWSTs) in PWRs may be added to the SSEL, even if they are not needed by or closely connected to any safe shutdown systems. Use of the guidelines in Section 7 for evaluation of large, flat-bottom, metal RWSTs and any other large, flat-bottom, metal storage tanks needed for safe shutdown, has been accepted by the NRC as one element for resolving Unresolved Safety Issue (USI) A-40, Seismic Design Criteria, as it applies to operating plants.

3.3.11 Cable and Conduit Raceways

Cable and conduit raceway systems are included in the scope of USI A-46 even though they are passive equipment; they should be evaluated for seismic adequacy using the guidelines contained in Section 8.

The scope of review should include all the cable and conduit raceway systems in the plant which support electrical cable for equipment on the Safe Shutdown Equipment List (SSEL). This procedure does not provide details for identifying these raceway systems. Instead it has been found, during SQUG trial plant reviews, that performing the seismic evaluation described in Section 8 for the whole plant may be easier than identifying which raceways support the power, control, and instrumentation wiring for individual items of equipment. However, if the details are readily available for identifying which cable and conduit raceway systems in the plant carry the cabling for safe shutdown equipment, then the scope of the review can be limited to those raceway systems.

3.4 SAFE SHUTDOWN FUNCTIONS

To achieve and maintain safe shutdown conditions during and following a safe shutdown earthquake, the following four safe shutdown functions should be accomplished:

- Reactor Reactivity Control
- Reactor Coolant Pressure Control
- Reactor Coolant Inventory Control
- Decay Heat Removal

These functions focus on controlling the nuclear, thermal, and hydraulic performance of the reactor and the reactor coolant system. To monitor that these safe shutdown functions are being accomplished, certain process variables should be measured.

These safe shutdown functions are described below along with examples of the process variables which should be considered for measurement to assure that th functions are being accomplished.

3.4.1 Reactor Reactivity Control Function

The reactivity control function is accomplished by insertion of negative reactivity shortly after obtaining the signal to shutdown. Additional negative reactivity is also needed to compensate for the combined effects of Xenon-135 decay and reactor coolant temperature decreases. A process variable which may be measured to monitor reactivity is core neutron flux. An alternative to measuring core reactivity directly is to measure other parameters which can be used to show that the core remains subcritical. For BWRs, the position of each control rod could be measured; if all the rods are fully inserted, the reactor will remain subcritical. For PWRs, measurements could be made of the position of all the control rods, the temperature of the reactor coolant cold leg, and the boron concentration in the reactor coolant system; fully inserted rods with sufficient boron concentration in the reactor coolant, for a given temperature, will result in the reactor remaining subcritical. Note that it may be possible to eliminate boron concentration measurements on a plant-specific basis if it can be shown that planned actions during the 72-hour safe shutdown period will not result in unacceptable boron dilution in the reactor coolant system.

3.4.2 Reactor Coolant Pressure Control Function

The pressure control function has several elements which should be accomplished to ensure that the reactor coolant system is operated properly:

- The reactor coolant system pressure should not exceed a maximum pressure.
- The pressure should be maintained within the reactor coolant system pressure-temperature limits of the plant's Technical Specifications to prevent reactor vessel brittle fracture.
- For PWRs there should be sufficient subcooling margin, consistent with plant operating procedures or plant Technical Specifications, to avoid formation of a steam bubble within the reactor vessel and to promote natural circulation between the core and the steam generators.
- For PWRs the differential pressure across the steam generator tubes should not exceed the pressure-temperature limits of the plant-specific Technical Specifications to prevent leaks and ruptures in these tubes.

If it is preferred (or required due to certain plant limitations), the plant may be brought to a cold shutdown condition during the 72 hours following an SSE instead of staying in the hot shutdown condition. However, if this is done, the following additional elements should also be accomplished:

- There should be a means for reducing the reactor coolant system pressure to the point where the low pressure residual heat removal system can be operated.
- When the reactor coolant system is connected to the low pressure residual heat removal system, the system pressure should not exceed a maximum pressure for the low pressure residual heat removal system.

Process variables which should be measured for monitoring the reactor coolant system pressure include reactor coolant pressure, reactor coolant temperature (or subcooling margin for PWRs), and pressurizer level (for PWRs) if pressurizer heaters are used for pressure control.

3.4.3 Reactor Coolant Inventory Control Function

The reactor coolant inventory control function is necessary to assure that the reactor core remains covered so that decay heat can be removed during and after the postulated earthquake. Inventory control has two elements which should be accomplished:

- Loss of reactor coolant from the reactor coolant system should be minimized.
- Sufficient makeup capacity should be available to compensate for losses due to leakage from the reactor coolant system and for fluid shrinkage when the reactor coolant temperature is lowered. Note: If it is possible to lose cooling capability to the reactor coolant pump seals, then makeup capacity and coolant supplies should be available to compensate for possible leakage from these seals.

Process variables which should be measured for monitoring the inventory of the reactor coolant system include water level in the reactor vessel for BWRs and water level in the pressurizer for PWRs. If the water level drops below the lowest pressurizer level instrument reading in a PWR (during a potential overcooling transient), then it may be necessary to also measure reactor vessel level so that the operator can monitor the actual inventory of water in the reactor coolant system.

3.4.4 Decay Heat Removal Function

The decay heat removal function is accomplished by removing decay heat and stored heat from the reactor core and reactor coolant system at a rate such that overall reactor coolant system temperatures can be lowered to and maintained within acceptable limits.

Process variables which should be measured for monitoring the decay heat removal function include reactor coolant temperature and pressure. For PWRs, both the hot leg (or core exit) temperature and the cold leg temperature should be measured during natural circulation decay heat removal conditions to verify that natural circulation is established between the reactor core and the steam generator.

3.5 SAFE SHUTDOWN ALTERNATIVES

Nuclear power plants typically have several paths or methods which can be used to bring a plant to a safe shutdown condition; this is due to the redundancy and diversity designed into the plant. Typical alternative methods for accomplishing the four safe shutdown functions (described in the previous section) are outlined in this section. A detailed description of these generic alternatives is contained in Appendix A and may be used as guides for identifying the available alternative paths in a specific nuclear power plant.

To accomplish the purpose of this procedure it is necessary to show that the primary and backup equipment are seismically adequate for each of the four safe shutdown functions. The backup means for accomplishing these functions can be by using a different shutdown train or by using different equipment in the same shutdown train.

Some of the items which can be considered in selecting preferred safe shutdown alternatives are given below:

- The systems and equipment selected for shutting down the plant following a fire could be considered. It should be noted, however, that not all the safe shutdown equipment identified for this procedure may be the same as the equipment identified for 10 C.F.R. 50, Appendix R, even if the same general method is selected for shutting down the plant.
- The alternatives which rely on systems and equipment to operate in their normal mode can be considered.

- The alternatives which are straightforward and present the least challenge to the operators can be considered.

- The status of the seismic classification, design, and documentation for the equipment in the plant can be an important factor in selecting the preferred safe shutdown alternatives.

- The results of previous seismic reviews and walkdowns can be considered.

- The location (elevation) of the equipment within the plant can be considered (the lower the elevation, the lower the seismic excitation).

- The operating procedures (normal or emergency) and operator training used to achieve and maintain safe shutdown conditions can be considered.

In addition, the following factors may also be considered:

- The alternatives which minimize the amount of effort, expense, and radiation exposure necessary to verify the seismic adequacy of the equipment can be considered.

- The practicality/difficulty and cost of returning the plant to normal operation after an SSE can be considered.

Selection of the preferred safe shutdown alternatives should be done with consultation of the plant operators and management.

The remainder of this section summarizes the major system alternatives typically available for accomplishing each of the four safe shutdown functions. The first four subsections below are for pressurized water reactors (PWRs); the next four subsections are for boiling water reactors (BWRs).

3.5.1 Reactor Reactivity Control (PWR)

The primary method of controlling reactivity in PWRs is by insertion of the control rods. Typically liquid poison (boron) should also be injected into the reactor coolant system to compensate for positive reactivity increases due to the combined effects of Xenon-135 decay and reduction of the reactor coolant temperature. Borated water can be injected via the chemical and volume control system (CVCS) or the high pressure coolant injection system (HPCI).

3.5.2 Reactor Coolant Pressure Control (PWR)

There are various pressure-temperature limits which should not be exceeded in the reactor coolant system of PWRs. These include:

- Reactor coolant system pressure should remain below the design limit.

- Subcooling margin should be maintained to permit natural circulation of reactor coolant between the core (heat source) and the steam generators (heat sink).

- Subcooling margin should also be maintained to provide sufficient net positive suction head (NPSH) on the residual heat removal (RHR) pump during low pressure decay heat removal.

- Reactor vessel brittle fracture limits should be avoided. This limit could be exceeded if the reactor coolant pressure is very high for a given temperature or the temperature is very low for a given pressure. (Figure A-3 in Appendix A illustrates this limit.)

- Steam generator tube differential pressure limit should be avoided. This limit could be exceeded if the reactor coolant system pressure (acting on tube ID) is not properly balanced by the steam generator pressure (acting on the tube OD) for a given temperature.

- Peak reactor coolant system pressure should not exceed a maximum pressure for the low pressure residual heat removal system when this system is in operation.

These limits can be avoided by increasing or decreasing the reactor coolant system pressure. Typical methods for decreasing the pressure include:

- Discharge of steam from the pressurizer power-operated relief valve (PORV).
- Discharge of steam from the pressurizer safety relief valve (SRV) at its set pressure.
- Collapse of the steam bubble in the pressurizer via injection of water with the pressurizer auxiliary spray. (Pressurizer spray driven by the pressure drop across the reactor coolant pumps would not available if offsite power is lost.)
- Discharge via the letdown system.
- Discharge via the residual heat removal (RHR) safety relief valve while at low pressure.

Typical methods for increasing reactor coolant system pressure include:

- Feed via the chemical and volume control system (CVCS).
- Feed via the high pressure coolant injection (HPCI) system.
- Increase the saturation temperature of the reactor coolant in the pressurizer via the pressurizer heaters.
- Feed via the low pressure coolant injection (LPCI) system while at low pressure.

3.5.3 Reactor Coolant Inventory Control (PWR)

The inventory of the reactor coolant system is controlled by feeding water into the system when it is low and minimizing the loss of water from the various openings in the system when the inventory is adequate. Note that the alternatives for inventory control are directly related to some of the alternatives for pressure control, e.g., adding water to the reactor coolant system increases the system pressure while removing steam decreases the pressure.

Typical methods for increasing reactor coolant system inventory in PWRs include:

- Feed via the chemical and volume control (CVCS) system.
- Feed via the high pressure coolant injection (HPCI) system.
- Feed via the low pressure coolant injection (LPCI) system (at low pressure only).

Typical ways in which the reactor coolant system inventory can be lost in PWRs include:

- Discharge via the reactor coolant pump seal[2] leakoff.
- Discharge via the normal and excess letdown paths.
- Discharge via the power-operated relief valve (PORV).
- Discharge via the safety relief valves (SRVs) at their set point.
- Discharge via other vents and drains.

3.5.4 Decay Heat Removal (PWR)

While the reactor coolant system is at high temperature, the steam generators can be used for removing decay heat from PWRs. Steam generator cooling can be accomplished by establishing natural circulation of reactor coolant from the core (heat source) to the steam generator (heat sink). Heat can be removed from the secondary side of the steam generator by discharging steam from the main steam atmospheric steam dump valve. The main steam safety relief valves (SRVs) can also be used to discharge steam if the secondary side pressure is allowed to go up to the SRV set point.

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2 Note that the reactor coolant pump seals may need a supply of water for cooling (closed cooling, injection, or both) to maintain their integrity while the reactor coolant system is at elevated temperature. If these services are not included in the selected safe shutdown approach, the consequences of seal failure leakage should also be addressed.

Makeup water can be fed into the secondary side of the steam generator via the auxiliary feedwater system.

If it is preferred (or required due to certain plant limitations) to bring the plant to a cold shutdown condition, the residual heat removal (RHR) system can be used to remove heat from the reactor coolant system after the reactor coolant system pressure and temperature are lowered into the hot shutdown region (typically below about 250 psia and 350°F). The heat from the RHR system is typically transferred to the environment via the component cooling water system and the service water system.

3.5.5 Reactor Reactivity Control (BWR)

The method of controlling reactivity in BWRs is by insertion of the control rods. A standby liquid poison control system is available as a backup method for reactivity control; however, it typically requires 1 to 2 hours to make the reactor subcritical if used by itself. Therefore control rod insertion is considered the only viable alternative for rapid shutdown (SCRAM) of the reactor.

3.5.6 Reactor Coolant Pressure Control (BWR)

In BWRs, the water in the reactor coolant system remains at saturation conditions so that pressure and temperature are mutually dependent variables. There are only two limits which should not be exceeded:

- Peak reactor coolant system pressure should not exceed a maximum pressure.
- Peak reactor coolant system pressure should not exceed a maximum pressure for the low pressure residual heat removal system when this system is in operation.

The reactor coolant system pressure is typically controlled by opening and closing the safety relief and safety valves which discharge steam to the suppression pool. Both of these types of valves will open automatically to provide overpressure protection when the system pressure exceeds their set points. The safety relief valves can also be opened manually to lower the system pressure so that available low pressure systems can be used for reactor coolant inventory control and decay heat removal. Safety valves on the low pressure residual heat removal system can also be used during low pressure decay heat removal to protect the low pressure system.

3.5.7 Reactor Coolant Inventory Control (BWR)

The water level in the reactor vessel of BWRs is maintained by controlling the flow of water to (feed) and from (discharge) the reactor coolant system.

Typical methods for increasing reactor coolant system inventory include:

- Feed via the high pressure coolant injection (HPCI) system or the high pressure core spray (HPCS) system.
- Feed via the reactor core isolation cooling (RCIC) system.
- Feed via the control rod drive (CRD) hydraulic system.
- Feed via the low pressure coolant injection (LPCI) system for use at low system pressure.
- Feed via the low pressure core spray (LPCS) system for use at low system pressure.

Typical ways in which the inventory of the reactor coolant systems can be lost include:

- Discharge via the safety relief and safety valves.
- Discharge via the normal letdown paths.
- Discharge via other vents and drains.

3.5.8 Decay Heat Removal (BWR)

There are two general methods for removing decay heat from the reactor coolant system of BWRs: bleed and feed cooling and shutdown or residual heat removal cooling. Some early BWRs also have an isolation condenser cooling system. These methods are summarized below.

The bleed and feed cooling method discharges (bleeds) steam from the reactor coolant system via the safety relief valves to the suppression pool. Typically heat is removed from the suppression pool to the ultimate heat sink, the environment, via the suppression pool cooling system, the reactor building closed cooling water system (RBCCW), and the emergency service water system (ESW). Water is injected (fed) into the reactor coolant system using one of the methods described earlier for increasing inventory (i.e., feed via HPCI, HPCS, RCIC, CRD hydraulic supply, LPCI, and/or LPCS).

The shutdown cooling (SC) or residual heat removal (RHR) systems can be used for decay heat removal after the reactor coolant system pressure has been reduced. These systems draw water from the reactor coolant system, cool it in heat exchangers, and pump it back into the reactor coolant system. The heat which is removed is sent to the environment via the RBCCW and the ESW systems.

Isolation condenser cooling can be used to remove decay heat from the reactor coolant system while the system is at high pressure. This system consists of heat exchangers (isolation condensers) located at a higher elevation in the plant than the reactor vessel. Steam moves up to these heat exchangers via a steam supply line where it is condensed on the inside of the tubes in the tube bundle of the heat exchanger, thereby giving up its heat of vaporization. The condensate flows back to the reactor vessel by gravity via a condensate return line. No pumps are needed to move the steam or condensate; the differences in fluid density, driven by gravity, cause this flow to occur spontaneously. The outside of the tube bundle in the heat exchanger is cooled by water which boils off and is released as steam to the atmosphere. Makeup water can be added to the shell side of the heat exchanger from a dedicated makeup storage tank (using gravity feed) or from the condensate storage tank (using pumps). Other sources of water can also be used to resupply the shell side of the heat exchanger (e.g., fire protection system, suppression pool, etc.).

3.6 IDENTIFICATION OF EQUIPMENT

The purpose of this subsection is to summarize the method of identifying the individual items of equipment contained in the alternatives selected for safe shutdown. A detailed description of this method is contained in Appendix A including a step-by-step procedure with a flow diagram.

The approach used to identify the safe shutdown equipment has five major steps:

- Identification of fluid system equipment.
- Identification of supporting system equipment.
- Preparation of a safe shutdown equipment list for seismic evaluation.

- Preliminary walkdown to locate and identify equipment for seismic evaluation.
- Preparation of a safe shutdown equipment list for relay evaluation.

These steps are summarized below.

3.6.1 Identification of Fluid System Equipment

The fluid system equipment for the selected safe shutdown alternatives should be identified separately for each of the four safe shutdown functions. This results in four separate safe shutdown equipment lists (SSELs). This method may result in some duplication of equipment on these separate SSELs; however, this will insure that all the equipment for all four safe shutdown functions is identified. Duplicate equipment are eliminated when the SSELs are combined into a complete, composite SSEL.

The suggested method for identifying the fluid system equipment is to trace the path taken by the fluid from its source to its ultimate destination. The piping and instrumentation diagrams (P&IDs) can be used to do this; see-through markers or highlighters can be used to mark up the diagram to ensure that all branch lines and alternate paths are considered. The scope of this review should extend up to and include the first closed or closeable isolation valve in the main and branch lines. The plant configuration during normal power operation should be used.

As one traces the fluid flow path and any branch lines, the equipment in the flow should be entered onto a safe shutdown equipment list (SSEL). A blank form showing the format for the SSEL is shown in Exhibit A-1 in

Appendix A. A completed SSEL is shown in Exhibit A-2 in Appendix A. The data to be entered on this SSEL include, for each item of equipment:

- SSEL line entry number (e.g., 4001, 4002,...).
- Train number (e.g., "1" for the primary train or component, "2" for the backup train or component)
- Equipment class number (from Table 3-1).
- Equipment identification number (plant unique).
- Name of the system and a description of the equipment.
- Drawing number and zone showing the location of the equipment on the schematic drawing (optional).
- Equipment location in plant (building, elevation, room or row and column).
- Type of evaluction field to distinguish a item of equipment to receive a seismic review (S") and/or a relay review ("R").
- Notes (optional).
- Normal and desired operating state.
- Whether power is required to operate or control the equipment to achieve or maintain the desired operating state.
- Reference drawing number(s) identifying the supporting system(s).
- List of required and supporting systems and components.

3.6.2 Identification of Supporting System Equipment

Most of the safe shutdown equipment will require support from some other systems to operate. Supporting systems include electrical power, pneumatic power, hydraulic power, lubrication, cooling, control, and instrumentation. The supporting systems for the equipment in the fluid system are identified in the first major step described in Section 3.6.1, above. The equipment in each of these supporting systems should then be identified in this second major step, using an approach similar to that described for fluid system equipment (i.e., trace the path of power, lubrication, cooling or instrument signal from its sources to the item of safe shutdown equipment). Marking up schematic diagrams with highlighters helps identify the path and branches in these supporting systems.

The equipment identified in the supporting systems can be entered as separate line items on the same SSEL as the fluid system equipment or separate SSELs can be developed for the supporting systems. The same information should be entered into the SSEL for the equipment in the supporting systems as was entered for the fluid systems.

Note that some of the equipment in the supporting systems requires support from other supporting systems. For example, pumps and valves in a fluid system may require electric power from a diesel generator which in turn may require cooling from a cooling water system. The process of identifying all the supporting systems and their equipment should continue until all the supporting system equipment are listed for all the equipment on the SSELs.

3.6.3 Preparation of Safe Shutdown Equipment List (SSEL) for Seismic Evaluation

A single safe shutdown equipment list (SSEL) should be generated from the various SSELs described in Sections 3.6.1 and 3.6.2 for use during the Screening Verification and Walkdown described in Section 4. This SSEL for seismic evaluation should contain only one line entry for each unique item of equipment; duplicate items of equipment should be deleted.

This seismic walkdown SSEL can be generated from a composite of the SSEL, described above, by selecting the records containing an "S" in the "Eval. Type" field of Exhibit A-1 in Appendix A. A blank seismic walkdown SSEL is shown in Exhibit A-3 in Appendix A; a completed one is shown in Exhibit A-4.

3.6.4 Preliminary Walkdown to Locate and Identify Equipment for Seismic Evaluation

A preliminary walkdown of all the equipment on the seismic walkdown SSEL should be conducted prior to the full seismic walkdown to accomplish the following objectives:

- Determine the location in the plant of each item of equipment on the SSEL.
- Identify any other equipment needed for safe shutdown which should be included on the SSEL.
- Group all the components mounted within the "box" of larger items of equipment.

The first objective (determining the equipment location) is important to minimize the walkdown time of the Seismic Review Team (SRT) during the Screening Verification and Walkdown. Information which should be obtained during the preliminary walkdown includes:

- Determine the actual location (building, elevation, room, row/column) of the equipment in the plant.
- Verify the equipment identification number (tag number).
- Determine whether special tools, equipment, or procedures would be needed to inspect the equipment (e.g., ladders, insulation removal, radiation work permits, security keys, etc.).

The second objective (identifying other equipment) is important since some of the equipment needed for safe shutdown may not be explicitly shown on schematic diagrams. This type of equipment would typically include supporting systems and equipment not mounted on or within the "box" of safe shutdown equipment. Examples of this type of equipment found during the SQUG trial plant reviews include:

- Oil reservoir tanks for the lube oil system of the service water pumps.
- Electrical control cabinets for the emergency diesel generators.
- Neutral ground resistors for emergency diesel generators.

Accomplishing the third objective (group components within the "box") is useful since schematic diagrams typically show many items of equipment which may be mounted on or within the "box" of a larger item of equipment. For example, schematic diagrams may show a cooling water heat exchanger for a diesel generator. If this heat exchanger is mounted on the diesel generator skid, then it is included within the "box" of the diesel generator and can be deleted from the SSEL. Likewise, instrumentation and solenoid-operated valves mounted on a valve needed for safe shutdown could be verified for seismic adequacy as a part of the valve assembly.

3.6.5 Preparation of Safe Shutdown Equipment List (SSEL) for Relay Evaluation

A single safe shutdown equipment list (SSEL) should be generated from the various SSELs described in Sections 3.6.1 and 3.6.2, for use during the Relay Functionality Review described in Section 6. This SSEL for relay evaluation should contain only one line entry for each unique item of equipment; duplicate items of equipment should be deleted.

The relay review SSEL can be generated from a composite of the SSEL described in Sections 3.6.1 and 3.6.2 by selecting the records containing an "R" in the "Eval. Type" field of Exhibit A-1 in Appendix A. A blank relay review SSEL is shown in Exhibit A-5 in Appendix A; a completed one is shown in Exhibit A-6.

3.6.6 Data Base Management System

A data base management system can be used to prepare the SSELs. A data base management program was used during the SQUG trial plant reviews to:

- Consolidate the separate SSELs into a single seismic walkdown SSEL and a single relay review SSEL.
- Sort equipment by equipment class and location in the plant for use during the Screening Verification and Walkdown.
- Print the headings on the Seismic Evaluation Work Sheets (SEWS) prior to the plant walkdown from the SSEL file. (The SEWS are contained in Appendix G.)
- Print out the Screening and Verification Data Sheets (SVDSs). (The SVDSs are described in Section 4.)

Use of a computer data base management program is optional.

3.7 OPERATIONS DEPARTMENT REVIEW OF SSEL

The Safe Shutdown Equipment List (SSEL) generated for resolution of USI A-46 should be reviewed for compatibility with the plant procedures for shutting down the plant. The purpose of this section is to provide suggested methods for performing this review by the plant's Operations Department. Note that the individuals performing this review should be familiar with the General Criteria and Governing Assumptions contained in Section 3.2 and the Scope of Equipment for the USI A-46 program contained in Section 3.3.

A review of the SSEL by a representative of the plant's Operations Department is required to confirm this compatibility. The intent of the Operations Department review of the SSEL is to verify that a trained operator, following existing plant procedures, will eventually be directed to the use of the safe shutdown equipment and instruments even though the operator may have first tried to shut down using equipment not included in the USI A-46 SSEL. It is not the intent that the operator be directed to use the USI A-46 shutdown path as his first priority or to change the symptom-based emergency operating procedures. Rather, this review is to ensure that the shutdown path selected for USI A-46 and included in the SSEL is a legitimate safe shutdown path consistent with plant procedures and operator training.

One method of reviewing the SSEL against the plant operating procedures is to do a "desk top" review of the applicable procedures. Using this method, the normal and emergency operating procedures are reviewed by an experienced Operations Department representative to check whether all equipment called out in the operating procedures for the selected path are included on the SSEL. This review should also verify that there are no paths from which an operator could not recover with the selected set of SSEL equipment. For those steps in the procedure which rely upon operator training (i.e., steps which only give an overview summary of the actions to be taken; detailed steps are omitted), the reviewer should mentally walk through the actions an operator would take and verify that all the equipment needed is on the SSEL.

Another method of reviewing the SSEL against the plant operating procedures is to program a simulator to have only those items of equipment on the SSEL available. A loss of offsite power could then be simulated. An operator could go through this simulated transient and be observed and/or interviewed to determine whether any problems are encountered.

Another method of reviewing the SSEL against the plant operating procedures is to perform a limit. control room walkdown in which an operator talks and walks through a plant shutdown following a postulated loss of offsite power. This could include not only the actions taken by the operator in the control room, but also operator actions taken in the plant wher equipment is operated from a local control panel or station.

The Operations Department of the plant should decide which of these approaches or combination of approaches would best accomplish the review of the SSEL against the plant's operating procedures.

3.8 DOCUMENTATION

A summary of the systems selected for shutting down the plant following a Safe Shutdown Earthquake (SSE) and the basis for selecting those systems should be documented. This summary can be similar to the generic summaries contained in Appendix A for PWRs or BWRs.

The scope of the equipment included on the Safe Shutdown Equipment List (SSEL) for each of the systems used to shut down the plant should be identified; this can be done using marked-up schematic drawings (P&IDs, electrical one-lines, etc.).

The Safe Shutdown Equipment Lists (SSELs) should be retained along with any special explanations for including or excluding certain items of equipment.

The method used by the plant's Operations Department to verify the compatibility of the SSELs with the plant operating procedures should be documented.

Section 9 summarizes the type of documentation which should be generated and that which should be included in the report submitted to the NRC.

Section 4

SCREENING VERIFICATION AND WALKDOWN

4.0 INTRODUCTION

The purpose of this section is to describe the Screening Verification and Walkdown which should be performed to verify the seismic adequacy of active mechanical and electrical equipment identified in Section 3 and any electrical equipment housing essential relays identified in Section 6. The guidelines contained in this section can be used as the first level of screening this equipment for seismic adequacy. Other more refined or sophisticated seismic qualification techniques may be used; however, these are not described in detail in this document.

Seismic Screening Guidelines

The procedure for performing the Screening Verification and Walkdown is depicted in Figure 4-1. As shown in the figure, each of the following four seismic screening guidelines should be used to verify the seismic adequacy of an item of equipment:

- Seismic Capacity Compared to Seismic Demand - The seismic capacity of the equipment, as defined by the earthquake experience data base, the generic seismic testing data base, or equipment-specific seismic qualification data, should be greater than the seismic demand imposed on the equipment by the safe shutdown earthquake (SSE).

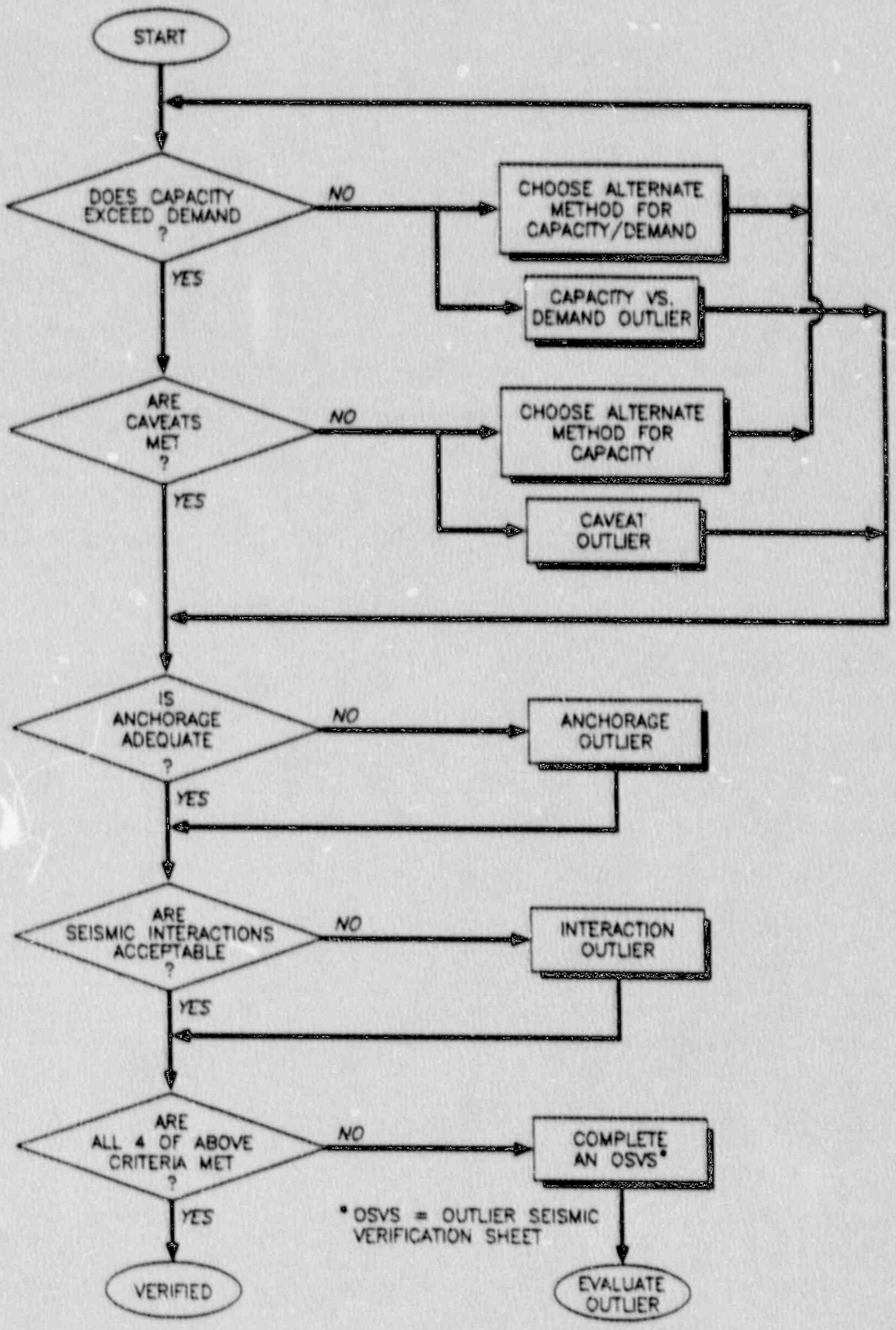


Figure 4-1. Overall Procedure for Performing Screening Verification and Walkdown

- Caveats - In order to use one of the seismic capacities defined by the earthquake experience data base or the generic seismic testing data base, the equipment should be similar to the equipment in the data base and meet the intent of the specific caveats for the data base class of equipment. If equipment-specific seismic qualification data is used, then any specific restrictions or caveats for that qualification data apply.
- Anchorage - The equipment anchorage capacity, installation, and stiffness should be adequate to withstand the seismic demand from the SSE at the equipment location.
- Seismic Interaction - The effect of possible seismic interactions with nearby equipment, systems, and structures should not cause the equipment to fail to perform its intended safe shutdown function.

The evaluation of equipment against each of these four screening guidelines should be based upon walkdown evaluations, calculations, and other supporting data.

Outlier Resolution

An outlier is defined as an item of equipment which does not meet the screening guidelines contained in this section. An outlier may be shown to be adequate for seismic loadings by performing additional evaluations such as the seismic qualification techniques currently being used in newer nuclear power plants. These additional evaluations and alternate methods should be thoroughly documented to permit independent review. Section 5 summarizes possible methods for evaluating outliers.

Seismic Capability Engineers

The guidelines described in this section should be applied by Seismic Capability Engineers as defined in Section 2. These engineers are expected to exercise engineering judgment based upon an understanding of the guidelines given in this document, the basis for these guidelines given in the reference documents and presented in the SQUG training course, and their own seismic engineering experience.

Other Types of Seismic Evaluations and Interfaces

In addition to the seismic evaluations covered in this section for active mechanical and electrical equipment, seismic evaluations for three other types of equipment are covered in other sections as follows:

- Section 6 - Relay Functionality Review
- Section 7 - Tanks and Heat Exchangers Review
- Section 8 - Cable and Conduit Raceways Review

While these other seismic evaluations can generally be performed independently from those for active mechanical and electrical equipment, there are a few areas where an interface with the Relay Functionality Review (Section 6) is appropriate:

- Any cabinets containing essential relays, as determined by the relay review in Section 6, should be evaluated for seismic adequacy using the guidelines contained in Section 4.
- A capacity reduction factor should be applied to expansion anchor bolts which secure cabinets containing essential relays. The capacity reduction factor is discussed in Section 4.4 and Appendix C.
- Seismic interaction, including even mild bumping, is not allowed on cabinets containing essential relays. This limitation is discussed in Section 4.5.
- In-cabinet amplification factors for cabinets containing essential relays may be estimated by the Seismic Capability Engineers for use in the Relay Functionality Review.

It is suggested that items of equipment containing essential relays be identified prior to the Screening Verification and Walkdown covered in this section so that the above evaluations may be accomplished during the Screening Verification and Walkdown.

Organization of Section

The remainder of this section is organized as follows:

- Section 4.1 lists the requirements to which SQUG utilities commit when adopting the Screening Verification and Walkdown procedure in this document for resolution of USI A-46.
- Sections 4.2 through 4.5 describe the four seismic adequacy criteria and the guidelines for performing the Screening Verification and Walkdown.
- Section 4.6 provides recommendations for documenting the results of the Screening Verification and Walkdown.

Guidelines for preparing for and conducting a Screening Verification and Walkdown are described Appendices E and F, respectively. Recommended checklists, called Screening Evaluation Work Sheets (SEWS), are provided in Appendix G for use during the Screening Verification and Walkdown.

4.1 SQUG COMMITMENTS

Members of SQUG adopting the Generic Implementation Procedure for USI A-46 resolution commit to the following in regard to verifying the seismic adequacy of active mechanical and electrical equipment in the identified safe shutdown path.

4.1.1 Basic Criteria

The licensee will use the following four screening guidelines to verify the seismic adequacy of safe shutdown equipment.

- The seismic capacity of the equipment will exceed the seismic demand associated with the safe shutdown earthquake (SSE).
- Equipment whose seismic capacity is based on earthquake experience data or generic seismic testing data will meet the intent of the specific caveats defining the bounds of these data bases.
- Anchorage capacity, stiffness, and installation will be adequate to withstand the seismic demand associated with the SSE.
- Seismic interactions with nearby equipment or structures will not adversely affect the required safe shutdown function of the equipment.

The methods for verifying the seismic adequacy of relays, tanks, heat exchangers, and cable and conduit raceways are discussed in other sections of this procedure.

4.1.2 Determination of Seismic Capacity

The licensee will determine the seismic capacity of safe shutdown equipment using:

- Earthquake experience data with capacity defined by the Bounding Spectrum,
- Seismic qualification test data which have been compiled into Generic Equipment Ruggedness Spectra (GERS), or
- Equipment-specific seismic qualification data, or data on similar equipment.

4.1.3 Use of Caveats

The licensee will evaluate whether the safe shutdown equipment meets the intent of the caveats summarized in Appendix B when verifying the seismic adequacy of equipment by use of the Bounding Spectrum or GERS.

4.1.4 Anchorage Verification

The licensee will verify anchorage adequacy with an approach incorporating three elements:

- Comparison of the anchorage capacity with the seismic demand.
- Evaluation of the anchorage to verify that it is adequately installed.
- Evaluation of the equipment anchorage load path to verify that there is adequate stiffness and strength.

All required anchorages of safe shutdown equipment will be inspected unless otherwise justified by the licensee, based on other anchorage evaluation results, radiation dose concerns, or other factors.

4.1.5 Seismic Interaction

The licensee will evaluate seismic interactions of safe shutdown equipment with nearby equipment and structures that may compromise the performance of the safe shutdown function. Three effects will be included in the review:

- Proximity effects
- Overhead or adjacent equipment failure
- Flexibility of attached lines or cables

4.1.6 Documentation

The licensee will document the results of the Screening Verification and Walkdown on Screening Verification Data Sheets (SVDS).

4.2 SEISMIC CAPACITY COMPARED TO SEISMIC DEMAND

The first screening guideline which should be satisfied to verify the seismic adequacy of an item of mechanical or electrical equipment is to confirm that the seismic capacity of the equipment is greater than or equal to the seismic demand imposed on it.

This section addresses the comparison of seismic capacity to seismic demand for the equipment itself. Note that a comparison of seismic capacity to seismic demand is also made for the anchorage of the equipment in Section 4.4 and for the relays mounted in the equipment in Section 6.

The seismic capacity of equipment can be represented by a "Bounding Spectrum" based on earthquake experience data, or a "Generic Equipment Ruggedness Spectrum" (GERS) based on generic seismic test data. These two types of seismic capacity spectra are described in Sections 4.2.1 and 4.2.2, respectively. Note that these two methods of representing seismic capacity of equipment can only be used if the equipment meets the intent of the caveats for its equipment class as described in Section 4.3.

The seismic capacity of an item of equipment can be compared to a seismic demand which is defined in terms of either a Ground Response Spectrum or an In-Structure Response Spectrum (e.g., floor response spectrum). Table 4-1 outlines these types of comparisons as either Method A or B. Method A is for making a comparison with a Ground Response Spectrum; Section 4.2.3

Table 4-1

METHODS FOR COMPARING EQUIPMENT SEISMIC CAPACITY TO SEISMIC DEMAND

Method A. - Comparisons With SSE Ground Response Spectra

An SSE ground response spectrum can be used for comparison to the Bounding Spectrum or the GERS when:

- Equipment is mounted within about 40 feet above the effective grade, and
- Equipment has natural frequency greater than about 8 Hz.

	Capacity		Demand
A.1	Bounding Spectrum	≥	SSE Ground Response Spectrum
A.2	GERS	≥	$1.5^{(a)}$ X $1.5^{(b)}$ X SSE Ground Response Spectrum

Method B. - Comparisons With In-Structure Response Spectra for the SSE

An in-structure response spectrum can be used for comparison to 1.5 X Bounding Spectrum or the GERS for equipment which is mounted at any elevation in the plant and/or for equipment with any natural frequency.

	Capacity		Demand
B.1	1.5 X Bounding Spectrum	≥	Realistic, Median-Centered[c], In-Structure SSE Response Spectrum
B.2	GERS	≥	Conservative, Design, In-Structure SSE Response Spectrum
B.3	GERS	≥	$1.5^{(a)}$ X Realistic, Median-Centered, In-Structure SSE Response Spectrum

(a) The 1.5 multiplier in Methods A.2 and B.3 is a factor of conservatism to account for uncertainty when comparing GERS to realistic, median-centered, in-structure response spectra.

(b) The second 1.5 factor in Method A.2 effectively converts the ground response spectrum to a realistic, median-centered, in-structure response spectrum.

(c) Conservative, design, in-structure response spectra may be used for seismic demand with Method B.1 instead of realistic, median-centered in-structure response spectra, however substantial conservative may be introduced.

discusses this type of comparison. Method B is a comparison with an In-Structure Response Spectrum; Section 4.2.4 discusses this type of comparison. Method A comparisons are generally easier to apply than Method B comparisons.

To verify seismic adequacy, in general, the seismic capacity spectrum should <u>envelop</u> the seismic demand spectrum. There are three special exceptions to this general rule:

- The seismic capacity spectrum needs only to envelop the seismic demand spectrum for frequencies at and above the lowest natural frequency of the item of equipment being evaluated.
- The seismic capacity spectrum can be compared directly to an unbroadened seismic demand response spectrum. Uncertainty in the lowest natural frequency of an item of equipment should be addressed by shifting the frequency of the demand response spectrum peaks.
- Exceeding the seismic capacity spectrum at narrow peaks in the seismic demand response spectrum is acceptable if the average ratio of the demand spectrum to the capacity spectrum does not exceed unity over a frequency range of 10% of the subject frequency (e.g., 0.8 Hz range at 8 Hz).

Where it is necessary to determine the lowest natural frequency of an item of equipment, the Seismic Capability Engineers may, in most cases, estimate this frequency based on their experience and judgment without need for analysis or testing.

Equipment-specific seismic qualification techniques as used in newer nuclear power plants may be used instead of the methods given in this section. Specific guidelines for these equipment-specific qualification techniques are not provided herein.

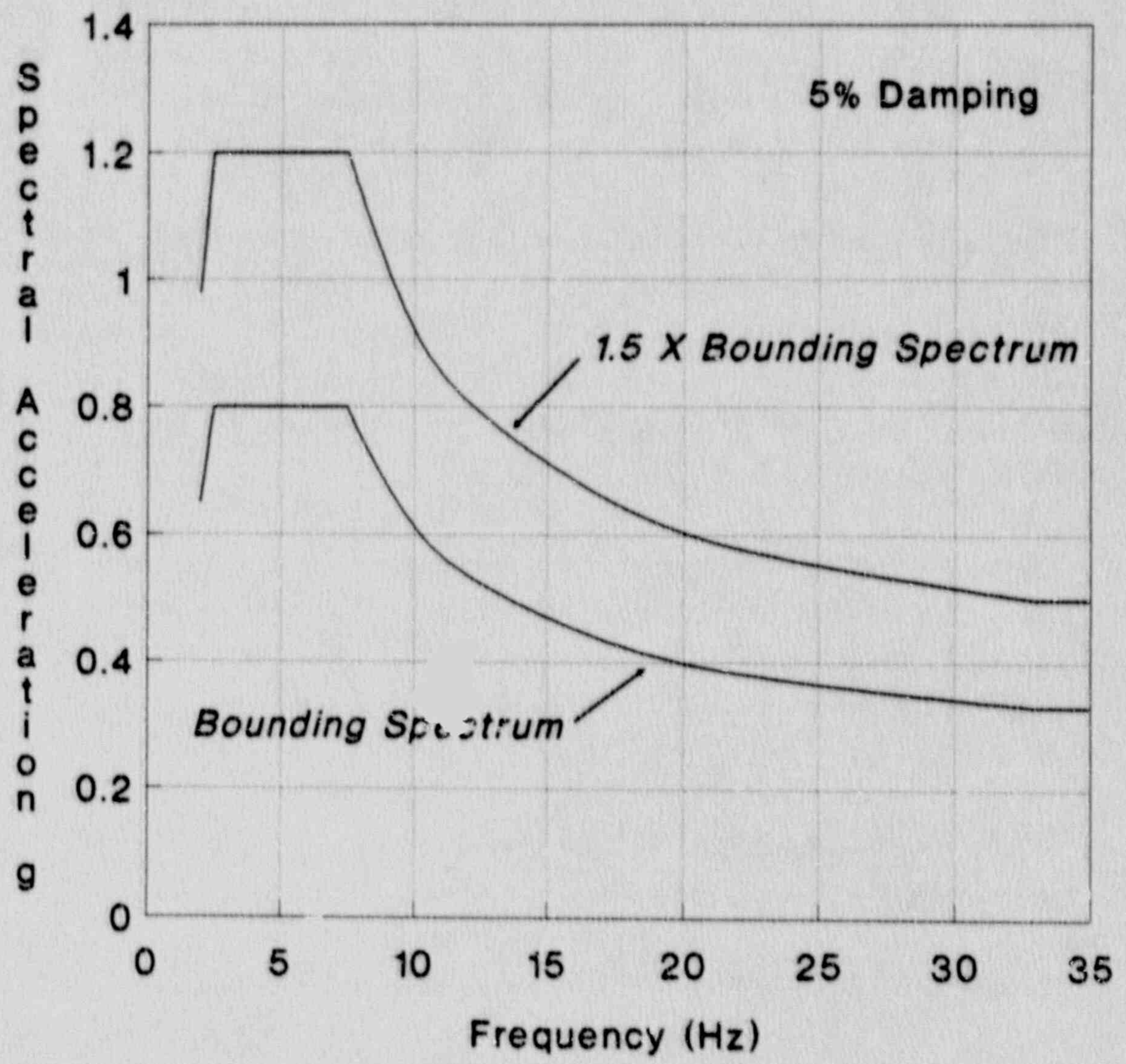
4.2.1 Seismic Capa 'ty Based on Earthquake Experience Data

Earthquake experience data was obtained by surveying and cataloging the effects of strong ground motion earthquakes on various classes of equipment mounted in conventional power plants and other industrial facilities. The results of this effort are summarized in Reference 4.

A "Bounding Spectrum" was developed which represents the seismic capacity of the data base equipment. A detailed description of the derivation and use of this Bounding Spectrum is contained in Reference 5; this reference should be reviewed by the Seismic Capability Engineers before using the Bounding Spectrum. The Bounding Spectrum (and 1.5 times the Bounding Spectrum) is shown in Figure 4-2.

The Bounding Spectrum can be used to represent the seismic capacity of equipment in a nuclear power plant when this equipment is determined to have characteristics similar to the data base equipment and meets the intent of the caveats for that class of equipment. Section 4.3 and Appendix B discuss this in more detail.

Use of the Bounding Spectrum for comparison with the ground response spectrum (Method A.1 in Table 4-1) is described in Section 4.2.3. Comparison of 1.5 times the Bounding Spectrum to the in-structure response spectrum (Method B.1 in Table 4-1) is described in Section 4.2.4. The 1.5 factor effectively converts the equipment seismic capacity defined in terms of a ground response spectrum to a capacity spectrum defined in terms of a realistic, median-centered, in-structure response spectrum.



Frequency (Hz)	2.0	2.5	7.5	8.0	10	12	16	20	28	33
1.5 X Bounding Spectrum (g)	.98	1.2	1.2	1.13	.90	.80	.68	.59	.53	.50
Bounding Spectrum (g)	.65	.80	.80	.75	.60	.53	.45	.39	.35	.33

Figure 4-2. Seismic Capacity Bounding Spectrum
Based on Earthquake Experience Data
(Source: Reference 5)

4.2.2 Seismic Capacity Based on Generic Seismic Testing Data

A large amount of data was collected from seismic qualification testing of nuclear power plant equipment. This data was used to establish a generic ruggedness level for various equipment classes in the form of Generic Equipment Ruggedness Spectra (GERS). The development of the GERS and the limitations on their use (caveats) are documented in Reference 6. Copies of the GERS along with a summary of the caveats to be used with them are included in Appendix B. Seismic Capability Engineers should review Reference 6 to understand the basis for the GERS.

GERS can be used to represent the seismic capacity of an item of equipment in a nuclear power plant when this equipment is determined to have characteristics which are similar to the testing data base equipment and meet the intent of the caveats for that class of equipment. Section 4.3 and Appendix B discuss this in more detail.

Use of the GERS by comparison to 1.5 X 1.5 X the <u>ground</u> response spectrum (Method A.2 in Table 4-1) is described in Section 4.2.3. Use of the GERS by comparison to a conservative, design <u>in-structure</u> response spectrum or 1.5 X the realistic, median-centered <u>in-structure</u> response spectrum (Methods B.2 and B.3 in Table 4-1) is described in Section 4.2.4.

One of the 1.5 factors used with the ground response spectrum for Method A.2 effectively converts the ground response spectrum to a realistic, median-centered, in-structure response spectrum. The other 1.5 factor applied to the ground response spectrum in Method A.2 and the 1.5 factor applied to the realistic, median-centered in-structure response spectra in Method B.3 is a factor of conservatism to account for uncertainty when comparing GERS to realistic, median-centered, in-structure response spectra instead of conservative, design in-structure response spectra.

4.2.3 Method A - Comparison of Seismic Capacity to Ground Response Spectra

The ground response spectrum for the Safe Shutdown Earthquake (SSE) can be used to represent the seismic demand applied to nuclear plant equipment when one of the following two comparisons is made:

- The Bounding Spectrum envelops the SSE ground response spectrum (5% damping).
- The GERS envelops 1.5 X 1.5 X the SSE ground response spectrum (5% damping).

These comparisons are shown as Methods A.1 and A.2 in Table 4-1. The remainder of this section provides a definition of terms, the advantage and limitations of using these comparisons with ground response spectra, and guidance for evaluating in-line equipment.

Definition of Terms. The terms used in this section are defined below.

The "ground response spectrum" which should be used in the comparisons is the largest horizontal component of the 5% damped, free-field, Safe Shutdown Earthquake (SSE) ground response spectrum to which the nuclear plant is licensed.

The vertical component of the ground response spectrum is not explicitly considered for equipment adequacy assessment (except for anchorage evaluations discussed in Section 4.4). Evaluation of vertical component effects is implicit in the horizontal motion assessment since the data base plants typically experienced relatively more vertical motion (compared to horizontal) than that postulated for most nuclear plants. When using GERS, the test data base includes effects of vertical motion which is consistent with that postulated for nuclear plants. It is considered that, in general, equipment is more sensitive to horizontal motion than vertical motion.

"Effective grade" at a nuclear plant is defined as the average elevation of the ground surrounding the building along its perimeter. If the plant is founded on rock or a very stiff soil site without controlled, compacted backfill, then the "effective grade" is the elevation where the structure receives significant lateral support from the surrounding soil or rock; for example, the top of the base mat. Similarly, "effective grade" should be taken at the foundation level if crushable foam insulation or other measures are used to isolate the structure from lateral support from the surrounding soil or rock. If an internal structure of the building is supported primarily at the base mat without significant lateral support from the surrounding structure, then the "effective grade" is the elevation at the top of the base mat.

Advantage and Limitations. The advantage of using ground response comparisons is that with the applicable restrictions and limitations, all the equipment covered by the Bounding Spectrum or the GERS can be evaluated for seismic adequacy without the need for using floor response spectra which are often based on very conservative modeling techniques or may not be available.

The restrictions and limitations on use of the ground response spectrum for comparison to the Bounding Spectrum and the GERS is based on the conditions that the amplification factor between the free-field response spectra and the in-structure response spectra will not be more than about 1.5, and that the natural frequency of the equipment is not in the high energy range as follows:

- The equipment should be mounted in the nuclear plant at an elevation within about 40 feet above the effective grade, and
- The equipment, including its supports, should have a fundamental natural frequency greater than about 8 Hz.

Seismic Capability Engineers should be alert for unusual, plant-specific situations which could cause the amplification factor to be greater than that of typical nuclear plant structures. The 1.5 amplification factor is only applicable to reinforced concrete frame and shear wall structures and to heavily-braced steel frame structures.

Guidance for Evaluating In-Line Equipment. When using the Bounding Spectrum for the seismic capacity of equipment mounted on a piping system (i.e., valves, valve operators, and sensors), the 8 Hz limitation does not apply. That is, the piping system can have a natural frequency lower than about 8 Hz at the location where the item of equipment is mounted. Low frequency piping systems are well represented in the earthquake experience data so special measures to address amplification of input motion are not necessary.

When using the GERS for the seismic capacity of equipment mounted on a piping system (i.e., valves, valve operators, and sensors), the seismic demand should be based on the response spectra of the piping system at the location where the equipment is mounted, not the floor response spectra. The piping response spectra can be obtained from a dynamic piping analysis if one is available. As an alternative, an amplification factor may be estimated to account for amplification between the anchor point of the piping system (i.e., the floor or wall of the building) and the point on the piping system where the item of equipment is mounted. Reference 15 provides guidance on the development of simple, conservative pipe response spectra.

4.2.4 Method B - Comparison of Seismic Capacity to In-Structure Response Spectra

The in-structure response spectrum associated with the SSE can be used to represent the seismic demand applied to nuclear plant equipment when one of the following three comparisons is made:

- 1.5 X Bounding Spectrum envelops the realistic, median-centered, in-structure response spectrum (or conservative, design in-structure response spectrum) (5% damping).
- The GERS envelops the conservative, design, in-structure response spectrum (5% damping).
- The GERS envelops 1.5 X the realistic, median-centered, in-structure response spectrum (5% damping).

These comparisons are shown as Methods B.1, B.2, and B.3, respectively, in Table 4-1.

For these comparisons, the largest horizontal component of the 5% damped in-structure response spectra is used, for the location in the plant where the item of equipment is mounted.

The in-structure response spectra referred to in this section should be based on the ground response spectrum to which the nuclear plant is licensed for the Safe Shutdown Earthquake (SSE). The specific values for building damping and analysis assumptions made in generating floor response curves should be reviewed by the Seismic Capability Engineers using the guidance provided in Appendix A of Reference 5.

The in-structure response spectrum used for the seismic demand should be representative of the elevation in the building where the equipment is anchored and receives its seismic input. This elevation should be determined by the Seismic Capability Engineers during the plant walkdown.

The remainder of this section provides a definition of terms, the advantages and limitations of using these comparisons with in-structure response spectra, and guidance for evaluating in-line equipment.

Definition of Terms. The terms used in this section are defined below.

"Conservative, design" in-structure response spectra are defined as response spectra which have been computed roughly in accordance with current NRC Regulatory Guidelines (such as Reg. Guide 1.61 for structural damping) and the Standard Review Plan.

"Realistic, median-centered" in-structure response spectra are defined as response spectra which are based on (1) realistic damping levels for the structure and the effects of embedment and wave-scattering, and (2) the results of a probabilistic analysis of the structural response having a 50 percent probability of being exceeded should the Safe Shutdown Earthquake (SSE) ground motion occur.

The Seismic Safety Margins Research Program (References 21 and 22) has demonstrated the large conservatism which exists in traditionally-computed, conservative floor response spectra versus realistic, median-centered floor response spectra. Structural damping values associated with realistic, median-centered floor response spectra, when applied to Regulatory Guide 1.60 design spectra, are the upper limits of the recommended damping values defined in NUREG/CR-0098, "Development of Criteria for Seismic Review of Selected Nuclear Power Plants," May 1978. The specific assumptions made in generating floor response curves should be reviewed by the Seismic Capability Engineers using the guidance provided in Appendix A of Reference 5.

Advantages and Limitations. The advantage of using floor response spectra comparisons is that the equipment can be mounted at any elevation in the plant (i.e., higher than 40 feet above effective grade) and/or the equipment can have any natural frequency.

Note that for comparison to 1.5 X the Bounding Spectrum (comparison using Method B.1), it is preferable to use realistic, median-centered, in-structure response spectra. Unfortunately, these type of spectra may not be readily available for the older plants in the USI A-46 program. Conservative, design, in-structure response spectra may be used instead; however, this may introduce substantial conservatism, particularly at higher elevations in the plant.

Guidance for Evaluating In-Line Equipment. The amplified response of in-line equipment which is supported by piping (e.g., valves, valve operators, and sensors) is handled differently when using the Bounding Spectrum or the GERS as the seismic capacity of the equipment. When using 1.5 X the Bounding Spectrum (comparison using Method B.1), it is not necessary to account for amplification of the piping system between the anchor point of the piping system (i.e., the floor or wall of the building) and the point on the piping system where the item of equipment is attached. This is because the effect of amplified response in piping systems is accounted for in the earthquake experience data base.

When using GERS as the seismic capacity of equipment (comparisons using Method. B.2 and B.3), piping system amplifications should be accounted for when establishing the seismic demand on the in-line item of equipment. The amplification factor can be obtained from a dynamic piping analysis if one is available. As an alternative, the amplification factor may be estimated using judgment. Reference 15 provides guidance on the development of simple, conservative pipe response spectra.

4.3 EQUIPMENT CLASS SIMILARITY AND CAVEATS

The second screening guideline which should be satisfied to verify the seismic adequacy of an item of mechanical or electrical equipment is to confirm that the equipment has generally similar characteristics to and meets the intent of the specific caveats of the equipment classes in the earthquake experience data base or in the generic seismic testing data base. This review is only necessary when the Bounding Spectrum or the GERS is used to represent the seismic capacity of an item of equipment (as described in Section 4.2). If equipment-specific seismic qualification data is used, then only the specific restrictions applicable to that equipment-specific qualification data need be applied.

One important aspect of verifying the seismic adequacy of equipment included within the scope of this procedure is explained by the "rule of the box." For the equipment included in the seismic experience data base (Classes #1 through #20 in Table 3-1), all of the components mounted on or in this equipment are considered to be part of that equipment and do not have to be evaluated separately. Auxiliary components which are not mounted on the item of equipment but are needed by the equipment to fulfill its intended function should be evaluated separately. Additional discussion of the "rule of the box" is found in Section 3.3.3.

An item of equipment should have the same general characteristics as the equipment class in the earthquake or testing data base. The intent of this rule is to preclude items of equipment with unusual designs and characteristics which have not demonstrated seismic adequacy in earthquakes or tests. Appendix B contains a summary of the equipment class descriptions for the earthquake experience data base and for the generic seismic testing data base.

"Caveats" are defined as the set of inclusion and exclusion rules which represent specific characteristics and features particularly important for seismic adequacy of a particular class of equipment. Appendix B contains a summary of the equipment class caveats for the earthquake experience data base and for the generic seismic testing data base.

The "intent" of the caveats should be met when evaluating an item of equipment as they are not fixed, inflexible rules. Engineering judgment should be used to determine whether the specific seismic concern addressed by the caveat is met. Appendix B provides brief discussions of the intent of the caveats.

Note that the caveats of Appendix B are not necessarily a complete list of every seismically vulnerable detail that may exist since it is impossible to cover all such situations by meaningful caveats. Instead, the Seismic Capability Engineers should exercise their judgment and experience to seek out suspicious details or uncommon situations (not specifically covered by the caveats) which may make equipment vulnerable to SSE effects. For example, the Seismic Capability Engineers should note any areas of concern within the "box" which could be seismically vulnerable such as added attachments, missing or obviously inadequate anchorage of components, etc.

The summaries of the equipment class descriptions and caveats in Appendix B are based on information contained in References 4, 5, and 6. The Seismic Capability Engineers should use the summaries in Appendix B only after first reviewing and understanding the background of the equipment classes and bases for the caveats as described in these references. These references provide more details (such as photographs of the data base equipment) and more discussion than summarized in Appendix B.

4.4 ANCHORAGE ADEQUACY

The third screening guideline which should be satisfied to verify the seismic adequacy of an item of mechanical or electrical equipment is to confirm that the anchorage of the equipment is adequate. Lack of anchorage or inadequate anchorage has been a significant cause of equipment failing to function properly during and following past earthquakes.

The screening approach for verifying the seismic adequacy of equipment anchorage is based upon a combination of inspections, analyses, and engineering judgment. Inspections consist of measurements and visual evaluations of the equipment and its anchorage, supplemented by use of plant documentation and drawings. Analyses should be performed to compare the anchorage capacity to the seismic loadings (demand) imposed upon the anchorage. These analyses can be done using the guidelines contained in this section or by using the screening tables or computer code (EBAC) from Reference 7 or the computer code (ANCHOR) from Reference 14. Engineering judgment is also an important element in the evaluation of equipment anchorage. Guidance for making judgments is included, where appropriate, in this section and in the reference documents.

There are various combinations of inspections, analyses, and engineering judgment which can be used to verify the adequacy of equipment anchorage. The Seismic Capability Engineers should select the appropriate combination of elements for each anchorage installation based on the information available. For example, a simple hand calculation may be sufficient for a pump which has only a few, very rugged, anchor bolts in a symmetrical pattern. On the other hand, at times it may be advisable to use one of the anchorage computer codes to determine the loads applied to a multi-cabinet motor control center if its anchorage is not symmetrically located.

Likewise a trade-off can be made between the level of inspection performed and the factor of safety used for expansion anchor bolts. These types of trade-offs and others are discussed in this section.

The four main steps for evaluating the seismic adequacy of equipment anchorages include:

1. Anchorage Installation Inspection
2. Anchorage Capacity Determination
3. Seismic Demand Determination
4. Comparison of Capacity to Demand

It is not necessary to perform the above steps in the order given. Trade-offs between different alternative approaches could affect the order in which these steps are performed.

The remainder of this section describes the four main steps for evaluating the seismic adequacy of anchorages. In some cases specific inspection checks and evaluations apply to only certain types of anchors; additional details on these specific checks are covered in Appendix C. Appendix G also includes Screening and Evaluation Work Sheets (SEWS) which can be used as checklists to verify that all the appropriate steps in the anchorage evaluation procedure have been completed.

It is not necessary to perform an anchorage evaluation for in-line valves (Equipment Classes #7 and #8: fluid-operated, motor-operated, and solenoid-operated valves). Likewise temperature sensors (Equipment Class #19) are relatively light, normally attached to another piece of equipment, and do not need an anchorage evaluation.

The material contained in this section and in Appendix C is based upon References 5 and 7. The Seismic Capability Engineers should not use the material in this section or Appendix C unless they have thoroughly reviewed and understand these reference documents.

4.4.1 Anchorage Installation Inspection

The first main step in evaluating the seismic adequacy of anchorages is to check the anchorage installation and its connection to the base of the equipment. This inspection consists of visual checks and measurements along with a review of plant documentation and drawings where necessary.

All accessible anchorages should be visually inspected. Inaccessible anchorages not required for strength to secure the item of equipment need not be inspected. Inaccessible anchorages or those obstructed from view which are needed for strength to secure the item of equipment should be inspected on a best effort basis without resorting to equipment disassembly, removal, etc. The basis for the engineering judgment for not performing these inspections should be documented.

A check of the following equipment anchorage attributes should be made:

1. Equipment Characteristics (i.e., estimation of mass, center of gravity location, natural frequency, damping, and equipment base overturning moment center of rotation)
2. Type of Anchorage
3. Size and Location of Anchorage
4. Installation Adequacy
5. Embedment Length
6. Gap Size Between Equipment Base and Concrete
7. Spacing Between Anchorages
8. Edge Distance
9. Concrete Strength and Condition
10. Concrete Crack Locations and Sizes
11. Essential Relays in Cabinet
12. Equipment Base Stiffness and Prying Action
13. Equipment Base Strength and Structural Load Path
14. Embedment Steel and Pads

Not all of these attributes are applicable to all types of anchors. Table 4-2 summarizes the checks which should be made for the various types anchorages. General guidelines for performing these checks are provided below; specific guidelines are included in Appendix C for those types of anchors covered in this procedure.

Engineering judgment should be exercised when making these checks. For example, it is not necessary to measure the spacing between anchor bolts if it is obvious they are much farther apart than the minimum spacing guidelines given in Appendix C.

Table 4-2

ANCHORAGE INSTALLATION INSPECTION CHECKS

(V = Visual, D = Drawing Review, M = Measurement)

Attributes To Be Checked	Expansion Anchors	Cast-In-Place Bolts & Studs	Cast-In-Place J-Bolts	Grouted-In-Place Bolts	Welds to Embedded or Exposed Steel
1. Equipment Characteristics	V,M,D	V,M,D	V,M,D	V,M,D	V,M,D
2. Type of Anchorage	V,D	V,D	V,D	V,D	V,D
3. Size & Location of Anchorage	M	M	M	M	M
4. Installation Adequacy	V,M(1),(2)	V	V	V	V
5. Embedment Length	V(3)	D,M	D,M	D,M	--
6. Gap Between Base & Concrete	V	V	V	V	--
7. Spacing Between Anchorages	M	M	M	M	--
8. Edge Distance	M	M	M	M	--
9. Concrete Strength & Condition	D,V	D,V	D,V	D,V	--
10. Cracks in Concrete	V	V	V	V	V
11. Essential Relays in Cabinet	D(4)	--	--	--	--
12. Base Stiffness & Prying	V	V	V	V	V
13. Base Strength & Load Path	V	V	V	V	V
14. Embedment Steel & Pads	D,V,M	D,V,M	D,V,M	D,V,M	D,V,M

Notes:
(1) Tightness of expansion anchors can be measured by rotation of the nut using a standard wrench.
(2) Tightness checks are not needed for "Reduced Inspection" of expansion anchors. Instead, verify that all bolts have nuts in place.
(3) Embedment length need not be considered for "Reduced inspection" of expansion anchors.
(4) Presence of Essential Relays is determined in the Relay Functionality Review (Section 6).

Check 1 - Equipment Characteristics. To determine the seismic loading on the anchorage of an item of equipment, the following equipment characteristics should be estimated: mass, location of the center of gravity, natural frequency, component damping, and equipment base center of rotation for overturning moment.

The mass of the equipment is a primary parameter for determining the inertial loads applied to the anchorage. Equipment weight can be obtained from drawings and/or original purchase documents, if available. However, if this information is not available, then conservative estimates of equipment weight for several equipment classes are given in Section C.1 of Appendix C. These estimated masses are, in general, based on the heaviest (or most dense) item identified during a survey of typical nuclear plant equipment in each of the equipment classes. For unusual equipment, an independent mass calculation should be performed or a conservative estimate made.

The location of the center of gravity of the equipment is used to determine the overturning moment caused by the inertial loads. It should be estimated by performing a visual inspection of the equipment. If the equipment has relatively uniform density, the center of gravity can be taken at the geometric center of the equipment. If the mass of the equipment is skewed, then appropriate adjustments should be made to the center of gravity location. If component mass is centered significantly offset from the geometric centerline, then this should be noted and torsional effects included in the anchorage evaluations.

The lowest natural frequency (f_n) of the equipment is used to determine the amplified acceleration of the equipment from the in-structure response spectrum. Since equipment specific information is normally not available for determining the natural frequency of most types of equipment, approximate natural frequencies for certain classes of equipment are given in Section C.1 of Appendix C as either rigid (f_n > about 20 Hz) or flexible (f_n < about 20 Hz).

The equipment <u>damping</u> should be determined for flexible equipment so that an in-structure response spectrum, with the appropriate level of damping, is used. The damping values for certain classes of equipment are given in Section C.1. For those classes of equipment not covered in Section C.1, the relative flexibility/stiffness and damping should be estimated based on engineering judgment, past experience, and comparison to the equipment which is included in Section C.1.

The <u>center of rotation</u> of the equipment base is the line on the base about which the equipment would rotate due to an overturning moment. The location of the center of rotation should be estimated based on the following guidance. For very rigid equipment bases, such as heavy machinery on skid mounts, the equipment may be considered to pivot about its outer edge or far side bolt centerline. For flexible equipment bases, such as electrical cabinets with light base framing members, the center of rotation should be taken close to the equipment base centerline.

<u>Check 2 - Type of Anchorage</u>. The following five types of anchorages are covered in this procedure. If any other type of anchorage is used to secure an item of equipment, the anchorage for that piece of equipment should be classified as an outlier.

1. Expansion Anchors - Shell and Nonshell Types
2. Cast-In-Place Bolts and Headed Studs
3. Cast-In-Place J-Bolts
4. Grouted-In-Place Bolts
5. Welds to Embedded or Exposed Steel

It is important to identify which of these types of anchorage is used in an installation since these anchorages have different capacities and different installation parameters which should be checked during the inspection.

In most cases, it will be necessary to use plant drawings, specifications, general notes, purchase records, or other such documents to identify the type of anchorage used for an item of equipment. Welds to embedded steel can be distinguished from bolted anchorages without using drawings; however, concrete drawings will still be needed to check the embedment details of the steel. It is not necessary to have specific documented evidence for each item of equipment installed in the plant; i.e., it is permissible to rely upon generic installation drawings or specifications so long as the Seismic Capability Engineers have high confidence as to anchorage type and method of installation and remain alert for subtle differences in anchorage installations during the in-plant inspections. The Seismic Capability Engineers should visually inspect the anchorages to check that the actual installation appears to be the same as that specified on the drawing or installation specification.

If documents are not available to identify the type of bolted anchorage used for an installation, more detailed inspections should be done to develop a basis for the type of anchorage used and its adequacy.

For expansion anchors, it is important to identify the specific make and model of expansion anchor since there is considerable variance in seismic performance characteristics for different expansion anchor types. The makes and models of expansion anchors covered by this procedure are listed in Section C.2.2 of Appendix C along with appropriate capacity reduction factors. It is also important to distinguish between shell- and nonshell-type expansion anchors since different types of checks should be made to assure that they are properly installed. Section C.2.2 provides a description of the differences between shell and nonshell expansion anchors, how to tell them apart while they are installed, and what the capacity reduction factors are for the various makes and models.

Note that expansion anchors should generally not be used for securing vibratory equipment, such as pumps and air compressors. If such equipment is secured with expansion anchors, then there should be a large margin between the pullout loads and the pullout capacities; i.e., these expansion anchors should be loaded primarily in shear with very little pullout load. If a component which is secured with expansion anchors, has been in service for a long time and its expansion anchors remain tightly set, then this is a reasonable basis for ensuring installation adequacy. It is generally recommended that if expansion anchors need to be used for vibrating equipment, then undercut-type of expansion anchors should be installed.

Check 3 - Size and Location of Anchorage. The size of the anchors and the locations where they secure the item of equipment to the floor or wall are key parameters for establishing the capacity of the anchorage for that item of equipment. The nominal allowable capacities in Appendix C are listed according to the diameter of the anchor. Diameter is also used as a key parameter for defining the minimum embedment length, spacing between anchors, and edge distance. The number and location of the anchors which secure an item of equipment determine how the seismic loadings are distributed among all the anchors. Note that the nominal allowable capacities given in Appendix C also apply to anchors in the tension zone of concrete; e.g., on the ceiling.

Check 4 - Installation Adequacy. Several general installation checks should be made of the anchorage. For welds, a visual check of the adequacy of the welded joint should be performed; more details are provided in Section C.6.3 of Appendix C. For bolt or stud installation, a visual check should be made to determine whether the bolt or nut is in place and uses a washer where necessary. Oversized washers are recommended for thin equipment bases. Lock washers are recommended where even low-level vibration exists. For expansion anchors, a tightness check should be made to determine whether the anchors were properly installed and are not obviously loose in the hole. The remainder of the discussion on Check 4 below provides an overview of the checks to be made on expansion anchors; details are provided in Section C.2.3 of Appendix C.

The tightness check for expansion anchors can be accomplished by applying a torque to the anchor by hand until the anchor is "wrench tight," i.e., tightened without excessive exertion. If the anchor bolt or nut rotates less than about 1/4 turn, then the anchor is considered tight. This tightness check is <u>not</u> intended to be a proof test of the capacity of the anchorage. This check is merely meant to provide a reasonable assurance that the expansion anchor was properly installed and has not loosened significantly.

It is not the intent of this procedure to require disassembly of cabinets and structures or removal of electrical cabling and conduit to provide access to the expansion anchors for this tightness check. Therefore, in those cases where expansion anchors are inaccessible, either during plant operation or during shutdown, the Seismic Capability Engineers should make a judgment as to whether the number and distribution of tightness checks which have already been made in the plant is sufficient, considering both the problem of inaccessibility and the results of the other tightness checks. One concern with not checking the tightness of inaccessible expansion anchors is that these types of anchors may not have been properly installed <u>because</u> access to them was limited during installation; therefore, the reason for inaccessibility should be considered when deciding not to check the tightness of expansion anchors.

For plants which have a large number of similar expansion anchors installed, a sampling program may be used for the tightness check based on achieving 95% confidence that no more than 5% of the expansion anchors fail the tightness test. Guidelines for conducting a sampling program are provided in Section C.2.3 of Appendix C.

It is not necessary to perform a tightness check of an expansion anchor if the anchorage for that piece of equipment is robust; i.e., there is a large margin between the applied load and the anchorage capacity. Guidelines for evaluating whether there is sufficient margin in the anchorage are provided in Section C.2.10 of Appendix C, Reduced Inspection Alternative.

It is not necessary to perform a tightness check of expansion anchors which are loaded in tension due to dead weight, since the adequacy of the anchor set is effectively proof-tested by the dead weight loading. Judgment should be exercised to assess the need for tightness checks when multiple expansion anchors are used to secure a base plate loaded in tension by dead loads.

Seismic Capability Engineers should be aware that a tightness check alone for shell-type expansion anchors may not be sufficient to check anchor installation adequacy. If the top of the shell is in contact with the equipment base, then the tightness check may simply be tightening the shell against the bottom of the equipment base as shown in Figure 4-3. Seismic Capability Engineers should exercise engineering judgment and spot check for this type of installation defect by removing a few bolts from shell-type anchors and inspecting them to ensure that the shell anchor and the equipment base are not in contact. If this spot check indicates that these types of bolts may not be properly installed, then the inspection check should be expanded accordingly.

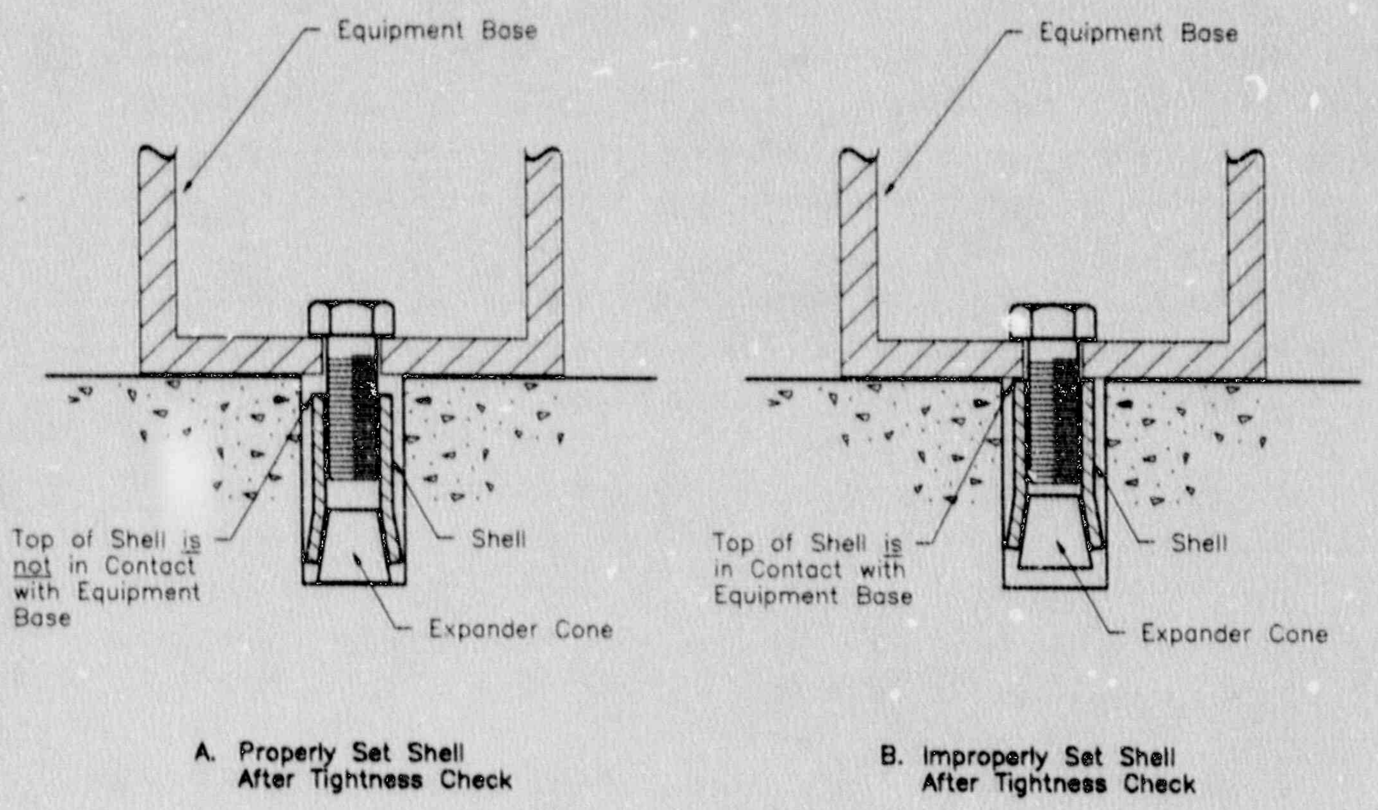


Figure 4-3. Installation of Shell-Type Expansion Anchors

Embedment length is determined from the point on the anchor (defined in Appendix C for the various types of anchors) to the surface of the structural concrete. Note: Grout pads should not be included in the embedment length.

Check 5 - Embedment Length. The embedment length of an anchor should be checked to confirm that it meets the minimum value so that nominal allowable anchor capacities can be used. A capacity reduction factor can be applied to the nominal allowable capacities for certain types of anchors with less embedment. Minimum embedments and reduction factors are given in Appendix C for each type of anchor covered in this procedure.

The minimum embedments for expansion anchors are based on the manufacturer's recommendations. Expansion anchors which have deeper embedments may use the higher recommended capacities contained in the manufacturer's catalog in place of the nominal allowable capacities in Appendix C. The minimum embedments for cast-in-place bolts and headed studs and for grouted-in-place bolts are set to be sufficiently long so that the anchorage will fail in a ductile manner; i.e., in the bolt or stud, not in the concrete. Grouted-in-place anchor embedments are the same as those for cast-in-place anchors; a higher factor of safety is assigned to the pullout capacities of grouted-in-place anchors to account for uncertainties in the bolt installation. The minimum embedment for smooth bar J-bolts is based primarily on the bond strength between the bar and the concrete.

The embedment length of expansion anchors can be checked by: (1) confirming that the anchor is one of the makes and models covered by this procedure (i.e., Check 2, "Type of Anchorage"), and (2) performing a visual inspection of the installation using the guidelines in Section C.2.4. For many types of nonshell anchors, ultrasonic testing can be used to determine bolt length.

It is not necessary to perform an embedment length check of an expansion anchor if the anchorage for that piece of equipment is robust, i.e., there is a large margin between the applied load and the anchorage capacity. Guidelines for evaluating whether there is sufficient margin in the anchorage are provided in Section C.2.10 of Appendix C, Reduced Inspection Alternative.

The embedment length for anchor types other than expansion anchors can be determined from concrete installation drawings, ultrasonic testing, or other appropriate means.

<u>Check 6 - Gap Size Between Equipment Base and Concrete</u>. The size of the gap between the base of the equipment and the surface of the concrete should be less than about 1/4 inch, as illustrated in Figure 4-4, for equipment with bolt-or stud-type anchorages. This limitation is necessary to prevent excessive flexural stresses in the anchor bolt or stud and excessive bending moments on the concrete anchorage. Anchorages with gaps larger than about 1/4 inch should be classified as an outlier and evaluated in more detail.

There should be <u>no</u> gap for equipment containing essential relays. Gaps beneath the base of this equipment are not allowed since they have the potential for opening and closing during earthquake load reversals. This may create high frequency impact loadings on the equipment and any essential relays mounted therein could chatter. The gap size can be checked by performing a visual inspection; a detailed measurement of the gap size is not necessary. The check for the presence of essential relays in equipment can be done in conjunction with the Relay Functionality Review described in Section 6.

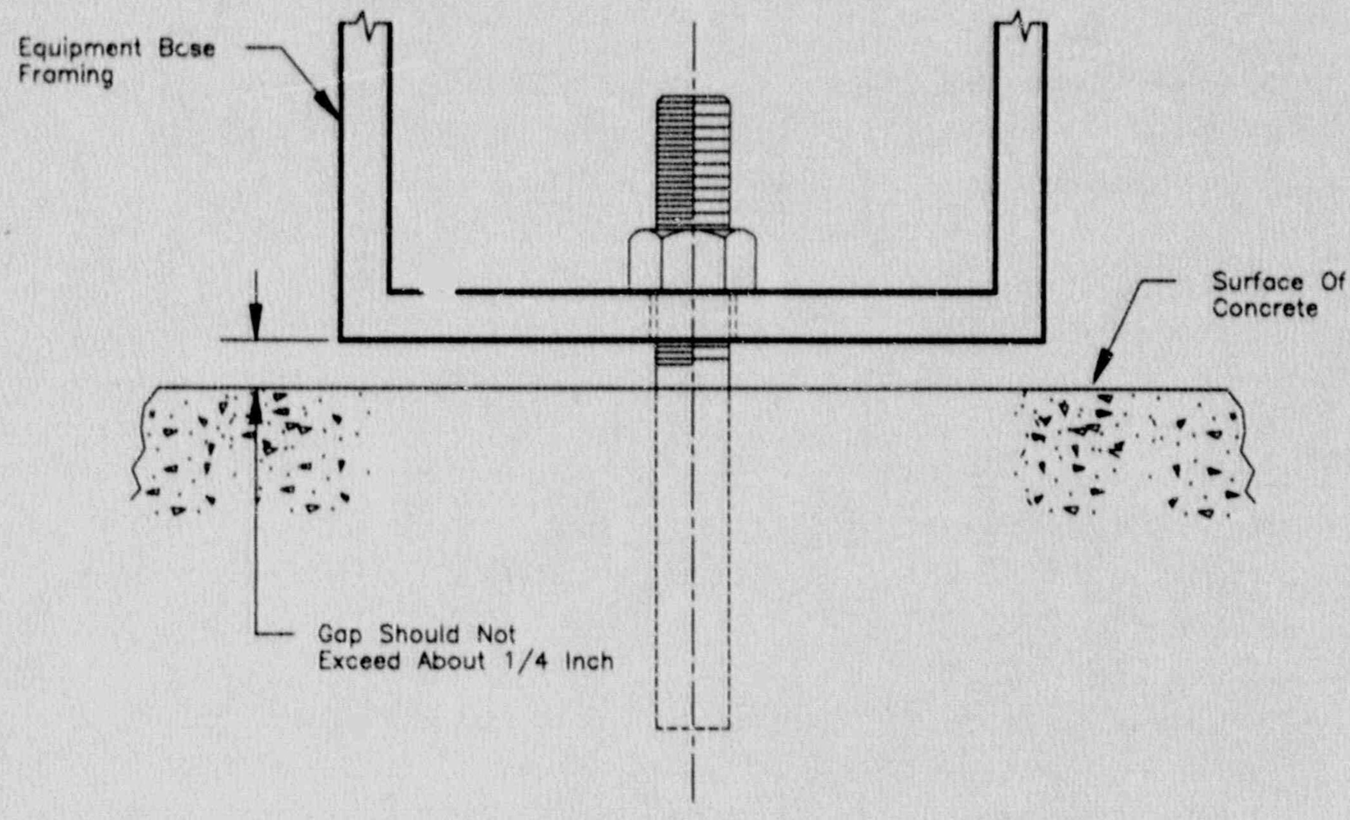


Figure 4.4. Equipment Base With Gap. (Source: Reference 7)

Check 7 - Spacing Between Anchorages. The spacing from an anchor to each nearby anchor should be checked to confirm that it meets the minimum value so that nominal allowable anchor capacities can be used. A capacity reduction factor can be used when bolt-to-bolt spacing is less than the minimum specified value. Minimum spacings and reduction factors are given in Appendix C for each type of anchor covered in this procedure.

For expansion anchors, these spacing guidelines are based primarily on anchor capacity test results. The pullout capacity of cast-in-place anchors and headed studs is based on the shear cone theory. The minimum spacings given in Appendix C are for distances between adjacent anchors in which the cones of influence just touch each other at the surface of the concrete. These minimum spacings are for anchors with the minimum embedment. Greater spacings are necessary to develop the full pullout capacities of deeply embedded anchors if higher capacity values are used.

The shear capacity of anchors is not affected as significantly as tension capacity by closely-spaced anchors. Recommended minimum spacings for shear loads are given in Appendix C, along with the corresponding capacity reduction factors for closely-spaced anchors.

For clusters of closely-spaced anchors, a capacity reduction factor should be applied to an anchor for every other nearby anchor. For example, if there are three anchors in a line, and all are closer than the minimum spacing, then the center anchor should have two reduction factors applied to its nominal capacity allowable; the outside anchors should have only one reduction factor applied.

The spacings between anchors can be checked in the field by a visual inspection and, if necessary, the spacings can be measured. Measurements should be made from anchor centerline to anchor centerline.

Check 8 - Edge Distance. The distance from an anchor to a free edge of concrete should be checked to confirm that it meets the minimum value so that the nominal allowable anchor capacities can be used. A capacity reduction factor can be used for an anchor which is closer to an edge than the minimum. Minimum edge distances and reduction factors are given in Appendix C for each type of anchor covered in this procedure.

For expansion anchors, these edge distance guidelines are based primarily on anchor capacity test results. Full pullout and shear capacity can be developed for cast-in-place anchors and headed studs which are no closer to a free edge than the radius of the projected shear cone. The minimum edge distances given in Appendix C correspond to the shear cone just touching the free edge of concrete at the surface (no credit is taken for concrete reinforcement). These minimum edge distances apply to anchors with the minimum embedment. Greater edge distances are necessary to develop the full pullout capacities of deeply embedded anchors if higher capacities are used.

When an anchor is near more than one free concrete edge, a capacity reduction factor should be applied for each nearby edge. For example, if an anchor is near a corner, then two reduction factors apply.

The edge distances can be checked in the field by a visual inspection and, if necessary, the edge distances can be measured. Measurements should be made from anchor centerline to the free edge.

Check 9 - Concrete Strength and Condition. The concrete compressive strength (f'_c) should be obtained from design documentation or tests to confirm that it meets the minimum value so that the nominal allowable anchor capacities can be used. A capacity reduction factor can be used for concrete which has lower strength than the minimum. Minimum concrete strength and reduction factors are given in Appendix C for each type of anchor covered in this procedure.

In addition, the concrete in the vicinity of the anchor should be checked to be sure that it is free of gross defects which could affect the holding strength of the anchor. This check should be done in conjunction with Check 10, "Concrete Crack Locations and Sizes." Surface defects such as hairline shrinkage cracks are not of concern.

Note that this procedure covers anchors installed only in poured, structural concrete. If any equipment is secured to other types of concrete or masonry structures, such as concrete block masonry walls, the anchorage for that item of equipment should be classified as an outlier and evaluated separately.

The compressive strength of the concrete can normally be obtained from plant construction drawings, specifications, or other documents. If this information is not available, core sample information can be used or new samples can be taken and tested.

<u>Check 10 - Concrete Crack Locations and Sizes</u>. The concrete should be checked to confirm that it is free of significant structural cracks in the vicinity of the installed anchors so that the nominal pullout capacities given in Appendix C can be used. A pullout capacity reduction factor can be used for concrete which has cracks which are larger than the acceptable maximum widths and are located in the vicinity of the anchor. Maximum acceptable crack sizes and capacity reduction factors are given in Appendix C for each type of anchor covered in this procedure.

Significant structural cracks in concrete are those which appear at the concrete surface and pass through the concrete shear cone of an anchor installation or the location of the expansion wedge. Concrete with surface (craze) cracks or shrinkage cracks which only affect the surface of the concrete should be considered uncracked.

The check for cracks in the concrete can be done by a visual inspection of the anchorage installation. It may be necessary to exercise judgment to establish whether cracks in the vicinity of an anchor actually pass through the installation. It is sufficient to estimate the width of cracks without making detailed measurements. This check should be done in conjunction with Check 9, "Concrete Strength and Condition," to find other gross defects which could affect the holding strength of an anchor.

Check 11 - Essential Relays in Cabinets. Electrical cabinets and other equipment which are secured with expansion anchors should be checked to determine whether they house essential relays. If essential relays are present, a capacity reduction factor of 0.75 should be used for cabinets which are secured with expansion anchors. This reduction factor is also described in Section C.2.9 of Appendix C.

The basis for this capacity reduction factor is that expansion anchors have a tendency to loosen slightly when they are heavily loaded; i.e., they pull out of the concrete slightly. This effect does not significantly reduce the ultimate load carrying capability of expansion anchors; however, the slight gap between the base of the equipment and the surface of the concrete can open during the first part of an earthquake load cycle and then slam closed during the second part of the cycle. This creates high frequency impact loadings on the equipment, and the relays mounted therein could chatter. Use of a capacity reduction factor for the expansion anchors which secure this type of equipment lowers the maximum load which the anchor will experience; therefore this minimizes the amount of loosening and hence the potential for introducing high frequency impact loadings into the equipment.

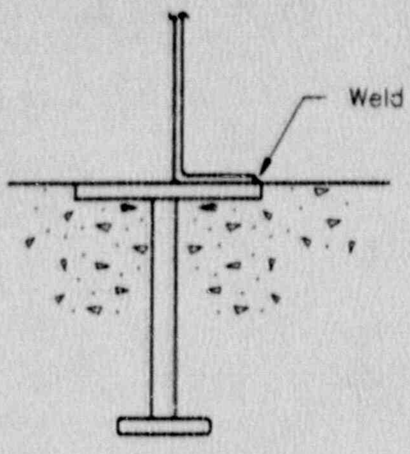
The check for the presence of essential relays in equipment can be done in conjunction with the Relay Functionality Review described in Section 6.

Check 12 - Base Stiffness and Prying Action. The base and anchorage load path of the equipment should be inspected to confirm that there is adequate stiffness and there is no significant prying action applied to the anchors. One special case of base flexibility is base isolation systems. Guidelines for evaluating base isolators are included at the end of this Check 12 section.

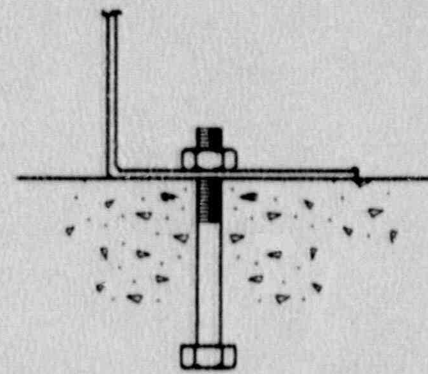
There are two main concerns with the lack of adequate stiffness in the anchorage and load path. First, the natural frequency of the item of equipment could be lowered into the frequency range where dynamic earthquake loadings are higher (i.e., below about 8 Hz in Boundary Spectrum comparisons, or below about 20 Hz for equipment anchorage evaluations). Second, the cabinet could lift up off the floor during an earthquake resulting in high frequency impact loadings on the equipment, and any essential relays mounted therein could chatter.

Prying action can result from eccentric loads within the equipment itself and between the equipment and the anchors. The concern is that these prying actions can result in a lack of adequate stiffness and strength and in additional moment loadings within the equipment or on the anchors.

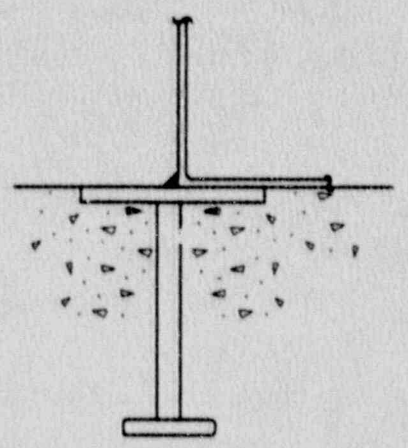
Equipment constructed of sheet metal, such as motor control centers, switchgear, and instrumentation and control cabinets, is susceptible to these effects and should be carefully inspected for lack of stiffness and prying action. Figure 4-5 shows examples of stiff and excessively flexible anchorage connections with prying action.



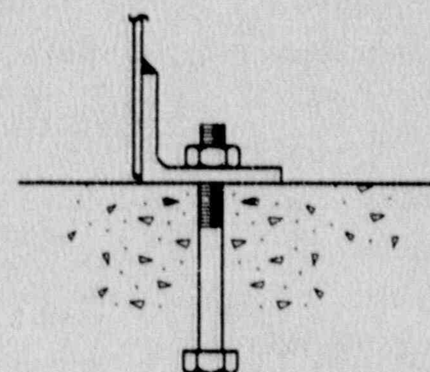
A **Undesirable Flexible Welded Anchorage**
Uplift causes sheet metal frame to bend.



B **Undesirable Flexible Bolted Anchorage**
Uplift causes sheet metal to bend.



C **Desirable Stiff Welded Anchorage**
Loads pass through sheet metal wall.



D **Desirable Stiff Bolted Anchorage**
Structural angle base provides adequate stiffness.

E **Undesirable Flexible Base Anchorage**
Plate can bend from uplift loads and base frame might bend from shear loads.

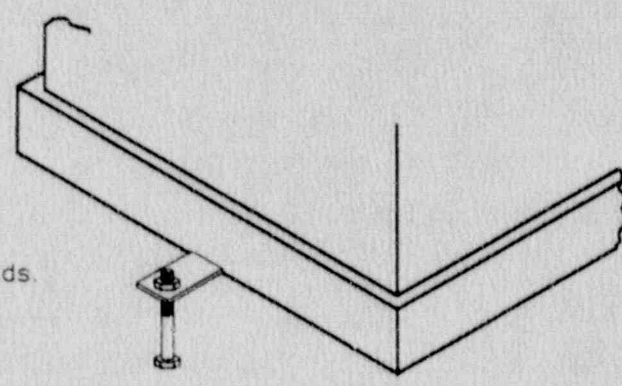


Figure 4-5. Examples of Stiff and Excessively Flexible Anchorage Connections. (Source: Reference 5)

The checks for adequate stiffness and lack of prying action require considerable engineering judgment and can be done by a visual inspection of the anchorage installation. Seismic Capability Engineers should also review by visual inspection the entire anchorage load path of the equipment for adequate stiffness.

If the base is flexible or if prying action could occur, then the Seismic Capability Engineers should exercise their judgment to lower the capacity of the anchorage accordingly.

If the equipment is mounted on a base isolation system, then the isolators should be evaluated for seismic adequacy using the guidelines provided below.

Base isolators are vulnerable to failure during an earthquake for several reasons. Vibration isolators, consisting primarily of one or several springs, have failed during earthquakes when the springs could not resist lateral loads. Isolators manufactured of cast iron can shatter when subjected to earthquakes. Rubber and elastomer products in isolators can fail when bonding adhesives or the material itself fails. Other isolators have steel sections surrounding the spring element which at first appear stout; however, detailed review can reveal that seismic loads may be carried through small fillet or tack welds and through flat bearing plates which bend along their weak axis.

For a base isolator system to be acceptable for seismic loads, the isolator system should have a complete set of bumpers to prevent excessive lateral movement in all directions. The bumpers sh[illegible] not only prevent any excessive lateral movement and torsion, but [illegible] positive method of resisting uplift should also be provided other than the springs themselves, or the rubber or adhesives in tension. If the bumpers do not have elastomeric pads to prevent hard impact, the effect of that impact on the equipment should be evaluated. (Note: Essential relays should not be mounted in such equipment.) Isolators which were specifically designed for seismic applications (not cast iron, unbraced springs, weak elastomers, etc.) may be accepted, provided suitable check calculations verify that all possible load combinations and eccentricities within the isolator itself, including possible impact loads, can be taken by the isolator system.

Check 13 - Equipment Base Strength and Structural Load Path. The equipment base and structural load path should be checked to confirm that it has adequate strength to transmit the seismic loads from the center of gravity of the equipment to the anchorage. This check should include such items as whether a washer is present under the nut or the head of the bolt, and if not present, whether one is necessary. A washer is not necessary if the base of the equipment is at least as thick as a standard washer with a hole no larger than the hole in a standard washer. Another item to check is whether the internal bolting and welds near the base of the equipment can carry the anchorage loads.

One example of inadequate strength in the equipment base was demonstrated during a shake table test of a motor control center in which all four corners of the assembly broke loose. The weld between the base channel and the shake table remained intact; however, the small 5/16-inch bolted connections between the base channel and the frame of the assembly broke.

The check for adequate strength in the equipment base can be done by a visual inspection of the anchorage installation. This check should be done in conjunction with Check 12, "Equipment Base Stiffness and Prying Action."

Check 14 - Embedment Steel and Pads. If an item of equipment is welded to embedded steel or it is mounted on a grout pad or a large concrete pad, the adequacy of the embedded steel, the grout pad, or the large concrete pad should be evaluated.

Welds made to embedded steel transmit the anchor load to the embedment. The location of the weld should be such that large eccentric loads are not applied to the embedded steel. If the embedment uses headed studs, the strength criteria given in Section C.3 should be used together with the generic guidelines contained in this section. Other types of embedments are not covered in this procedure; however, their holding strength can be determined by testing or by application of the principles set forth in ACI 349, Appendix B (Reference 30). Engineering judgment should be exercised to establish a conservative estimate of the concrete failure surface for these other types of embedments. Manufacturer's test information or plant specific test information may be used to assess other types of embedments as appropriate. Factors of safety consistent with this procedure should be followed.

Equipment mounted on grout pads should be checked to confirm that the anchorages penetrate through the grout pad into the structural concrete beneath. Anchorages installed only in the grout pad have failed in past earthquakes and do not have the capacity values assigned to anchors in structural concrete.

If an item of equipment is anchored to a large concrete pad, the pad should have reinforcing steel and be of sound construction (i.e., no prominent cracks). The pad/floor interface should also be evaluated to determine whether it can transmit the earthquake loads. For example, if there are sufficient reinforcement bars connecting the floor to the pad, then the connection is adequate. Also, if a chemical bonding agent was used between the pad and floor, the adhesion strength can typically develop the same strength as the concrete in tension and shear.

If there are no reinforcement bars or chemical bond between the pad and the floor, then the interface can typically resist only shear loadings (if the interface had been roughened at the time the pad was poured). It may be possible, in this case, to show that there are no tensile loads on the pad/floor interface due to either: (1) the center of gravity of the item of equipment being low, or (2) the weight of the pad itself acting as a ballast to resist the overturning moment.

The adequacy check of the embedded steel, grout pad, and large concrete pad can be done with a visual inspection together with measurements and the use of drawings and other documents where necessary. This check should be done in conjunction with Check 9, "Concrete Strength and Condition" and Check 10, "Concrete Crack Locations and Sizes."

4.4.2 Anchorage Capacity Determination

The second main step in evaluating the seismic adequacy of anchorages is to determine the allowable capacity of the anchors used to secure an item of equipment. The allowable capacity is obtained by multiplying the nominal allowable capacities by the applicable capacity reduction factors. The nominal capacities and reduction factors can be obtained from Appendix C, based on the results of the anchorage installation inspection checks described in Section 4.4.1.

The pullout capacity allowable is based on the product of the nominal pullout capacity and the applicable capacity reduction factors:

$$P_{all} = P_{nom} \; RT_p \; RL_p \; RS_p \; RE_p \; RF_p \; RC_p \; RR_p$$

Where:
- P_{all} = Allowable Pullout capacity of installed anchor (kip)
- P_{nom} = Nominal allowable Pullout capacity (kip)
- RT_p = Reduction factor for the Type of expansion anchors
- RL_p = Reduction factor for short embedment Lengths
- RS_p = Reduction factor for closely Spaced anchors

RE_p = Reduction factor for near Edge anchors

RF_p = Reduction factor for low strength (f'_c) concrete

RC_p = Reduction factor for Cracked concrete

RR_p = Reduction factor for expansion anchors securing equipment with essential Relays

The shear capacity allowable is based on the product of the nominal shear capacity and the applicable capacity reduction factors:

$$V_{all} = V_{nom}\ RT_s\ RL_s\ RS_s\ RE_s\ RF_s\ RR_s$$

Where: V_{all} = Allowable shear capacity of installed anchor (kip)

V_{nom} = Nominal allowable shear capacity (kip)

RT_s = Reduction factor for the Type of expansion anchors

RL_s = Reduction factor for short embedment Lengths

RS_s = Reduction factor for closely Spaced anchors

RE_s = Reduction factor for near Edge anchors

RF_s = Reduction factor for low strength (f'_c) concrete

RR_s = Reduction factor for expansion anchors securing equipment with essential Relays

Note that the pullout and shear capacities for anchors given above are based on having adequate stiffness in the base of the equipment and on the base not applying significant prying action to the anchor. If the Anchorage Installation Inspection Check 12 shows that stiffness is not adequate or that significant prying action is applied to the anchors, then the Seismic Capability Engineers should lower the allowable capacity loads accordingly.

4.4.3 Seismic Demand Determination

The third main step in evaluating the seismic adequacy of anchorages is to determine the loads applied to the anchorages by the seismic demand imposed on the item of equipment. This is done using the following five steps:

1. Determine the appropriate input seismic accelerations for the item of equipment for each of the three directions of motion.

2. Determine the seismic inertial equipment loads for each of the three directions of motion using the equivalent static load method.

3. Determine the seismic inertial anchor loads by calculating the various load components for each direction of motion.

4. Calculate the combined seismic loads on each anchor from each of the three directions of seismic motion. Then combine the load components from these three directions using the Square Root Sum of the Squares (SRSS) method.

5. Calculate the total loads on each anchor by adding the combined seismic loads to the equipment deadweight loads and any other loads on the equipment.

These five steps are described below:

Step 1 - Input Seismic Accelerations. The first step in determining the seismic demand loads on the anchorage is to compute the input seismic accelerations from an appropriate in-structure response spectrum, at the damping and natural frequency of the equipment, for the location in the plant where the equipment is mounted.

If the equipment is located in an area where there are two applicable lateral response spectra (nominally one N-S and one E-W), then one of the following alternatives can be used to define a single horizontal seismic demand acceleration for load calculation:

- Use the higher acceleration for both horizontal directions.
- Use the acceleration value (either N-S or E-W) which aligns with the direction of the "weak" anchorage for that item of equipment.
- Use the actual direction N-S and E-W accelerations for the N-S and E-W loads on each item of equipment.

The vertical component of acceleration can be conservatively taken as 2/3 of the horizontal component of acceleration. For most equipment classes, the vertical direction fundamental frequency is in the rigid range. For this reason, even if the equipment is flexible in a horizontal direction, then 2/3 of the horizontal ZPA may be used as the vertical acceleration as appropriate.

The following factors which should be considered in determining the input seismic accelerations are covered below: equipment damping, natural frequency of the equipment, use of unbroadened response spectra, and factors of conservatism for various types of in-structure response spectra.

<u>Equipment Damping</u>. A 5% damping value can be used for most of the equipment classes covered by this procedure. Section C.1 of Appendix C lists the equipment classes for which 5% damping is recommended. This level of damping is adequate for these classes because the equipment either exhibits this level of damping or it is essentially rigid (natural frequency greater than about 20 Hz) so that the damping level is nearly irrelevant. Section C.1 of Appendix C also lists the classes of equipment which have lower damping (3% damping) and which are, in general, flexible. This equipment includes electrical equipment (Equipment Classes #1, #2, #3, #4, #14, #15, #16, #18, and #20) and some types of Vertical Pumps (Equipment Class #6). Inspection Check 1 can be used to verify that the equipment does not have unusual features which could lower its damping below the values given in Section C.1.

In-structure response spectra for the plant may not be available at the 5% or 3% damping levels recommended in this procedure for anchorage evaluations. Therefore available response spectra may be normalized to the desired spectral damping level using one of the following methods (from Appendix A of Reference 6):

For <u>in-structure response spectra</u> which have a shape similar to the Bounding Spectrum shown in Figure 4-2, i.e., without very narrow peaks, the spectral acceleration for a desired damping ratio β_2 can be estimated from an available response spectrum with a damping ratio of β_1 by using the following relationship:

$$Sa_{i2} = Sa_{i1} \sqrt{\frac{\beta_1}{\beta_2}}$$

However this spectral acceleration Sa_{i2} is limited to:

$$Sa_{i2} \geq ZPA$$

for frequencies (f_i) in the high frequency region, i.e.; frequencies greater than the frequency associated with the peak of the response spectrum.

The meaning of the symbols used above is as follows:

Sa_{i1} = available spectral acceleration at frequency f_i associated with a damping ration β_1

Sa_{i2} = desired spectral acceleration at frequency f_i associated with a damping ratio β_2

β_1 = damping ratio of available response spectrum

β_2 = damping ratio of desired response spectrum

ZPA = Zero Period Acceleration

f_i = frequency of interest

For <u>estimated in-structure response spectra</u> based on 1.5 x horizontal ground response spectrum (at 5% damping) for equipment which (1) is mounted within (i.e., below) about 40 above grade and (2) has a fundamental natural frequency greater than about 8 Hz, the spectral acceleration for a desired damping ratio β_2 can be estimated from the 5% damped estimated response spectrum by using one of the following three relationships:

For $f_i \le 8$ Hz:

$$Sa_{i2} = Sa_{i1}\sqrt{\frac{\beta_1}{\beta_2}}$$

For $f_i \ge 20$ Hz:

$$Sa_{i2} = Sa_{i1}$$

For 8 Hz < f_i < 20 Hz:

Sa_{i2} = linear interpolation of Sa_{i2} on a log-log scale between 8 Hz and 20 Hz based on the above two formulas:

$$= e^{(m \ln f_i + \ln b)}$$

Where:

Sa_{i1} = available spectral acceleration at frequency f_i associated with a 5% damping ratio (β_1)

Sa_{i2} = desired spectral acceleration at frequency f_i associated with a damping ratio β_2

β_1 = damping ratio (5%) of available estimated response spectrum

β_2 = damping ratio of desired response spectrum

f_i = frequency of interest

m = slope of line on log-log scale between 8 Hz and 20 Hz

$$= \frac{\ln Sa_{8Hz,2} - \ln Sa_{20Hz,2}}{\ln 8 - \ln 20}$$

$Sa_{8Hz,2}$ = spectral acceleration at 8 Hz associated with the damping ratio β_2

$Sa_{20Hz,2}$ = spectral acceleration at 20 Hz associated with the damping ratio β_2

b = intercept of line on log-log scale

$$= e^{(\ln Sa_{8Hz,2} - m \ln 8)}$$

Natural Frequency. The lowest natural frequency (f_n) of the equipment may be estimated by past experience with testing or analysis. The natural frequency of the equipment can be determined in Inspection Check 1 during the inspection of the anchorage installation. Note that conservative estimates of equipment natural frequency for several equipment classes are given in Section C.1 of Appendix C as either rigid (f_n > about 20 Hz) or flexible (f_n < about 20 Hz). The following classes of equipment can generally be considered as rigid (i.e., natural frequency greater than about 20 Hz) if anchored stiffly:

- Equipment Class #5 - Horizontal Pump
- Equipment Class #12 - Air Compressors
- Equipment Class #13 - Motor-Generators
- Equipment Class #17 - Engine-Generators

Rigid equipment can use a damping value of 5% since it is not significantly amplified over the Zero Period Acceleration (ZPA).

If the natural frequency of the equipment is estimated to be high (i.e., greater than about 20 Hz), then the equipment should be considered "rigid" and the Zero Period Acceleration (ZPA) should be used for anchorage load calculations. If the natural frequency is estimated to be below about 20 Hz, then the equipment should be considered "flexible" and the peak of the response spectrum may conservatively be used for anchorage load calculations. If the natural frequency of the equipment is known (by calculation, test, or other means), the maximum acceleration from the response spectrum for the frequency range of interest (from equipment natural frequency to 33 Hz) can be used instead of the peak.

<u>Unbroadened Response Spectra.</u> Unbroadened in-structure response spectra can be used for comparison to seismic capacity spectra. Uncertainty in the natural frequency of an item of equipment can be handled by shifting the frequency of the spectrum peaks.

<u>Factors of Conservatism.</u> The spectral accelerations determined from an in-structure response spectrum should be multiplied by a factor of conservatism from Table 4-3 below, based on the type of in-structure response spectrum used. The 1.25 factor of conservatism given in this table accounts for uncertainties inherent in median-centered type of response spectra. The types of response spectra given in this table and the terminology used to describe them are defined in Section 4.2.

The first type of response spectrum given in Table 4-3 (1.5 X SSE horizontal ground response spectrum) is considered a median-centered type of response spectrum for elevations below about 40 feet when the equipment has its lowest natural frequency above about 8 Hz. The 1.5 factor is an effective amplification factor between the free-field ground motion and the floors in the plant.

Table 4-3

FACTORS OF CONSERVATISM FOR DIFFERENT TYPES OF IN-STRUCTURE RESPONSE SPECTRA

Type of In-Structure Response Spectrum	Additional Factor of Conservatism
• 1.5 X SSE horizontal, ground response spectrum for equipment which: - Is mounted under about 40 feet above the effective grade and - Has its lowest natural frequency above about 8 Hz	1.25
• Realistic, median-centered, horizontal in-structure response spectrum for SSE	1.25
• Conservative, design, horizontal in-structure response spectrum for SSE	1.0

Step 2 - Seismic Inertial Equipment Loads. The second step in determining the seismic demand loads on the anchorage is to compute the seismic inertial equipment loads for each of the three directions of motion using the equivalent static load method. In this method, the seismic analysis is performed statically by applying the inertial load at the center of gravity of the equipment. The inertial load in each direction is equal to the input seismic accelerations, times an equivalent static coefficient, times the mass of the equipment.

An equivalent static coefficient of 1.0 can be used for the classes of equipment covered by this procedure; the basis for this is described in Reference 7. The mass of the equipment is determined in Inspection Check 1 during the inspection of the anchorage installation. Note that conservative estimates of equipment mass for several equipment classes are given in Section C.1 of Appendix C.

Step 3 - Seismic Inertial Anchor Loads. The third step in determining the seismic demand loads on the anchorage is to compute the seismic inertial anchor loads for each of the three directions of motion. This is done by applying the seismic inertial equipment loads determined in the previous step to the center of gravity of the item of equipment and calculating the free-body loads on the anchors. The location of the center of gravity of the equipment is determined in Inspection Check 1 during the inspection of the anchorage installation. The location of the center of gravity can be taken as the geometric center of the equipment if the equipment is of uniform density. If the mass of the equipment is skewed, then appropriate adjustments should be made to the center of gravity location.

The following types of seismic inertial anchor loads should be determined. Note that these loads are applicable whether the equipment is mounted on the floor, wall, or ceiling.

- Anchor shear loads due to the lateral component of force caused by the seismic inertial equipment loads, including, if significant, the anchor shear loads due to any torsional moments (center of gravity does not correspond to the centroid of the group of anchors).
- Anchor pullout loads due to the overturning moment caused by the seismic inertial equipment loads, with an appropriately estimated location of the overturning axis. (See below for guidance on estimating the location of the overturning axis.)
- Anchor pullout loads caused by the seismic inertial equipment loads due to the component of force which is in the line with the axes of the anchor bolts; e.g., vertical for floor-mounted equipment.

The anchor loads caused by the equipment overturning moment can be based on the assumption that plane sections remain plane during loading and that the material in the equipment and the anchors behave in a linear-elastic manner. This results in a linear distribution of anchor loads for a set of anchors which are equal in stiffness and size.

The recommended location for the overturning axis is at the equipment centerline for equipment with flexible bases. For rigid base equipment, the overturning axes can be taken at the edge of the equipment.

Step 4 - Combined Seismic Loads. The fourth step in determining the seismic demand loads on the anchorage is to compute the combined seismic anchor loads by taking the Square Root Sum of the Squares (SRSS) of the seismic loads on each anchor from the three directions of earthquake motion.

Step 5 - Total Anchor Loads. The total loads on the anchorage are computed by combining the combined seismic anchor loads from the previous step to the equipment deadweight loads and any other significant loads which would be applied to the equipment, e.g.; pipe reaction loads on pumps.

4.4.4 Comparison of Capacity to Demand

The fourth and final main step in evaluating the seismic adequacy of anchorages is to compare the seismic capacity loads of the anchors (determined in Section 4.4.2 above) to the total anchor loads (determined in Section 4.4.3 above). This comparison can be done using the shear-tension interaction formulations given in Appendix C for each of the anchor types covered by this procedure.

4.5 SEISMIC INTERACTION

The fourth and final screening guideline which should be satisfied to verify the seismic adequacy of an item of mechanical or electrical equipment is to confirm that there are no adverse seismic spatial interactions with nearby equipment, systems, and structures which could cause the equipment to fail to perform its intended safe shutdown function. The interactions of concern are (1) proximity effects, (2) structural failure and falling, and (3) flexibility of attached lines and cables. Guidelines for judging interaction effects when verifying the seismic adequacy of equipment are presented in Appendix D.

It is the intent of the USI A-46 seismic interaction evaluation that real (i.e., credible and significant) interaction hazards be identified and evaluated. The interaction evaluations described in Appendix D focus on areas of concern based on past earthquake experience. Systems and equipment which have not been specifically designed for seismic loads should not be arbitrarily assumed to fail under earthquake loads; instead, Seismic Capability Engineers are expected to differentiate between likely and unlikely interactions, using their judgment and past earthquake experience. Examples of specific areas which warrant attention in the interaction evaluation are presented in Appendix D.

Note that special attention should be given to the seismic interaction of electrical cabinets containing relays. If the relays in the electrical cabinets are essential; i.e., the relays should not chatter during an earthquake, then <u>any</u> impact on the cabinet should be considered an unacceptable seismic interaction and cause for identifying that item of equipment as an outlier.

Guidance for evaluating the consequences of relay chatter due to earthquake motions, including cabinet impact interactions, are presented in Section 6 and Reference 8.

4.6 DOCUMENTATION

The results of the Screening Verification and Walkdown should be documented on Screening Verification Data Sheets (SVDSs), shown in Exhibit 4-1 at the end of this section. Preparation of the SVDSs includes a review of generic and plant-specific seismic documentation and a plant walkdown of the safe shutdown equipment. The completed SVDSs constitute the formal documentation of the Screening Verification and Walkdown, and reflect the final judgment of the Seismic Capability Engineers.

Other, informal documentation may be used by the Seismic Capability Engineers as an aid during the Screening Verification and Walkdown, in addition to the SVDSs. These may include individual equipment work sheets and checklists such as the Screening Evaluation Work Sheets (SEWS) included in Appendix G. Other types of informal documentation which may be used are calculations, sketches, photographs, etc. Use of informal documentation is optional.

The SVDS is arranged in rows and columns. Each row contains one item of safe shutdown equipment. The columns contain information about the equipment and the results of the Screening Verification and Walkdown. Guidelines for completing each of the columns are provided below.

At the bottom of the SVDS are two sets of certifications to be signed by those performing the Seismic Verification and Walkdown. The first certification should be signed by all the Seismic Capability Engineers who performed the Screening Verification and Walkdown; there should be at least two such signatories, one of which should be a licensed professional engineer. A signature on this certification indicates the Seismic Capability Engineer is in agreement with all the entries and conclusions entered on the SVDS. All signatories should agree with all the entries and conclusions.

The second certification at the bottom of the SVDS is for use by a systems or operations engineer who may provide information to the Seismic Capability Engineers during their seismic evaluation of the equipment. It is left to the Seismic Capability Engineers to determine whether this second certification is needed. This certification should be completed by a systems or operations engineer if he/she provides information critical to the evaluation of the seismic adequacy of the equipment. Examples of such information include how a piece of equipment operates or whether a feature on the equipment is needed to accomplish a safe shutdown function. Information of this type is particularly important if an item of equipment is found during the walkdown which should be added to the safe shutdown equipment list (SSEL). Only the signature of the systems or operations engineer should be documented on the SVDS; details of the information supplied to the Seismic Capability Engineers need not be included.

Note that the completed SVDSs, with the certifications at the bottom, reflect the final judgment of the Seismic Capability Engineers. There may be several walkdowns, additional calculations, and other seismic evaluations which form the basis for certifying whether the equipment meets the screening guidelines contained in this procedure.

Compilation of the information on the SVDSs can be done using a data base management system. This makes it possible to manipulate the order in which the equipment is listed on the sheets. During the SQUG trial plant reviews, it was convenient to print out SVDSs by location in the plant. This optimized the routing of the Seismic Capability Engineers during the walkdowns so that backtracking was minimized and separate teams of Seismic Capability Engineers could cover different parts of the plant. After the walkdown is complete, the data base management system can be used to sort the equipment on the SVDSs into lists of outliers or other categories of equipment. Exhibit 4-2 shows an example of a completed SVDS using a data base management system.

The contents of each of the 16 columns of the SVDS shown in Exhibit 4-1 is described below.

Columns 1 through 6 contain information for identifying and locating the equipment. These columns are the same as the comparable six columns on the Safe Shutdown Equipment List (SSEL) shown in Appendix A.

<u>Column 1</u> contains the equipment class number from Table 3-1 of Section 3.

<u>Column 2</u> contains the plant identification or tag number for the equipment. This is normally an alphanumeric designation by which an item of equipment is uniquely identified in the plant. This identifier will permit direct access and a cross-reference to the existing plant files or data system for the item of equipment.

<u>Column 3</u> contains both a designation of the plant system to which the equipment belongs and a description of the equipment. If the system designation is placed at the beginning of this field, then the equipment list can be sorted by system with a data base management system.

<u>Column 4</u> identifies the building in which the equipment is located.

<u>Column 5</u> contains the floor elevation from which the item of equipment can be viewed by the Seismic Capability Engineers.

<u>Column 6</u> contains a designation of the location of the equipment within the building. An example of this is by building column line intersection, such as F-12. This indicates the intersection of column lines F and 12. Alternatively, the room designation can be given; e.g., diesel generator room (DG room).

Columns 7 through 10 are used to document the source of the seismic capacity and the source of the seismic demand.

<u>Column 7</u> contains the elevation at which the equipment is mounted; i.e., the elevation at which the equipment receives its seismic input (demand). This elevation should be determined by the Seismic Capability Engineers during the walkdown. Note that this elevation may not be the same as the <u>floor</u> elevation given in Column 5.

Column 8 indicates whether the equipment is mounted lower in the building than about 40 feet above grade. A "yes" answer to this question means the ground response spectrum can be used for comparison to the seismic capacity of the equipment. As an alternative, the actual number of feet above grade could be entered into this column.

Column 9 identifies the source of the seismic capacity. The following codes may be used:

DOC	Component-Specific Seismic Qualification Documentation.
SPEC	Bounding Spectrum.
GERS - XXX	Generic Equipment Ruggedness Spectra, GERS.

If the GERS are used, a number designation (XXX) should also be given to indicate which unique GERS is used. If seismic qualification documentation is used, reference to the documentation should be noted in Column 16.

Column 10 indicates the method used to define the seismic demand. The following codes may be used:

GRS	Ground Response Spectra.
ARS	Amplified In-Structure (Floor) Response Spectra.

If the amplified response spectra are used, a number designation should also be given to indicate which unique ARS is used.

Columns 11 through 14 are used to document the results of the evaluation of the equipment against the four seismic screening guidelines: comparison of seismic capacity to seismic demand, caveat compliance, anchorage adequacy, and seismic interaction.

<u>Column 11</u> indicates whether capacity of the equipment exceeds the demand imposed on it. The following codes may be used:

- Y Yes, capacity exceeds demand.
- N No, capacity does not exceed demand.
- U Unknown whether capacity exceeds demand.

<u>Column 12</u> indicates whether the equipment is within the scope of the earthquake/test data base and meets the intent of all the caveats for the equipment class to which it belongs. The following codes may be used:

- Y Yes, the equipment is in the data base, and the intent of all applicable caveats is satisfied.
- N No, the equipment is not in the data base, or the intent of all applicable caveats is not satisfied.
- U Unknown whether the equipment is in the data base or whether the intent of all applicable caveats is satisfied.
- N/A The earthquake/test data base and the caveats are not applicable to this equipment.

Column 13 indicates whether the equipment anchorage meets the anchorage screening guidelines. The following codes may be used:

- Y   Yes, anchorage capacities equal or exceed seismic demand, and anchorage is adequately installed and adequately stiff.
- N   No, anchorage capacities do not equal or exceed the seismic demand, or anchorage is not adequately installed, or anchorage is not adequately stiff.
- U   Unknown whether anchorage capacities equal or exceed seismic demand, or whether anchorage is adequately installed or adequately stiff.
- N/A   Anchorage guidelines are not applicable to this equipment; e.g., valves are not evaluated for anchorage.

Column 14 indicates whether the equipment is free of adverse seismic interaction effects. The following codes may be used:

- Y   Yes, the equipment is free of interaction effects, or the interaction effects are acceptable and do not compromise the safe shutdown function of the equipment.
- N   No, the equipment is not free of adverse interaction effects.
- U   Unknown whether interaction effects will compromise the safe shutdown function of the equipment.

Columns 15 and 16 are used to document the overall result of the equipment evaluation and to record a note number for explaining anything unusual for an item of equipment, respectively.

Column 15 indicates whether, in the final judgment of the Seismic Capability Engineers, the seismic adequacy of the equipment is verified. Note that this judgment may be based on one or more walkdowns, additional calculations, and other supporting data. The following codes are used:

Y Yes, seismic adequacy has been verified (i.e., code "Y", for all the applicable screening guidelines: (1) seismic capacity is greater than demand, (2) the equipment is in the earthquake/test data base and the intent of all the caveats is met (for use with Bounding Spectrum or GERS only), (3) equipment anchorage is adequate, and (4) seismic interaction effects will not compromise the safe shutdown function of the item of equipment).

N No, seismic adequacy does not meet one or more of the seismic evaluation criteria. Equipment is identified as an outlier requiring further verification effort in accordance with Section 5.

Note that there is no "Unknown" category in Column 15 since this column represents the final judgment by the Seismic Capability Engineers. At this point, the item of equipment should be either verified to be seismically adequate (Y) or found to be lacking in one or more areas (N) and should be evaluated as an outlier in accordance with Section 5.

Column 16 can be used for explanatory notes. A number can be entered in this field which corresponds to a list of notes which provide additional information on the seismic evaluation of equipment. For example, a note could indicate that a solenoid-operated valve is mounted on the yoke of an air-operated valve (AOV) and is evaluated as a component mounted within the "box" of this AOV.

Exhibit 4-1

SCREENING VERIFICATION DATA SHEET (SVDS)

Equip. Class (1)	Equip. ID No. (2)	System/Equipment Description (3)	Bldg. (4)	Floor Elev. (5)	Room or Row/Col. (6)	Base Elev. (7)	<40'? (8)	Capacity Spectrum (9)	Demand Spectrum (10)	Cap. > Demand? (11)	Caveats OK? (12)	Anchorage OK? (13)	Interact. OK? (14)	Equipment OK? (15)	Notes (16)

CERTIFICATION:

All the information contained on this Screening Verification Data Sheet (SVDS) is, to the best of our knowledge and belief, correct and accurate. "All information" includes each entry and conclusion (whether verified to be seismically adequate or not).

Approved: (Signatures of all Seismic Capability Engineers on the Seismic Review Team (SRT) are required; there should be at least two on the SRT. All signatories should agree with all of the entries and conclusions. One signatory should be a licensed professional engineer.)

Print or Type Name ______ Signature ______ Date ______

Print or Type Name ______ Signature ______ Date ______

Print or Type Name ______ Signature ______ Date ______

CERTIFICATION:

The information provided to the Seismic Capability Engineers regarding systems and operations of the equipment contained on this SVDS is, to the best of our knowledge and and belief, correct and accurate.

Approved: (One signature of Systems or Operations Engineer is required if the Seismic Capability Engineers deem it necessary.)

Print or Type Name ______ Signature ______ Date ______

Print or Type Name ______ Signature ______ Date ______

Print or Type Name ______ Signature ______ Date ______

Exhibit 4-2

Report Date/Time: 08-15-90 / 09:51:11

SCREENING VERIFICATION DATA SHEET (SVDS)

Data Base File Name/Date/Time: NMP1WD4.DBF / 08-15-90 / 09:19:36
Index File Name/Date/Time: WD_UNI04.NDX / 08-15-90 / 09:27:20
Index File Contents: compid
Program File Name & Version: NMP1SQUG v1.3

Eq. Cl.	Equip. ID No.	System/Equipment Description	Bldg.	Floor Elev.	Room or Row/Col	Base Elev.	<40'?	Capacity Spectrum	Demand Spectrum	Cap. > Demand?	Caveats Ok?	Anchor Ok?	Inter-act Ok?	Equip. Ok?	Notes
20	CP167#	AP/COMPUTER POWER SUPPLY MG SET #167 CONTROL PNL	TB	277	AA9, AB9	277	YES	SPEC	GRS	YES	YES	YES	YES	YES	
20	CP171#	AP/BATTERY CHARGER MG SET #171 CONTROL PNL	TB	261	A11, 12	261	YES	SPEC	GRS	YES	YES	YES	YES	YES	1
20	CP172#	AP/REACTOR PROTECTION SYS MG SET #172 CONTROL PNL	TB	277	D2	277	YES	SPEC	GRS	YES	YES	YES	YES	YES	1
20	DC102#	AP/EDG 102 CONTROL CABINET	TB	261	DG 102 RM	261	YES	SPEC	GRS	YES	YES	YES	YES	YES	1
20	DC103#	AP/EDG 103 CONTROL CABINET	TB	261	DG 103 RM	261	YES	SPEC	GRS	YES	YES	YES	YES	YES	1
14	DG102 IB	AP/DG 102 EMERGENCY DC ISOLATION BREAKER CABINET	TB	261	DG 102 RM	261	YES	SPEC	GRS	YES	YES	YES	YES	YES	1
3	DG102#	AP/DG 102 NEUTRAL BREAKER CUBICLE	TB	261	DG 102 RM	261	YES	SPEC	GRS	YES	YES	NO	YES	NO	1
14	DG103 IB	AP/DG 103 EMERGENCY DC ISOLATION BREAKER CABINET	TB	261	DG 103 RM	261	YES	SPEC	GRS	YES	YES	YES	YES	YES	1
3	DG103#	AP/DG 103 NEUTRAL BREAKER CUBICLE	TB	261	DG 103 RM	261	YES	SPEC	GRS	YES	YES	NO	YES	NO	1
20	E#	CTRL/CONSOLE E CONTL RM ELECT CONTROL CONSOLE	TB	277	CR	277	YES	SPEC	GRS	YES	YES	YES	YES	YES	
18	ECVVR*	EC/EMERGENCY CONDENSER VENT VALVE RACK	TB	340	P8	340	NO	SPEC	AFS	YES	YES	?	YES	NO	
17	EDG102#	AP/EMERGENCY DIESEL GENERATOR #102	TB	261	BG, BE18	261	YES	SPEC	GRS	YES	YES	YES	YES	YES	1
17	EDG103#	AP/EMERGENCY DIESEL GENERATOR #103	TB	261	BC18	261	YES	SPEC	GRS	YES	YES	YES	YES	YES	1

CERTIFICATION:

All the information contained on this Screening Verification Data Sheet (SVDS) is, to the best of our knowledge and belief, correct and accurate. "All information" includes each entry and conclusion (whether verified to be seismically adequate or not).

Approved: (Signatures of all Seismic Capability Engineers on the Seismic Review Team (SRT) are required; there should be at least two on the SRT. All signatories should agree with all of the entries and conclusions. One signatory should be a licensed professional engineer.)

Print or Type Name ______ Signature ______ Date ______

Print or Type Name ______ Signature ______ Date ______

Print or Type Name ______ Signature ______ Date ______

CERTIFICATION:

The information provided to the Seismic Capability Engineers regarding systems and operations of the equipment contained on this SVDS is, to the best of our knowledge and and belief, correct and accurate.

Approved: (One signature of Systems or Operations Engineer is required if the Seismic Capability Engineers deem it necessary.)

Print or Type Name ______ Signature ______ Date ______

Print or Type Name ______ Signature ______ Date ______

Print or Type Name ______ Signature ______ Date ______

Section 5

OUTLIER IDENTIFICATION AND RESOLUTION

5.0 INTRODUCTION

The purpose of this section is to define the term outliers, how they should be identified and documented, and how they may be resolved.

An outlier is an item of equipment which does not comply with all of the screening guidelines provided in this Generic Implementation Procedure (GIP). The GIP screening guidelines are intended to be conservative since they are to be used as a generic basis for evaluating the seismic adequacy of equipment. If an item of equipment fails to pass these generic screens, it may still be shown to be adequate for seismic loading by additional evaluations.

This section describes how outliers should be identified and documented for equipment which does not pass the screening guidelines for:

- Active mechanical and electrical equipment (Section 4),
- Relays (Section 6),
- Tanks and heat exchangers (Section 7), and
- Cable and conduit raceways (Section 8).

Several generic methods for resolving outliers are summarized in this section. Specific methods for addressing the different types of equipment are also discussed in the sections where the screening guidelines are described (Sections 4, 6, 7, and 8).

The remainder of the section is organized as follows:

- The requirements to which SQUG utilities commit in regard to identification and resolution of outliers for resolution of USI A-46 are given in Section 5.1.
- The reasons for classifying an item of equipment as an outlier are described in Section 5.2 along with a description of how outliers should be documented.
- A summary of generic methods for resolving outliers is contained in Section 5.3.
- Suggested methods for grouping and pooling of outliers from several different plants for efficient reconciliation are provided in Section 5.4.

5.1 SQUG COMMITMENTS

Members of SQUG adopting the Generic Implementation Procedure for USI A-46 resolution commit to the following in regard to the identification and resolution of outliers.

5.1.1 Identification of Outliers

When performing the screening evaluations as set forth in Sections 4, 6, 7, and 8, the licensee will classify an item of identified safe shutdown equipment as an outlier if the screening guidelines defined in these sections cannot be met and the issue cannot be resolved by the judgment of the Seismic Capability Engineers (or the Lead Relay Reviewer in the case of the relay evaluation addressed in Section 6).

5.1.2 Resolution of Outliers

The licensee will assign suitably-qualified persons to the task of outlier resolution. If engineering judgment is used to resolve outliers based on the guidelines in this procedure, assigned persons will have the qualifications of a Seismic Capability Engineer (or Lead Relay Reviewer for relay evaluations) as set forth in Section 2. If additional systems evaluations are required, assigned persons will have the qualifications of the Systems Engineers as set forth in Section 2.

5.2 OUTLIER IDENTIFICATION

An item of safe shutdown equipment should be identified as an outlier if it does not meet the screening guidelines covered in the other section of this procedure. The topics included in these screening guidelines are listed below for the various types of equipment covered by this procedure:

<u>Section 4 - Active Mechanical and Electrical Equipment</u>
(Equipment Class #0 through #20)

- Capacity versus Demand
- Caveats
- Anchorage
- Seismic Interaction

<u>Section 6 - Essential Relays</u>

- Capacity versus Demand
- Spot Check of Relay Mounting, Type, and Location

<u>Section 7 - Tanks and Heat Exchangers</u>
(Equipment Class #21)

- Shell Buckling of Large, Flat-Bottom, Vertical Tanks
- Anchor Bolts and Embedments
- Anchorage Connections Between the Anchor Bolt and the Tank Shell
- Flexibility of Piping Attached to Large, Flat-Bottom, Vertical Tanks

<u>Section 8 - Cable and Conduit Raceways</u>
(Equipment Class #22)

- Inclusion Rules
- Other Seismic Performance Concerns
- Limited Analytical Review

If an item of equipment is identified as an outlier during a screening evaluation in one of these other sections of the GIP, then the reason(s) for failing to satisfy the screening guidelines should be documented on an Outlier Seismic Verification Sheet (OSVS), shown in Exhibit 5-1. A separate OSVS should be completed for each item of equipment classified as an outlier. The information to be included in each of the four sections of the OSVS is described below.

Section 1 of the OSVS describes the item of equipment identified as an outlier. This is the same information as found in the first six columns of the SVDS, shown in Exhibit 4-1. On the OSVS, however, more space is provided to describe the equipment so that more details can be included to facilitate later resolution of this outlier issue without requiring repeated trips into the plant.

Section 2 of the OSVS defines those conditions which cause that item of equipment to be classified as an outlier. This section should identify which of the conditions is the cause for the item of equipment becoming an outlier. More than one condition may be the cause for the outlier. In addition, the reason(s) for the equipment being an outlier should be described in more detail. For example, the Seismic Capability Engineers could indicate at what frequencies the demand exceeded the capacity.

Section 3 of the OSVS can be used to provide a proposed method for resolving the outlier issue, based on the experience and detailed evaluation of that item of equipment by the Seismic Capability Engineers or the Lead Relay Reviewer. This is an optional part of the outlier identification process. This section also provides space for supplying any additional information which may be used to implement the proposed method of resolution. This may include information such as an estimate of the fundamental natural frequency of the equipment.

For Equipment Classes #0 through #22, as defined in Table 3-1, all the Seismic Capability Engineers on the Seismic Review Team (SRT) should sign the OSVS. Each SRT should have at least two Seismic Capability Engineers; one of whom is a licensed professional engineer. For essential relays, the Lead Relay Reviewer should sign the OSVS. By signing this form, each individual is certifying that once the outlier issue(s) described in Section 2 of the OSVS are satisfied, the item of equipment is considered seismically adequate.

5.3 OUTLIER RESOLUTION

Several generic methods for resolving outliers are summarized below. Additional specific methods for addressing outliers for the different types of equipment are also discussed in the sections where the screening guidelines are described (Sections 4, 6, 7, and 8). The details for resolving outliers, however, are beyond the scope of this procedure. It is the responsibility of the utility to resolve outliers using their existing engineering procedures as they would resolve any other seismic concern.

It is permissible to resolve outliers by performing additional evaluations and applying engineering judgment to address those areas which do not meet the screening guidelines contained in this procedure. Strict adherence to the screening guidelines in the GIP is not absolutely required; however, these additional outlier evaluations and the application of engineering judgment should be based on a thorough understanding of the screening guidelines contained in the GIP and the background and philosophy used to develop these guidelines as given in the applicable references. The justification and reasoning for considering an outlier to be acceptable should be based on mechanistic principles and sound engineering judgment.

The screening guidelines contained in Sections 4, 6, 7, and 8 have been thoroughly reviewed by industry experts to ensure that they are conservative for generic use; however, the resolution of outliers for individual plants will not likely receive the same level of industry review as the generic screening guidelines. Therefore, it is recommended that the evaluations and judgments used to resolve outliers be thoroughly documented so that independent reviews can be performed if necessary.

Some of the methods summarized below for resolving outliers build upon the use of the earthquake experience/test data base. The utility may use the Screening Verification and Walkdown procedure described in Section 4 in applying earthquake experience/test data which was not available during the initial walkdown for resolution of outliers, or it may develop an alternative approach which best fits the circumstances of the specific outlier issue. Outlier issues may also be resolved using current licensing procedures and criteria.

As an alternative, the utility may choose to provide justification for not performing corrective modifications or replacement of outliers. Then the NRC must meet the requirements of 10 C.F.R § 50.109 (backfit rule) in order to require the corrective modifications or replacements be completed.

Methods which can be used to resolve outliers include the following:

1. The earthquake experience data base may be expanded to include the equipment or specific equipment features of interest. The scope of the experience data which is documented in References 4 and 5 represents only a portion of the total data available. The expansion of this documented data base could include a more detailed breakdown by type, model or manufacturer of a particular class of equipment, less restrictive requirements for inclusion within a class, or development of a sub-category with higher

capacity. Extensions of the generic experience data base are subject to NRC review.

2. The subject equipment or its anchorage may be evaluated more rigorously or modified to strengthen it and bring it within the scope of the experience/test data base or in compliance with some other seismic qualification method. For example, the equipment or its supports may be stiffened so that its resonant frequency is increased to a frequency where the seismic demand is less. Providing an upper lateral support to a floor-mounted item of equipment would typically increase the fundamental frequency to above the 8 Hz cutoff frequency for use of the Bounding Spectrum.

3. The subject equipment may be replaced with equipment which is contained in the experience/test data base or has been seismically qualified by some other means.

4. Detailed engineering analyses may be performed to more carefully and/or accurately evaluate the seismic capacity of the equipment and/or the seismic demand to which it is exposed. In using more accurate analytical procedures, consideration should be given to using "as-built" rather than specified minimum material properties for the equipment.

5. In-situ tests may be performed on the equipment of interest to determine more accurately the equipment dynamic properties.

6. Shake table tests may be performed on the same or similar equipment to check its seismic capacity or evaluate more carefully its dynamic properties.

7. Information not available during the Screening Verification and Walkdown may be obtained.

The most appropriate type of outlier evaluation will depend upon a number of factors, including the reason that the equipment failed the screening guidelines, whether the outlier lends itself to additional review of the experience data base or an additional analytical evaluation, the cost of design or hardware modifications, and how extensive the problem is in the plant and in other plants.

The NRC should be provided with a proposed schedule for complete resolution or future modifications and replacement of outliers. Documentation of the actual methods selected by the utility for resolution of outlier issues and tracking of their implementation is discussed in Section 9, Documentation.

5.4 METHODS FOR GROUPING AND POOLING OF OUTLIERS

Once an outlier has been identified and an OSVS is prepared for that item of equipment, the OSVS could then be placed in an appropriate outlier category or "basket". There could be one basket for each class of equipment for which there are outliers. Within each basket the outliers could be further divided into the various reasons that the equipment failed the screening verification (e.g., capacity vs. demand, caveats, anchorage, or interactions). The organization of the outliers in this manner can facilitate reconciliation of recurring outlier issues.

One method to efficiently reconcile recurring outliers in SQUG plants is for the members of SQUG to pool the outlier information obtained during walkdowns. One means of pooling this information is to tabulate the outliers, including the information contained on the SVDS and, if available, the method ultimately used to verify the seismic adequacy of the outlier. These tables may be generated and organized, using a data base management program. This summary may be distributed to the members of SQUG so that common outliers may be evaluated using the experience obtained from other plants. For example, one utility may have one or several unreconciled outliers that an SRT at another plant was able to verify. The utility with the unreconciled outliers may be able to employ a similar methodology if the detailed information used in the outlier resolution is shared. Also, outliers from several SQUG plants may be resolved more cost-effectively using shared funding.

Exhibit 5-1

OUTLIER SEISMIC VERIFICATION SHEET (OSVS)

1. OUTLIER IDENTIFICATION, DESCRIPTION, AND LOCATION

Equipment ID Number __________ Equipment Class ___________

Equipment Location: Building _________ Floor Elevation__________

Room or Row/Column___ Base Elevation _________

Equipment Description ____

____

2. OUTLIER ISSUE DEFINITION

a. Identify all the screening guidelines which are not met. (Check more than one if several guidelines could not be satisfied.)

Mechanical and Electrical Equipment		Tanks and Heat Exchangers	
Capacity vs. Demand	____	Shell Buckling[1]	____
Caveats	____	Anchor Bolts and Embedment	____
Anchorage	____	Anchorage Connections	____
Seismic Interaction	____	Flexibility of Attached Piping[1]	____
Other	____	Other	____

Essential Relays		Cable and Conduit Raceways	
Capacity vs. Demand	____	Inclusion Rules	____
Mounting, Type, Location	____	Other Seismic Performance Concerns	____
Other	____	Limited Analytical Review	____
		Other	____

1 Shell buckling and flexibility of attached piping only apply to large, flat-bottom, vertical tanks.

b. Describe all the reasons for the outlier (i.e., if all the listed outlier issues were resolved, then the signatories would consider this item of equipment to be verified for seismic adequacy):

____

____

____

____

____

____

Exhibit 5-1 (Cont'd)

OUTLIER SEISMIC VERIFICATION SHEET (OSVS)

Equipment ID Number______________

3. PROPOSED METHOD OF OUTLIER RESOLUTION (OPTIONAL)

   a. Define proposed method(s) for resolving outlier.

   ____
   ____
   ____
   ____

   b. Provide information needed to implement proposed method(s) for resolving outlier (e.g., estimate of fundamental frequency).

   ____
   ____
   ____
   ____
   ____
   ____

4. CERTIFICATION:

The information on this OSVS is, to the best of our knowledge and belief, correct and accurate, and resolution of the outlier issues listed on the previous page will satisfy the requirements for this item of equipment to be verified for seismic adequacy:

Approved by: (For Equipment Classes #0 - #22, all the Seismic Capability Engineers on the Seismic Review Team (SRT) should sign; there should be at least two on the SRT. One signatory should be a licensed professional engineer. For Relays, the Lead Relay Reviewer should sign.)

Print or Type Name	Signature	Date
Print or Type Name	Signature	Date
Print or Type Name	Signature	Date

Section 6

RELAY FUNCTIONALITY REVIEW

6.0 INTRODUCTION

As part of the resolution of USI A-46, it is necessary to perform a relay seismic functionality review. The purpose of this review is to determine if the plant safe shutdown systems could be adversely affected by relay malfunction[1] in the event of an SSE and to evaluate the seismic adequacy of those relays for which malfunction is unacceptable.

The purpose of this section of the GIP is to provide an overview of the relay evaluation procedure and describe the interfaces between other GIP activities and the relay evaluation. The overview in this section is based upon the "Procedure for Evaluating Nuclear Power Plant Relay Seismic Functionality," Reference 8. This reference should be used when performing the relay functionality review since it contains the necessary data, forms, and additional details to implement this procedure.

The material contained in this section of the GIP is as follows.

- Section 6.1, SQUG Commitments, lists the requirements to which SQUG utilities commit when adopting the Relay Functionality Review procedure in Reference 8 for resolution of USI A-46.
- Section 6.2, Relay Evaluation Methodology, provides an overview of the methods for performing the relay seismic functionality review.

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1 The term "relay malfunction" is used throughout this section as short hand notation to designate relay, contractor, motor starter, and switch chatter or inadvertent change of state.

- Section 6.3, Identification of Essential Relays, describes the methods to be used to: (1) identify the safe shutdown equipment for which a relay review is necessary, and (2) identify the essential relays in the circuits of this equipment for which relay malfunction is unacceptable.

- Section 6.4, Comparison of Relay Seismic Capacity to Seismic Demand, describes the methods used to evaluate the seismic adequacy of the essential relays.

- Section 6.5, Relay Walkdown, describes the plant walkdown which should be performed as a part of the relay evaluation. This walkdown may be combined in part with the main seismic walkdown described in Section 4.

- Section 6.6, Outliers, summarizes the additional evaluations and alternative methods which could be used to resolve outliers which do not pass the screening evaluations described in this section of the GIP.

- Section 6.7, Documentation of Results, describes the method whereby a traceable record of the results of the review is developed for all relays reviewed.

The personnel qualifications and training for the individuals performing this relay review are described in Section 2.

6.1 SQUG COMMITMENTS

Members of SQUG adopting the Generic Implementation Procedure for USI A-46 resolution commit to the following in regard to identification and evaluation of relays:

6.1.1 Identification of Relays To Be Evaluated

The licensee will identify the relays to be evaluated using a two-step process. First, the systems to be examined will be those identified pursuant to Section 3. Using this approach, the licensee will develop a Safe Shutdown Equipment List (SSEL) for relays which will include: (1)

electrically-controlled or -powered safe shutdown equipment whose function could be affected by relay malfunction, and (2) inactive safe shutdown equipment for which relay malfunction could cause spurious operation. Second, plant electrical drawings of the circuits associated with the above safe shutdown equipment will be used to identify relays to be evaluated. Certain additional assumptions will be used to establish the scope of the relay review:

- Relays will not be damaged by the earthquake, with the exception of certain particularly fragile types.
- Unqualified relays are assumed to malfunction during the short period of strong motion during an earthquake.
- Relay types to be reviewed include auxiliary relays, protective relays, contactors, control switches, and other similar contact devices occurring in circuits controlling the systems identified.
- Solid state relays and mechanically-actuated switches are considered to be seismically rugged and need not be evaluated for contact chatter.

6.1.2 Evaluation of Consequences of Relay Malfunction

The licensee will evaluate the relays as set forth in Section 6.1.1 for the consequences of relay malfunction on safe shutdown functions. The relays whose malfunction will not prevent achievement of any safe shutdown function and will not otherwise cause unacceptable spurious actuation of equipment will not be further evaluated. The seismic adequacy of the remaining essential relays will be verified to assure that safe shutdown can be achieved and maintained in the event of a Safe Shutdown Earthquake (SSE).

6.1.3 Assessment of Relay Seismic Adequacy

The licensee will verify the seismic adequacy of the essential relays identified pursuant to Sections 6.1.1 and 6.1.2, above, by comparing the relay seismic capacity to the seismic demand imposed upon the relay. Three types of data can be used to establish the seismic capacity of essential relays:

- Generic Equipment Ruggedness Spectra (GERS)
- Earthquake Experience Data
- Plant-specific or relay-specific seismic test data

6.1.4 Relay Walkdown

The licensee will conduct one or more walkdowns, as needed, to accomplish four objectives:

- Obtain information as required to determine in-cabinet amplification, including identification of cabinets, panels and/or racks which house or support essential relays.
- Verify the adequacy of the anchorage of cabinets/enclosures which support essential relays.
- Spot check relay mountings.
- Spot check relay types and locations.

The relay walkdowns can be accomplished together with, or separate from, the main USI A-46 walkdown conducted pursuant to Section 4.

6.1.5 Documentation

The licensee will document the results of the relay review, and will include the following information in the summary report prepared according to Section 9 of the GIP:

- SSEL used to initiate relay procedure
- Identification of essential relays
- Screening and evaluation results
- Walkdown results
- Outliers and corrective actions, if any

6.2 RELAY EVALUATION METHODOLOGY

The methodology for evaluation of the seismic functionality of relays is based on a two-part screening process. The first part: (1) identifies a minimum set of plant systems and items of equipment which should function properly to maintain the plant in a safe condition during and immediately after an earthquake; and (2) evaluates the consequences of malfunction of the associated electrical relays on system performance to determine if proper function of the relays is essential to safe shutdown. Relays whose malfunction is acceptable need not be seismically rugged. This screening process is intended to significantly reduce the number of systems, equipment electrical circuits and, in turn, relays which are considered essential to plant safety in an earthquake, and, therefore, to reduce the number of relay types whose seismic functionality must be demonstrated.

The second part of the relay evaluation process uses relay GERS and test data to assess the seismic adequacy of the essential relay types. Taken together, these two screening approaches are expected to make the relay functionality verification under USI A-46 manageable and significantly more cost-effective than would be the case using current licensing criteria, while at the same time providing good assurance that the affected plants can be safely shut down during an earthquake. The two parts of the screening processes are (1) identifying those relays whose function is essential to safe shutdown and (2) assessing their seismic ruggedness. These parts are described below.

6.3 IDENTIFICATION OF ESSENTIAL RELAYS

The starting point for the relay evaluation is the identification of safe shutdown equipment to be examined during the USI A-46 resolution. Section 3 provides directions for generating two Safe Shutdown Equipment Lists (SSELs), one for use in conducting the plant walkdown of equipment to verify its seismic adequacy as described in Section 4, and the other for performing the relay functionality review as described in this section. These SSELs can be prepared in a computerized form to facilitate ease of use. The relay screening procedures provide guidance for reviewing each item of equipment on the relay review SSEL to identify essential relays and to assess the seismic adequacy of the essential relays.

The principal elements in the identification of the minimum set of essential relays are as follows:

<u>USI A-46 Safe Shutdown Criteria and Assumptions</u>

For resolution of USI A-46, it is not necessary to verify the seismic adequacy of all plant equipment defined as Seismic Category I, e.g., in NRC Regulatory Guide 1.29. Instead, only those systems, subsystems and equipment needed to bring the plant from a normal operating condition to a safe shutdown condition need be identified to ensure safety during and following a Safe Shutdown Earthquake (SSE). As a result, the scope of the seismic verification is limited to equipment and supporting systems which provide functions necessary to achieve and maintain safe shutdown.

The criteria and assumptions need to define the systems and equipment which are needed to bring the plant to a safe shutdown condition are described in detail in Section 3 and summarized as follows:

- The plant should be brought to a hot shutdown condition (as defined by the plant's Technical Specifications) and maintained there for 72 hours following the SSE.
- The earthquake does not cause a loss of coolant accident (LOCA) or other such events.
- A LOCA is not postulated to occur simultaneously with or during the SSE.
- Offsite AC power may be lost during or after the SSE.
- There should be sufficient redundancy such that the failure of the active function of a single item of safe shutdown equipment may occur without losing the ability to achieve and maintain safe shutdown conditions.

In addition to these general criteria, the following specific assumptions provide the bases for the relay evaluation:

- Unqualified relays are assumed to malfunction during the short period of strong motion during an earthquake. Such a malfunction, typically chatter, may result in loss of system function or inadvertent actuation of systems during the strong shaking period. It is also possible that relay malfunction during strong shaking can result in unacceptable seal-in or lockout of specific circuits which are designed to have this feature. In such cases, operator actions to reset or restore such circuits to their original condition may be acceptable provided there are sufficient time, awareness, access and procedures for the operators to take this action.

- Earthquake experience data and test data show that, in general, relays are not structurally damaged during an earthquake; therefore, with the exception of certain particularly fragile relay types, which are identified in the screening procedure of Reference 8, it is assumed that relays are not damaged as a result of the earthquake and will be functional after the period of strong shaking.

- Relay types to be evaluated under this program include those devices which are provided to cause contact operation in electric control circuits. In general, they fall into three categories as shown in Figure 6-1. The largest category is designated auxiliary relays. This category typically includes electromechanical, pneumatic timing and solid state relays used for general purpose control, blocking, closing, lockout, seal-in and other logic or control functions.

  ' -cond category includes protective electromechanical and solid . relays whose function is to protect equipment from system faults and other abnormal or dangerous conditions by automatically initiating appropriate control circuit action. Protective relays include over-current and under-voltage relays.

  The third general category of relays is contactors. A contactor is a heavy duty relay which may carry significant amounts of current. It is distinguished from a circuit breaker such as is used in switchgear in that its contacts are moved by a small solenoid-type mechanism rather than by compressed springs or other actuating mechanisms.

  Other devices which have contacts, such as control switches which are used in relay logic control circuits, are also addressed in the relay evaluation, even though they are not considered relays.

The foregoing criteria and assumptions focus the relay evaluation by defining the objectives of the reviews, the relay types to be considered, the failure modes to be assumed and other important criteria.

Identification of Safe Shutdown Equipment

As described in detail in Section 3, a nuclear plant should accomplish each of the following safe shutdown functions to achieve and maintain safe shutdown conditions during and following an SSE.

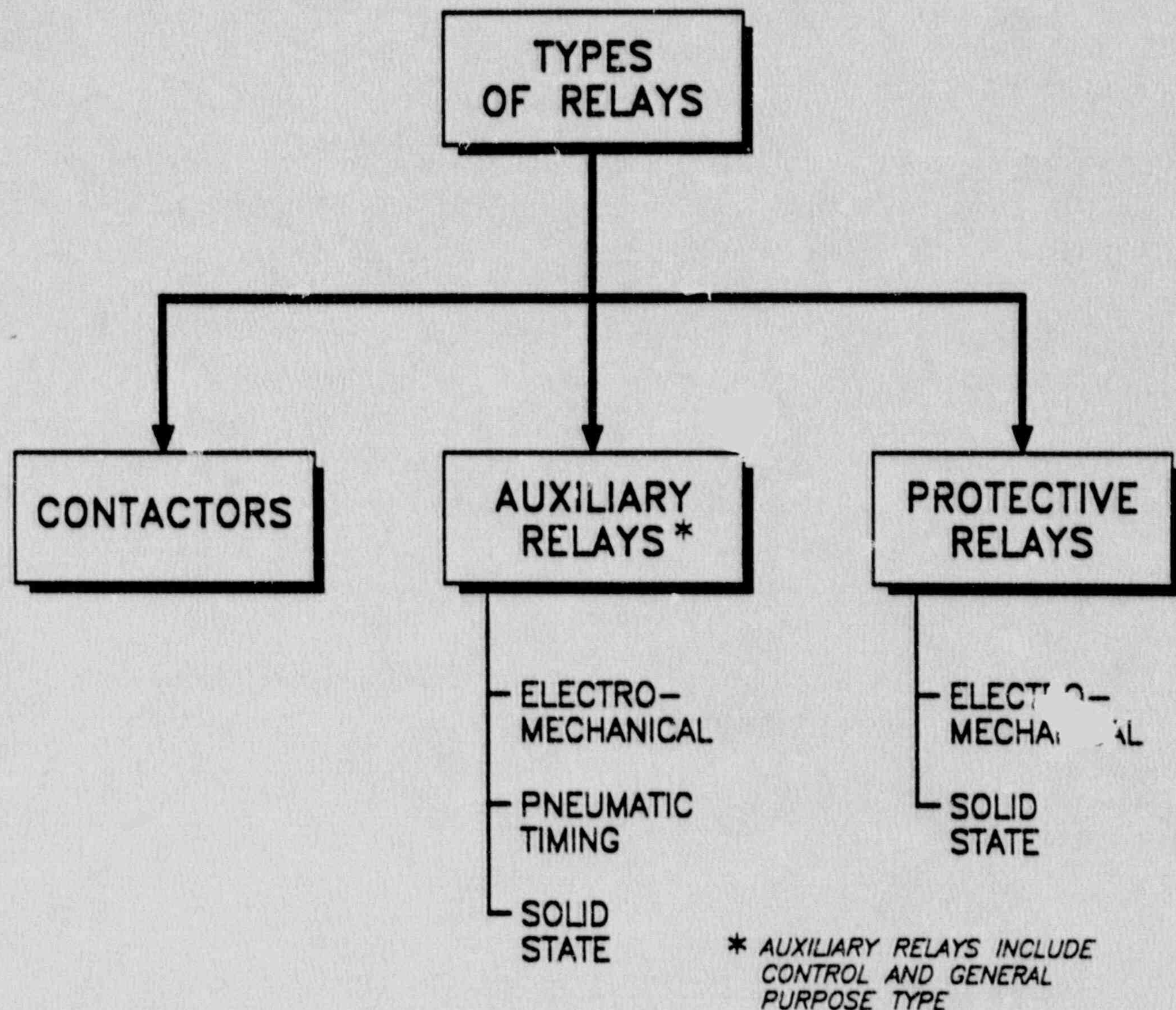


Figure 6-1. Relay Classification

- Reactor reactivity control
- Reactor coolant pressure control
- Reactor coolant inventory control
- Decay heat removal

In addition, certain instrumentation is needed to provide the capability to monitor safe shutdown conditions and to verify that these safe shutdown functions are being accomplished.

Several alternative methods for accomplishing each of the safe shutdown functions listed above are typically available in nuclear power plants. A preferred alternative should be selected and the individual items of active mechanical and electrical equipment in this alternative should then be identified. The guidelines for redundancy per Section 3.2.6 should be satisfied. Two safe shutdown equipment lists (SSELs) should be developed; one for the seismic walkdown and one for the relay evaluation.

The SSEL for relay evaluation includes electrically-controlled or -powered safe shutdown equipment whose function could be affected by relay malfunction. This list also includes inactive safe shutdown equipment which could inadvertently change state or become active due to relay malfunction and result in unacceptable consequences (e.g., loss of coolant inventory).

<u>Identification of Circuits, Relays, Consequences of Relay Malfunction</u>

Using the SSEL developed for the relay evaluation, drawings of the electrical control circuit(s) for each SSEL item of equipment should be identified. The electrical circuits used to operate and control the equipment should then be reviewed. The relays identified in this review should then be evaluated.

Once the list of system equipment, circuits, and relays needed for safe shutdown is narrowed to only those required to function (i.e., change state or maintain a state) during and immediately after the earthquake, an evaluation should be made of the consequences of relay malfunction in those systems and circuits. Relay malfunction includes chatter of the contacts in the relay itself and any other spurious signals from other devices which control the operation of the relay. The other devices could include other relays which chatter or instruments which send spurious signals due to the earthquake vibration (e.g., water sloshing in a tank could trigger a low water level signal from the level instrument).

The evaluation of the consequences of relay malfunction is comparable to a failure modes and effects analysis and is intended to identify those specific relays whose malfunction is important and those whose malfunction is inconsequential--that is, those relays whose malfunction will not prevent the essential function from occurring, either because of the specific circuit design or the failure logic employed. For example, many control and power circuits for systems in nuclear power plants are designed such that component malfunction (including relay malfunction) results in the system failing in a safe manner. An example of this fail-safe design approach is the circuitry for initiating reactor shutdown, or "SCRAM". In this case, failure of normally energized relays or their power supplies results in reactor SCRAM which, in the case of an earthquake, is an acceptable safe action. Relays in these shutdown systems would not be included on the list of essential relays because their malfunction is inconsequential from an earthquake resistance standpoint.

The relay screening and evaluation procedure (Reference 8) includes other screening methods to eliminate relays from the final group of essential relays. In one such method, relay malfunction may lead to inadvertent equipment or system operation which is acceptable. For example, spurious operation of some pumps and valves may not prevent safe shutdown functions and can be considered acceptable. Also, some relay-controlled devices respond slowly enough that relay chatter may cause either no operation or only a temporary but acceptable spurious operation of the controlled device (e.g., relay chatter leading to partial valve opening and then reclosing, or momentary energization of pumps which do not affect the safe shutdown of the plant). Also, operator actions can be relied upon in certain situations to correct the effects of relay malfunction by resetting the affected relays. These screening methods and others are described in detail in the step-by-step relay evaluation procedure in Reference 8.

The functional screening process described above will result in the minimum set of essential electrical relays whose seismic capacity, (that is, operability under design seismic loading) should be verified to ensure that the plant can be brought to a safe shutdown condition under the criteria established in USI A-46. It will also identify those cabinets, panels, racks and other enclosures which support or house essential relays. These cabinets and panels will require evaluation as part of the equipment walkdown described in Section 4 to ensure they are properly anchored and not subject to unacceptable seismic interaction effects.

6.4 COMPARISON OF RELAY SEISMIC CAPACITY TO SEISMIC DEMAND

This section summarizes the screening method for evaluating the seismic capacity of essential relays (those relays identified using the method described in Section 6.3) compared to the seismic load (demand) imposed upon them by a seismic event. The details for performing this screening evaluation are described in Reference 8.

Under current design and licensing criteria for nuclear power plants, relays in safety-related systems are qualified by shake table tests, most often in the specific cabinet or panel arrangement in which they are mounted. This is generally not practical for older operating plants nor is it necessary since actual experience with power plants which have undergone strong earthquakes has not shown significant or widespread problems with standard power plant equipment, including most relays. Therefore, this alternative to formal qualification testing has been developed which uses available seismic test data and actual earthquake experience data to establish the seismic capacity of a wide variety of relay types. A method for determining the seismic demand on an essential relay in a cabinet is also included in this screening method.

The following two subsections describe the method for: (1) establishing the seismic capacity of relays, and (2) comparing this capacity to the seismic demand.

6.4.1 Seismic Capacity of Relays

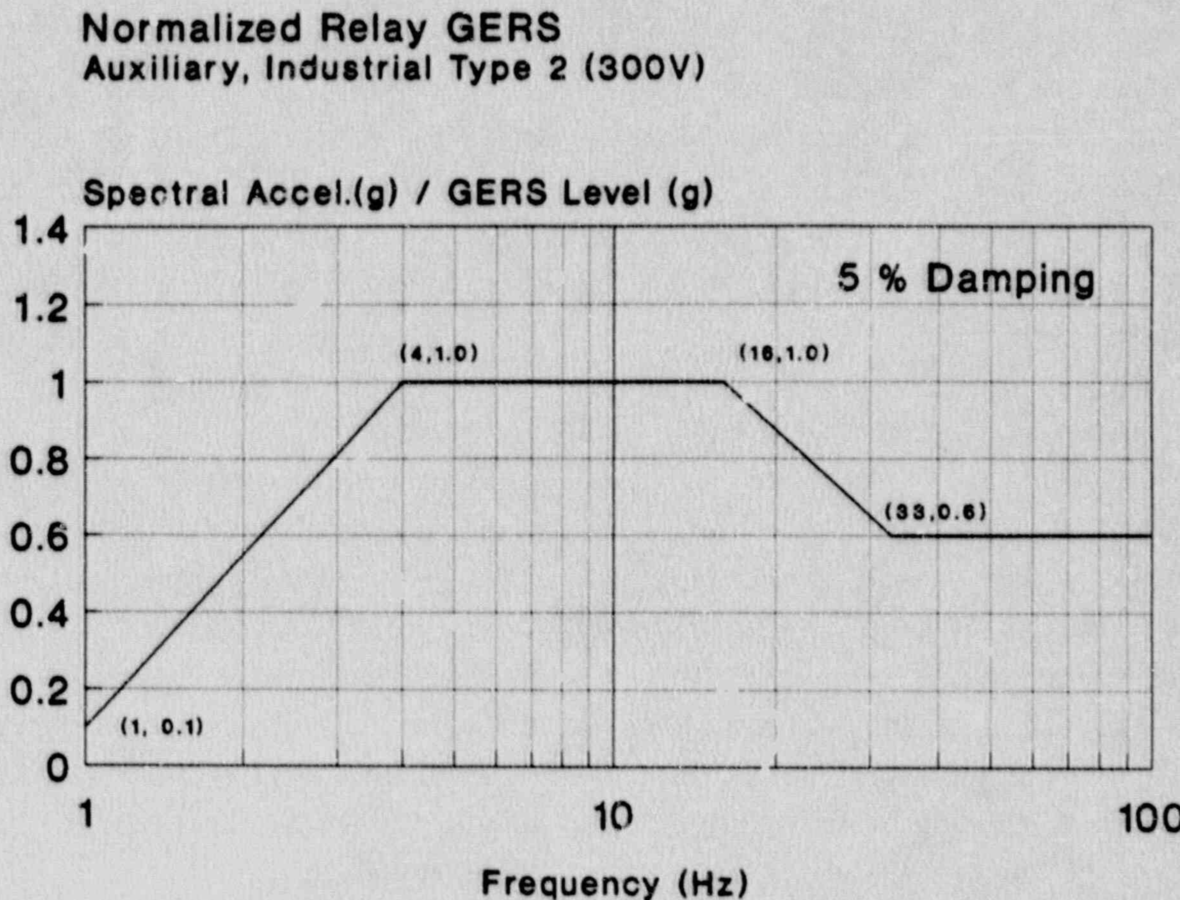
Three methods can be used to establish the seismic capacity of essential relays:

- Generic seismic test data,
- Earthquake experience data, and
- Relay-specific test data.

These methods are described below.

Generic Seismic Test Data. Available seismic test data on a variety of types of relays have been either gathered or generated, evaluated, and consolidated. These data have been reduced to Generic Equipment Ruggedness Spectra (GERS) in Reference 32 for relays which define seismic acceleration levels below which relays can be expected to function without chatter or other damage. The GERS are seismic response spectra within which a class or subclass of relays has functioned properly during shake-table tests. In some cases the GERS are based on "success" data (that is, seismic test spectra for which no relay malfunction occurred). In this case, the test spectra for one or more relays in a given class represent a lower bound of the seismic ruggedness of the class. In other cases, the GERS may be based on "fragility" data (that is, seismic response spectra in which failures or malfunctions occurred). In this case, the GERS represent an upper bound of the seismic ruggedness of the relay class. Where both success and fragility data are available for a given relay class, the GERS fall between the two spectra. Engineering judgment was used in developing the GERS level to smooth out sharp peaks and valleys in the test response spectra and to ensure conservatism. An example GERS for several auxiliary relay types is shown in Figure 6-2. A normalized GERS shape is illustrated at the top of this figure; GERS levels (i.e., the peak acceleration) for specific relays are tabulated at the bottom of this figure. Complete sets of all available GERS for relays are given in Reference 32.

<u>Earthquake Experience Data</u>. Data have been obtained on relay performance, specific failures, relay vulnerabilities, and other information from actual earthquake experience in power plants and other facilities which have undergone significant earthquakes. This information has been used to identify unacceptable relay types such as those which are known to be susceptible to damage or chatter due to moderate shaking. Unacceptable relays and related contact devices which must be avoided are listed and considered in the screening procedure given in Reference 8. Based on earthquake experience data and on test data, solid state relays and mechanically-actuated switches are considered seismically rugged and need not be evaluated for relay chatter. Details and restrictions regarding the screening of both the low-ruggedness and high-ruggedness classes of control circuit devices are described in Reference 8.



Type and Submodel Identification	GERS Level[1] Non-Operate NO[2]	GERS Level[1] Non-Operate NC[2]	GERS Level[1] Operate NO/NC[2]
GE CR120A	10	9	10
Westinghouse BFD	10	9	10
Westinghouse BF	10	-[3]	10
Cutler-Hammer D26MPR	10	9	10
Square D G080	10	5	10
Allen-Bradley 700-N	10	10	10

1 "GERS Level" is the spectral acceleration (g) from 4 to 15 Hz for 5% damping.
2 "NO" = Normally Open; "NC" = Normally Closed; "NO/NC" = Change State.
3 "-" = Data not available.

Figure 6-2. GERS for Auxiliary Relays. (Source: Reference 32)

Relay-Specific Test Data. The GERS and earthquake experience data discussed above are expected to apply to the majority of installed relay types in essential circuits. Plant-specific and relay-specific seismic test data, where available, can also be used. This seismic test data is generally maintained by specific plants and/or relay suppliers and has not been included in the relay GERS. It may be used on a relay-specific or plant-specific basis.

6.4.2 Seismic Capacity Compared to Seismic Demand

There are four methods for comparing the seismic capacity of an essential relay to the seismic demand imposed upon it. These are described below in a multi-level screening approach which starts with an approximate, but conservative capacity screening criterion based on earthquake experience, test experience and analysis. The final screening level is a very detailed, relay-specific and installation-specific analysis and/or test. Seismic adequacy of essential relays can be confirmed by successful application of any one of these screening methods.

In addition to this screening approach for use with relays in general, a special case is also described below for evaluating the seismic adequacy of relays which control the operation of a switchgear breaker.

Screening Level 1 - High Capacity Relays. This first screening level can be used if the following conditions are met:

- The largest horizontal component of the 5% damped, free-field, Safe Shutdown Earthquake (SSE) ground response spectrum, to which the nuclear plant is licensed, is enveloped by the Bounding Spectrum (shown in Figure 4-2 of Section 4).
- The equipment or cabinet containing the essential relay is mounted at an elevation in the plant which is no higher than about 40 feet above the effective grade of the plant. The "effective grade" is defined in Section 4.

- The essential relay is not one of the low-ruggedness types listed in Appendix E of Reference 8.

If the above conditions are met, then an essential relay is sufficiently rugged when the relay is mounted in one of the types of structures defined below and the relay has a seismic capacity at least as large as that given below for each of these structure types:

- When the essential relay is mounted in a cabinet similar to a conventional motor control center (MCC), the relay should have a defined spectral acceleration capacity of 5g or higher. Guidelines for classifying cabinets as MCCs are given in Appendix I of Reference 8. GERS or relay-specific seismic data (e.g., IEEE-344 and/or IEEE-501 type tests) can be used to establish the spectral acceleration capacity of the essential relay.

- When the essential relay is mounted on an unsupported panel or in a typical conventional switchgear cabinet, or it is mounted on a control room panel or benchboard, the relay should have a defined spectral acceleration capacity of 8g or higher. Guidelines for classifying these types of cabinets and panels are given in Appendix I of Reference 8. GERS or relay-specific seismic qualification data (e.g., IEEE-344 and/or IEEE-501 type tests) can be used to establish the spectral acceleration capacity of the essential relay.

If the relay is not mounted in one of the these types of structures, then the Screening Level 1 method cannot be used and one of the following screening methods should be used instead.

<u>Screening Level 2 - Use of In-Cabinet Amplification Factors</u>. The second screening level for comparing relay seismic capacity to demand is based on: (1) using an in-structure (i.e., floor) response spectrum at the base of the cabinet containing the relay, (2) multiplying the peak of this spectra by an in-cabinet amplification factor, and (3) comparing this seismic demand to the relay seismic capacity based on GERS or relay-specific seismic test data.

To use this screening method, the essential relay should not be one of the low-ruggedness types listed in Appendix E of Reference 8.

The types of in-structure response spectra which can be used are listed in Table 6-1. The types of response spectra given in this table and the terminology used to describe them are defined in Section 4.2. The first two types of response spectra in Table 6-1 should be multiplied by the factors of conservatism given in this table. The 1.25 factor of conservatism accounts for uncertainties inherent in median-centered type of response spectra. (Both of the first two response spectra listed are considered median-centered.) The 1.1 factor accounts for uncertainties in the relay GERS when used with realistic, median-centered type of response spectra. These factors of conservation are not needed for the third type of response spectra in Table 6-1 the relay GERS when used with realistic, median-centered type of response spectra. These factors of conservation are not needed for the third type of response spectra in Table 6-1 (conservative, design, in-structure response spectra) since this type of spectra already has sufficient margin.

The in-cabinet amplification factors which can be used for various types of cabinets are given in Table 6-2. Guidelines and criteria for determining cabinet types are included in Appendix I of Reference 8.

The seismic capacity of an essential relay can be represented by either an applicable relay GERS or relay-specific seismic test data (e.g., IEEE-344 and/or IEEE-501 type tests). When using relay-specific seismic test data, it is not necessary to use the 1.1 factor from Table 6-1 with the in-structure response spectra.

Table 6-1

FACTORS OF CONSERVATISM TO BE APPLIED TO DIFFERENT TYPES OF IN-STRUCTURE RESPONSE SPECTRA

Type of In-Structure Response Spectrum	Factors of Conservatism
• 1.5 X SSE horizontal, ground response spectrum (For equipment which is mounted under about 40 feet above the effective grade and has a natural frequency greater than about 8 Hz)	1.25[a] x 1.1[b]
• Realistic, median-centered, horizontal in-structure response spectrum for the SSE	1.25[a] x 1.1[b]
• Conservative, design, horizontal in-structure response spectrum for the SSE	1.0

(a) The 1.25 factor accounts for uncertainties inherent in median-centered type of response spectra.

(b) The 1.1 factor accounts for uncertainties in the relay GERS when used with realistic, median-centered type of response spectra. It does not need to be used with relay-specific seismic test data.

Table 6-2

IN-CABINET AMPLIFICATION FACTORS FOR
USE WITH LEVEL 2 RELAY SCREENING METHOD

Type of Cabinet	In-Cabinet Ampl. Factor
• MCC-type cabinet (Defined in Appendix I of Reference 8)	3
• Conventional control panel or benchboard (Defined in Appendix I of Reference 8)	4.5
• Switchgear-type cabinet or similar large unsupported panel (Defined in Appendix I of Reference 8)	7
• Other type of cabinet, panel, or enclosure for which cabinet-specific amplification data exist	*

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* For the "Other" type of cabinets, use an effective broad-based amplification factor. This is obtained by multiplying the measured peak amplification factor, for the location in the cabinet where the relay is mounted, times an appropriate reduction factor. Appropriate reduction factors are discussed in Reference 33; for typical, narrow peak amplification spectra, the reduction factor is 0.6.

A relay is considered seismically adequate if the seismic demand spectrum is bounded by the relay capacity spectrum in the frequency range from 4 - 16 Hz. If the guidelines for this screening method cannot be applied, or the seismic demand is not bounded by the seismic capacity of the relay, then one of the following screening methods should be used instead.

Screening Level 3 - Use of In-Cabinet Response Spectra. In this screening level, the seismic demand applied to essential relays can be estimated by one of the following methods:

- An amplified, in-cabinet response spectrum is determined using the methodology and software described in Reference 33 for control room benchboards and panels. In this option, the cabinet or panel evaluated must meet the restrictions (or caveats) given in Reference 33.

- For other types of cabinets and panels which are not covered by Reference 33, an amplified, in-cabinet response spectrum is determined using analytical and/or test methods which are suitable for the specific case, and which are justified in the relay evaluation report (Reference 8). (This is equivalent to the case-specific analysis and/or test approach acceptable under current licensing criteria.)

The guidelines for determining relay seismic capacity and comparison of seismic capacity to seismic demand are the same as in Screening Level 2, above.

If the guidelines for this screening method cannot be applied, or the seismic demand is not bounded by the seismic capacity of the relay, then the following screening method should be used instead.

Screening Level 4 - Use of Current Qualification Methods. Use of seismic qualification methods currently specified in NRC-approved IEEE standards (e.g., IEEE 344-1975,-1987) and current licensing criteria (e.g., NRC Standard Review Plan and Regulatory Guides) are acceptable means for evaluating the seismic adequacy of relays.

If none of the above screening methods result in an acceptable comparison of seismic capacity to demand, then the relay should be classified as an outlier as discussed in Section 6.6 below. Note that it is permissible to declare a relay an outlier without applying all of the above screening methods.

Seismic Adequacy of Relays in Switchgear. A special case can be used for essential relays which directly control the operation of switchgear. To show that this type of essential relay is seismically adequate, it is not necessary to use the above screening methods. Instead the relay can be shown to be adequate if: (1) the cabinet containing the relay has been shown to be seismically adequate using the seismic evaluation method given in Section 4, and (2) the essential relay is not one of the low-ruggedness types listed in Appendix E of Reference 8. Note that these relays which control the operation of the circuit breaker may be mounted in the switchgear cabinet or in another cabinet. Further details on screening of essential relays in switchgear are provided in Reference 8.

6.5 RELAY WALKDOWN

A walkdown should be performed as a part of the relay evaluation. The purposes of the relay walkdown are to:

- Obtain information needed to determine cabinet types which house essential relays and to determine the in-cabinet amplification, where needed, for the seismic capacity screening described above.
- Verify the adequacy of the anchorage of the cabinets or enclosures which support the essential relays.
- Spot check mountings of essential relays.
- Spot check the essential relays to verify their types and locations, including checks for vulnerable relays (as listed in Appendix E of Reference 8).

These purposes can be accomplished during one walkdown or separately during different walkdowns. To accomplish the first purpose of the relay walkdown, the cabinets or panels which house essential relays should be identified and the information needed to determine in-cabinet amplification should be reviewed. A Seismic Capability Engineer and a Relay Reviewer (as defined in Section 2) should accomplish this purpose.

The second purpose, evaluation of the anchorage of the cabinet/enclosure supporting the relay, should be done as a part of the Screening Verification and Walkdown as described in Section 4. Note that the cabinets or enclosures supporting essential relays should be identified prior to this walkdown.

The third purpose of the relay walkdown is to spot check relay mountings to confirm that relays are mounted in accordance with manufacturer's recommendations. The objective of the spot checks is to identify any abnormal or atypical relay mounting techniques. The specific number of relays to be checked is not quantified because the bulk of the relays addressed in the relay evaluation procedure are typically located in a few specific plant areas and can be easily checked. Most of the relays encountered in the relay evaluation can be checked by opening relay cabinets in the following plant areas:

- Control room
- Relay room or auxiliary control room
- Switchgear rooms
- Diesel generator control panel area

Spot checking relay mountings can be performed during a separate relay walkdown by personnel familiar with relay installation. Alternatively, relay mountings may be spot checked during the seismic walkdown when in-cabinet amplification information is gathered. Special preparation or training is not required for spot checking relay mountings. Indications such as proper relay label orientation, mounting bolts in place and tight, and whether the relay is snug in its mounting bracket are sufficient to judge the adequacy of the mounting; analytical checks are not intended except as a means to verify atypical mountings.

The fourth purpose of the relay walkdown is to confirm relay types and locations. This can be performed at the same time that the relay mountings are checked and by the same individuals. The approach for confirming relay types by the relay walkdown team includes noting relay types observed in the cabinets and then comparing this with the relays identified on electrical drawings. It is important to note that relay mountings are considered to be standard and the circuit drawings are assumed to be correct and up-to-date. Spot checks of the relay mountings and relay types are a mechanism to confirm these assumptions. Any significant spot check discrepancies will necessitate more thorough relay inspections.

6.6 OUTLIERS

An outlier is defined as an essential relay which does not meet the screening guidelines for:

- Comparison of relay seismic capacity to seismic demand as given in Section 6.4 or,
- Relay mounting as given in Section 6.5.

When an outlier is identified, proceed to Section 5, Outlier Identification and Resolution, and document the cause(s) for not meeting the screening guidelines. The Outlier Seismic Verification Sheet (OSVS), found in Exhibit 5-1, should be used.

The conservative screening criteria given in this section are intended for use as a generic basis to evaluate the seismic adequacy of essential relays. Therefore, if an essential relay fails this generic screen, it may not necessarily be deficient for seismic loading; however, additional evaluations are needed to show that it is adequate. Some of the additional evaluations and alternative methods for demonstrating seismic adequacy are summarized below. Generic methods for resolving outliers are also provided in Section 5.

- Refine the seismic screening requirements and/or analyses.
- Test the relay and/or the cabinet in question.
- Re-design and modify the circuit to make the relay function nonessential.
- Relocate the relay to reduce the seismic demand imposed upon it.
- Replace the relay with a seismically qualified one.
- Stiffen the relay mounting.
- Use other justifiable approaches.

6.7 DOCUMENTATION OF RESULTS

The relay functionality screening and evaluation procedure in Reference 8 defines the recommended documentation for plant-specific relay evaluations. This documentation consists of tabulation forms which provide a record of the evaluation and includes:

- Identification and listing of all safe shutdown equipment for relay evaluation.
- Identification and listing of all relays or groups of relays which affect the operation of the safe shutdown equipment. The documentation should be sufficiently detailed such that a reviewer can trace the conclusions reached regarding the effect of relay malfunction on operation of any safe shutdown item of equipment. The

relays (including all contact devices) which are screened out because chatter is acceptable or by use of the other screening approaches which do not require relay-specific evaluation do not need to be identified individually. Only the essential relays which require relay-specific seismic capacity evaluation need to be individually identified.

- Identification of essential relays in switchgear.
- Functional screening results.
- Comparison of relay seismic capacity to seismic demand results.
- Identification of cabinets, panels and other enclosures which house essential relays.
- Results of walkdown spot checks.
- Outliers, if any.
- Recommended corrective actions.

By using the tabulation forms provided with the relay evaluation procedure, every relay and contact (or group of relays and contacts when appropriate) in the control circuits for a safe shutdown item of equipment should be identified and referenced to a plant drawing providing traceability. These forms also provide for documentation of the conclusion of the evaluation made for each relay and contact or each group of relays and contacts.

If any of the essential relays are classified as outliers, the Outlier Seismic Verification Sheet (OSVS), found in Exhibit 5-1, should be completed to document the cause(s) for not meeting the screening guidelines described in this section.

Section 7

TANKS AND HEAT EXCHANGERS REVIEW

7.0 INTRODUCTION

This section describes the guidelines which should be used for evaluating the seismic adequacy of tanks and heat exchangers which are needed for safe shutdown during and following a Safe Shutdown Earthquake (SSE) as identified in Section 3.

The guidelines contained in this section are based on Reference 26. Note, however, that to provide consistency with the remainder of the GIP some of the nomenclature and symbols used in this section are slightly different than those used in Reference 26.

This section contains the commitments (Section 7.1), a description of the overall evaluation methodology (Section 7.2), the steps for verifying the seismic adequacy of vertical tanks (Section 7.3), the steps for verifying the seismic adequacy of horizontal tanks and heat exchangers (Section 7.4), a description of how to treat outliers (Section 7.5), and a description of how to document the results of the evaluations (Section 7.6).

Successful completion of the review described in this section for large, flat-bottom, cylindrical vertical tanks, which are needed for safe shutdown or for refueling water storage in PWRs, has been accepted by the NRC as resolving the seismic issues related to these types of tanks for Unresolved Safety Issue (USI) A-40, Seismic Design Criteria, as it applies to operating plants.

7.1 SQUG COMMITMENTS

Members of SQUG adopting the Generic Implementation Procedure for USI A-46 resolution commit to the following in regard to the verification of seismic adequacy of tanks and heat exchangers:

7.1.1 Scope of Equipment

The licensee will evaluate for seismic adequacy tanks and heat exchangers identified pursuant to Section 3 of the GIP.

7.1.2 Evaluation Methodology

For identified tanks and heat exchangers, the licensee will perform an engineering evaluation which checks for the seismic adequacy of: (1) tank wall stability to prevent buckling (for large vertical ground- or floor-mounted, flat-bottom tanks only) including the effects of hydrodynamic loadings and tank wall flexibility; (2) anchor bolt and embedment strength; (3) anchorage connection strength between the anchor bolts and the shell of the tank or heat exchanger; and (4) flexibility of piping attached to large, flat-bottom, vertical tanks.

7.1.3 Documentation

The licensee will document the tank and heat exchanger evaluations performed pursuant to this section, including all calculations, assumptions, and data used to support the evaluations.

7.2 EVALUATION METHODOLOGY

The screening evaluations described in this section for verifying the seismic adequacy of tanks and heat exchangers cover those features of tanks and heat exchangers which experience has shown can be vulnerable to seismic loadings. These evaluations include the following features:

- Check that the shell of large, flat-bottom, vertical tanks will not buckle. Loadings on these types of tanks should include the effects of hydrodynamic loadings and tank wall flexibility.
- Check that the anchor bolts and their embedments have adequate strength against breakage and pullout.
- Check that the anchorage connection between the anchor bolts and the tank shell (e.g., saddles, legs, chairs, etc.) have adequate strength.
- Check that the attached piping has adequate flexibility to accommodate the motion of large, flat-bottom, vertical tanks.

Two Seismic Capability Engineers (as defined in Section 2) should review these evaluations to verify that they meet the intent of these guidelines. This review should include a field inspection of the tank, the anchorage connections, and the anchor bolt installation against the guidelines described in this section and in Section 4.4 and Appendix C.

The derivation and technical justification for the guidelines in this section were developed specifically for: (1) large, flat bottom, cylindrical, vertical, storage tanks; and (2) horizontal cylindrical tanks and heat exchangers with support saddles made of plates. The types of loadings and analysis methods described in this section are considered to be appropriate for these types of tanks and heat exchangers; however, a generic procedure cannot cover all the possible design variations. Therefore, it is the responsibility of the Seismic Capability Engineer to assess the seismic adequacy of other design features not specifically covered in this section. For example, the guidelines in this section do not specifically include a check of the stress in the weld connecting the steel support saddles to the shell of a horizontal tank or heat exchanger since this weld is typically very strong compared to other parts of the saddle and its anchorage. However, if the seismic review team finds there to be very little weld attaching these parts, then this weld should be evaluated for its seismic adequacy.

Other types of tanks and heat exchangers (e.g., vertical tanks supported on skirts and structural legs) which are not specifically covered by the guidelines in this section, should be evaluated by the Seismic Capability Engineers using an approach similar to that described in this section. Reference 26 provides guidelines for evaluating vertical tanks on legs or skirts. Likewise, the utility may use existing analyses which verify the seismic adequacy of its tanks and heat exchangers in lieu of the GIP, provided the Seismic Capability Engineers verify that these other analyses address the same type of loading as the GIP (e.g., hydrodynamic loading on the flexible wall of vertical, flat-bottom tanks, etc.) and the same failure modes (e.g., shell buckling of vertical, flat-bottom tanks, etc.).

The screening guidelines described in this section were developed to simplify the complex dynamic fluid-structure interaction analyses for large vertical tanks and to further simplify the equivalent static analysis procedure for smaller horizontal tanks. To accomplish this, it was necessary to make certain simplifying assumptions and to limit the range of applicability of the guidelines. Most tanks and heat exchangers used in the nuclear power industry fall within the restrictions and range of values for which the screening guidelines were developed. However, for those tanks and heat exchangers which are not covered by, or do not pass the screening guidelines, it may be possible to perform tank-specific evaluations, using the approach described in Reference 26, to verify the seismic adequacy of the tank or heat exchanger.

The screening guidelines described in this section are based on using 4% damped ground or floor response spectra. If 4% damped response spectra are not directly available, then they may be estimated by scaling from spectra at other damping values using the standard technique described in Section 4.4.3 under the subsection "Equipment Damping."

7.3 VERTICAL TANKS

This section describes: (1) the scope of vertical tanks and the range of parameters which are covered by the screening guidelines; (2) the analysis procedure for determining the seismic demand applied to vertical tanks; and (3) the analysis procedure for determining the seismic capacity of vertical tanks. The evaluations include the following:

- Overturning moment capacity vs. demand
- Shear load capacity vs. demand
- Freeboard clearance vs. slosh height
- Anchorage connection capacity vs. demand
- Attached piping flexibility

7.3.1 Scope of Vertical Tanks

The type of vertical tanks covered by the screening guidelines are large, cylindrical tanks whose axis of symmetry is vertical and are supported, on their flat bottoms, directly on a concrete pad or a floor. A section through a typical large vertical tank is shown in Figure 7-1. (Note: All figures and tables applicable to vertical tanks are grouped together after Step 23 at the end of Section 7.3.) The range of parameters and assumptions which are applicable when using the guidelines to evaluate large vertical tanks are listed in Table 7-1. The nomenclature and symbols used for vertical tanks are listed in Table 7-2.

The guidelines assume that the tank shell material is carbon steel (ASTM A36 or A283 Grade C) or stainless steel (ASTM A240 Type 304) or aluminum. The number of bolts used to anchor down the tank is assumed to be 8 or more cast-in-place anchor bolts or J-bolts made of regular-strength or high-strength carbon steel (ASTM A36 or A307 or better material A325). These bolts are assumed to be spaced evenly around the circumference of the tank. These assumptions and the range of parameters given in Table 7-1 have been selected to cover the majority of vertical storage tanks in nuclear power plants.

7.3.2 Seismic Demand Applied to Vertical Tanks

The seismic demand applied to vertical tanks in the screening guidelines is based on using the maximum horizontal component of the ground or floor response spectra. The tank should be evaluated for the condition where it is filled with fluid to the maximum level to which the tank is filled during operation; this is the most severe loading condition for typical tanks at nuclear power plants. Other types of loads, such as nozzle loads, are not considered in this screening method since they are typically very small compared to the tank inertial loads.

The horizontal response of fluid-filled vertical tanks has been found to be reasonably represented by two modes of response. One is a low frequency mode called the sloshing mode, in which the contained fluid sloshes within the tank. The other is a high frequency mode wherein the structure and fluid move together, called the impulsive mode. Previously, tank walls were assumed to be rigid in determining the response from these two modes. More recent work has shown that while the assumption is appropriate for the sloshing mode, it is not appropriate for the impulsive mode. For large, thin-walled tanks, the tank may deform under the impulsive mode pressures and vibrate at frequencies in the amplified response range of earthquake motion (2 to 20 Hz). These screening guidelines account for fluid-structure interaction in the impulsive mode.

These hydrodynamic loads on the tank are characterized in the screening guidelines in terms of the tank overturning moment (M) and the base shear load (Q). By using certain simplifying assumptions and limiting the range of applicability, these loads can be determined using the step-by-step procedure given below.

Step 1 - Determine the following input data:

Tank Material:

- R (Nominal radius of tank) [in.]
- H' (Height of tank shell) [in.]
- t_{min} (Minimum shell thickness along the height of the tank shell (H'), usually at the top of the tank) [in.]
- t_s (Minimum thickness of the tank shell in the lowest 10% of the shell height H') [in.]
- σ_y (Yield strength of tank shell material) [psi]
- h_c (Height of shell compression zone at base of tank - usually height of chair) [in.]
- E_s (Elastic modulus of tank shell material) [psi]
- V_s Average shear wave velocity of soil for tanks located at grade) [ft/sec]

Fluid:

- γ_f (Weight density of fluid in tank) [lbf/in^3]
- H (Height of fluid at the maximum level to which the tank will be filled) [in.]
- h_f (Height of freeboard above fluid surface at the maximum level to which the tank will be filled) [in.]

Bolts:

N (Number of anchor bolts)

d (Diameter of anchor bolt) [in.]

F_b (Allowable tensile stress of bolt; calculated from loads obtained from Section 4 and Appendix C) [psi]

h_b (Effective length of anchor bolt being stretched - usually from the top of the chair to embedded anchor plate) [in.]

E_b (Elastic modulus of anchor bolt material) [psi]

Loading:

Ground or floor response spectrum acceleration at 4% damping.

Step 2 - Calculate the following ratios and values:

H/R

t_s/R

$$t_{av} = \frac{\sum_{i=1}^{n} t_i h_i}{H'}$$ (Thickness of the tank shell averaged over the linear height of the tank shell (H')) [in.]

Where:

n = total number of sections of the tank shell with different thicknesses

i = counter digit

t_i = thickness of the i^{th} section of the tank shell [in.]

h_i = height of the i^{th} section of the tank shell [in.]

H' = total height of tank shell [in.]

Note that $\sum_{i=1}^{r} h_i = H'$

$t_{ef} = \dfrac{t_{av} + t_{min}}{2}$ (Effective thickness of tank shell [in.]

t_{ef}/R

$A_b = \dfrac{\pi d^2}{4}$ (Cross-sectional area of embedded anchor bolt) [in^2]

$t' = \left(\dfrac{N\ A_b}{2\pi R}\right)\left(\dfrac{E_b}{E_s}\right)$ (Equivalent shell thickness having the same cross-sectional area as the anchor bolts) [in.]

$c' = \left(\dfrac{t'}{t_s}\right)\left(\dfrac{h_c}{h_b}\right)$ ...ient of tank wall thicknesses and ...under stress)

$W = \pi R^2 H \gamma_f$ (Weight of fluid in tank) [lbf]

Confirm that the parameters, values, and ratios determined in these first two steps are within the ranges given in Table 7-1. If they are, then the procedure given in this section is applicable to the subject vertical tank; proceed to Step 3. If the tank does not meet this guideline, classify the tank as an outlier and proceed to Section 5, Outlier Identification and Resolution.

Step 3 - Determine the fluid-structure modal frequency for vertical carbon steel tanks containing water.

F_f [Hz] (from Table 7-3)

by entering Table 7-3 with:

R [in] (from Step 1)

t_{ef}/R (from Step 2)

H/R (from Step 2)

Alternatively, enter Figure 7-2 with t_{ef}/R and H/R to obtain F'_f. Then compute F_f:

$$F_f = F'_f \left[\frac{8.33}{R}\right]$$

This frequency is for carbon steel tanks containing water. For other tank material (stainless steel or aluminum) with modulus of elasticity E_s (psi) and fluid other than water with weight density γ_f [lbf/in^3], the frequency F_f (s, f) may be computed from F_f, determined above, as follows:

$$F_f(s\ ,f) = F_f \sqrt{\frac{0.0361}{\gamma_f}} \sqrt{\frac{E_s}{30x10^6}}$$

<u>Step 4</u> - Determine the spectral acceleration (Sa_f) for the fluid-structure modal frequency. Enter the horizontal ground or floor response spectrum (the maximum horizontal component) for the surface on which the tank is mounted, with:

F_f [Hz] (from Step 3)

and determine the maximum spectral acceleration:

Sa_f [g] (from horizontal response spectrum)

over the following frequency (F) range:

$0.8\ F_f < F < 1.2\ F_f$

For tanks with concrete pads founded on <u>ground</u>, soil-structure interaction (SSI) effects on frequency F_f, and thus on Sa_f, must be accounted for if V_s is less than 3,500 ft/sec. The SSI effects on frequency may be computed explicitly by appropriate methods as discussed in Reference [illegible], or by the following simplified procedure:

(a) If frequency F_f is smaller than the frequency at the peak of the applicable ground response spectrum, SSI effects may be ignored.

(b) If frequency F_f is larger than the peak frequency of the spectrum, then use the peak spectrum value for Sa_f.

Step 5 - Determine the base shear load (Q). Enter Figure 7-3 with:

H/R (from Step 2)

t_{ef}/R (from Step 2)

and determine the base shear load coefficient:

Q' (from Figure 7-3)

Compute the shear load at the base of the tank:

$Q = Q' \, W \, Sa_f$ [lbf]

Step 6 - Determine the base overturning moment (M). Enter Figure 7-4 with:

H/R (from Step 2)

t_{ef}/R (from Step 2)

and determine the base overturning moment coefficient:

M' (from Figure 7-4)

Compute the overturning moment at the base of the tank:

$M = M' \, W \, H \, Sa_f$ [in-lbf]

This completes the determination of the seismic demand applied to a vertical tank.

7.3.3 Overturning Moment Capacity

The seismic capacity of the tank shell and its anchorage to resist the overturning moment (M) is determined below. The overturning moment is resisted by compression in the tank wall and tension in the anchor bolts. The overturning moment capacity is thus controlled by shell buckling on one side and anchor bolt capacity on the other side.

The anchor bolt capacity is determined by the procedure given in Section 4 and Appendix C for cast-in-place bolts or J-bolts and is taken as the bolt yield capacity. The analysis procedure described below calculates the capacity of the shell to withstand buckling assuming the anchor bolts stretch inelastically. The assumption of allowing the anchor bolts to stretch inelastically is used in these screening guidelines to distribute the overturning moment more evenly among several anchor bolts. Note, however, that the anchor bolt load using this allowable is subject to verification that there is adequate strength in the bolt chair and its connection to the shell; this is evaluated in Section 7.3.6. If it is determined that the bolt connection has lower capacity than that determined for the bolt itself, then this lower capacity must be used. It must also be determined whether the failure mode governing the connection capacity is ductile or brittle. For brittle failure mode, the moment capacity is determined without allowing inelastic stretching (yielding) of the bolt.

The compressive axial buckling stress capacity of the tank shell is most likely limited by the "elephant-foot" buckling mode near the base of the tank wall. Another possible buckling mode for vertical tanks is the "diamond-shape" buckling mode. Both of these buckling modes are dependent upon the hydrodynamic and hydrostatic pressure acting at the base of the tank which is determined below:

<u>Step 7</u> - Determine the fluid pressure for elephant-foot buckling (P_e) by entering Figure 7-5 with:

Sa_f [g] (from Step 4)

H/R (from Step 2)

and determine the pressure coefficient for elephant-foot buckling of the tank:

P_e' (from Figure 7-5)

Compute the fluid pressure at the base of the vertical tank for elephant-foot buckling:

$$P_e = P_e' \gamma_f R \quad [psi]$$

Step 8 - Determine the elephant-foot buckling stress capacity factor

$$\sigma_{pe} \quad [ksi] \qquad \text{(from Figure 7-6)}$$

by entering Figure 7-6 with:

$$P_e \quad [psi] \qquad \text{(from Step 7)}$$

$$t_s/R \qquad \text{(from Step 2)}$$

Convert σ_{pe} into units of psi by multiplying by 1000.

This value of σ_{pe} is for :rbon steel. For other material, use the following formula:

$$\sigma_{pe} = \frac{0.6E_s}{(R/t_s)} \left[1 - \left(\frac{P_e R}{\sigma_y t_s}\right)^2\right] \left[1 - \frac{1}{1.12 + S_1^{1.5}}\right] \left[\frac{S_1 + \sigma_y/36{,}000\ psi}{S_1 + 1}\right] [psi]$$

where:

S_1 = $\dfrac{R}{400\ t_s}$

σ_y = yield strength of tank shell material [psi]

E_s = elasticity modulus of tank shell material [psi]

t_s = minimum thickness of tank shell in the lowest 10% of the shell height (H') [in.]

R = nominal radius of tank [in.]

P_e = fluid pressure at the base of tank for elephant-foot buckling of tank shell [psi]

<u>Step 9</u> - Determine the fluid pressure for diamond-shape buckling (P_d) by entering Figure 7-7 with:

Sa_f [g] (from Step 4)

H/R (from Step 2)

and determine the pressure coefficient for diamond-shape buckling of the tank:

P_d' (from Figure 7-7)

Compute the fluid pressure at the base of the vertical tank for diamond-shape buckling:

$$P_d = P_d' \gamma_f R \quad \text{[psi]}$$

<u>Step 10</u> - Determine the diamond-shape buckling stress capacity factor:

σ_{pd} [ksi] (from Figure 7-8)

by entering Figure 7-8 with:

P_d [psi] (from Step 9)

t_s/R (from Step 2)

Convert σ_{pd} into units of psi by multiplying by 1000.

This value of σ_{pd} is for carbon steel. For other material use the following formula:

$$\sigma_{pd} = (0.6\gamma + \Delta\gamma) \frac{E_s}{R/t_s}$$

where:

$\gamma \quad = 1 - 0.73(1-e^{-\phi})$

$\phi \quad = \frac{1}{16}\sqrt{\frac{R}{t_s}}$

E_s = elastic modulus of tank shell material [psi]

R = nominal radius of tank [in.]

t_s = minimum thickness of tank shell in the lowest 10% of the shell height (H') [in.]

$\Delta\gamma$ = increase factor for internal pressure given in Figure 7-9.

<u>Step 11</u> - Select the allowable buckling stress, σ_c, as 90% of the lower value of σ_{pe} or σ_{pd}:

$$\sigma_c = 0.9 \times \min(\sigma_{pe}, \sigma_{pd}) \quad \text{[psi]}$$

<u>Step 12</u> - Determine bolt tensile load capacity, P_u (lbf), per guidelines for cast-in-place bolts in Section 4 and Appendix C. This value should reflect any effects of less than minimum embedment, spacing, and edge distance as well as concrete cracking as detailed in Section 4 and Appendix C. The bolt capacities from Section 4 and Appendix C are based on the weak link being the anchor bolt rather than the concrete such that the postulated failure mode is <u>ductile</u>. Compute the allowable bolt stress, F_b (psi):

$$F_b = \frac{P_u}{A_b} \quad \text{[psi]}$$

where:

P_u = bolt tensile load capacity [lbf] (from Section 4, Appendix C)

A_b = cross-sectional area of embedded anchor bolt [in^2] (from Step 2)

If the Section 4 and Appendix C criteria are not met for the anchorage, then the concrete is considered the weak link in the load path and the postulated failure mode is <u>brittle</u>. Determine an appropriate reduced allowable anchor bolt stress (F_r) per applicable code requirements or, alternately, classify the tank as an outlier and proceed to Section 5, Outlier Identification and Resolution after completing all the evaluations in this section.

<u>Step 13</u> - The overturning moment capacity, M_{cap}, is dependent upon whether the postulated weak link failure mode is ductile or brittle. Determining the weak link in the load path is an iterative process. If the weak link is from ductile stretching or bending, e.g., anchor bolt stretching (Step 12), chair top plate bending (Step 19), or tank shell bending (Step 20), then go to Step (a) below for ductile failure mode. If the weak link is from shearing, e.g., concrete cone failure (Step 12), chair stiffener plates (Step 21), or chair-to-tank wall welds (Step 22), then go to Step (b) below for brittle failure mode.

After determining the base overturning moment coefficient (M'_{cap}) from either Step (a) or (b), then go to Step (c) and calculate the overturning moment capacity of the tank (M'_{cap}).

(a) If the anchorage (or load path) fails in <u>ductile</u> manner, then enter Figure 7-10 with:

c' [dimensionless] (from Step 2)

σ_c [psi] (from Step 11)

F_b = smaller of F_b (from Step 12) or F_r (from Steps 19 or 20) [psi]

h_c = [in] (from Step 1)

h_b = [in] (from Step 1)

and determine the base overturning moment coefficient for ductile failure:

M'_{cap} [dimensionless] (from Figure 7-10)

Go to Step (c) below.

(b) If the anchorage or load path fails in a brittle manner, then enter Table 7-4 with:

c' [dimensionless] (from Step 2)

and determine the base overturning moment coefficient for the elastic limit:

M'_{cap} [dimensionless] (from Table 7-4)

Go to Step (c) below.

(c) Compute M_{cap}:

$$M_{cap} = (M'_{cap})\ (2F_b)\ (R^2 t_s)\ (h_b/h_c)$$

using:

M'_{cap} [dimensionless] (from Step 13(a) or 13(b))

F_b = smaller of F_b or F_r (from Steps 12, 19, 20, 21, or 22) [psi]

R = [in.] (from Step 1)

t_s = [in.] (from Step 1)

h_b = [in.] (from Step 1)

h_c = [in.] (from Step 1)

Step 14 - Compare the overturning moment capacity of the tank (M_{cap}, from Step 13) with the overturning moment (M, from Step 6). If

$$M_{cap} \geq M$$

then the tank is adequate for this loading; proceed to Step 15. If the tank does not meet this guideline, classify the tank as an outlier and proceed to Section 5, Outlier Identification and Resolution, after completing the remainder of the evaluations in this section.

7.3.4 Shear Load Capacity

The seismic capacity of the tank to resist the shear load (Q) is determined below. The shear load is assumed to be resisted by sliding friction between the tank base plate and the supporting foundation material. The base shear load capacity is therefore a function of the friction coefficient and the pressure on the base plate. A friction coefficient of 0.55 is used in the screening guidelines. The pressure on the base plate is made up of hydrostatic pressure from the weight of the contained fluid less the hydrodynamic pressure from the vertical component of the earthquake. The hydrodynamic pressure from the horizontal component (from overturning moment) of the earthquake is ignored since its net or average pressure distribution over the entire base plate is zero. The weight of the tank shell is conservatively neglected.

Step 15 - Compute the base shear load capacity of the tank:

$$Q_{cap} = 0.55\ (1 - 0.21\ Sa_f)\ W$$

using:

S_{af}	[g]	(from Step 4)
W	[lbf]	(from Step 2)

Step 16 - Compare the base shear load capacity of the tank (Q_{cap}, from Step 15) with the shear load (Q, from Step 5). If

$$Q_{cap} \geq Q$$

then the tank is adequate for this loading; proceed to Step 17. If the tank does not meet this guideline, classify the tank as an outlier and proceed to Section 5, Outlier Identification and Resolution, after completing the remainder of the evaluations in this section.

This procedure assumes that no shear load is carried by the anchor bolts. Note that this assumption is theoretically valid only if there is a slight gap between the hole in the tank base and the anchor bolt; this is usually the case.

7.3.5 Freeboard Clearance

The screening guidelines described above are based on the assumption that there is enough freeboard clearance available between the liquid surface and the tank roof such that the tank roof is not subjected to significant forces from sloshing liquid. The procedure given below simply compares the freeboard clearance to the slosh height; this is considered to be conservative since it allows no contact of the fluid with the tank roof.

Step 17 - Determine the slosh height by entering Table 7-5 with:

H/R	(from Step 2)
R [in.]	(from Step 1)

and determine the slosh height of the fluid in the tank for a ZPA of 1g at the base of the tank:

h'_s [in.] (from Table 7-5)

Compute the slosh height of the fluid in the tank for the ZPA of the ground or floor on which the tank is mounted:

$$h_s = h'_s \text{ ZPA}$$

using:

h'_s	[in.]	(from above)
ZPA	[g]	(from horizontal response spectrum)

Step 18 - Determine the available freeboard above the fluid surface at the maximum level to which the tank will be filled (h_f, in.).

For conical tank roofs, measure the freeboard from the fluid surface to the intersection of the wall and the roof (a distance R from the tank centerline).

For tanks with a domed roof, measure the freeboard from the fluid surface to the point where the roof surface is at a distance of 0.9R from the tank centerline.

Compare the available freeboard (h_f) to the slosh height of the fluid (h_s, from Step 17). If

$$h_f \geq h_s$$

then the tank is adequate for this condition; proceed to Step 19. If the tank does not meet this guideline, classify the tank as an outlier and proceed to Section 5. Outlier Identification and Resolution, after completing the remainder of the evaluations in this section.

7.3.6 Anchorage Connection Capacity

In the procedure presented above for determining overturning moment capacity of vertical tanks, it is assumed that the anchorage connection details are adequate for the bolt to develop its yield capacity in tension, and subsequently deform in a ductile manner. For this type of ductile behavior to occur, it should be possible to transfer loads at least equal to the anchor bolt allowable capacity to the tank wall local to the anchor bolts, the connection between the tank wall and the anchor bolt chair, and the anchor bolt chair itself.

The purpose of this check is to determine if the capacity of the load path is greater than the tensile capacity, P_u, of the anchor bolt. The evaluation guidelines given in this section which primarily uses the design guidelines developed by the American Iron and Steel Institute (Reference 27) are taken from Reference 26 . Figure 7-11 shows a typical detail of a vertical tank anchor bolt chair. The chair includes two vertical stiffener plates welded to the tank wall. A top plate, through which the bolt passes, transfers loads from the bolt to the stiffeners which, in turn, transfer the loads into the tank wall. Figure 7-12 depicts two other less commonly-used anchor chair details. The detail shown in Figure 7-12(b) is an example of a poor anchorage connection design and is unlikely to satisfy the strength criteria for the connection. The procedure for checking the capacities of the various components of the anchorage connection is given below. This procedure applies to the typical chair assembly shown in Figure 7-11. A similar approach can be used for other types of anchor bolt chairs; however, the tank wall stress equation given below in Step 22 is only applicable for the type of chair assembly shown in Figure 7-11.

If each of the anchorage connection component meets the acceptance criteria defined below, then the anchorage of the tanks is controlled by the ductile bolts, and the assumptions used in the tank overturning moment capacity procedure in Section 7.3.3 are valid. If, however, any of the components does not meet these guidelines, the anchor bolt tension capacity used in the procedure for determining tank anchorage overturning moment capacity (M_{cap}) should be recalculated (in Section 7.3.3), using the reduced, equivalent value of anchor bolt allowable stress (F_r) based on the weak link capacity. Note that, if the failure mode of the weak link is nonductile, the procedure for computing M_{cap} (in Section 7.3.3) is slightly different. Typically, plate or weld shear failure is considered nonductile, while tension yielding of the bolt or plastic bending failure is considered ductile.

The procedure given below, Steps 19 through 22, is for carbon steel material (for tanks, connection elements and bolts), and is based on allowable stresses (adjusted for SSE loading) per AISC specifications. Adjustments should be made for other material such as stainless steel and aluminum for the allowable stress per applicable codes.

<u>Step 19 - Top Plate</u>. The top plate transfers the anchor bolt load to the vertical stiffeners and the tank wall. The critical stress in the top plate occurs between the bolt hole and the free edge of the plate (the area identified by dimension f in Figure 7-11). This bending stress is estimated using the following equation. Note that if the top plate projects radially beyond the vertical plates, no more than 1/2 inch of this projecting plate can be included in the dimension f used in the following equation. The maximum bending stress in the top plate is:

$$\sigma = \frac{(0.375g - 0.22d)\, P_u}{fc^2} \quad \text{[psi]}$$

The top plate is adequate if the following guideline is satisfied:

$$\sigma < f_y$$

If the top plate does not meet this guideline, it is considered to fail in a ductile manner; therefore a load reduction factor:

$$\frac{f_y}{\sigma}$$

should be computed and multiplied by the anchor bolt allowable tensile stress (F_b):

$$F_r = F_b \left[\frac{f_y}{\sigma}\right] \quad \text{[psi]}$$

This reduced allowable anchor bolt stress should then be used to re-compute the overturning moment capacity in Section 7.3.3.

<u>Step 20 - Tank Shell Stress</u>. The anchor bolt loads are transferred into the tank shell as a combination of direct vertical load and out-of-plane bending moment (due to the ecce.. ricity between the bolt centerline and the tank wall). A check of shell stresses is considered necessary only for large, flat-bottom, vertical storage tanks because of past experience with such tanks in earthquakes.

The maximum bending stress in the tank shell is:

$$\sigma = \frac{P_u e}{t_s^2}\left[\frac{1.32\ Z}{\dfrac{1.43\ a\ h^2}{R\ t_s} + (4a\ h^2)^{0.333}} + \frac{0.031}{\sqrt{R\ t_s}}\right] \quad \text{[psi]}$$

where:

$$Z = \frac{1.0}{\frac{0.177 a\, t_b}{\sqrt{R t_s}} \left[\frac{t_b}{t_s}\right]^2 + 1.0}$$

The tank shell is adequate if the following guideline is satisfied:

$$\sigma < f_y$$

If the tank shell does not meet this guideline, it is considered to fail in a ductile manner; therefore a load reduction factor:

$$\frac{f_y}{\sigma}$$

should be computed and multiplied by the anchor bolt allowable tensile stress (F_b).

$$F_r = F_b \left(\frac{f_y}{\sigma}\right) \text{ [psi]}$$

This reduced allowable anchor bolt stress should then be used to re-compute the overturning moment capacity in Section 7.3.3.

Step 21 - Vertical Stiffener Plates. The vertical stiffener plates are considered adequate for shear stress, buckling, and compressive stress if the following three guidelines are satisfied:

- $\frac{k}{j} < \frac{95}{\sqrt{f_y}}$

- $j > 0.04\ (h - c)$ and $j > 0.5$ in.

- $$\frac{P_u}{2\ k\ j} < 21{,}000 \text{ psi}$$

If the vertical stiffener plates do not meet these guidelines, then the anchorage will fail in a nonductile manner before the anchor bolts will yield. Determine an appropriate reduced allowable anchor bolt stress (F_r) per applicable code requirements, and re-compute the overturning moment capacity in Section 7.3.3. Alternately, classify the tank as an outlier and proceed to Section 5, Outlier Identification and Resolution, after completing the remainder of the evaluations in this section.

<u>Step 22 - Chair-to-Tank Wall Weld</u>. The load per linear inch of weld between the anchor bolt chair (i.e., the top plate plus the vertical stiffener plates) and the tank wall is determined from the following equation for an inverted U-weld pattern of uniform thickness:

$$W_w = P_u \sqrt{\left[\frac{1}{a + 2\ h}\right]^2 + \left[\frac{e}{a\ h + 0.667\ h^2}\right]^2}$$

The weld is adequate if the following guideline is satisfied:

$$W_w \leq \frac{30{,}6000\ t_w}{\sqrt{2}}$$

where 30,600 psi in the above equation is the allowable weld strength.

If the chair-to-tank wall weld does meet this guideline, then the anchorage will fail in a nonductile manner before the anchor bolts will yield. Determine an appropriate reduced allowable anchor bolt stress (F_r) per applicable code requirements, and re-compute the overturning moment capacity in Section 7.3.3. Alternately, classify the tank as an outlier and proceed to Section 5, Outlier Identification and Resolution, after completing the remainder of the evaluations in this section.

This completes the evaluation of the anchorage connection capacity for vertical tanks.

7.3.7 Attached Piping Flexibility

For evaluation of large, flat-bottom, cylindrical, vertical tanks, the loads imposed on the tank due to the inertial response of attached piping can be neglected. It is considered that these piping loads have very little effect on the loads applied to the anchorage of large, flat-bottom tanks compared to the large hydrodynamic inertial loads from the tank and its contents. However, the relative motion between the tank and the piping presents a potential failure mode for the attached piping which could result in rapid loss of the tank's contents. This has occurred under certain circumstances in past earthquakes. Therefore this concern is addressed by requiring adequate flexibility in the piping system to accommodate tank motion as described below:

Step 23 - Flexibility of Attached Piping. The Seismic Review Team should be aware that the analytical evaluation method for vertical tanks allows for a limited amount of base anchorage inelastic behavior. This, in turn, means that there may be a very slight uplift of the tank during seismic motion. When performing in-plant evaluations of tank anchorage, the Seismic Review Team should assess attached piping near the base of the tank to ensure that the piping has adequate flexibility to accommodate any anticipated tank motion. Near the top of the tank, there will be considerably more motion and any attached piping should have substantial flexibility.

This completes the seismic evaluation for vertical tanks.

Table 7-1
APPLICABLE RANGE OF PARAMETERS AND ASSUMPTIONS FOR VERTICAL TANKS

Tank Material[1]	Carbon or Stainless steel, Aluminum		
Tank Fluid Content	Water or similar		
Nominal Radius of Tank	R	=	5 to 35 ft. (60 to 420 in.)
Height of Tank Shell	H′	=	10 to 80 ft. (120 to 960 in.)
Height of Fluid at the Maximum Level to Which the Tank Will be Filled	H	=	10 to 80 ft. (120 to 960 in.)
Minimum Thickness of the Tank Shell in the Lowest 10% of the Shell Height (H′)	t_s	=	3/16 to 1 in.
Effective Thickness of Tank Shell Based on the Mean of the Average Thickness (t_{av}) and the Minimum Thickness (t_{min})	t_{ef}	=	3/16 to 1 in.
Diameter of Anchor Bolt[2]	d	=	1/2 to 2 in.
Number of Anchor Bolts[3]	N	=	8 or more
Tank Wall Thickness (at Base)-to-Tank Radius Ratio	t_s/R	=	0.001 to 0.01
Effective Tank Wall Thickness-to-Tank Radius Ratio	t_{ef}/R	=	0.001 to 0.01
Fluid Height-to-Tank Radius Ratio	H/R	=	1.0 to 5.0

Assumptions:

1 The tank material is assumed to be carbon steel (ASTM A36 or A283 Grade C), stainless steel (ASTM A240 Type 304), aluminum, or better material.

2 Anchor bolts are assumed to be cast-in-place or J-bolts and made of regular-strength or high-strength carbon steel (ASTM A36 or A307 or better material A325).

3 Anchor bolts are assumed to be evenly spaced around the circumference of the tank.

Table 7-2

NOMENCLATURE USED FOR VERTICAL TANKS

Symbol		Description [Units]
A_b	-	Cross-sectional area of embedded anchor bolt [in.^{2}]
a	-	Width of chair top plate parallel to shell (see Figure 7-11) [in.]
b	-	Depth of chair top plate perpendicular to shell (see Figure 7-11) [in.]
c	-	Thickness of chair top plate (see Figure 7-11) [in.]
c′	-	Coefficient of tank wall thicknesses and lengths under stress [dimensionless]
d	-	Diameter of anchor bolt [in.]
E_s	-	Elastic modulus of tank shell material [psi]
E_b	-	Elastic modulus of anchor bolt material [psi]
e	-	Eccentricity of anchor bolt with respect to shell outside surface (see Figure 7-11) [in.]
F	-	Frequency [Hz]
F_b	-	Allowable tensile stress of bolt [psi]
F_f	-	Frequency of fluid-structure interaction mode [Hz]
F_r	-	Reduced allowable tensile stress of bolt [psi]
f	-	Distance from outside edge of chair top plate to edge of hole (see Figure 7-11) [in.]
f_y	-	Minimum specified yield strength of shell, chair, saddle, or base plate material [psi]
g	-	Distance between vertical plates of chair (see Figure 7-11) [in.]
H	-	Height of fluid at the maximum level to which the tank will be filled (see Figure 7-1) [in.]
H′	-	Height of tank shell (see Figure 7-1) [in.]

Table 7-2 (Continued)

NOMENCLATURE USED FOR VERTICAL TANKS

Symbol		Description [Units]
h	-	Height of chair (see Figure 7-11) [in.]
h_b	-	Effective length of anchor bolt being stretched (usually from top of chair to embedded anchor plate) (see Figure 7-1) [in.]
h_c	-	Height of shell compression zone at base of tank (usually height of chair) (see Figure 7-1) [in.]
h_f	-	Height of freeboard above fluid surface at the maximum level to which the tank will be filled (see Figure 7-1) [in.]
h_s	-	Slosh height of fluid in tank [in.]
h_s'	-	Slosh height of fluid for a ZPA of 1g applied at tank base [in.]
j	-	Thickness of chair vertical plate (see Figure 7-11) [in.]
k	-	Width of chair vertical plate (see Figure 7-11). Use average width for tapered plates [in.].
M	-	Overturning moment at base of tank [in-lbf]
M'	-	Base overturning moment coefficient [dimensionless]
M_{cap}	-	Overturning moment capacity of tank [in-lbf]
M'_{cap}	-	Base overturning moment capacity coefficient [dimensionless]
N	-	Number of anchor bolts [dimensionless]
P_e	-	Fluid pressure at base of tank for elephant-foot buckling of tank shell [psi]
P_e'	-	Pressure coefficient for elephant-foot buckling [dimensionless]
P_d	-	Fluid pressure at base of tank for diamond-shape buckling of tank shell [psi]
P_d'	-	Pressure coefficient for diamond-shape buckling [dimensionless]

Table 7-2 (Continued)

NOMENCLATURE USED FOR VERTICAL TANKS

Symbol		Description [Units]
P_u	-	Allowable tensile load of anchor bolt [lbf]
Q	-	Shear load at base of tank [lbf]
Q'	-	Base shear load coefficient [dimensionless]
Q_{cap}	-	Base shear load capacity of tank [lbf]
R	-	Nominal radius of tank [in.] (see Figure 7-1)
r	-	Least radius of gyration of vertical stiffener plate cross-sectional area about a centroidal axis [in.]
S_1	-	Coefficient of tank radius to shell thickness $\left[\frac{R}{400\ t_s}\right]$ [dimensionless]
Sa	-	Spectral acceleration of ground or floor [g]
Sa_f	-	Spectral acceleration of the ground or floor on which the tank is mounted at the frequency of the fluid-structure interaction mode (F_f) [g]
t_{av}	-	Thickness of the tank shell averaged over the linear height of the tank shell (H') [in.]
t_b	-	Thickness of bottom or base plate of tank (see Figure 7-11) [in.]
t_{ef}	-	Effective thickness of tank shell based on the mean of the average thickness (t_{av}) and the minimum thickness (t_{min}) [in.]
t_{min}	-	Minimum shell thickness anywhere along the height of the tank shell (H'), usually at the top of the tank [in.]
t_s	-	Minimum thickness of the tank shell in the lowest 10% of the shell height (H') [in.]
t_w	-	Thickness of leg of weld [in.]

Table 7-2 (Continued)

NOMENCLATURE USED FOR VERTICAL TANKS

Symbol		Description [Units]
t'	-	Equivalent shell thickness having the same cross-sectional area as the anchor bolts [in.]
V_s	-	Average shear wave velocity of soil for tanks founded at grade [ft/sec]
W	-	Weight of fluid contained in tank [lbf]
W_t	-	Weight of tank without fluid [lbf]
W_w	-	Average shear load on weld connecting anchor bolt chair to tank shell per unit length of weld (i.e., total shear load on chair divided by total length of chair/shell weld) [lbf/in. of weld]
Z	-	Tank shell stress reduction factor [dimensionless]
ZPA	-	Zero period acceleration [g]
β	-	Percentage damping [%]
γ	-	Coefficient $[1 - 0.73\ (1 - e^{-\phi})]$ [dimensionless]
γ_f	-	Weight density of fluid in tank [lbf/in^3]
$\Delta\gamma$	-	Increase factor for internal pressure; given in Figure 7-9
σ	-	Stress at a point [psi]
σ_c	-	Stress at which shell buckles [psi]
σ_{pe}	-	Stress at which shell buckles in elephant-foot pattern [psi]
σ_{pd}	-	Stress at which shell buckles in diamond-shape pattern [psi]
σ_y	-	Yield strength of tank shell material [psi]

Table 7-3

FLUID-STRUCTURE IMPULSIVE MODE FREQUENCIES (F_f, Hz)
FOR VERTICAL CARBON STEEL TANKS CONTAINING WATER

(Source: Reference 26, Table 2.2)

		TANK RADIUS (R, in.)						
H/R	t_{ef}/R	60	120	180	240	300	360	420
1.0	0.001	46.7	23.3	15.6	11.7	9.3	7.8	6.7
1.0	0.002	65.2	32.6	21.7	16.3	13.0	10.9	9.3
1.0	0.003	79.3	39.7	26.4	19.8	15.9	13.2	11.3
1.0	0.004	91.2	45.6	30.4	22.8	18.2	15.2	13.0
1.0	0.005	101.6	50.8	33.9	25.4	20.3	16.9	14.5
1.0	0.007	119.5	59.7	39.8	29.9	23.9	19.9	17.1
1.0	0.010	142.0	71.0	47.3	35.5	28.4	23.7	20.3
1.5	0.001	32.2	16.1	10.7	8.0	6.4	5.4	4.6
1.5	0.002	45.1	22.6	15.0	11.3	9.0	7.5	6.4
1.5	0.003	55.0	27.5	18.3	13.7	11.0	9.2	7.9
1.5	0.004	63.3	31.6	21.1	15.8	12.7	10.5	9.0
1.5	0.005	70.5	35.3	23.5	17.6	14.1	11.8	10.1
1.5	0.007	83.2	41.6	27.7	20.8	16.6	13.9	11.9
1.5	0.010	99.0	49.5	33.0	24.7	19.8	16.5	14.1
2.0	0.001	23.6	11.8	7.9	5.9	4.7	3.9	3.4
2.0	0.002	33.0	16.5	11.0	8.2	6.6	5.5	4.7
2.0	0.003	40.1	20.1	13.4	10.0	8.0	6.7	5.7
2.0	0.004	46.1	23.1	15.4	11.5	9.2	7.7	6.6
2.0	0.005	51.4	25.7	17.1	12.8	10.3	8.6	7.3
2.0	0.007	60.5	30.2	20.2	15.1	12.1	10.1	8.6
2.0	0.010	71.8	35.9	23.9	18.0	14.4	12.0	10.3
2.5	0.001	17.8	8.9	5.9	4.5	3.6	3.0	2.5
2.5	0.002	25.0	12.5	8.3	6.2	5.0	4.2	3.5
2.5	0.003	30.4	15.2	10.1	7.6	6.1	5.1	4.3
2.5	0.004	35.0	17.5	11.7	8.7	7.0	5.8	5.0
2.5	0.005	39.0	19.5	13.0	9.7	7.8	6.5	5.6
2.5	0.007	45.9	23.0	15.3	11.5	9.2	7.7	6.6
2.5	0.010	54.6	27.3	18.2	13.7	10.9	9.1	7.8
3.0	0.001	13.9	7.0	4.6	3.5	2.8	2.3	2.0
3.0	0.002	19.5	9.7	6.5	5.9	3.9	3.2	2.8
3.0	0.003	23.7	11.8	7.9	4.9	4.7	3.9	3.4
3.0	0.004	27.2	13.6	9.1	6.8	5.4	4.5	3.9
3.0	0.005	30.3	15.1	10.1	7.6	6.1	5.0	4.3
3.0	0.007	35.6	17.8	11.9	8.9	7.1	5.9	5.1
3.0	0.010	42.2	21.1	14.1	10.6	8.4	7.0	6.0

Table 7-3 (Continued)

FLUID-STRUCTURE IMPULSIVE MODE FREQUENCIES (F_f, Hz)
FOR VERTICAL CARBON STEEL TANKS CONTAINING WATER

(Source: Reference 26, Table 2.2)

		TANK RADIUS (R, in.)						
H/R	t_{ef}/R	60	120	180	240	300	360	420
3.5	0.001	11.2	5.6	3.7	2.8	2.2	1.9	1.6
3.5	0.002	15.5	7.8	5.2	3.9	3.1	2.6	2.2
3.5	0.003	18.8	9.4	6.3	4.7	3.8	3.1	2.7
3.5	0.004	21.6	10.8	7.2	5.4	4.3	3.6	3.1
3.5	0.005	24.0	12.0	8.0	6.0	4.8	4.0	3.4
3.5	0.007	28.2	14.1	9.4	7.0	5.6	4.7	4.0
3.5	0.010	33.4	16.7	11.1	8.3	6.7	5.6	4.8
4.0	0.001	9.1	4.6	3.0	2.3	1.8	1.5	1.3
4.0	0.002	12.6	6.3	4.2	3.2	2.5	2.1	1.8
4.0	0.003	15.2	7.6	5.1	3.8	3.0	2.5	2.2
4.0	0.004	17.4	8.7	5.8	4.4	3.5	2.9	2.5
4.0	0.005	19.3	9.7	6.4	4.8	3.9	3.2	2.8
4.0	0.007	22.6	11.3	7.5	5.7	4.5	3.8	3.2
4.0	0.010	26.7	13.4	8.9	6.7	5.3	4.5	3.8
4.5	0.001	7.5	3.8	2.5	1.9	1.5	1.3	1.1
4.5	0.002	10.3	5.2	3.4	2.6	2.1	1.7	1.5
4.5	0.003	12.4	6.2	4.1	3.1	2.5	2.1	1.8
4.5	0.004	14.2	7.1	4.7	3.5	2.8	2.4	2.0
4.5	0.005	15.7	7.9	5.2	3.9	3.1	2.6	2.2
4.5	0.007	18.3	9.2	6.1	4.6	3.7	3.1	2.6
4.5	0.010	21.6	10.8	7.2	5.4	4.3	3.6	3.1
5.0	0.001	6.2	3.1	2.1	1.6	1.2	1.0	0.9
5.0	0.002	8.5	4.2	2.8	2.1	1.7	1.4	1.2
5.0	0.003	10.2	5.1	3.4	2.5	2.0	1.7	1.5
5.0	0.004	11.6	5.8	3.9	2.9	2.3	1.9	1.7
5.0	0.005	12.8	6.4	4.3	3.2	2.6	2.1	1.8
5.0	0.007	14.9	7.4	5.0	3.7	3.0	2.5	2.1
5.0	0.010	17.5	8.7	5.8	4.4	3.5	2.9	2.5

Table 7-4

BASE OVERTURNING MOMENT CAPACITY ELASTIC LIMIT VALUES

(Source: Reference 26, Table 2.5)

c'	$\left(\frac{\sigma_c}{F_b}\right)\left(\frac{h_c}{h_b}\right)$	M'_{cap}
0.01	0.052	0.0231
0.02	0.081	0.0454
0.05	0.147	0.1092
0.10	0.230	0.2087
0.15	0.300	0.3045
0.20	0.358	0.3932
0.40	0.560	0.7271

Table 7-5

SLOSH HEIGHT OF WATER (h′, in.) IN
VERTICAL TANKS FOR 1G LATERAL ACCELERATION

(Source: Adapted From Reference 26, Table 2.7)

	TANK RADIUS (R, in.)						
H/R	60	120	180	240	300	360	420
1.0	39.0	60.2	78.7	95.5	111.5	126.7	141.4
1.5	39.6	61.2	79.8	96.8	112.9	128.3	143.2
2.0	39.7	61.3	79.9	97.1	113.2	128.5	143.4
2.5	39.7	61.3	80.0	97.1	113.2	128.6	143.4
3.0	39.7	61.3	80.0	97.1	113.2	128.6	143.4
3.5	39.7	61.3	80.0	97.1	113.2	128.6	143.4
4.0	39.7	61.3	80.0	97.1	113.2	128.6	143.4
4.5	39.7	61.3	80.0	97.1	113.2	128.6	143.4
5.0	39.7	61.3	80.0	97.1	113.2	128.6	143.4

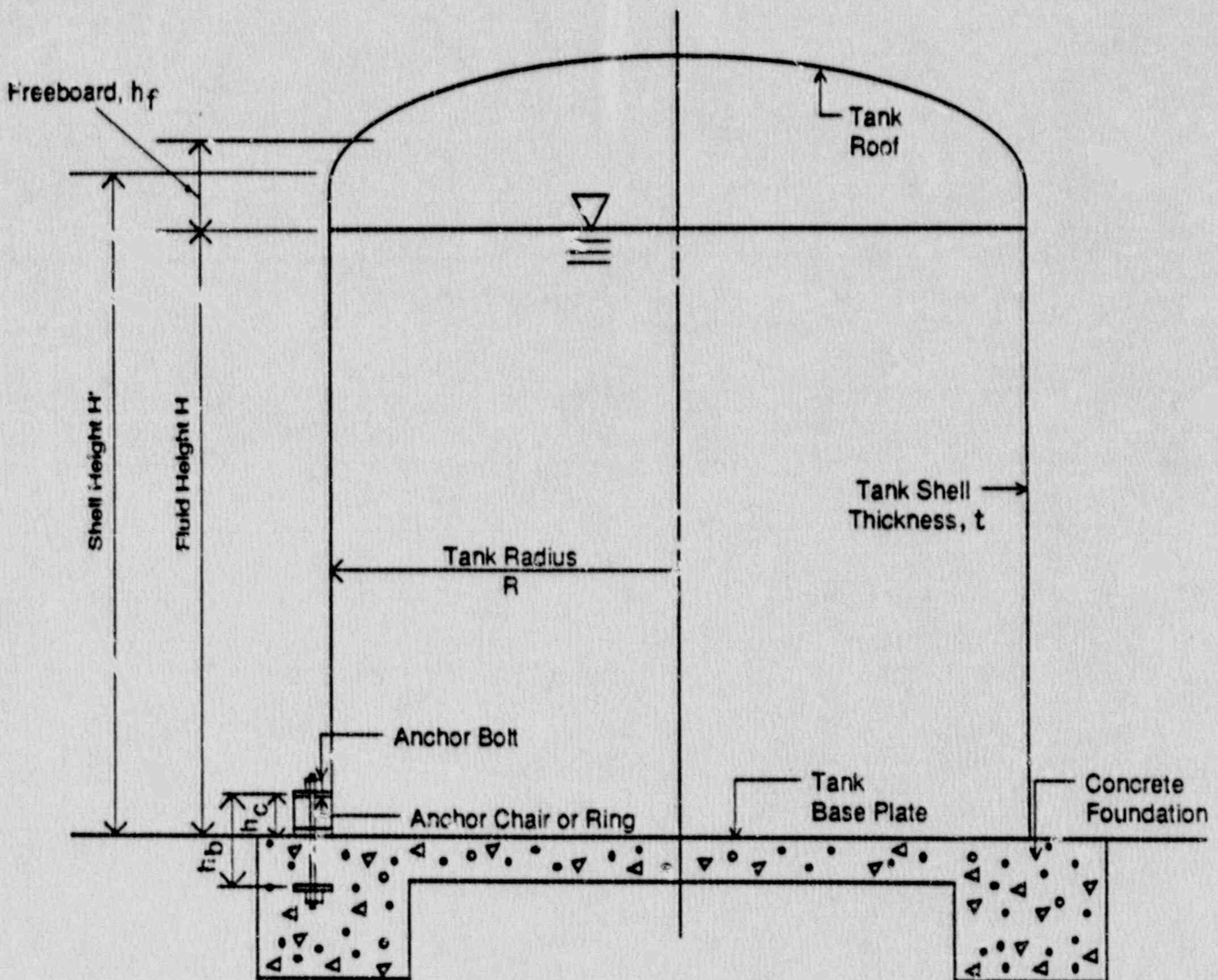


Figure 7-1. Large Vertical Tank
(Source: Reference 26, Figure 2.1)

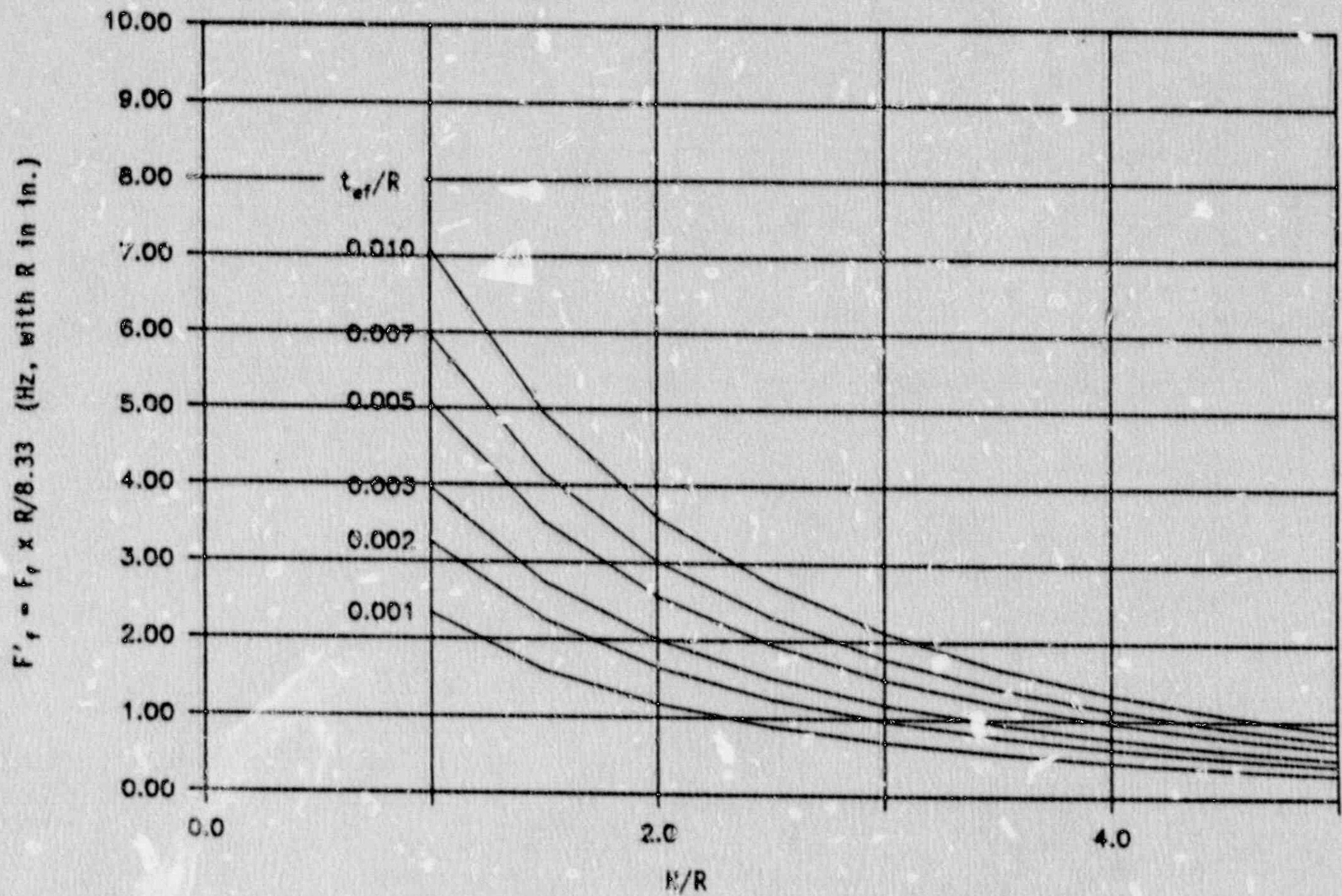


Figure 7-2. Fluid-Structure Impulsive Mode Frequency Coefficient for Vertical Carbon Steel Tanks Containing Water. (Source: Reference 26, Figure 2.3)

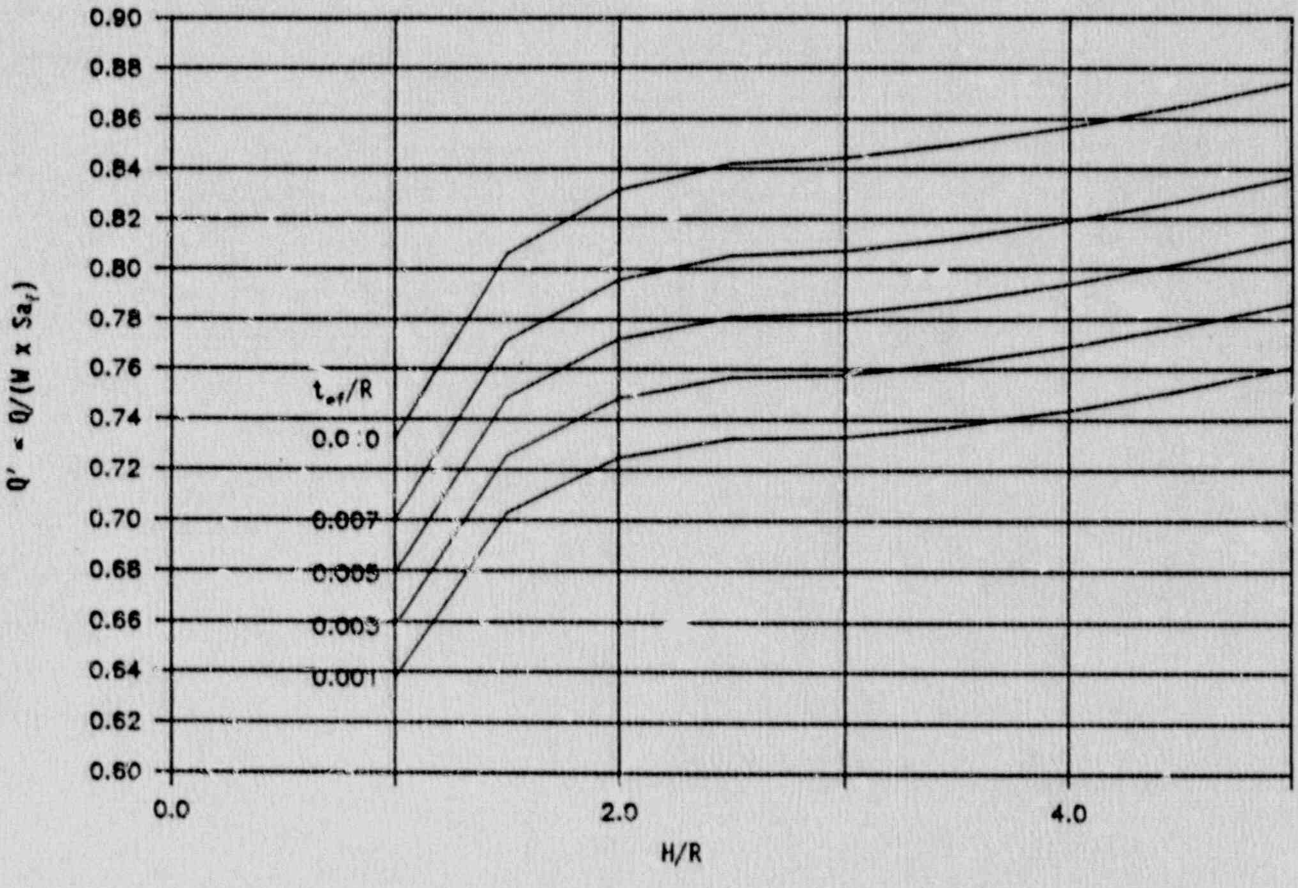


Figure 7-3. Base Shear Load Coefficient For Vertical Tanks
(Source: Reference 26, Figure 2.3)

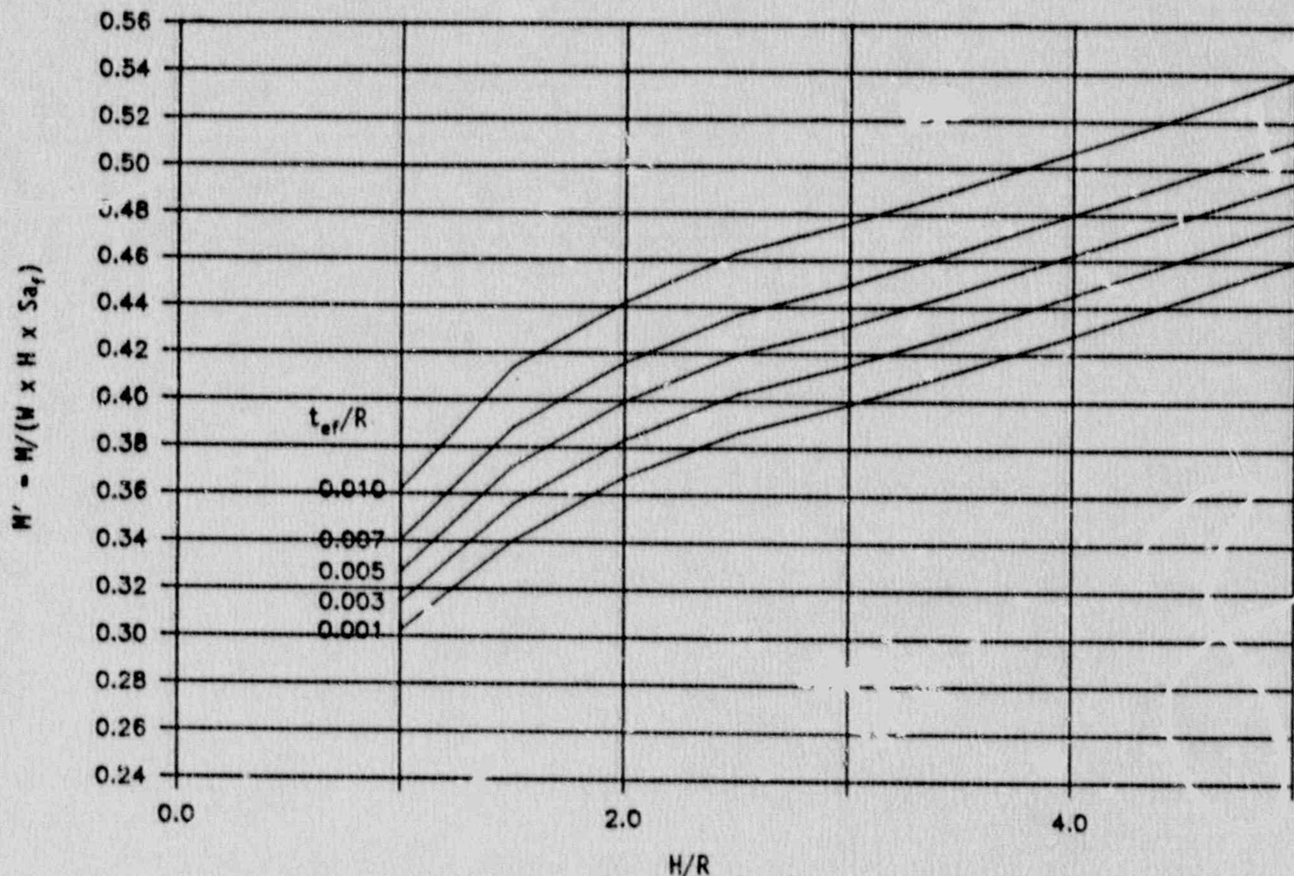


Figure 7-4. Base Overturning Moment Coefficient For Vertical Tanks (Source: Reference 26, Figure 2.4)

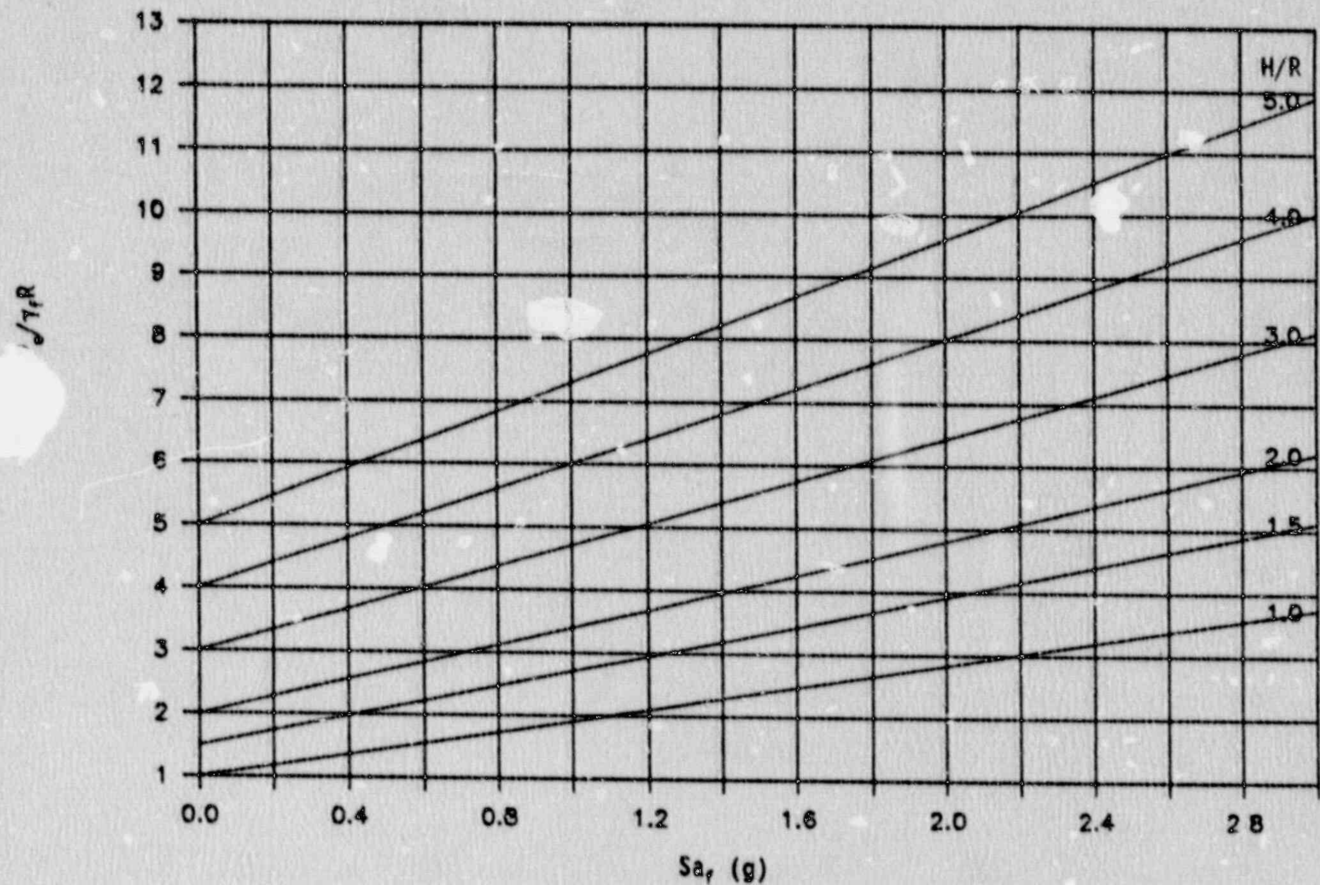


Figure 7-5. Pressure Coefficient For Elephant-Foot Buckling of Vertical Tanks (Source: Reference 26, Figure 2.6)

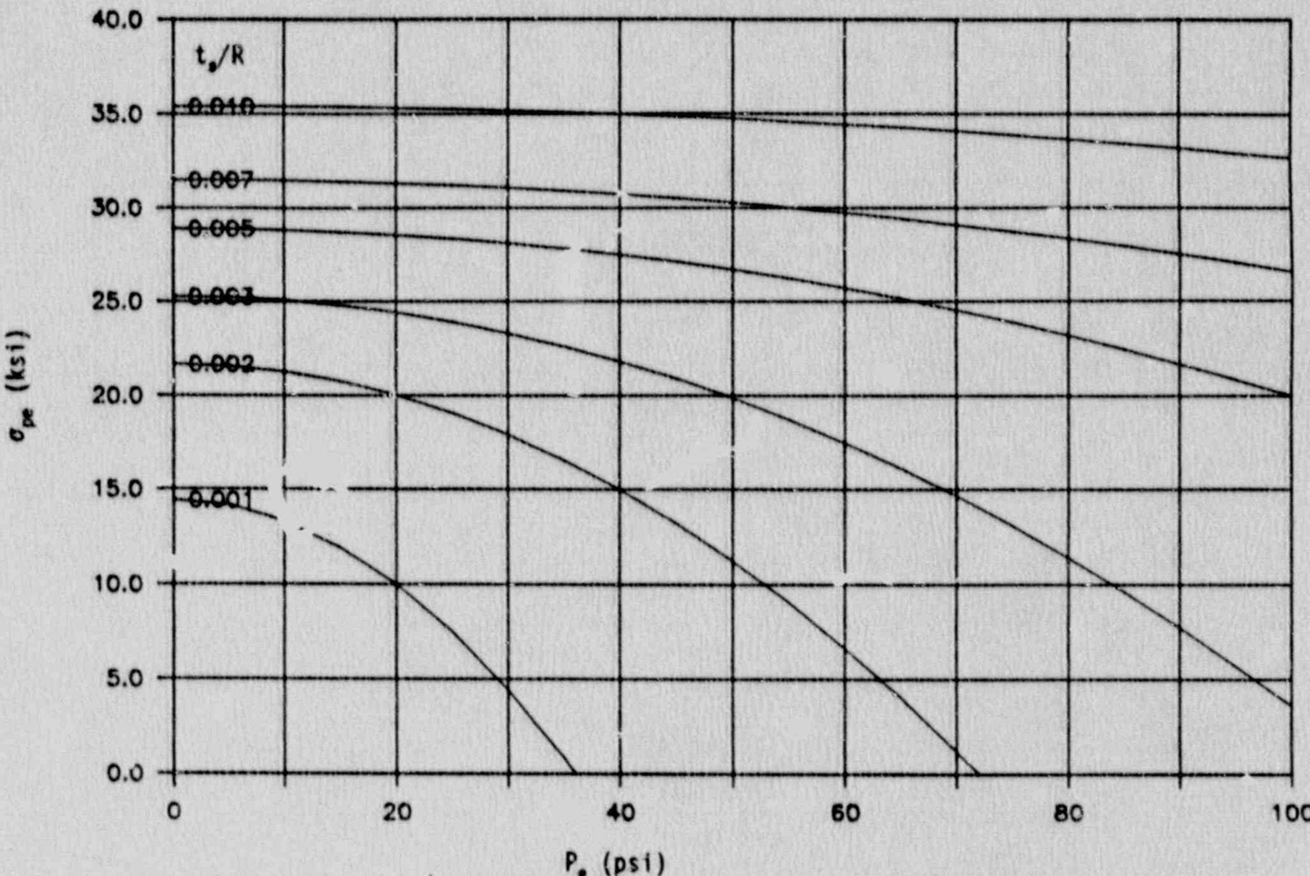


Figure 7-6. Compressive Axial Stress Capacity For Vertical Tanks, Elephant-Foot Buckling (Steel, E = 30,000 psi, σ_y = 36,000 psi) (Source: Reference 26, Figure 2.8)

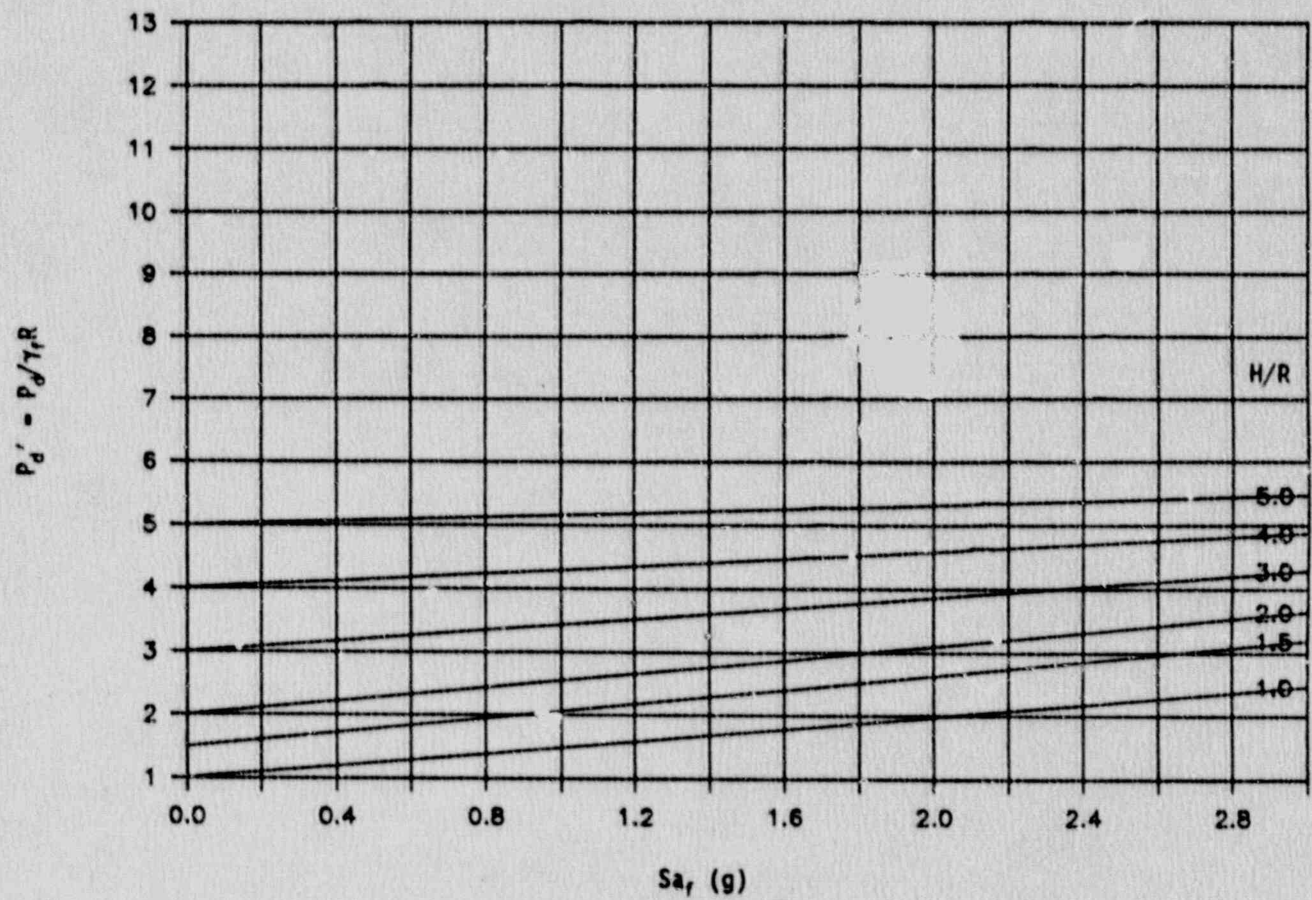


Figure 7-7. Pressure Coefficient For Diamond-Shape Buckling of Vertical Tanks (Source: Reference 26, Figure 2.7)

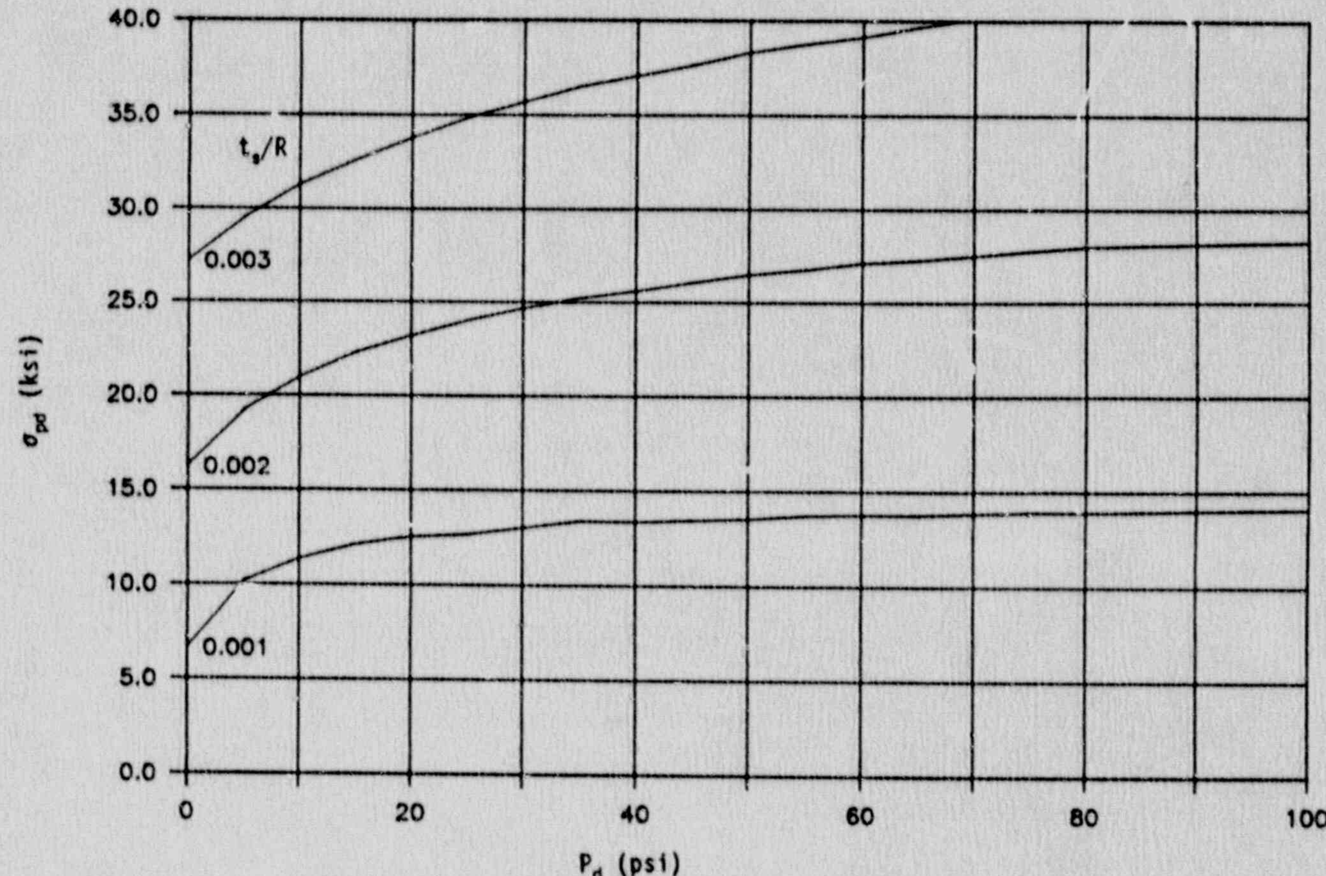


Figure 7-8. Compressive Axial Stress Capacity for Vertical Tanks, Diamond-Shape Buckling (Steel, E = 30,000 psi) (Source: Reference 26, Figure 2.10)

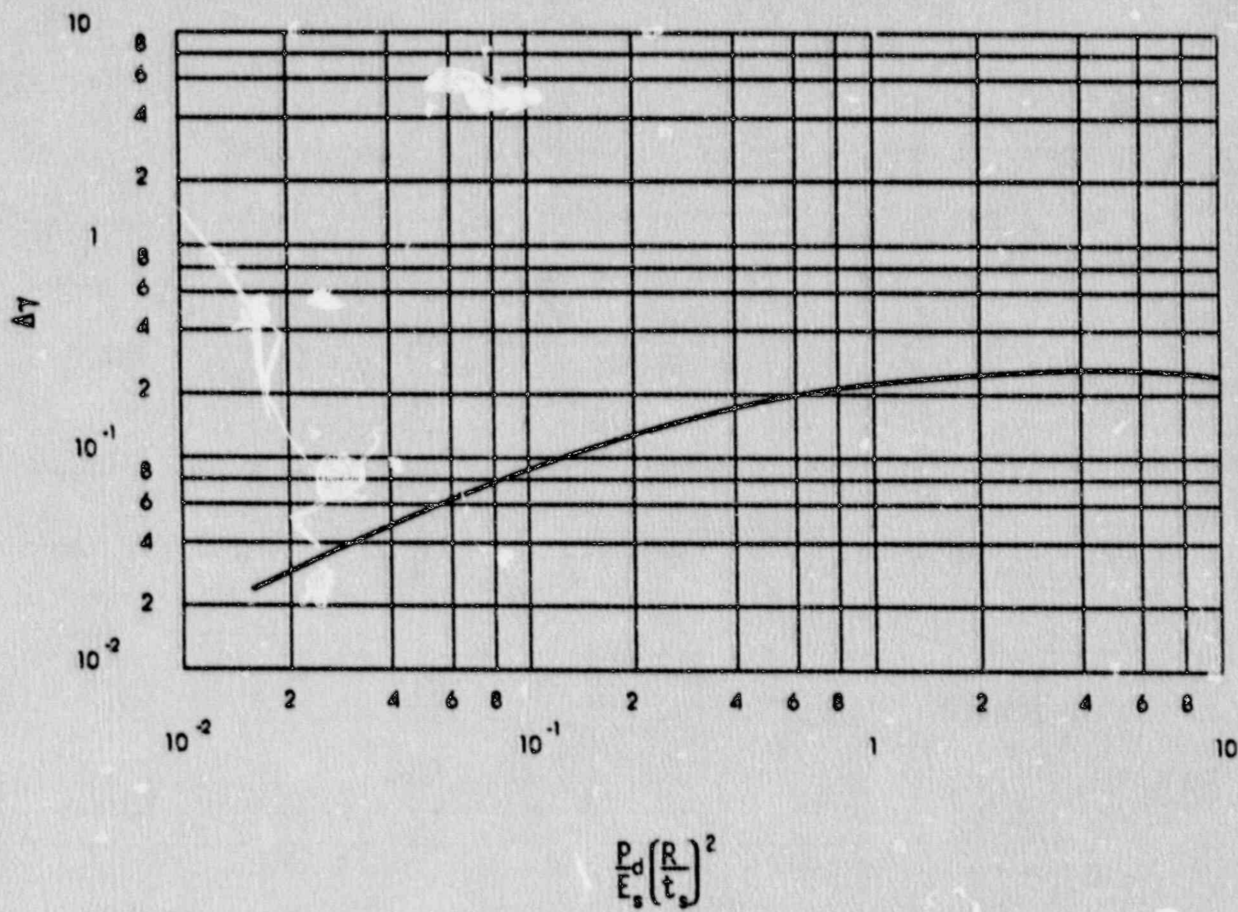


Figure 7-9. Increase Factor $\Delta\gamma$ for Diamond-Shape Buckling (Source: Reference 26, Figure 2.9)

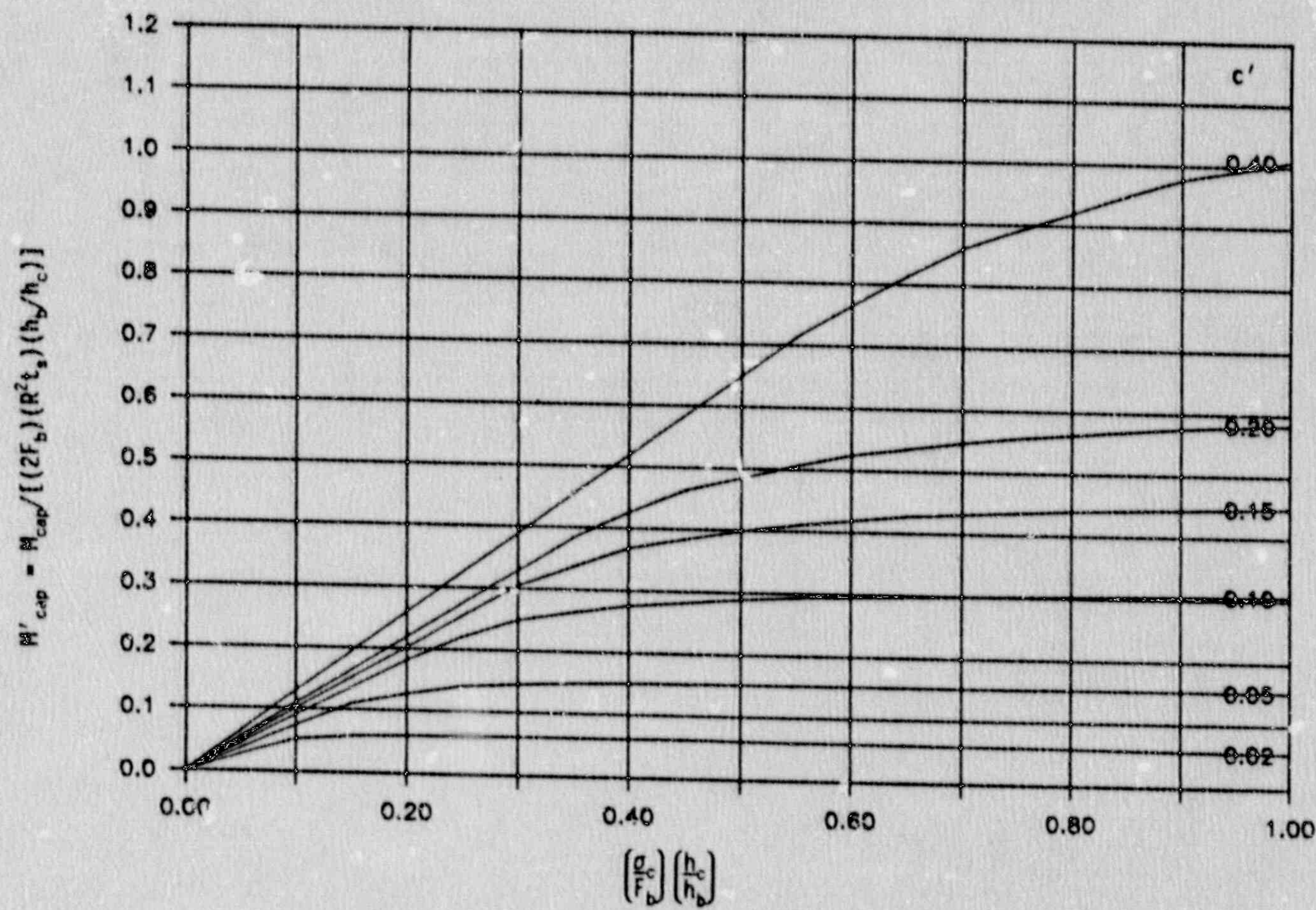
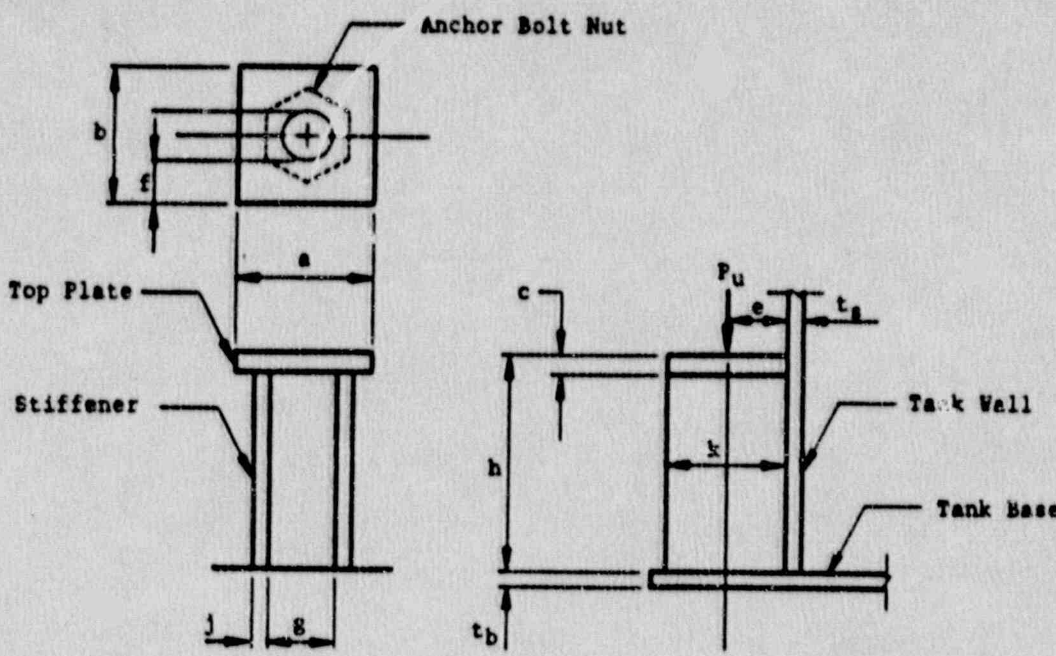


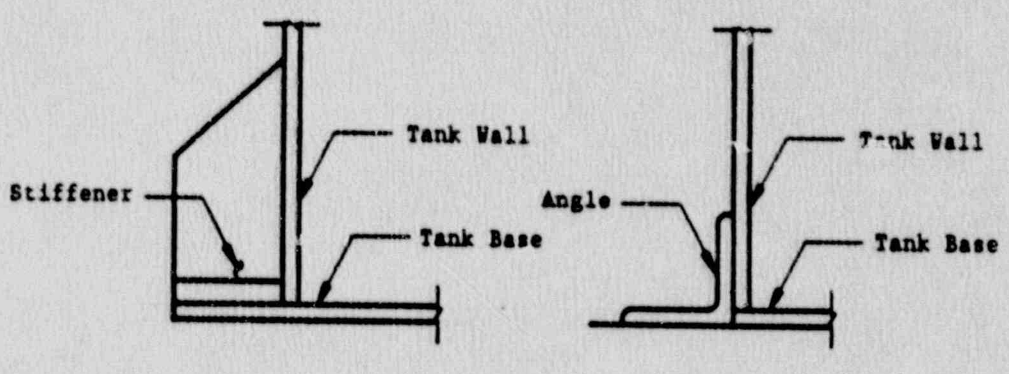
Figure 7-10. Base Overturning Moment Capacity Coefficient For Vertical Tanks (Source: Reference 26, Figure 2.12)



(a) Typical Plan and Outside Views

(b) Side View

Figure 7-11. Typical Anchor Bolt Chair
(Source: Reference 26, Figure 2.13)



(a) Side View

(b) Angle Chair Side View

Figure 7-12. Alternate Anchor Bolt Chairs
(Source: Reference 26, Figure 2.14)

7.4 HORIZONTAL TANKS

This section describes (1) the scope of horizontal tanks and heat exchangers and range of parameters which are covered by the screening guidelines and (2) the analysis procedure for determining the seismic demand on, and the seismic capacity of horizontal tanks and heat exchangers including their supports and anchorages.

7.4.1 Scope of Horizontal Tanks

The types of tanks covered by the screening guidelines in this section are cylindrical steel tanks and heat exchangers whose axes of symmetry are horizontal and are supported on their curved bottom by steel saddle plates. These types of tanks will be called "horizontal tanks" throughout this section. A typical horizontal tank on saddles is shown in Figure 7-13. (Note: All the figures and tables applicable to horizontal tanks are grouped together after Step 11 at the end of Section 7.4.) The range of parameters and assumptions which are applicable when using the guidelines to evaluate horizontal tanks are listed in Table 7-6. The nomenclature and symbols used for horizontal tanks are listed in Table 7-7.

The screening guidelines are based on the assumption that the horizontal tanks are anchored to a stiff foundation which has adequate strength to resist the seismic loads applied to the tank. All the base plates under the saddles are assumed to have slotted anchor bolt holes in the longitudinal direction to permit thermal growth of the tank, except for the saddle at one end of the tank which is fixed. The saddles are assumed to be uniformly spaced a distance S apart, with the two ends of the tank overhanging the end saddles a maximum distance of S/2. These assumptions and the range of parameters given in Table 7-6 have been selected to cover the majority of horizontal tanks and heat exchangers in nuclear power plants.

7.4.2 Seismic Demand/Capacity of Horizontal Tanks

A simple, equivalent static method is used to determine the seismic demand on and capacity of the anchorages and the supports for horizontal tanks. This approach is similar to the seismic demand/capacity evaluations described in Section 4.4 and Appendix C for other types of equipment requiring anchorage verification (switchgear, transformers, pumps, battery chargers, etc.). Note that it is not necessary to evaluate the seismic adequacy of the shell of horizontal tanks or the shell-to-support welds since these items are normally rugged enough to withstand the loads which can be transmitted to them from the anchor bolts and support saddles.

The screening guidelines contained in this section specifically address only the seismic loads due to the inertial response of horizontal tanks. If, during the Screening Verification and Walkdown of a tank, the Seismic Capability Engineers determine that the imposed nozzle loads due to the seismic response of attached piping may be significant, then these loads should be included in the seismic demand applied to the anchorage and supports of the tank. There is some discussion provided on this subject for piping loads applied to horizontal pumps in Appendix B.5.1, HP/BS Caveat 4; this discussion is also applicable to horizontal tank evaluations.

The guidelines in this section are in the form of tables, charts, and a few simple calculations to determine the seismic capacity of horizontal tanks in terms of the peak acceleration the tanks can withstand. This peak acceleration capacity is assumed to be composed of a uniform acceleration, λ, in the two horizontal directions, and 2/3 λ in the vertical direction. The screening guidelines include the effect of combining the three directions of acceleration by the square-root-of-the-sum-of-squares (SRSS) method. The seismic acceleration capacity, λ, is then compared with either the ZPA or the peak of the 4% damped, horizontal floor response spectrum, depending on whether: (1) the horizontal tank is rigid in the vertical or traverse direction (i.e., whether the tank shell acts as a rigid or flexible beam between the saddles);

or (2) the horizontal tank and its support system is rigid in the longitudinal directi...

The seismic adequacy of the following critical parts of horizontal tanks are evaluated in these screening guidelines:

- Anchor bolts and their concrete embedment
- Base plate bending
- Base plate-to-saddle weld
- Saddle bending and compression

Step-By-Step Procedure for Horizontal Tanks

Step 1 - Determine the following input data. See Figure 7-13 for location of some of these dimensions.

Tank:	D	(Diameter of tank) [ft.]
	L	(Length of tank) [ft.]
	t	(Thickness of tank shell) [in.]
	W_{tf}	(Weight of tank plus fluid) [lbf]
	γ_t or γ_h	(Weight density of horizontal tank or heat exchanger including fluid) [lbf/ft^3]
	H_{cg}	(Height of center-of-gravity of tank and fluid above the floor where the tank is anchored) [ft.]
Saddles:	S	(Spacing between support saddles) [ft.]
	h	(Saddle Height of saddle plate from the bottom of the tank to the base plate) [in.]
	G	(Shear modulus of saddle plate and stiffener material) [psi]
	E	(Elastic modulus of saddle plate and stiffener material) [psi]
	NS	(Number of saddles)

Base Plate: t_b (Thickness of base plate under saddle) [in.]

f_y (Minimum specified yield strength of saddle base plate) [psi]

t_w (Thickness of leg of weld between saddle and base plate) [in.]

e_s (Eccentricity from the anchor bolt centerline to the vertical saddle plate) [in.]

Bolts: NL (Number of bolt locations on each saddle)

NB (Number of anchor bolts at each bolt location)

d (Diameter of anchor bolt) [in.]

D' (Distance between extreme anchor bolts in base plate of saddle) [ft.]

Loading: Floor response spectrum at 4% damping

Confirm that the parameters and values determined in this step are within the range of applicable parameters given in Table 7-6. If they are, then the procedure given in this section is applicable to the subject horizontal tank; proceed to Step 2. If the horizontal tank does not meet this guideline, classify the tank as an outlier and proceed to Section 5, Outlier Identification and Resolution.

Step 2 - Determine the anchor bolt tension and shear load allowables from Appendix C, accounting for the effects of embedment, spacing, edge distance, and cracking in concrete, as discussed in Section 4.4 and Appendix C.

P_u' [lbf] (from Section 4.4 and Appendix C)

V_u' [lbf] (from Section 4.4 and Appendix C)

Step 3 - Determine the base plate bending strength reduction factor (RB). The width of the base plate that is stressed in bending is conservatively assumed to be equal to twice the distance between the centerline of the bolt and the vertical saddle plate; i.e., $2e_s$. The strength reduction factor is determined by taking the ratio of the base plate yield strength (f_y) over the maximum bending stress (σ):

$$RB = \frac{f_y}{\sigma} = \frac{f_y\, t_b^2}{3 P_u'}$$

Step 4 - Determine the base plate weld strength reduction factor (RW). The length of weld assumed to carry the anchor bolt load is taken to be equal to the distance from the bolt centerline to the vertical saddle plate; i.e., e_s. The strength reduction factor is the ratio of the weld allowable strength (30,600 psi) over the weld stress (σ):

$$RW = \frac{30{,}600 \text{ psi}}{\sigma} = \frac{2\sqrt{2}\ t_w\, e_s\, (30{,}600 \text{ psi})}{P_u'}$$

Step 5 - Determine the anchorage tension allowable using the strength reduction factors. The tension allowable anchorage load is based on the smaller of the strength reduction factors for base plate bending or base plate weld:

$$P_u = P_u' \times (\text{Smaller of: } RB \text{ or } RW)\ [\text{lbf}]$$

The shear allowable anchorage load is:

$$V_u = V_u'\ [\text{lbf}]$$

Step 6 - Calculate the following ratios and values:

$$\alpha = P_u/V_u$$

$$W_b = \frac{W_{tf}}{NS \cdot NL \cdot NB}$$

$$V_u/W_b$$

H_{cg}/D'

H_{cg}/S

$$F_1 = \sqrt{(NS)^2 + 1}$$

$$F_2 = \sqrt{\frac{NL^2\left(\frac{H_{cg}}{D'}\right)^2 + \left(\frac{2}{3}\right)^2 + \left(\frac{H_{cg}}{S}\right)^2 (NS)^2}{(NS-1)^2}}$$

Step 7 - Determine the acceleration capacity of the tank anchorage. The acceleration capacity (λ) of the tank anchorage is defined as the smaller of the two anchorage acceleration capacities λ_l or λ_u:

$$\lambda_l = \left(\frac{V_u}{W_b}\right)\left(\frac{1}{F_1}\right) \quad [g]$$

$$\lambda_u = \frac{\frac{V_u}{W_b} + \frac{0.7}{\alpha}}{\left(\frac{0.7}{\alpha}\right) F_2 + F_1} \quad [g]$$

$$\lambda = (\text{Smaller of } \lambda_l \text{ or } \lambda_u) \quad [g]$$

Step 8 - Determine whether the tank is rigid or flexible in the transverse and vertical directions. Enter Figure 7-14 (for horizontal tanks with weight density $\gamma_t \leq 75$ lbf/ft^3) or Figure 7-15 (for horizontal heat exchangers with weight density $\gamma_h \leq 180$ lbf/ft^3) with:

D (Diameter of tank) [ft.]

t (Thickness of tank shell) [in.]

and determine the maximum saddle spacing for rigid transverse and vertical frequency response (i.e., $F_{trans.} \geq 30$ Hz):

S_c [ft.] (from Figure 7-14 or 7-15)

If the maximum saddle spacing (S_c) is more than or equal to the actual spacing (S):

$S_c \geq S$

then the tank is rigid in the transverse and vertical directions, otherwise it is flexible.

Step 9 - Determine whether the tank is rigid or flexible in the longitudinal direction. The rigidity of the one saddle not having slotted holes in its base plate controls the frequency response of the tank in the longitudinal direction. The longitudinal stiffness (k_s) of the tank is determined by assuming the saddle plate and its stiffeners bend with a fixed (built-in) connection at the tank and a pinned connection at the base plate. The moment of inertia (I_{yy}) of the cross-sectional area of the saddle plate and its stiffeners should be determined at a cross-section just below the bottom of the cylindrical tank. Compute the resonant frequency of the tank in the longitudinal direction using the following equation:

$$F_{long.} = \frac{1}{2\pi}\sqrt{\frac{k_s\, g}{W_{tf}}} \qquad \text{[Hz]}$$

Where the saddle stiffness (k_s) is:

$$k_s = \frac{1}{\dfrac{h^3}{3\,E\,I_{yy}} + \dfrac{h}{A_s\,G}} \qquad \text{[lbf/in]}$$

If the longitudinal resonant frequency (F_{long}) is greater than or equal to about 30 Hz:

$$F_{long.} \geq 30 \text{ Hz}$$

then the tank is rigid in the longitudinal direction, otherwise it is flexible.

<u>Step 10</u> - Determine the seismic demand acceleration and compare it to the capacity acceleration. If the tank is rigid in all three directions; i.e.,

$S_c \geq S$ and

$$F_{long.} \geq 30 \text{ Hz}$$

then determine the ZPA from the 4% damped floor response spectrum (maximum horizontal component):

ZPA [g] (from 4% damped floor response spectrum at 33 Hz)

and compare it to the acceleration capacity of the tank anchorage:

λ [g] (from Step 7)

If

$$\lambda \geq ZPA$$

then the tank anchorage is adequate; proceed to Step 11. If the tank anchorage does not meet this guideline, classify the tank as an outlier and proceed to Section 5, Outlier Identification and Resolution, after completing the remainder evaluations in this section.

If the tank is flexible in any of the three directions, i.e.,

$S_c < S$ or

$$F_{long.} < 30 \text{ Hz}$$

then determine the spectral peak acceleration* from the 4% damped floor response spectrum (maximum horizontal component):

SPA* [g] (from peak of 4% damped response spectrum)

and compare it to the acceleration capacity of the tank anchorage:

λ [g] (from Step 7)

If

$$\lambda \geq SPA$$

then the tank anchorage is adequate; proceed to Step 11. If the tank anchorage does not meet this guideline, classify the tank as an outlier and proceed to Section 5, Outlier Identification and Resolution, after completing the remainder of the evaluations in this section.

Step 11 - Check the saddle stresses. Longitudinal shear is the main load that the saddle and its stiffeners must carry if the other saddles have slotted anchor bolt holes in the base plate. Except for small tanks, the saddle which carries the longitudinal earthquake shear loading should have stiffeners to resist this weak axis bending. In addition to the longitudinal shear load, there are several other loads in the other directions which should be considered; these other loads are carried equally by all the saddles. The loads to include in determining the stresses in the saddle and its stiffeners are listed below.

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* This horizontal tank evaluation procedure uses the assumption that the tank is full of water. This assumption always results in a conservative evaluation when the peak of the response spectrum is used to estimate the seismic demand acceleration.

If, however, the Seismic Capability Engineers elect to determine the fundamental natural frequency of the tank more accurately, and use a spectral acceleration corresponding to a frequency less than the frequency at the peak of the demand spectrum, then they should also consider the case where the tank may not be full. For seismic demand spectra with sharp increases over small frequency changes, the seismic demand load for evaluation of the tank anchorage (weight x spectral acceleration) may be greater for the partially filled tank than for the full tank.

- Longitudinal seismic loads
- Vertical compression load from dead weight
- Vertical seismic loads
- Overturning moment from transverse seismic load

The stresses in the saddle and its stiffeners should be determined in accordance with the combined compression and bending provisions of Part 1 of the AISC Manual of Steel Construction (Reference 29). If the stresses are less than or equal to 1.7 x AISC allowables (for safe shutdown earthquake loading), then the saddle is adequate and hence the tank is satisfactory for seismic loadings. If the saddle stresses exceed the AISC allowable, then classify the tank as an outlier and proceed to Section 5, Outlier Identification and Resolution.

Table 7-6

APPLICABLE RANGE OF PARAMETERS AND ASSUMPTIONS FOR HORIZONTAL TANKS[1]

Diameter of Tank	D	= 1 to 14 ft.
Length of Tank	L	= 4 to 60 ft.
Height of Center-of-Gravity of Tank and Fluid Above the Floor Where the Tank is Anchored	H_{cg}	= 1 to 12 ft.
Number of Saddles[2]	NS	= 2 to 6
Spacing Between Support Saddles[3]	S	= 3 to 20 ft.
Number of Bolting Locations[4] per Saddle[5]	NL	= 2 or 3
Number of Anchor Bolts per Bolting Location	NB	= 1 to 2
Distance Between Extreme Anchor Bolts in Base Plate of Saddle	D'	= 1 to 12 ft.
Ratio of Tank C.G. Height-to-Saddle Spacing	H_{cg}/S	= 0.1 to 2.0
Ratio of Tank C.G. Height-to-Distance Between Extreme Anchor Bolts	H_{cg}/D'	= 0.5 to 2.0
Weight Density of Horizontal:		
- Tanks (including fluid)	γ_t	= 60 to 75 lbf/ft^3
- Heat Exchangers (including fluid)	γ_h	= 130 to 160 lbf/ft^3

<u>Assumptions</u>:

1 Tanks are assumed to be cylindrical, horizontally oriented, and made of carbon steel.

2 Tanks are assumed to be supported on carbon steel plate saddles.

3 Saddles are assumed to be uniformly spaced a distance S apart with the tank overhanging the end saddles a distance S/2.

4 One or two anchor bolts are assumed at each bolting location.

5 All the base plates under the saddles are assumed to have slotted anchor bolt holes in the longitudinal direction to permit thermal growth of the tank, except for the saddle at one end of the tank which is fixed.

Table 7-7

NOMENCLATURE USED FOR HORIZONTAL TANKS

Symbol		Description [Units]
A_s	-	Cross-sectional area of saddle plate and its stiffeners (see Figure 7-13) [in.^{2}]
D	-	Diameter of tank (see Figure 7-13) [ft.]
D′	-	Distance between extreme anchor bolts in base plate of a saddle (see Figure 7-13) [ft.]
d	-	Diameter of anchor bolt [in.]
E	-	Elastic modulus of saddle plate and stiffener material [psi]
e_s	-	Eccentricity (distance) from the anchor bolt centerline to the vertical saddle plate (see Figure 7-13) [in.]
$F_{long.}$	-	Resonant frequency of tank in longitudinal direction [Hz]
$F_{trans.}$	-	Resonant frequency of tank in transverse/vertical direction [Hz]
F_1	-	Coefficient [dimensionless]
F_2	-	Coefficient [dimensionless]
f_y	-	Minimum specified yield strength of shell, chair, saddle, or base plate material [psi]
G	-	Shear modulus of saddle plate and stiffener material [psi]
g	-	Acceleration of gravity [386 in/sec^2]
H_{cg}	-	Height of center-of-gravity of tank and fluid above the floor where the tank is anchored [ft.]
h	-	Height of saddle plate from the bottom of the tank to the base plate (see Figure 7-13) [in.]
I_{yy}	-	Moment of inertia of cross-sectional area of saddle plate and its stiffeners about axis Y-Y (see Plan of Support S1 in Figure 7-13) [in.^{4}]
k_s	-	Stiffness of the saddle plate and its stiffeners in the direction of the longitudinal axis of the tank [lbf/in]
L	-	Length of tank (see Figure 7-13) [ft.]

Table 7-7 (Continued)

NOMENCLATURE USED FOR HORIZONTAL TANKS

Symbol		Description [Units]
NB	-	Number of anchor bolts at each bolt location [dimensionless]
NL	-	Number of bolt locations on each saddle [dimensionless]
NS	-	Number of saddles [dimensionless]
P_u	-	Allowable tensile load of tank anchorage [lbf]
P_u'	-	Allowable tensile load of anchor bolts [lbf]
RB	-	Strength reduction factor for base plate bending [dimensionless]
RE	-	Strength reduction factor for an anchor bolt near an edge [dimensionless]
RS	-	Strength reduction factor for closely spaced anchor bolts [dimensionless]
RW	-	Strength reduction factor for base plate weld [dimensionless]
S	-	Spacing between support saddles (see Figure 7-13) [ft.]
S_c	-	Maximum saddle spacing for rigid tank ($F_t \geq 30$ Hz) [ft.]
SPA	-	Spectral peak acceleration [g]
t	-	Thickness of tank shell [in.]
t_b	-	Thickness of base plate under saddle [in.]
t_w	-	Thickness of leg of weld [in.]
V_u	-	Allowable shear load of tank anchorage [lbf]
V_u'	-	Allowable shear load of anchor bolts [lbf]
W_b	-	Weight of tank per anchor bolt,

$$W_b = \frac{W_{tf}}{NS \cdot NL \cdot NB} \quad [\text{lbf}]$$

Table 7-7 (Continued)

NOMENCLATURE USED FOR HORIZONTAL TANKS

Symbol		Description [Units]
W_{tf}	-	Weight of tank plus fluid [lbf]
ZPA	-	Zero period acceleration [g]
α	-	Ratio of tensile to shear allowable anchorage load, [dimensionless] $\alpha = \frac{P_u}{V_u}$
γ_h	-	Weight density of horizontal heat exchanger including fluid [lbf/ft^3]
γ_t	-	Weight density of horizontal tank including fluid [lbf/ft^3]
λ	-	Acceleration capacity of tank anchorage [g]
λ_l	-	Lower acceleration capacity of tank anchorages [g]
λ_u	-	Upper acceleration capacity of tank anchorages [g]
σ	-	Stress [psi]

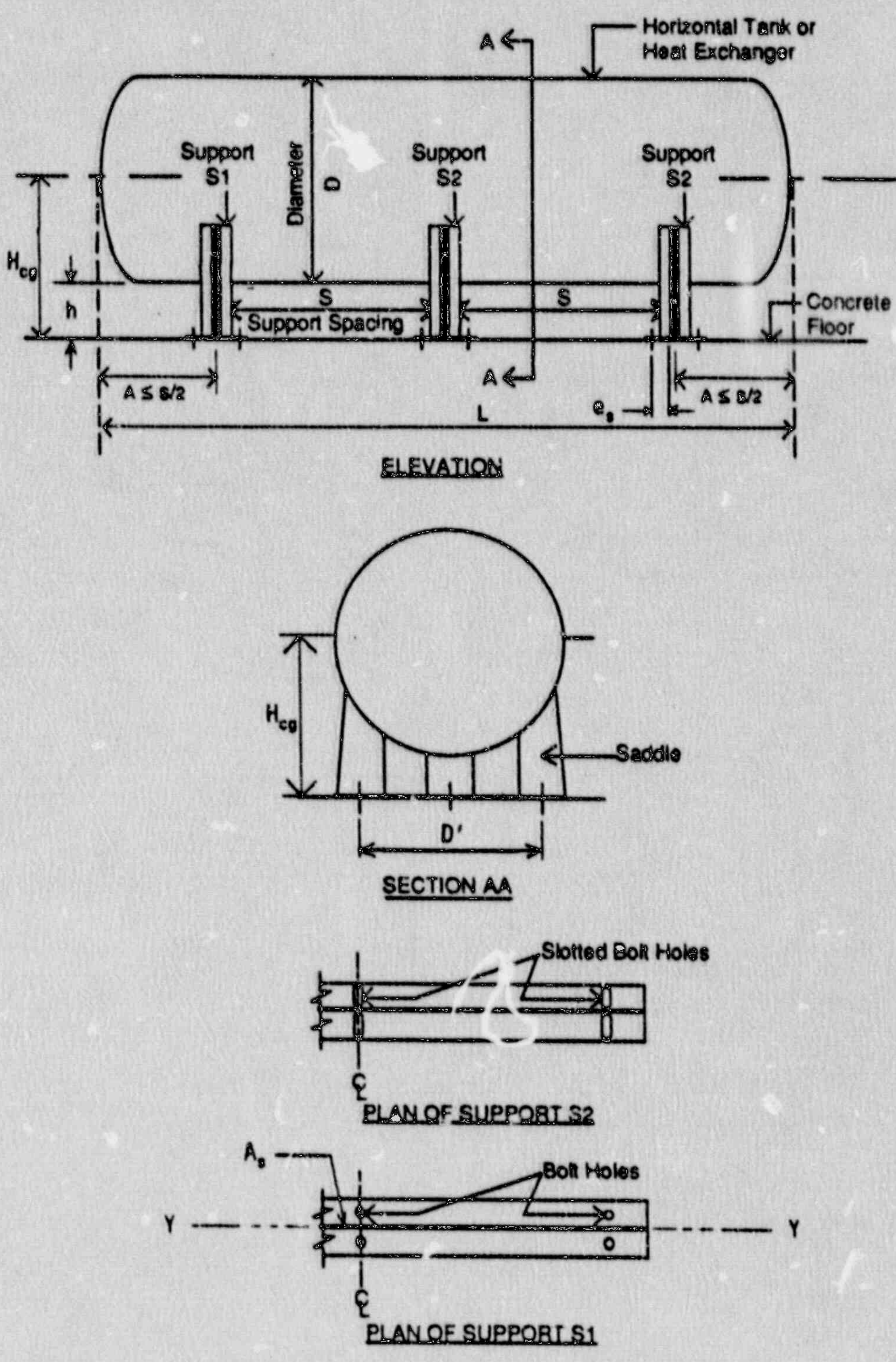


Figure 7-13. Horizontal Tank or Heat Exchanger
(Source: Reference 26, Figure 3.1)

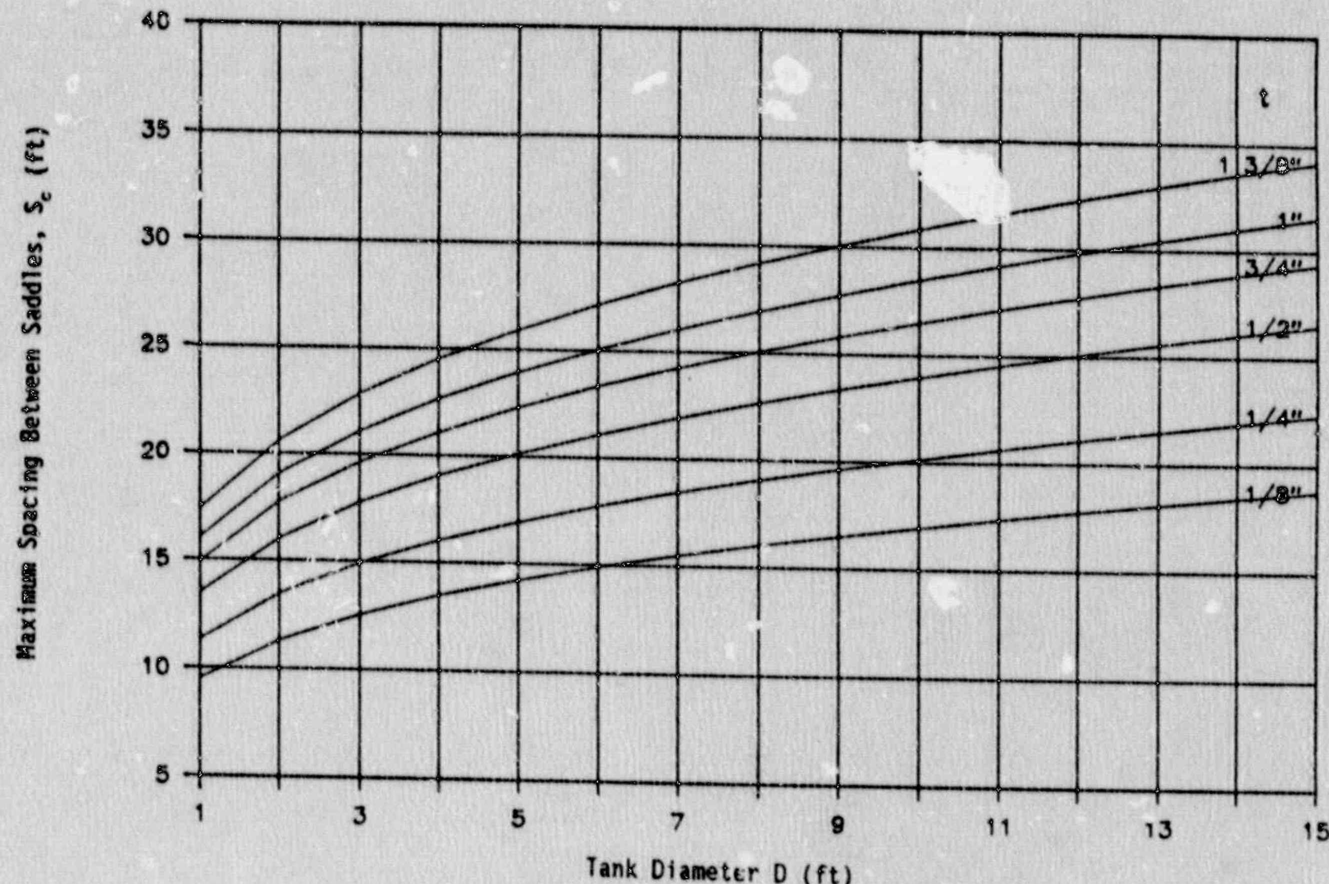


Figure 7-14. Maximum Saddle Spacing For Rigid ($F_{trans.} \geq 30$ Hz) Horizontal Tanks ($\gamma_t \leq 75$ lbf/ft^3) (Source: Reference 26, Figure 3.7)

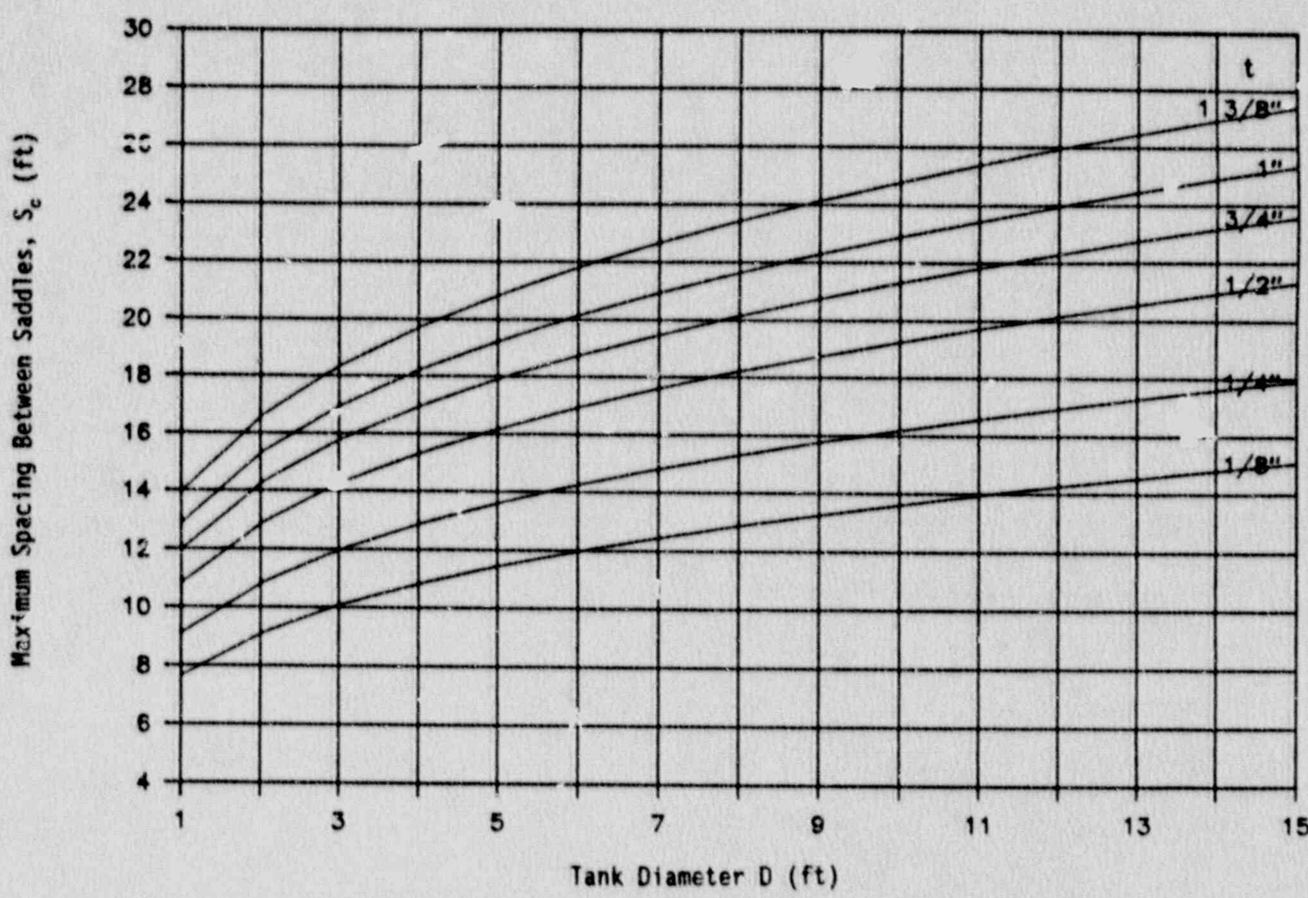


Figure 7-15. Maximum Saddle Spacing for Rigid (F_{trans} ≥ 30 Hz) Horizontal Heat Exchangers ($\gamma_h \leq 180$ lbf/ft^3) (Source: Reference 26, Figure 3.8)

7.5 OUTLIERS

An outlier is defined as a tank or heat exchanger which does not meet the screening guidelines for:

- Buckling of the shell of large, flat-bottom, vertical tanks,
- Adequacy of anchor bolts and their embedments,
- Adequacy of anchorage connections between the anchor bolts and the tank shell, or
- Flexibility of piping attached to large, flat-bottom, vertical tanks.

When an outlier is identified, proceed to Section 5, Outlier Identification and Resolution, and document the cause(s) for not meeting the screening guidelines on an Outlier Seismic Verification Sheet (OSVS) (Exhibit 5-1).

Note that all of the screening guidelines should be evaluated (i.e., go through all the steps in this procedure) so that <u>all</u> possible causes for a tank or heat exchanger being classified as an outlier are identified before proceeding to Section 5 to resolve it.

The conservative screening guidelines given in this section are intended for use as a generic screen to evaluate the seismic adequacy of tanks and heat exchangers. Therefore, if a tank or heat exchanger fails this generic screen, it may not necessarily be deficient for seismic loading; however, additional outlier evaluations are needed to show that it is adequate. Such analyses could include use of the principles and guidelines contained in this section and in Reference 26 for those types of tanks and heat exchangers not covered herein; e.g., vertical tanks supported on skirts or structural legs. When a tank or heat exchanger which is covered by this section fails to pass the screening guidelines, refined analyses could be performed which include use of more realistic or accurate methods instead of the simplified, conservative analysis methods used in this section and Reference 26. Other generic methods for resolving outlier are provided in Section 5.

7.6 DOCUMENTATION

The results of the engineering evaluations and field inspections performed using the guidelines in this section should be retained in the utility's files.

The results of the evaluations and inspections should also be documented by completing a Screening and Verification Data Sheet (SVDS) as described in Section 4.6. This SVDS would be included in the Seismic Evaluation Report submitted to the NRC at the completion of the Screening Verification and Walkdown.

If any of the screening guidelines contained in this section cannot be met, the tank should be classified as an outlier. The Outlier Seismic Verification Sheet (OSVS), found in Exhibit 5-1, should be completed to document the cause(s) for not meeting the screening guidelines.

Section 8

CABLE AND CONDUIT RACEWAY REVIEW

8.0 INTRODUCTION

The purpose of this section is to describe the Cable and Conduit Raceway Review which should be used to screen out from further consideration the cable and conduit raceways which can be shown to be seismically adequate.

The Cable and Conduit Raceway Review consists of: (1) a plant walkdown in which the raceways are evaluated against a set of Walkdown Guidelines, and (2) an analytical check of selected worst-case supports using a set of Limited Analytical Review Guidelines. Those portions of the raceway systems which do not pass these screening guidelines are classified as outliers and should be evaluated separately using alternative methods. The remainder of this Introduction summarizes the elements of the Cable and Conduit Raceway Review.

Basis for Screening Procedure

The screening procedure contained in this section is based primarily on the use of earthquake experience and shake table test data. With few exceptions, raceway systems have exhibited superior performance in past earthquakes and in shake table tests. This successful performance has occurred despite the fact that most of the raceway systems in the data base had not been designed for earthquakes. This section of the GIP provides guidance for understanding those aspects of raceway construction that provide acceptable performance and those features that might lead to poor performance. Other more refined or sophisticated seismic qualification techniques may be used to verify the seismic adequacy of cable and conduit raceway systems; however, these other methods are not described in detail in this document.

Seismic Review Guidelines

The seismic review guidelines contained in this section are applicable to steel and aluminum cable tray and conduit support systems at any elevation in a nuclear power plant, provided the Bounding Spectrum (shown in Section 4, Figure 4-2) envelopes the largest horizontal component of the 5% damped, free-field, safe shutdown earthquake (SSE) ground response spectrum to which the nuclear plant is licensed.

Cable and conduit raceway systems are considered seismically adequate if, during and following a safe shutdown earthquake, the electrical cables being supported by the raceway systems can continue to function and the raceway systems continue to maintain overhead support as defined in this section. Minor damage, such as member buckling or connection yielding, is considered acceptable behavior. The following guidelines are provided in this section:

- Walkdown Guidelines - The purpose of the walkdown guidelines is to verify that the raceway systems are bounded by the earthquake experience and shake table test data bases. This is done by checking the raceway systems against a set of "Inclusion Rules." Guidelines are also provided to assess "Other Seismic Performance Concerns" which could result in unacceptable damage. Finally, the Walkdown Guidelines provide guidance for selecting worst-case samples of the raceway support systems in the plant for which "Limited Analytical Reviews" should be performed. Section 8.2 covers these Walkdown Guidelines.
- Limited Analytical Review Guidelines - The purpose of the Limited Analytical Review is to check that selected worst-case, representative samples of the raceway support systems in the plant are at least as rugged under seismic loadings as those in the earthquake experience and shake table test data bases that performed well. If these samples do not pass this Limited Analytical Review, further evaluations should be conducted and the sample expanded as appropriate. Section 8.3 covers these Limited Analytical Review Guidelines.

The background for these guidelines is described in Reference 9. A summary of available experience data from earthquakes and shake table tests can be found in Reference 10. Additional background on the philosophy behind several aspects of the guidelines are included in Reference 11. These references should be studied in conjunction with the guidelines in this section before conducting the seismic adequacy rev[illegible] of raceway systems.

Outlier Resolution

An outlier is defined as a raceway hardware feature which does not meet the Inclusion Rules, has significant Other Seism[illegible] Performance Concerns, or does not satisfy the Limited Analytical Review Guidelines contained in this section. An outlier may be adequate for seismic loadings, however, additional evaluations should be performed or alternative methods used beyond the scope of evaluations contained in this section. Section 8.4 summarizes some of the methods for evaluating raceway outliers. These additional evaluations and alternative methods should be thoroughly documented to permit independent review.

Seismic Capability Engineers

The screening guidelines for performing in-plant walkdowns and limited analytical reviews should be applied by a Seismic Review Team (SRT) consisting of at least two Seismic Capability Engineers who meet the qualification and training guidelines given in Section 2. These engineers are expected to exercise engineering judgment based upon the guidelines given in this section and the background and philosophy used to develop these guidelines as described in References 9, 10, and 11. They should understand those aspects of raceway construction that provide acceptable performance and those features that may lead to poor performance.

When resolving outliers, it is especially important that the Seismic Capability Engineers exercise professional judgment since strict adherence to the guidelines in this section is not absolutely required since these guidelines are conservative to cover a wide range of applications. Instead the Seismic Review Team should be satisfied that the specific raceway system under review is adequately supported, based upon an understanding of the background and philosophy used to develop the guidel... in this section.

Scope of Review

The scope of review includes all the cable and conduit raceway systems in the plant which support electrical wire for equipment on the Safe Shutdown Equipment List (SSEL), as developed in Section 3.

In some older power plants it may be difficult to identify which raceways support the power, control, and instrumentation wiring for individual items of equipment. If this detailed information is not available, then all the cable and conduit raceway systems in the plant which could carry wiring for safe shutdown equipment should be reviewed using the guidelines contained in this section.

Organization of Section

The remainder of this section is organized as follows:

- Section 8.1 contains the requirements to which SQUG utilities commit when adopting the Cable and Conduit Raceway Review procedure for resolution of USI A-46.
- Section 8.2 contains the Walkdown Guidelines for conducting in-plant seismic adequacy reviews of as-installed conduit, cable trays, and their support systems.
- Section 8.3 contains the Limited Analytical Review Guidelines for checking the seismic adequacy of a bounding sample of the plant raceway support systems.
- Section 8.4 contains a summary of additional evaluations and alternative methods for assessing the seismic adequacy of raceway outliers.
- Section 8.5 contains guidelines on how to document the results of the Cable and Conduit Raceway Review.

8.1 SQUG COMMITMENTS

Members of SQUG adopting the Generic Implementation Procedure for USI A-46 resolution commit to the following in regard to the verification of seismic adequacy of cable and conduit raceways.

8.1.1 Walkdown of Cable and Conduit Raceways

The licensee shall conduct an in-plant review of conduit, cable trays, and their support systems. This review will accomplish the following objectives.

- Check in-plant raceway systems against Inclusion Rules (see Section 8.2.2 below for guidance).
- Judge whether Other Seismic Performance Concerns (discussed further in Section 8.2.3 below) which are noticed during the in-plant review could compromise the seismic adequacy of the raceway system.
- Select a representative, worst-case sample of raceway supports which will receive a Limited Analytical Review (discussed further in Section 8.3 below).

8.1.2 Limited Analytical Review

The licensee will conduct a Limited Analytical Review of selected cable tray and conduit supports considered to be representative worst-cases.

8.1.3 Documentation

The licensee will document the results of the cable and conduit raceway walkdown and the results of the Limited Analytical Review.

8.2 WALKDOWN GUIDELINES

Guidelines for conducting an in-plant seismic adequacy review of as-installed conduit, cable trays, and their support systems are presented in this section. The in-plant review has two purposes. The first is to check the raceway systems against certain Inclusion Rules to show the plant raceway systems are within the envelope of the earthquake experience and shake table test data bases. Guidelines are also provided to assess Other Seismic Performance Concerns which could result in unacceptable damage.

The second purpose of the in-plant review is to select representative, worst-case samples of the raceway supports in the plant on which Limited Analytical Reviews will be performed. The samples selected should encompass the diversity of the plant's support systems. The guidelines for performing the Limited Analytical Review are covered in Section 8.3.

8.2.1 General Walkdown Procedure

The general walkdown procedure given in this subsection describes a method for performing detailed in-plant screening and assessment of conduit and cable tray systems for seismic adequacy. This evaluation relies in part upon engineering judgment which should be exercised during the plant walkdown. This engineering judgment should be based on a good understanding of the performance of raceway systems in past earthquakes and in shake table tests.

The individuals on the raceway evaluation walkdown team should meet the requirements for Seismic Capability Engineers as defined in Section 2. The walkdown should be conducted by one or more Seismic Review Teams (SRT), each consisting of at least two Seismic Capability Engineers. The SRT should have a clear understanding and working knowledge of the screening guidelines presented below and have studied References 9, 10, and 11 thoroughly. They should also become familiar with the raceway design and construction practices of the plant, as well as with the general plant layout, raceway routing, and the design of raceway systems which cross building separations.

It is expected that the SRT will spend from one to two weeks in the plant. The duration may vary depending on the number of SRTs, the size of the plant, the complexity and accessibility of the plant raceway systems, and so forth.

It is recommended that the SRT take general notes, including rough sketches or photographs, as appropriate, of typical system attributes. More detailed notes should be taken to document decisions and evaluations made in the field. Walkdowns may be conducted on an area-by-area, system-by-system, or run-by-run basis. Time should be set aside on a daily basis for the SRT to review notes and sketches; to collect plant drawings or information, if needed; and to check selected supports by preliminary calculations, if warranted. Recommended documentation for the review is discussed in Section 8.5.

During the plant walkdown, the SRT should verify that the cable and conduit raceway systems meet the Inclusion Rules given in Section 8.2.2. In addition, the SRT should note and evaluate any of the Other Seismic Performance Concerns given in Section 8.2.3.

The Inclusion Rules identify the important limits of the earthquake experience and shake table test data bases and certain undesirable details which, if violated, could significantly compromise the seismic adequacy of a raceway system.

It is not necessary to check for compliance with the Inclusion Rules on every raceway system span or support, or even a large number of them in the plant. Instead, the SRT should examine in detail several supports or spans at a variety of locations in the plant to determine whether the general construction practice in the plant is in agreement with the Inclusion Rules. Thereafter, the SRT should be alert for, and evaluate any instances of non-compliance with the Inclusion Rules, if and when they are noticed as part of the walkdown. In this manner the SRT should visually inspect all the raceway systems within the scope of review.

If it appears that any of the Inclusion Rules are not met, then the SRT should investigate that portion of the raceway system in sufficient detail so that the team is convinced they understand the extent of the identified condition. That portion of the raceway system should then be classified as an outlier and evaluated using the guidelines given in Section 8.4.

The Other Seismic Performance Concerns given in Section 8.2.3 represent less significant or less well-defined conditions which should be evaluated during the plant walkdown. They are included in the guidelines of this section as representative of the type of concerns which the SRT should look for and evaluate to determine whether they could significantly compromise the seismic adequacy of the raceway system.

It is not necessary for all of the raceway systems in the plant to be inspected in detail for the Other Seismic Performance Concerns. Instead, the SRT should note and evaluate any of these concerns, if and when they are noticed as a part of the walkdown.

If it appears that any of the other Seismic Performance Concerns are not met, then the SRT should exercise their engineering judgment in assessing whether the condition significantly compromises the seismic adequacy of the raceway system. If it appears that the area of concern is not significant, then the SRT should note the condition on the walkdown documentation and provide a written explanation for their conclusion. However, if, in their judgment, the area of concern is significant, then that portion of the raceway system should be classified as an outlier and evaluated in a manner similar to an Inclusion Rule outlier.

Most of the plant walkdown should be conducted from the floor level. As different support configurations are observed during the plant walkdown, the SRT should examine them to familiarize themselves with the construction and details of the raceway system. When any suspect condition is observed from the floor level which may violate one of the Inclusion Rules or may represent a significant Other Seismic Performance Concern, then a closer examination should be carried out.

In general, the level of effort of the review should be enough to give the SRT confidence in the seismic adequacy of the plant raceway systems. Ultimately the SRT is responsible for the seismic evaluations. Their sound engineering judgment is the key to successful execution of these guidelines so that the review is both safety-effective and cost-effective. In this spirit, these guidelines are only guidelines, not requirements; the sound engineering judgment of the SRT is the most important factor, particularly when evaluating the seismic adequacy of outliers.

8.2.2 Inclusion Rules

The Inclusion Rules in this section identify the important limits of the earthquake experience and shake table test data bases and certain undesirable details which, if violated, could significantly compromise the seismic adequacy of a raceway system. These Inclusion Rules should be evaluated using the general walkdown procedure given in Section 8.2.1.

Rule 1 - Cable Tray Span. The length of unsupported cable tray between adjacent supports should not exceed about 10 feet in the direction of the run. When the cable tray extends beyond the last support in a run, it should not cantilever out (overhang) beyond this support more than 1/2 the maximum unsupported span length, i.e., 5 feet. This span and cantilever overhang were selected because they are supported by earthquake experience data.

Rule 2 - Conduit Span. The length of unsupported conduit in the direction of the run between adjacent supports, or the length of unsupported conduit cantilevered out from the last support in a run should not exceed the spans and overhangs given in the following table. These spans and overhangs were selected because they are supported by earthquake experience data and are consistent with the National Electrical Code (Reference 18).

Conduit Size (inches)	Approximate Maximum Spans Between Adjacent Supports (feet)	Approximate Maximum Cantilever Overhang (feet)
1/2 and 3/4	10	5
1	12	6
1-1/4 and 1-1/2	14	7
2 and 2-1/2	16	8
3 and larger	20	10

Rule 3 - Raceway Member Tie-downs. For cantilever bracket-supported systems, cable trays and conduit should be secured to their supports so the trays or conduit cannot slide and fall off the supports. Normal industrial friction type hardware, such as the "z-clip" commonly used for cable trays, is a sufficient means of attachment.

Systems do not have to be secured to every support, unless the supports are at the maximum spacing described above. For example, consider a 60-foot length of cable tray. If there is a support at each end and the interior supports are at the maximum span of 10 feet described in Rule 1, then the raceway system should be tied down at all seven supports in the 60-foot run. If there are more than seven supports, the trays need to be secured to only seven of these supports in any 60-foot run, regardless of how many additional supports there actually are in the run.

Rule 4 - Channel Nuts. Channel nuts used with light metal framing systems should have teeth or ridges stamped into the nuts where they bear on the lip of a channel as shown in Figure 8-1.

Rule 5 - Rigid Boot Connection. Strut systems supported by "boots" or similar rigid devices, especially plant-specific designs, should be evaluated on a case-by-case basis. Shake table tests have shown that a rigid boot overhead connection detail, as shown in Figure 8-2(a), has a significantly-reduced, vertical load-carrying capacity in seismic motion. Any gap between the vertical support member and the boot prevents the development of high clamping forces in the connection and thus causes a significantly reduced load-carrying capacity. Cable tray test specimens with this detail have collapsed in shake table tests.

A rigid boot connection with gaps can be upgraded to an acceptable connection by using a through bolt as shown in Figure 8-2(b). This connection has been shown to be acceptable by shake table tests.

Rule 6 - Beam Clamps. Beam clamps should not be oriented in such a way that gravity loads are resisted only by the clamping or frictional forces developed by the clamps. The earthquake experience data base includes many examples of beam clamps attached to the lower flange of structural steel beams such that the gravity loads are resisted by bearing of the inside top of the clamp on the top of the lower flange of the beam. On the other hand, beam clamps oriented so gravity load is resisted only by the clamping frictional force, as shown in Figure 8-3, might loosen and slip off in an earthquake and possibly cause a collapse.

Rule 7 - Cast-Iron Anchor Embedment. Threaded rod-hanger anchor embedments constructed of cast iron should be specially evaluated since there is a potential for a brittle failure mode. Plant documentation should be used to determine whether anchor embedments are cast iron. The earthquake experience data base includes examples where heavily-loaded rod hangers threaded into cast-iron inserts failed. The cast-iron anchor detail is shown in Figure 8-4. Failure modes included anchor pullout and anchor fracture where rods were only partially threaded into the anchor.

8.2.3 Other Seismic Performance Concerns

The Other Seismic Performance Concerns in this section represent less significant or less well-defined conditions which should be evaluated during the plant walkdown. They are included in the guidelines of this raceway evaluation section as representative of the type of concerns which the Seismic Review Team (SRT) should be looking for during the plant walkdown. When one of these Other Seismic Performance Concerns is found, the SRT should determine whether the area of concern could significantly compromise the seismic adequacy of the raceway system. These seismic concerns should be evaluated using the general walkdown procedure given in Section 8.2.1.

Concern 1 - Anchorage. The SRT should pay close attention to the review of anchorages for the raceway supports. The team should pay particular attention to system anchorages for heavily-loaded supports. When the type of anchorage detail cannot be determined by visual inspection, other methods of determining the anchorage detail may be used, provided the SRT is convinced they understand the actual details. For example, the plant design drawings, construction records, or procurement specifications may provide the unknown details. If overhead welds are not visible (for example, they are covered by fire retardant), other similar supports without the coating can be inspected, or as-installed plant documentation reviewed to gain understanding of the weld adequacy.

Adequacy of other types of anchorage such as plastic inserts or lead shield plugs for cable tray systems are not covered by these guidelines. However, the adequacy of anchorage such as plastic inserts or lead shield plugs on lightly-loaded conduit supports rigidly attached to a wall may be evaluated on a case-specific basis by using manufacturers' information, performing plant-specific tests, or performing proof tests. In addition, anchorage adequacy for lightly-loaded conduit supports which are rigidly attached to a wall with less than about 15 pounds dead load may be verified by giving the conduit a tug by hand.

Concern 2 - Cracks in Concrete. Visible large cracks, significantly spalled concrete, serious honeycomb or other gross defects in the concrete to which the cable tray or conduit supports are attached should be evaluated for their potential effects on structural integrity during an earthquake. The walkdown team should include supports of raceways anchored into concrete with gross defects in the sample selected for the Limited Analytical Review (Section 8.3).

Concern 3 - Corrosion. Excessive corrosion of cable trays, conduit, or supports should be evaluated for its effect on structural integrity. Evaluations should consider the alternative of estimating the strength reduction due to corrosion, if appropriate.

Concern 4 - Sag of Conduit and Cable Trays. There should not be a noticeable sag of the conduit or cable tray. As a general guideline, noticeable sags are defined as about 1 inch of deflection in 10 feet. If a noticeable sag is found, its cause should be determined before concluding corrective action is required. For example, the sag may have occurred during construction, have no relation to structural integrity, and thus not require any corrective measures. The walkdown team should include supports of raceways sagging due to heavy loads in the sample selected for the Limited Analytical Review (Section 8.3).

Concern 5 - Broken or Missing Components. Broken or missing cable tray and conduit components should be repaired or replaced. Locations where cable is routed near rough, sharp edges such as sheet metal cutouts should be evaluated for their potential to cause insulation damage in an earthquake.

Concern 6 - Restraint of Cables. Any cables above the top of the side rail should be restrained to keep them in the tray during an earthquake. Isolated cables in the center of the tray do not have to be restrained. If cables are not restrained, they should be evaluated to determine if they are a credible earthquake hazard to themselves (through flopping or falling out of the trays and becoming pinched or cut) or whether they are a hazard to nearby plant features (for example, by impacting a fragile component).

When cable trays have vertical drops of more than about 20 feet and flapping of the cables during an earthquake might cause pinching or cutting of the cables or impact with nearby fragile equipment, the cables should be restrained to keep them in the tray.

Concern 7 - Aging of Plastic Cable Ties. There is concern that old cable ties which are made of plastic-type materials may not have sufficient strength as a result of aging. Cable ties are frequently used to restrain cables within cable trays. If restraining straps are required on vertical drops or when trays are filled above the top of their side rails and those restraining straps are of a plastic-type material, then the walkdown engineers should make a brief qualitative evaluation by physically pulling or tugging on a few of the straps or enclosed cables to ensure that the straps have not become brittle. If the straps break or easily fail under this simple test, then their effectiveness in an earthquake is obviously questionable and they should be replaced in those areas where they are needed.

Concern 8 - Hard Spots. Occasional stiff supports in long flexible runs of cable trays or conduit should be evaluated to determine if the seismic movement of the run could cause the stiff support to fail. This concern is mainly associated with longitudinal motion. Cable tray or conduit systems with a long run of supports that are relatively flexible in the longitudinal direction may also contain a support that is relatively stiff as shown in Figure 8-5. The stiff support may thus be subjected to considerable load and fail due to loads from earthquake-induced, longitudinal movement of the cable tray or conduit run. Where the stiff support is located around the bend from the long run, the flexibility and ductility of the bend in the tray or conduit will typically prevent failure of the stiff support from being a credible event. The SRT should review Reference 19 which provides examples of undamaged long, raceway runs from the earthquake experience data base.

The Limited Analytical Review Guidelines in Section 8.3 include an evaluation for fatigue effects of fixed-end rod hanger trapeze supports. The walkdown team should note instances of occasional short, fixed-end rod hangers (stiff supports) in raceway runs with predominantly longer, more flexible supports. These should be specially evaluated for possible failure due to fatigue using the Rod Hanger Fatigue Evaluation methodology given in Section 8.3.6. Rod hanger trapeze support systems which are eccentrically-braced should also be evaluated.

Concern 9 - Seismic Interaction. The SRT should use the seismic interaction assessment guidelines given in Section 4.5 and Appendix D to look for potential seismic interaction hazards. Raceway systems attached to or in the vicinity of unanchored components, or unrestrained block walls, should be noted and evaluated.

It may also be necessary to evaluate the seismic interaction effect of a single isolated support which could fail and fall onto a nearby fragile item of safe shutdown equipment.

As described in Section 8.3.9, a single isolated support in a cable tray system can be assumed to fail if its adjacent support members provide sufficient redundancy to carry its share of the load.

8.2.4 Selection of Sample for Limited Analytical Review

The purpose of this subsection is to provide guidelines for selecting representative, worst-case samples of raceway supports on which Limited Analytical Reviews will be performed. The samples should include representative samples of the major different types of raceway support configurations in the plant. The sample size will vary with the diversity and complexity of the design and construction of each specific plant's raceway support system. As a general guideline, 10 to 20 different sample supports should be selected.

Before the samples are selected, the Seismic Capability Engineers should become familiar with the Limited Analytical Review Guidelines in Section 8.3 and should review the sample evaluations contained in Reference 9.

During the plant walkdown, notes should be taken which describe the basis for selection of each sample. The location of the selected sample should be noted, and detailed sketches of the as-installed support should be made. As-built sketches should include the support configuration, dimensions, connection details and anchorage attributes, member sizes, and loading. Any additional information that may be considered relevant to the seismic adequacy of the sample support should be noted in detail.

The Seismic Capability Engineers should seek out the most heavily-loaded raceway support for each configuration. Deep cable fill, long spans, sagging raceways, multiple tier systems, top supports at vertical runs, and fire protective coatings are indicators of heavy load. Of particular importance are raceway support systems that appear to have possibly more load than originally designed for. These can be identified by the presence of other plant components attached to the raceway support, such as pipe supports, HVAC duct supports, and tack welded-on conduit supports.

Conduit and cable tray supports with anchorages that appear marginal for the supported weight are good candidates for sample evaluation. Anchorages of undersized welds, incomplete welds, or welds of poor quality should also be included as samples. When overhead miscellaneous support steel, such as steel angle, is used specifically as an anchor point to support the raceways, its anchorage to the building structure should also be reviewed, and included as part of the sample, especially if its anchorage appears to be the weak link in the load path back to the structure.

It may facilitate decision-making processes in the plant if some sample calculations are performed prior to walkdowns. As an example, simple screening tables can be developed which list anchor capacities and raceway system weights. These tables would enable rapid assessment of certain anchors appearing marginal for the supported load.

8.3 LIMITED ANALYTICAL REVIEW GUIDELINES

This subsection describes the Limited Analytical Review which should be performed on cable tray and conduit supports. Analytical review calculations should be conducted to evaluate the structural integrity of the raceway supports chosen as representative, worst-case samples of the plant raceway support systems. The Limited Analytical Review Guidelines given in this section address structural integrity by correlation with raceway support systems that performed well in past earthquakes. The purpose of the calculations is not to estimate actual seismic response and system performance during an earthquake. Rather, the purpose of the calculations is to show that cable tray and conduit supports are at least as rugged as those that performed well as evidenced by past experience. It is important to understand the difference between these two purposes.

The Limited Analytical Review Guidelines are primarily based on the back-calculated capacities of raceway supports in the seismic experience data base. The checks of these guidelines are formulated to ensure that cable tray and conduit supports are seismically rugged, consistent with the seismic experience success data. The checks include the use of static load coefficients, plastic behavior structural theory, and engineering judgment. Reference 11 should be read by the Seismic Capability Engineers since it provides considerable discussion and background information on the philosophy for the analytical review process.

The analytical checks and evaluations discussed in this section are as follows:

- Dead Load Check
- Ductility Check
- Vertical Capacity Check
- Lateral Load Check
- Limit State Check
- Rod Hanger Fatigue Evaluations
- Floor-to-Ceiling Support Evaluations
- Base-Mounted Support Evaluations
- Redundancy and Consequence Test

Allowable capacities and raceway system weights are also discussed in this section.

The relationship between the above analytical checks for suspended raceway support systems is shown in a logic diagram in Figure 8-6. It is suggested that this figure be used while reading the following descriptions of these analytical checks.

The raceway supports should pass a normal engineering dead load design review to working stress level allowable loads. This Dead Load Check is described in Section 8.3.1. This is the only check needed for rigid, wall-mounted supports. Rigid-mounted conduit and cable trays are inherently very stable and subject to minimal seismic amplification. A detailed dead load design review of these systems provides ample margin for seismic effects. The working stress level allowable loads which should be used are described in Section 8.3.10.

The Ductility Check is described in Section 8.3.2. As shown in Figure 8-6, supports characterized as ductile do not require an explicit lateral load check. Instead, seismic ruggedness for ductile supports is assured by the 3 times dead load (3 X DL) Vertical Capacity Check (Section 8.3.3). The high vertical capacity of the ductile data base raceway supports is the main attribute credited for their good seismic performance.

Supports that may not respond to seismic loads in a ductile manner should be checked for lateral load capacity. The Lateral Load Check, described in Section 8.3.4, is in the form of an equivalent static lateral load coefficient. Because this static coefficient is derived from the earthquake experience data base, it is considered applicable to ground motion consistent with the Bounding Spectrum shown in Section 4, Figure 4-2. A method for scaling down the load coefficient for sites with lower ground motion response spectra is provided in Section 8.3.4.

The simple equivalent static lateral load method becomes overly conservative for suspended supports with long drop vertical support members from overhead. This is because calculated moments at the ceiling connection become very large. Unless the vertical support member is very rigid, lateral load effects may be limited by seismic response peak displacements. Section 8.3.4 provides a method for determining more realistic, deflection-controlled lateral loads for evaluation of these cases.

As shown in Figure 8-6, ductile supports not passing the Vertical Capacity Check may instead be evaluated by a Limit State Check as discussed in Section 8.3.5. The simple 3 X DL Vertical Capacity Check of Section 8.3.3 provides a quick, conservative means for assuring seismic ruggedness, consistent with the experience data; however, for certain configurations of raceway support systems, especially unbraced rod hanger trapeze systems, the Vertical Capacity Check may be too conservative.

The principle behind the Limit State Check, as described in Section 8.3.5, is that the support anchorage capacity need only be greater than the maximum possible reactions from plastic hinge formation in the support, while also under dead load. This principle only applies to supports that are suspended from above and that are characterized as ductile following the guidelines of Section 8.3.2.

Although rod hanger trapeze supports may be characterized as ductile for seismic loading, the fatigue life of the threaded rod hangers may limit seismic capacity when fixed-end connections are subject to large bending strains. Rod Hanger Fatigue Evaluations should be done using the guidelines in Section 8.3.6 for rod hanger trapeze supports with fixed-end rods.

The checks described above and illustrated in the Figure 8-6 logic diagram directly apply only to seismic evaluations of suspended (and wall-mounted) raceway supports. Similarly, simple evaluation methods may also be applied to floor-to-ceiling supports and base-mounted supports, as long as consideration is given to lack of pendulum restoring force effects and instabilities that may arise from plastic hinge formation.

Floor-to-Ceiling Support Evaluations are discussed in Section 8.3.7. Ductility arguments may only be used if the support's base mount can be neglected (i.e., treating the support as if it is suspended). When the base mount is required to help resist vertical load, Lateral Load Checks of the top and bottom connections, as well as buckling capacity checks of the vertical support member, are warranted.

Base-Mounted Support Evaluations are discussed in Section 8.3.8. These supports cannot be characterized as inherently ductile, and strength checks are required for both equivalent lateral and longitudinal loads. In addition, the base connection hardware details should be reviewed for rigidity. Slight connection slips that may lead to acceptable behavior for suspended systems can result in an additional overturning moment due to P-delta effects (i.e., eccentric loadings) for base-mounted supports and should be reviewed.

The Limited Analytical Review Guidelines provide a conservative means for screening out those raceway supports which are seismically adequate. Isolated instances of supports which do not meet the Limited Analytical Review checks may be accepted if there is adequate redundancy in the adjacent raceway support system, and if there is no safety consequence associated with failure of the isolated support. The Redundancy and Consequence Check is described in Section 8.3.9 and is illustrated in the logic diagram of Figure 8-6.

If a support fails to meet the Limited Analytical Review Guidelines, then it should be considered to be an outlier only for this simple screening evaluation method. More detailed analyses or tests may be performed on the outlier to demonstrate its seismic ruggedness. For example, the raceway system network, especially in areas such as dense cable spreading rooms, may be too stiff to transfer significant seismic loads to its supports.

If supports of the worst-case sample selection do not meet the Limited Analytical Review checks, the review team should develop an understanding of what supports in the plant are impacted by this analysis result. It is not intended that the bounding sample be grossly expanded and that many calculations be generated if the analytical checks are not met.

Note that the Limited Analytical Review Guidelines only have to be satisfied in an approximate manner. For example, if a support has a capacity which is about 10% less than the allowable (e.g., only 2.7 times Dead Load rather than the desired 3.0 times Dead Load), the team may still find the support acceptable based on their professional judgment.

The Vertical Capacity and Lateral Load Checks should be done using realistic capacity allowables as discussed in Section 8.3.10.

The raceway system weights that should be used for these Limited Analytical Reviews are described in Section 8.3.11.

8.3.1 Dead Load Check

Back-analysis of raceway supports in the data base indicates that most systems have adequate dead load design. A detailed dead load design review of the worst-case sample conduit and cable tray supports should be conducted using normal design working stress allowable loads. The check should consider the as-installed configuration, connection detailing, and loading condition of the raceway support. All components such as bracket members, support members, conduit clamps, internal framing connections, and support anchorage should be checked. All system eccentricities, including load to anchor point eccentricity, should be considered, excluding evaluation of clip angle bending stresses. (Note, however, that clip angle bending stress should be considered during evaluation of base connections of floor-mounted supports as discussed in Section 8.3.8.) Loads from other attached systems, such as piping or ducting, should be considered.

This is the only check recommended for cable tray and conduit supports directly mounted to or rigidly cantilevered from an adjacent structural wall. These support types have been shown to be inherently rugged by past experience. The mounting configuration is generally rigid for lateral response, so dynamic amplification of seismic motion is minimal. Performing a detailed dead load design review for these support types ensures adequate margin for seismic loads.

Consideration should also be given to the seismic adequacy of the wall to which cable tray and conduit raceway supports are attached. Reinforced concrete structural walls are not a concern. With the exception of very light conduit, anchorage into transite walls (asbestos fiber board) and gypsum board partitions should be considered outliers. Masonry walls should be checked to verify that they have been reviewed for seismic adequacy as part of the IE Bulletin 80-11 program. The anchor capacities in Appendix C cannot be used for expansion anchors in masonry block walls (especially if the anchorages are installed in hollow block cores or mortar joints) or in nonstructural material; reduced values should be used. The anchorage of partition walls and shielding walls should be checked.

8.3.2 Ductility Check

An evaluation should be conducted of the supports selected for review to characterize their response to lateral seismic motion as either ductile or potentially non-ductile. Supports suspended only from overhead may be characterized as ductile if they can respond to lateral seismic motion by swinging freely without degradation of primary vertical support connections and anchorage. Ductile, inelastic performance such as clip angle yielding or vertical support member yielding is acceptable so long as deformation does not lead to brittle or premature failure of overhead vertical support.

Review of typical conduit and cable tray support systems in the earthquake experience and shake table test data bases indicates that many overhead mounted support types are inherently ductile for lateral seismic motion. Back-analysis of many data base conduit and cable tray supports predicts yielding of members and connections. These data base systems performed well, with no visible signs of distress. Ductile yielding of suspended supports results in a stable, damped swaying response mode. This is considered to be acceptable seismic response.

The ductility review of anchorage connection details is most important for rigid-type suspended raceway supports. Supports with rigid, non-ductile anchorage that do not have the capacity to develop the plastic strength of the vertical support members can possibly behave in a non-ductile fashion. Examples include large tube steel supports welded to overhead steel with relatively light welds, or rigid supports welded to large base plates and outfitted with relatively light anchorage. These types of support systems are not well represented in the data base.

The seismic design of certain raceway support members may have been controlled by high frequency requirements rather than design loads, yet anchors may have been sized by the design loads. These types of supports may have low seismic margin due to loads placed on the support which were not considered by the original design. Supports with rigid, non-ductile anchorage are subject to further horizontal load strength review (see Section 8.3.4).

Examples of ductile and non-ductile raceway support connection details and configurations are shown in Figures 8-7 and 8-8, respectively, and are described below.

<u>Standard Catalog Light Metal, Strut Framing Members, Clip Angles, and Bolts With Channel Nuts</u>. The seismic experience data include many examples of unbraced supports suspended from overhead, constructed of standard catalog light metal, strut framing channels, clip angles, and bolts with channel nuts as shown in Figures 8-7A, B, C, and D. The good performance of these support types indicates that they may be characterized as ductile. This is even true of supports constructed of standard catalog light metal strut framing, gusseted, clip angle connections. Review of shake table tests of raceway support systems shows that slight slipping of channel nuts due to prying action of gusseted clip angles leads to acceptable behavior for suspended supports. The tests show that once the overhead moment connection is relaxed by this slippage, the support system is free to swing without additional degradation of the overhead connection.

<u>Welded Steel Members</u>. The philosophy of acceptable seismic response involving clip angle connection yielding for supports constructed of light metal, strut framing is extended to supports constructed of welded steel members as shown in Figure 8-7F. If an anchor point connection weld is stronger than the vertical member, then a plastic hinge will be able to form in the vertical member, allowing ductile response without weld failure. A support is seismically rugged so long as overhead support is maintained. In this case, plastic hinge action in the vertical member prevents transmission of loads capable of failing the welded anchorage point. For open channel structural sections, an all-around fillet weld whose combined throat thicknesses exceed the thickness of the part fastened, may be considered capable of developing the plastic hinge capacity of the open channel section vertical member. If the plastic hinge capacity of the framing support member exceeds the capacity of the weld, as shown in Figures 8-8A and B, then a brittle failure is possible, which is not acceptable seismic performance. For light metal, strut framing members, welded connections are likely to be non-ductile and thus not capable of developing plastic moment capacity of the framing member.

<u>Ceiling Connection Plate Secured with Expansion Anchors</u>. Raceway supports with overhead anchorage provided by a plate attached to concrete with expansion anchors may also be shown to be ductile. The anchorage may be characterized as ductile if it is stronger than the plastic flexural strength of the vertical support member. A simple anchor moment capacity estimate may be used, by multiplying the bolt pullout capacity times the distance between the bolts or center of bolt groups. In some cases, it may be possible to demonstrate ductility if the ceiling connection plate is the weak link in the anchorage load path. This is similar to the case of clip angle bending. The key to characterizing a support as ductile or non-ductile is reviewing the anchorage load path, and determining if the weak link responds in a ductile or brittle manner.

<u>Braced Cantilever Bracket and Trapeze Frame Supports</u>. The presence of a diagonal brace in a support, as shown in Figures 8-8E and F, has the potential of significantly increasing the pullout loads on anchorage when the support is subjected to horizontal motion. This is a function of the support geometric configuration, the realistic capacity of the brace, and the realistic capacity of the anchorage. Non-ductile behavior is possible when the brace reaction to horizontal load plus dead load has the capability of exceeding the primary the support anchor capacity. If a brace buckles or has a connection failure before primary support anchor capacity is reached, then the support may be considered as ductile. Braced supports are subject to further horizontal load capability review in Section 8.3.4 with a focus on primary support anchorage.

<u>Unbraced Rigid Trapeze Frames</u>. Trapeze frames constructed as moment-resisting frames, such as those with a number of stiff cross-beam members welded to the two vertical supports as shown in Figure 8-8D, have the potential of significantly increasing the pullout loads on anchor bolts when the frame is subject to horizontal motion. Non-ductile behavior is possible when the rigid frame anchor point reactions to horizontal load exceed the anchor capacity. Unbraced rigid trapeze frames are subject to further horizontal load strength review in Section 8.3.4 with focus on anchorage.

<u>Floor-Mounted Supports</u>. Plastic behavior of floor-mounted supports may lead to structural instability. Ductility, as defined by these guidelines, only applies to suspended systems. Floor-mounted supports are characterized as non-ductile, and are subject to further horizontal strength review in Sections 8.3.7 and 8.3.8 with focus on stability.

<u>Rod Hanger Trapeze Supports</u>. Supports constructed of threaded steel rods with fixed-end connection details at the ends of the rods behave in a ductile manner under horizontal motion; however, relatively short rods may undergo very large strains due to bending imposed by horizontal seismic motion, at the fixed ends of the rods. Low cycle fatigue may govern response. Rod hanger trapeze supports with short, fixed-end rods should be evaluated for low cycle fatigue effects in Section 8.3.6.

No further review of horizontal response capability is required of supports characterized as ductile. Only the support vertical capacity need be verified, as discussed in Sections 8.3.1 and 8.3.3. If a support is characterized as non-ductile or has questionable ductility, then its lateral load capacity should be verified, as discussed in Section 8.3.4, as shown in the logic diagram for making these decisions in Figure 8-6.

8.3.3 Vertical Capacity Check

This check concentrates on the support anchorage, focusing on the weak link in the support anchorage load path. Back-analysis of conduit and cable tray support systems in the data base indicates that most supports have relatively high, vertical anchorage capacity. The high capacities are inherent in standard available connection hardware used for raceway support systems. The high vertical capacity is one of the primary design attributes that is given credit for good seismic performance. The Vertical Capacity Check evaluates whether the vertical capacity to dead load demand ratio is in the range of support systems in the data base that performed well. The high vertical capacity provides considerable margin for horizontal earthquake loading.

This Vertical Capacity Check is only applicable to raceway supports suspended from overhead and characterized as ductile; non-ductile raceway supports are subjected to the lateral Load Check and need not have a Vertical Capacity Check applied. The Vertical Capacity Check is an equivalent static load check, in which the support is subjected to 3.0 times Dead Load in the downward direction, using the capacities discussed in Section 8.3.10. This check is limited to the primary raceway support connections and the anchorage of suspended support systems. It is not necessary to evaluate clip angle bending stress or secondary support members. Base-mounted supports are not subject to this check (see Section 8.3.8); however, the lower support member of floor-to-ceiling configurations should be checked for buckling if the upper connection cannot resist 3.0 times Dead Load by itself as discussed in Section 8.3.7.

Eccentricities resulting in anchor prying and eccentricities between vertical support members and anchor points should, in general, be ignored. For cantilever bracket support types, the eccentricity of the cantilevered dead load should be ignored. This concept is the result of back-analyses of data base cable tray supports and is consistent with limit state conditions observed in test laboratories. Even if overhead moment capacity is completely lost, the vertical support integrity is maintained, as the support balances itself with the center of mass below the anchor point. It is important to realize that this calculational method is only used to demonstrate seismic adequacy by comparison with experience data. It is not expected, and it has not been shown by the experience data, that a support will end up in this deformed position after an earthquake on the order of the Bounding Spectrum shown in Figure 4-2 of Section 4.

For trapeze frame and rod-hung supports, load distribution between the two vertical framing members should be considered if the center of the load is significantly distant from the centerline of the support frame. The bending strength and stiffness of frame members should be checked for transfer of the load between anchor bolts when overhead support is provided by light metal framing with anchor bolts spaced at relatively large intervals and when multiple anchor bolts are needed to resist the vertical load.

For most conduit and cable tray support systems, the anchorage is the weak link in the load path. For these support systems the Vertical Capacity Check is simply a comparison of anchor capacity to 3.0 times the supported load. The 3.0 times dead load static coefficient should not be reduced if the design basis earthquake ground motion response spectrum for that plant site is less than the Bounding Spectrum shown in Figure 4-2. This is because there are only a few supports in the earthquake experience data base which have back-calculated vertical capacities less than 3.0 times Dead Load. However, if the 3.0 times Dead Load guideline is not met, which may be the case for certain flexible trapeze frame raceway supports, then vertical capacity may instead be verified by performing a Lateral Load Check (Section 8.3.4) or Limit State Check (Section 8.3.5).

8.3.4 Lateral Load Check

A Lateral Load Check should be performed for the bounding case raceway supports that are characterized as potentially non-ductile. The Lateral Load Check is in the form of an equivalent static lateral load coefficient. The Lateral Load Check compares the ratio of horizontal load capacity divided by dead load demand (for potentially non-ductile supports) to the same ratios for support systems in the seismic experience data base that performed well. Because many of these data base raceway systems were subjected to earthquake ground motions that may have been greater than the Safe Shutdown Earthquakes (SSEs) for many plants, provisions for scaling down the equivalent static horizontal loads are given below.

If a support is ductile, then no further review of horizontal response capability is required, and the support may be shown to be seismically rugged by the Vertical Capacity Check (Section 8.3.3). If a support is non-ductile or has questionable ductility, then it should be analyzed for one of the following transverse load conditions:

- Dead load plus a 2.0g horizontal acceleration in the transverse direction. The horizontal acceleration may be scaled down linearly by the minimum ratio of the design basis earthquake ground motion spectral acceleration for the plant site divided by the corresponding spectral acceleration of the Bounding Spectrum given in Figure 4-2.
- Dead load plus a transverse acceleration of 2.5 times the Zero Period Acceleration (ZPA) of the floor response spectrum for the anchor point in the plant where the raceway system is attached.
- For elevations lower than about 40 feet above plant grade (see definition of "effective grade," in Section 4.2.3), dead load plus a transverse acceleration of 2.5 times the floor ZPA where the floor ZPA is equal to the free-field ground ZPA times 1.5 (to account for building amplification), times 1.25 (to adjust for median-centered response).

For these loading conditions, only the tributary mass corresponding to dead load on the support should be considered.

The loading condition selected should be used consistently for all the plant raceway support systems selected as samples in any particular building. Different methods may be used for different structures. For example, the floor ZPA scaling method may be preferable for rock-founded structures or soil-founded structures for which realistic floor response spectra may be available. The scaled 2.0g method may be preferable for soil-founded structures, such as diesel generator buildings, for which realistic floor response spectra may not be available.

The simple equivalent static load coefficient method may be too conservative for supports with long drops from the ceiling anchorage to the raceways. The static coefficient method predicts very high connection bending moments in these cases. In this case, the bending moment imposed on the ceiling connection may be limited by peak seismic deflection and not seismic accelerations. This is consistent with observations of back-calculated static coefficient capacities from the experience data. The lowest back-calculated capacities were often from supports with long drops and were not considered representative (i.e., they were not used to attempt to justify a static coefficient less than 2.0g).

If the support has long vertical members and has low natural frequency, then an alternative loading condition of dead load plus reaction forces due to a realistic estimate for seismic deflection imposed in the transverse direction may be used. A conservative estimate for seismic deflection may be obtained by using floor spectral displacement at a lower bound frequency estimate considering only single degree of freedom pendulum response of the support.

For diagonally-braced supports with ductile overhead anchorages, the load reaction imposed on the support anchorage during the Lateral Load Check does not need to exceed the buckling capacity of the brace or its connections. For example, if it is shown that a brace buckles at 0.80g lateral load, then this load should be used for the Lateral Load Check and not 2.0g. For diagonally-braced supports where the anchorage is not ductile, the portion of the lateral load that is not resisted by the brace should be redistributed as bending stress to the overhead connection. The loads in the diagonal brace will cause additional vertical and horizontal loads on the anchorage, which should be accounted for.

An upper and lower bound estimate should be used for buckling capacity of the brace, whichever is worse, for the overhead anchorage. There is considerable variation in test data capacity for light metal strut framing connections. An upper bound estimate of 2.0 times the realistic capacities discussed in Section 8.3.10 can be used for these connection types.

The evaluation method of ensuring that anchor capacities are greater than reactions from inelastic response of other components in the support system is referred to as limit state evaluations. The optional Limit State Check is discussed in Section 8.3.5. Note that it is also permissible to check a ductile support for lateral loading instead of performing the Vertical Capacity Check.

8.3.5 <u>Limit State Check</u>

A limit state evaluation may be used as an alternative to the Vertical Capacity Check (3.0 times Dead Load) in Section 8.3.3 for verification of support vertical capacity for ductile supports. The limit state evaluation provides a check of anchorage and anchorage connection capacity. The seismic demand applied to the anchor point using the limit state evaluation method is based on dead load plus anchor reaction due to formation of plastic hinges at credible support joint locations. Realistic upper bound estimates should be used for the support joint plastic hinge moment capacities, based on test results if possible.

The basic philosophy for the Limit State Check is that for ductile supports suspended from the overhead, anchor connection capacity need only exceed the maximum possible reactions resulting from the plastic hinges developed in the support, plus dead loads.

For rod hanger trapeze supports with fixed-end connection details, the Limit State Check is straightforward. The anchor capacity should be greater than dead load reaction plus the reaction from plastic hinges formed in the hanger rods at fixed-end connections. For multiple tier hangers, as a first approximation, plastic hinge formation may be assumed at all joints at all tiers. If the lateral deflection corresponding to onset of all these plastic hinges is excessive, such as if it is greater than the peak floor spectral displacement, then a more refined evaluation may be conducted. This may be accomplished by considering a realistic deflected shape for those locations where credible plastic hinges can be formed.

For threaded rods, the plastic hinge moment capacity should be consistent with those observed in the rod hanger fatigue tests (see Reference 20). The plastic moment capacity may be calculated using the rod hanger's cross-sectional moment of inertia based on the root diameter of the threaded section, a 1.7 shape factor, and a 90 ksi apparent yield stress. For example, the plastic moment capacity of a 1/2-inch diameter threaded rod may be taken as 1,010 inch-pounds.

The anchorage shear load for the Limit State Check may be calculated by estimating a point of inflection in the limit state deflection shape. For example, for a rod hanger trapeze support, the point of inflection may be taken as the mid-point between the top tier cross beam and the overhead anchorage.

Limit State Checks of light metal strut framing trapeze supports constructed with clip angles may assume that plastic hinges develop in all clip angles, with the strut framing members remaining rigid. The anchorage capacity should be greater than dead load reaction, plus frame reaction at the anchor point due to the formation of plastic hinges at all clip angles, plus reaction due to local prying action at the anchor due to a plastic moment in its clip angle.

The local prying anchor load may be taken as the connection ultimate moment capacity divided by the distance between anchors for double clip angle connections. For single clip connections, the moment may be divided by the distance from the anchor bolt to the far edge of the light metal strut framing vertical member. The moment capacities for clip angle connections can be very difficult to estimate by calculation so it is best to base these moment capacities on test data if possible.

8.3.6 Rod Hanger Fatigue Evaluations

Shake table tests have shown that the seismic capacity of fixed-end rod hanger trapeze supports is limited by the fatigue life of the hanger rods. Rod hanger trapeze supports should be evaluated for possible fatigue effects if they are constructed with fixed-end connection details. This fatigue evaluation should be done in addition to the checks described in the previous sections.

Fixed-end connection details include double-nutted rod ends at connections to flanges of steel members, rods threaded into shell-type concrete expansion anchors, and rods connected by rod coupler nuts to nonshell concrete expansion anchors. Fixed-end connection details also include rods with lock nuts at cast-in-place light metal strut channels and rod coupler nuts welded to overhead steel.

This section describes a screening method for evaluating rod hangers for fatigue based on the use of rod fatigue bounding spectra (shown in Figure 8-9) and generic rod fatigue evaluation screening charts (shown in Figures 8-10 to 8-14). This screening method is based upon generic, bounding case fatigue evaluations in Reference 20.

The screening charts are directly applicable to hangers constructed of manufactured all-thread rods in raceway system runs with uniform length hangers. The charts may also be used for evaluation of supports constructed of field-threaded rods, and for short, isolated fixed-end rod hangers in more flexible systems with relatively much longer rod hangers; guidance is given later in this section on how to adjust the parameters when evaluating these special cases.

Manufactured All-Thread Rods

The fatigue evaluation for short, fixed-end rod hangers (manufactured all-thread) in trapeze supported raceway runs with all of the rods of uniform length, should proceed as follows:

- Obtain the 5% damped floor response spectrum for the location of the support.
- Enter Figure 8-9 which contains Rod Fatigue Bounding Spectrum anchored to 0.33g, 0.50g, and 0.75g. Select a spectrum which envelopes the floor response spectrum. If the selected spectrum does not entirely envelop the floor response spectrum, then select a spectrum that envelops the floor response spectrum at the resonant frequency of the support.

  Support resonant frequency may be estimated as follows:

$$f_{support} = \frac{1}{2\pi}\sqrt{\frac{K_s}{M_s}}$$

Where:

M_s = W/g
K_s = $2(12EI/L^3) + W/L$
W = total dead weight on the pair of rod supports
g = gravitational constant
E = elastic modulus of steel
I = moment of inertia of rod root section
L = length of rod above top tier

- Enter one of the Fatigue Evaluation Screening Charts shown in Figures 8-10 to 8-14 corresponding to the diameter of the threaded rod. Focus on the curve associated with the acceleration (0.33g, 0.50g, or 0.75g) of the Rod Fatigue Bounding Spectrum selected in the previous step. These charts do not directly apply to field-threaded rods (see discussion below).

- Compare the rod hanger length (L, length of rod above top tier) and rod hanger weight (W, total dead weight on the pair of rod supports) with acceptable combinations of length and weight on the screening charts. Acceptable regions of the Fatigue Evaluation Screening Charts are below and to the right of the Screening Chart curve selected in the previous step.

If the support parameters are within acceptable regions on the Fatigue Evaluation Screening Chart, then the rod hanger support is seismically adequate.

The screening charts also include the 3 times Dead Load limit associated with the Vertical Capacity Check (Section 8.3.3) which can be used to facilitate evaluation of expansion anchors (based on mean capacity divided by four) for rod hanger trapeze supports.

Field-Threaded Rods

Rod fatigue tests have shown that field-threaded rods have less fatigue life than all-thread, manufactured rods. The evaluation method for field-threaded rods proceeds the same way as for manufactured threaded rods, except that adjusted weights and lengths should be used for comparison with the Fatigue Evaluation Screening Charts. For field-threaded rods, enter the Screening Charts with double the actual weight and 2/3 the actual length of the rods. If these modified parameters are in acceptable regions of the Screening Charts, then the rod hanger is seismically adequate.

Isolated, Short, Fixed-End Rod Hangers

If an isolated, short, fixed-end rod hanger is used in a system with predominantly longer, more flexible hangers, a special evaluation should be conducted if the isolated support does not meet the Redundancy and Consequence Test as described in Section 8.3.9 below. The special evaluation method is as follows:

- Estimate the frequency of the support system, neglecting the isolated, short rod. The frequency estimation formula given above may be used. The length of the longer rods should be used in the formula.

- Enter the applicable Fatigue Evaluation Screening Chart (Figures 8-10 to 8-14) which corresponds to the Rod Fatigue Bounding Spectrum (Figure 8-9) that envelops the plant floor response spectrum (5% damping) at the frequency of interest which was calculated in the previous step.

- Back-calculate an equivalent weight for evaluation of the isolated short rod hanger, using the frequency of the longer rod hanger supports, with the following formula:

$$W_{equiv.} = \frac{24EIg}{(2\pi f)^2 L^3 - gL^2}$$

- Enter the appropriate Fatigue Evaluation Screening Chart (Figures 8-10 to 8-14) by using the above calculated equivalent weight and the length of the isolated short rod hanger.

If these parameters are in an acceptable region on the Fatigue Evaluation Screening Chart, then the isolated, short, fixed-end rod hanger is seismically adequate.

Reference 20 may be reviewed to obtain an understanding of the analytical methods used to develop the Fatigue Evaluation Screening Charts. When using the charts, the simple equations given in this section for calculating response frequency should be used for consistency since these are the same equations used to generate the screening charts (i.e., the screening charts are based on the simplified results obtained from detailed fatigue analysis, considering capacities determined by component test results).

8.3.7 Floor-to-Ceiling Support Evaluations

Floor-to-ceiling supports may be evaluated as suspended raceway supports if they can meet the previous Limited Analytical Review Checks by neglecting the floor connection and anchorage. This is a conservative evaluation method.

Seismic ruggedness for floor-to-ceiling supports that depend on the floor connection may be evaluated as follows. The checks described here ensure seismic adequacy by showing that the supports maintain high vertical capacity, demonstrate ductility, and maintain connection shear resistance.

The lower vertical support column member should be checked for buckling. The imposed buckling load should be the portion of 3.0 times Dead Load that cannot be resisted by the overhead anchorage. In addition, the support should be subject to a Lateral Load Check. The imposed lateral load static coefficient should be obtained as described in Section 8.3.4. The top and bottom connections and anchors should be checked for dead load plus the equivalent static lateral load reactions. Clip angle bending stresses may be ignored. The support columns themselves do not have to be checked for lateral loading; however, the entire support should be checked for design dead load as described in Section 8.3.1.

8.3.8 Base-Mounted Support Evaluations

Base-mounted supports present a different case than suspended supports in that, with excessive deflections and inelastic response effects, the base-mounted supports tend to become unstable whereas suspended supports have increased pendulum restoring force. The checks which should be performed include a detailed Dead Load Check and Lateral Load Check non-concurrently in both orthogonal directions, including P-delta effects if base hardware slip may be anticipated. P-delta effects include the second order increases in base overturning moment due to additional eccentricity of the supported dead load during seismic deflections of the support. These P-delta effects may become significant if the connection hardware at the base of the support does not remain rigid. Base hardware slips that should be considered are discussed below. Reference 11 provides considerable discussion on the philosophy of the base-mounted support evaluations.

A detailed, Dead Load Check should be performed, similar to the check described in Section 8.3.1. The only exception is that clip angle bending stresses should be evaluated at the base connections. Base flexibility associated with clip angle inelastic behavior may lead to increased deflection and subsequent P-delta effects and possibly instability.

A Vertical Capacity Check should not be conducted since the philosophy behind the Vertical Capacity Check only applies to ductile, suspended raceway supports. A Dead Load plus equivalent static Lateral Load Check should be performed instead, for loading non-concurrently in both orthogonal directions.

The equivalent static lateral load should be determined as outlined in Section 8.3.4. The Lateral Load Check should evaluate all members, connections, and anchors associated with the primary support frame and its bracing (if present). Realistic capacities should be used for the evaluation. If brace members (lower bound capacity estimate) cannot resist all of the lateral load, the portion of load exceeding the brace capacity may be transmitted to the base and resisted by the base moment capacity.

If light metal strut framing clip angle construction is used, bolt (with channel nut) slip of 1/16 inch should be considered for P-delta evaluation. If the nominal capacities given in Appendix C are used for nonshell expansion anchors, anchor bolt slip of 1/8 inch should be considered for P-delta evaluation. For P-delta evaluation, all these bolt slips should be used to obtain an estimate for maximum possible base connection rotation. Using this base rotation, and considering the displacement due to the flexibility of the vertical support post, a deflection of the raceways should be calculated. This additional deflection times dead load provides the effective P-delta base moment. If this moment is more than about 5% of the total moment from the Dead Load plus Lateral Load Check, it should be included in the Dead Load plus Lateral Load Check.

Torsional moments at the base of the support post that may result from lateral or longitudinal load checks may be ignored. Stresses in the support brackets due to longitudinal loading may also be ignored. These forces resulting from longitudinal loading are not considered realistic due to raceway member framing action and inelasticity of other components in the load resistance chain such as restraining clips. The goal of the lateral and longitudinal checks is to demonstrate seismic ruggedness.

8.3.9 Redundancy and Consequence Test

Isolated cases of a support not meeting the Limited Analytical Review Guidelines described above may be accepted if the raceway support system has high redundancy, and if postulated support failure has no adverse consequence to plant safety. High redundancy can be demonstrated by showing that the adjacent supports are suspended and meet the Vertical Capacity Check (3 times Dead Load) of Section 8.3.3, and either the

Ductility Check of Section 8.3.2 or the Lateral Load Check of Section 8.3.4.

"Isolated" means that it is not acceptable for as many as every other support to fail to meet the guidelines. In other words, there should be at least two supports, each of which meets the guidelines of Section 8.3.3 and either Section 8.3.2 or Section 8.3.4, between each "isolated" support.

The consequence of a failed isolated support should also be evaluated to determine whether there is any undesirable effect on nearby equipment. Engineering judgment should be used by the Seismic Capability Engineers to make this evaluation. If it is not credible for the support to swing away or fall, then there is no safety consequence. If it is credible for the support to swing away or fall, then it should be treated as a source of seismic interaction. In this case, there is no safety consequence if there are no fragile, safety-related targets in the vicinity or below.

Use of the Redundancy and Consequence Test described above should not form the basis for evaluating the general, overall seismic ruggedness of the plant's raceway support systems. Rather, this option should be used during the walkdown to screen out isolated instances of supports which appear marginal, so as to exclude them from the bounding case sample.

8.3.10 Allowable Capacities

The allowable capacities which can be used in the Limited Analytical Review are discussed in this section. For the Dead Load Check (Section 8.3.1), normal engineering design working stress allowable capacities should be used. For example, the capacities defined in Part 1 of the AISC Specification for Steel Design (Reference 29) can be used.

More realistic allowable capacities can be used for the remainder of the checks in the Limited Analytical Review (Sections 8.3.2 to 8.3.8). The remainder of this subsection defines these capacities for expansion anchors, cast-in-place anchors, embedded plates and channels, welds, steel bolts, structural steel, and other support members.

Capacity values for expansion anchors are provided in Appendix C. The guidelines for using these anchorage capacities, as defined in Section 4.4 and Appendix C, should be followed, including edge distance, bolt spacing, and inspection procedures. Note that tightness checks need not be conducted for anchor bolts of supports which resist tensile force under dead load. Tightness checks are waived because suspended and some wall-mounted raceway systems cause these types of anchorages to be subjected to constant tension under dead load and therefore the anchorages are, in effect, continuously proof-tested. The tightness checks should be carried out, however, for floor-mounted support anchors.

Capacities for other anchor types, such as cast-in-place anchors or embedded plates, should be estimated by factored ultimate strength design calculations following ACI Standard 349 (Reference 30). The plant design or as-built drawings for cast-in-place anchors and steel plates should be reviewed to obtain details on these anchorage types. Anchor capacities for cast-in-place light metal strut framing channels should be taken as the manufacturer's catalog values with published factors of safety, or may be determined by available test information with appropriate factors of safety, or may be calculated as in Reference 30.

Capacities for welds, structural steel, and steel bolts should be taken as defined in Part 2 of the AISC Specification for Steel Design (Reference 29). Capacity values for light metal strut framing hardware are taken as the manufacturer's recommended design values, including the published factor of safety. This factor of safety is considered sufficient to encompass the lower bounds of strength values, such as may result from minor product variation or low bolt torque.

When upper-bound strength estimates are required, such as in ductility reviews or limit state evaluations, the manufacturer's catalog capacities should be increased. A recommended upper bound estimate for bolts with channel nuts is double the manufacturer's published design values.

Tests may be used to establish realistic, ultimate capacities of raceway components. Appropriate factors of safety should be used with these test results. Dynamic tests should be performed to establish ultimate capacities of friction-type connections in most cases.

8.3.11 Raceway System Weights

Cable tray weights may be estimated as 25 pounds per square foot for a standard tray with 4 inches of cable fill. It is suggested that the cable trays be considered to be completely full during the initial attempt at using the screening guidelines described above. Linear adjustment may be made for trays with more and less cable fill. Sprayed-on fireproof insulation may be conservatively assumed to have the same unit weight by itself as the cable in the tray it covers.

Estimated weights for steel and aluminum conduit may be taken as follows:

Conduit Diameter (inches)	Conduit Weight Including Cable (pounds per foot) Steel	Aluminum
1/2	1.0	0.5
3/4	1.4	0.7
1	2.2	1.1
1-1/2	3.6	1.8
2	5.1	2.8
2-1/2	8.9	5.2
3	12.8	7.9
4	16.5	9.5
5	23.0	13.6

Conservative estimates should be made for the weights of other miscellaneous items attached to the raceway support, such as HVAC ducting, piping, and lighting.

8.4 OUTLIERS

An outlier is defined as a raceway hardware feature which does not meet one or more of the screening guidelines contained in this section. Namely, an outlier:

- Does not meet the Inclusion Rules given in Section 8.2.2,
- Has significant Other Seismic Performance Concerns as given in Section 8.2.3, or
- Does not satisfy the Limited Analytical Review Guidelines given in Section 8.3.

When an outlier is identified, proceed to Section 5, Outlier Identification and Resolution, and document the cause(s) for not meeting the screening guidelines on an Outlier Seismic Verification Sheet (OSVS), shown in Exhibit 5-1.

The conservative screening criteria given earlier in this section are intended for use as a generic basis to evaluate the seismic adequacy of cable and conduit raceway systems. If a raceway hardware feature fails this generic screen, it may not necessarily be deficient for seismic loading; however, additional evaluations are needed to show that it is adequate. Some of the additional evaluations and alternate methods for demonstrating seismic adequacy are summarized below. Additional details are also found in the previous subsections where these generic screening guidelines are described. Other generic methods for resolving outliers are found in Section 5.

In some cases it may be necessary to exercise engineering judgment when resolving outliers, since strict adherence to the screening guidelines in the previous subsections is not absolutely required for raceway support systems to be seismically adequate. These judgments, however, should be based on a thorough understanding of the background and philosophy used to develop these screening guidelines as described in References 9, 10, and 11. The justification and reasoning for considering an outlier to be acceptable should be based on mechanistic principles and sound engineering judgment.

The screening guidelines contained in the previous subsections have been thoroughly reviewed by industry experts to ensure that they are conservative for generic use; however, the alternative evaluation methods and engineering judgments used to resolve outliers are not subject to the same level of peer review. Therefore, the evaluations and judgments used to resolve outliers should be thoroughly documented so that independent reviews can be performed if necessary.

Guidelines for performing outlier evaluations are provided below:

Cable Tray Span and Conduit Span. As discussed in Inclusion Rules 1 and 2, the span lengths given there are not necessarily rigid requirements. For example, an isolated cable tray span of about 13 feet may be acceptable if the tray is lightly loaded and of rugged construction (for example, the tray meets the NEMA standards in Reference 31 and the cable loading is no more than one-half that in Table 3-1 of Reference 31). An isolated conduit overspan may be acceptable if its vertical deflection is limited by other plant features in proximity. In addition, 3.0 times dead load vertical static load tests can be used to show that an isolated overspan is acceptable.

Raceway Member Tie-downs. Tie-downs should be installed until Inclusion Rule 3 is satisfied. As an alternative, analyses or a static lateral pull test of the lateral load-carrying capacity of the as-built trays or conduit can be performed to show that the trays or conduit are not capable of falling off the support. The amount of static lateral force used in this evaluation should be consistent with one of the options in the Lateral Load Check given in Section 8.3.4. It is preferable, and usually not a difficult maintenance activity, to add missing raceway member tie-downs.

Channel Nuts. Channel nuts without teeth should be replaced with nuts with teeth or an extensive plant-specific dynamic testing program can be performed to show that the channel nuts without teeth are capable of carrying the anticipated seismic load.

Rigid Boot Connection. Rigid boots are considered to be outliers even when there is only a small gap between the boot and the member it supports. If the boot was field assembled in such a way that no gaps exist and the boot fits the member tightly, then this connection can be considered acceptable. The basis for the finding that there are no gaps should be thoroughly documented. One simple fix to a rigid boot with gaps is to replace the individual bolts with one through bolt.

Beam Clamps. The clamp should be replaced with a positive connection or the clamp oriented so that gravity loads are not resisted by the clamping friction; however, if supported loads are less than about 15 pounds, the adequacy of an isolated clamp oriented in the wrong direction can simply be verified by tugging and shaking it by hand.

If an entire run of small conduit with light support dead loads (less than about 15 pounds per support) is anchored with beam clamps which resist dead load only by clamping friction, then a sufficient number of supports representative of the entire conduit run should be tugged to verify adequacy.

Cast-Iron Anchor Embedment. The cast-iron anchor embedment should be replaced with an acceptable anchorage or the support braced horizontally and the stress in the anchor kept very low.

Analytical Outliers. Outliers that do not satisfy the Limited Analytical Review guidelines, as illustrated in Figure 8-6, can be evaluated further using more detailed analytical models of the raceway system or in-plant testing to demonstrate that the raceways are as rugged as required. Remember, however, that the analytical guidelines only have to be satisfied in an approximate manner. As illustrated earlier, if a support has a capacity of only 2.7 times Dead Load rather than the desired 3.0 times Dead Load, the seismic review team performing the screening evaluation may still find the support acceptable based on their professional judgment.

For certain supports which do not meet the Limited Analytical Review Checks, it may be preferable to strengthen these supports rather than expend resources on more refined analyses and evaluations.

When upgrading raceway supports, the utility may wish to use these Limited Analytical Review guidelines as the starting point in the design process. It is recommended that new designs or retrofit designs use additional factors of safety, especially for anchorage, since the incremental added cost for larger anchor bolts is not significant but it leads to significantly larger seismic margin.

8.5 DOCUMENTATION

A summary package should be assembled to document and track the Seismic Capability Engineer's evaluation activities. Documentation should include records of the plant areas evaluated, the dates of the walkdowns, the names of the engineers conducting the evaluations, and a summary of results. Recommended data sheets for the summary package are given in Exhibits 8-1 to 8-3 and are described below. Outlier Seismic Verification Sheets (OSVS) are given in Section 5, Exhibit 5-1.

Exhibit 8-1 provides a Plant Area Summary Sheet. A separate summary sheet should be completed for each designated room number or plant location where evaluations are conducted. The sheet includes reminders, as a checklist, for primary aspects of the evaluation guidelines; however, the walkdown engineers should be familiar with all aspects of the seismic evaluation guidelines during in-plant screening reviews and not rely solely on the checklist. The Seismic Capability Engineers who sign these sheets are ultimately responsible for the seismic evaluations conducted.

Exhibit 8-2 provides an Analytical Review Data Sheet for recording information on the supports selected as the worst-case, representative samples.

Exhibit 8-3 provides a Tracking Summary for the Analytical Review Data Sheets. As items are completed and resolved, the responsible engineers should initial the line item on the tracking sheets to confirm final closure.

Exhibit 5-1 (Section 5) provides an Outlier Seismic Verification Sheet. When collecting these data, the Seismic Capability Engineers should record ample information so that repeated trips to the plant are not required for final outlier resolution.

Photographs may be used to supplement documentation, as required. When used as formal documentation for the summary packages, photographs should be clearly labeled for identification.

Exhibit 8-1

PLANT AREA SUMMARY SHEET Sheet 1 of 2

Room No.:__________________ Plant Location:______________________

Raceway Designation No.:____

Inclusion Rule Review	Acceptance	
Cable Tray Spans:________________________________	____ Yes	____ No
Conduit Spans:________________________________	____ Yes	____ No
Tie Downs:________________________________	____ Yes	____ No
Channel Nuts:________________________________	____ Yes	____ No
Rigid Boots:________________________________	____ Yes	____ No
Beam Clamps:________________________________	____ Yes	____ No
Cast Iron Inserts: ________________________________	____ Yes	____ No
Other Seismic Performance Concern Review	**Acceptance**	
Anchor Bolts:________________________________	____ Yes	____ No
Welded Connections:________________________________	____ Yes	____ No
Concrete Condition:________________________________	____ Yes	____ No
Corrosion:________________________________	____ Yes	____ No
Sagging Raceways:________________________________	____ Yes	____ No
Broken Components and Sharp Edges:________________	____ Yes	____ No
Bare Cables:________________________________	____ Yes	____ No
Cable Fill/Ties:________________________________	____ Yes	____ No
Aging of Plastic Ties:________________________________	____ Yes	____ No
System Hardspots:________________________________	____ Yes	____ No
Short Rods:________________________________	____ Yes	____ No
Seismic Interaction Review	**Acceptance**	
Proximate Features:________________________________	____ Yes	____ No
Falling Hazards:________________________________	____ Yes	____ No
Differential Displacement:________________________	____ Yes	____ No
Isolated Outliers:________________________________	____ Yes	____ No

Additional Comments:____

____

____

Exhibit 8-1

PLANT AREA SUMMARY SHEET Sheet 2 of 2

Room No.:____________________ Plant Location:________________________

Raceway Designation No.:____

Outlier Descriptions

Total No. of Attached OSVS (Exhibit 5-1):________________________

Outlier Nos.:____

Analytical Review Support Selection

Total No. of Attached Analytical Review Data Sheets: ____________________

Selection Nos.:____

Additional Field Notes

CERTIFICATION: (Signatures of at least two Seismic Capability Engineers are required; one of whom is a licensed professional engineer.)

Print or Type Name/Title	Signature	Date
Print or Type Name/Title	Signature	Date

Exhibit 8-2

ANALYTICAL REVIEW DATA SHEET Sheet ___ of ___

Room No.:______________________________ Selection No.:______________

Plant Location :________________________

Description and Sketch:

Reference Calculation:____

Additional Notes:

CERTIFICATION: (Signatures of at least two Seismic Capability Engineers are required; one of whom is a licensed professional engineer.)

Print or Type Name/Title	Signature	Date
Print or Type Name/Title	Signature	Date

Exhibit 8-3

ANALYTICAL REVIEW TRACKING SUMMARY Sheet ___ of ___

Room Number	Plant Location	Selection Number	Final Resolution	Initials/ Date

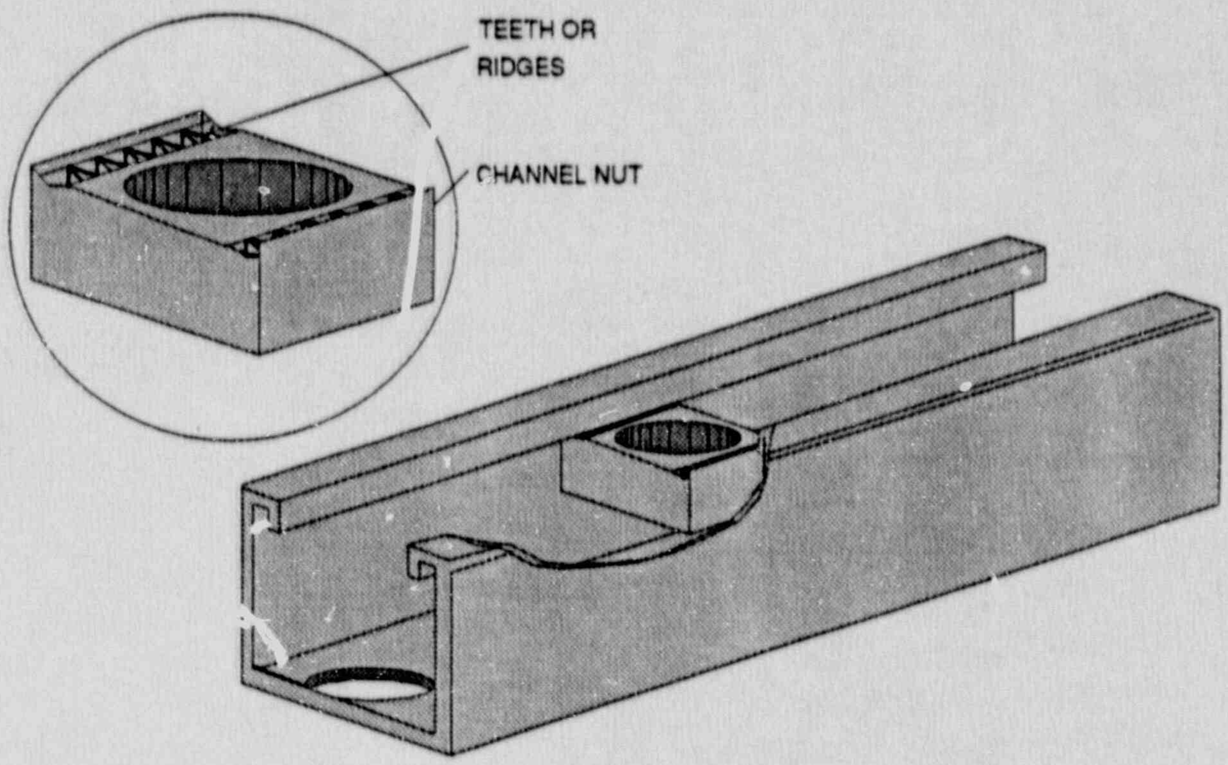
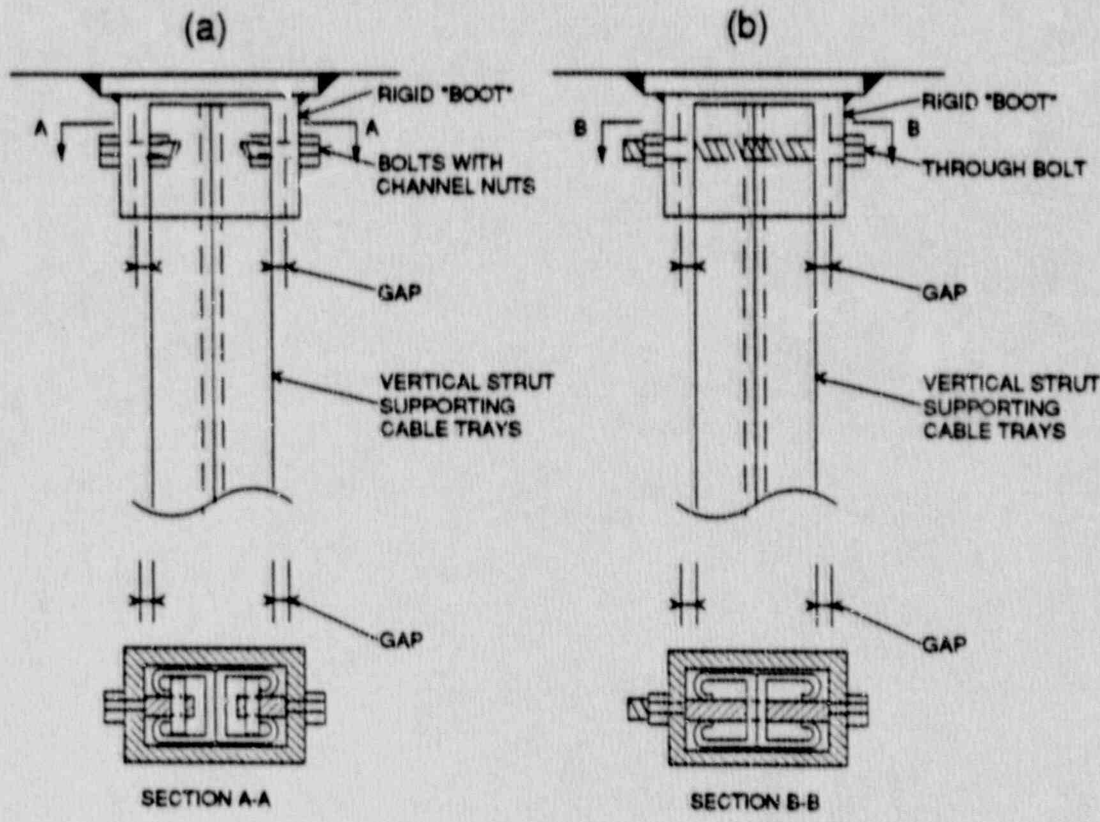


Figure 8-1. Channel Nut With Teeth or Ridges in Light Metal Framing Strut. (Source: Reference 9)

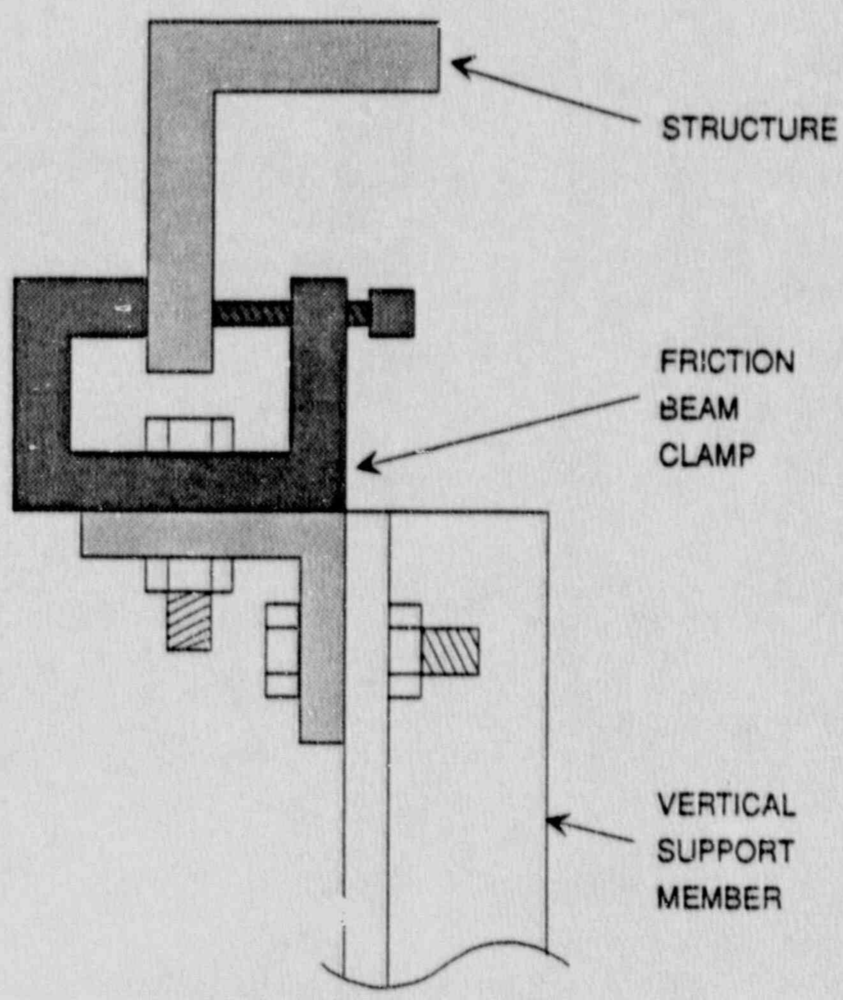


(a) Addition of a Through Bolt Corrected the Design Flaw.

(b) Rigid "Boot" Connection Detail That Failed in Shake Table Test.

Note: The size of the gap is exaggerated for emphasis. Any size gap, no matter how small, is a possible concern.

Figure 8-2. Rigid Boot Connection Details. (Source: Reference 9)



Note: This arrangement may loosen and slip, resulting in support collapse.

Figure 8-3. Beam Clamps Oriented With Dead Load Resisted Only By Clamping Friction. (Source: Reference 9)

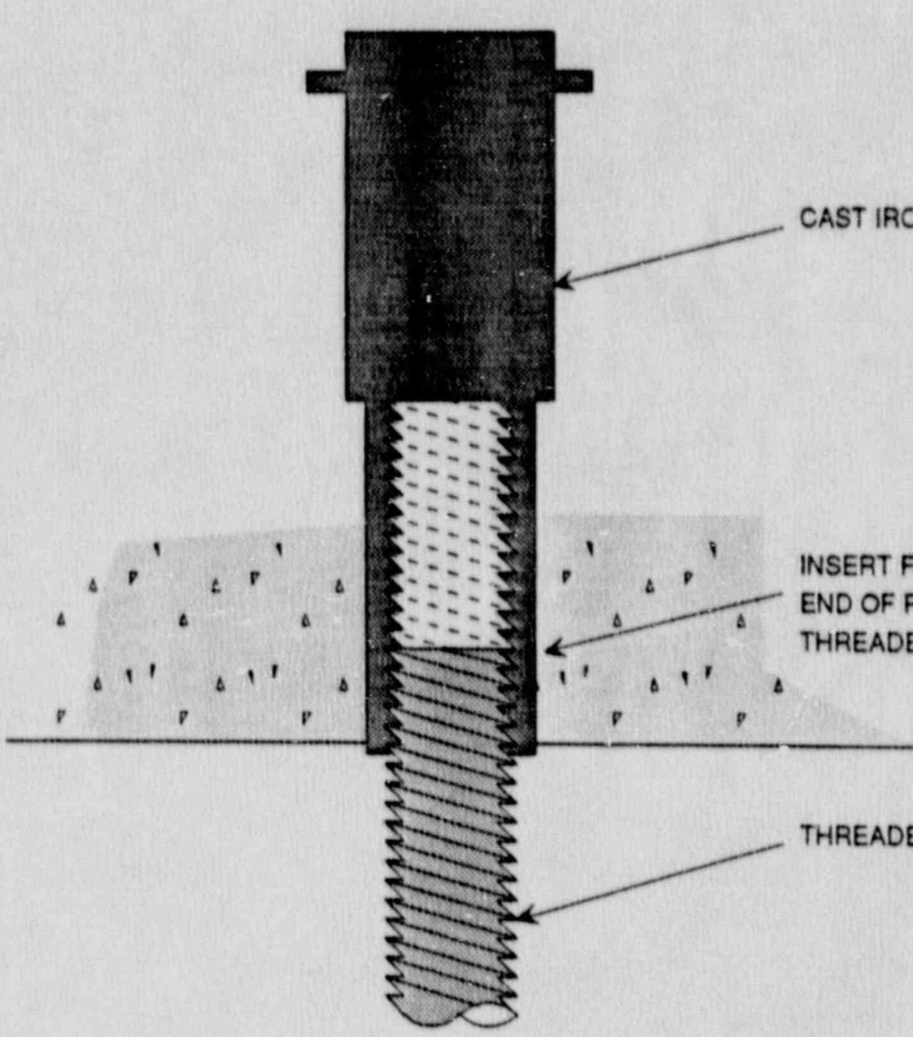
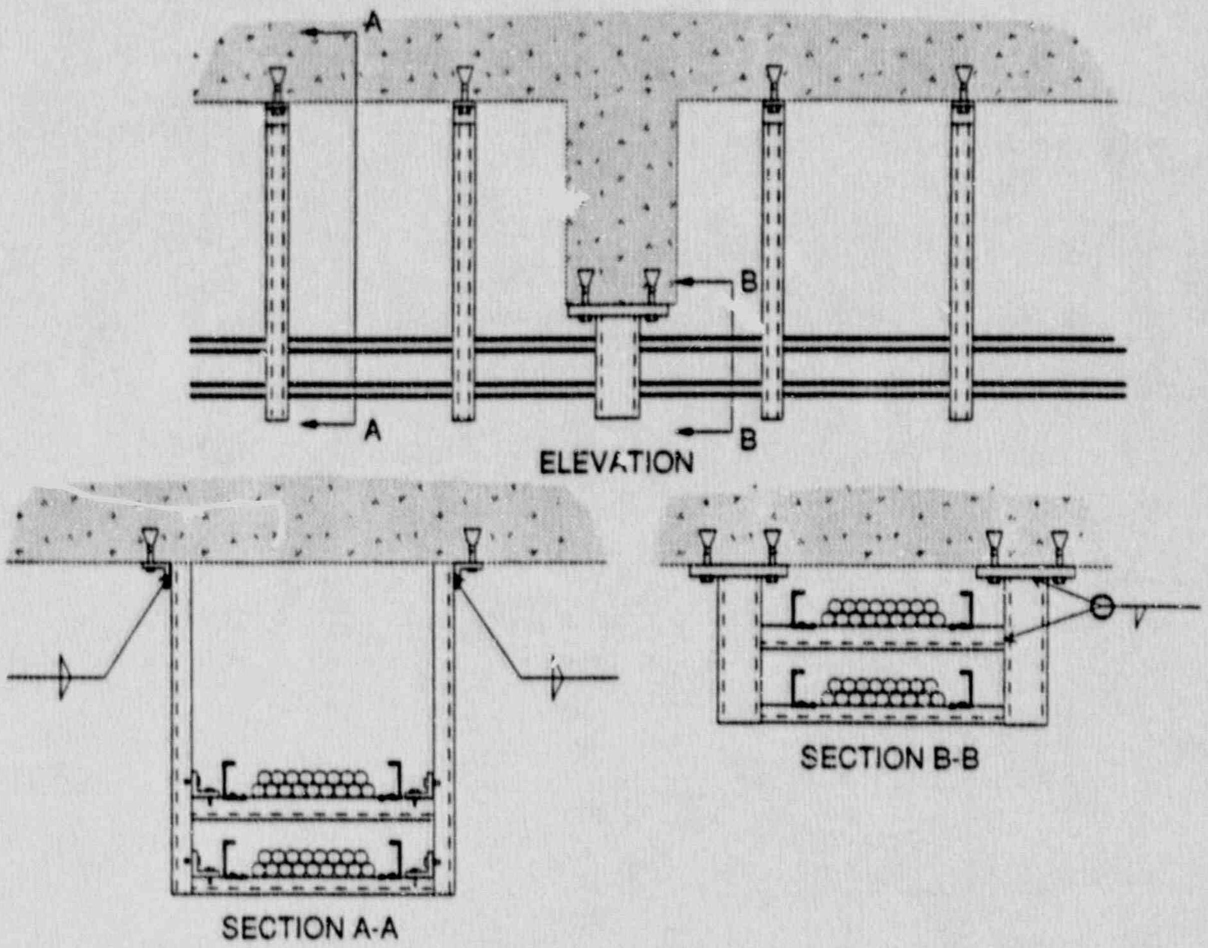


Figure 8-4. Cast-Iron Anchorage Detail That Failed at the Pacific Bell Alhambra Station, 1987 Whittier Earthquake. (Source: Reference 9)



Note: The short, stiff sup...t may attract considerable load from longitudinal motion during an earthquake.

Figure 8-5. Short, Stiff Support In a System of Longer, More Flexible Supports. (Source: Reference 9)

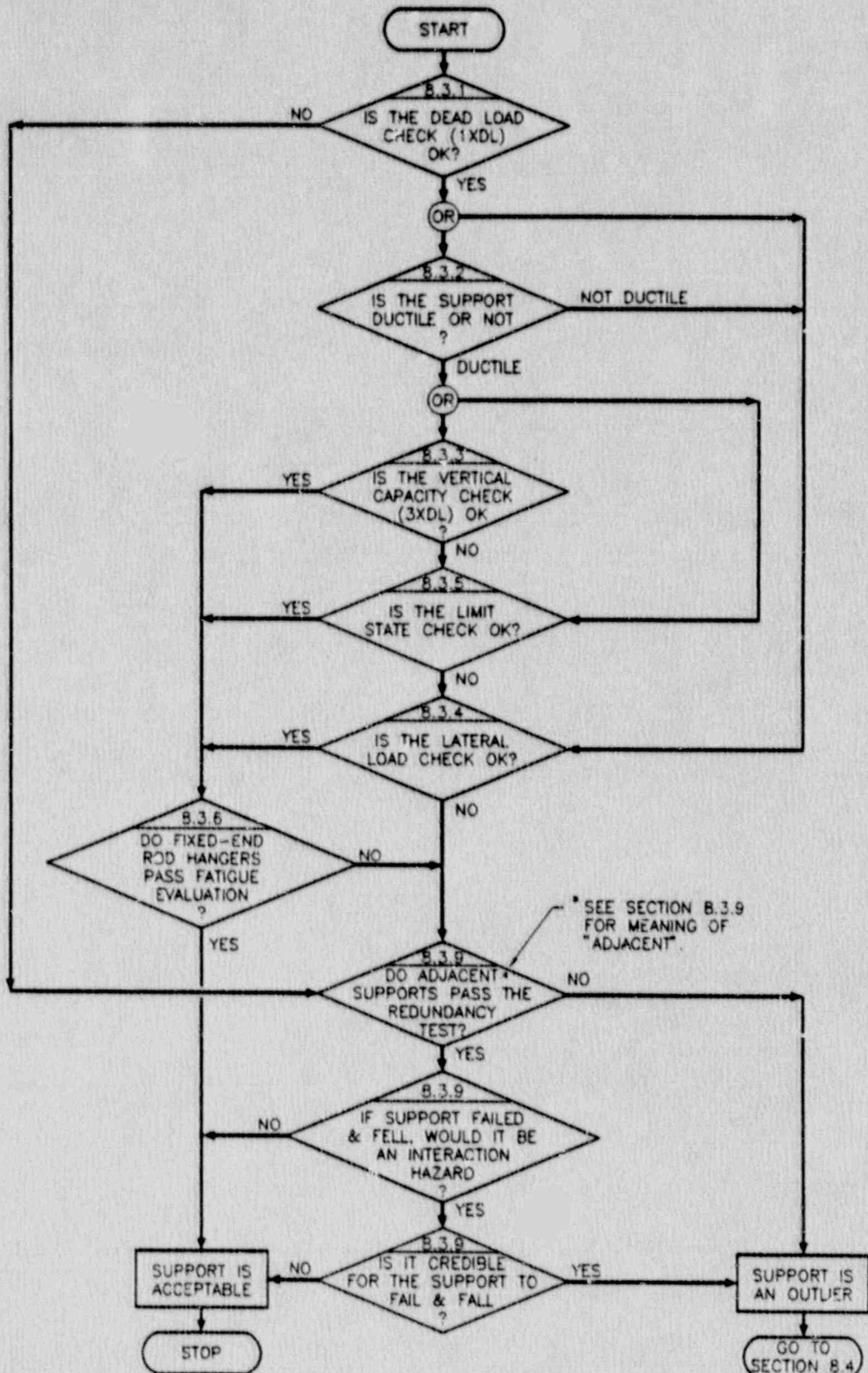
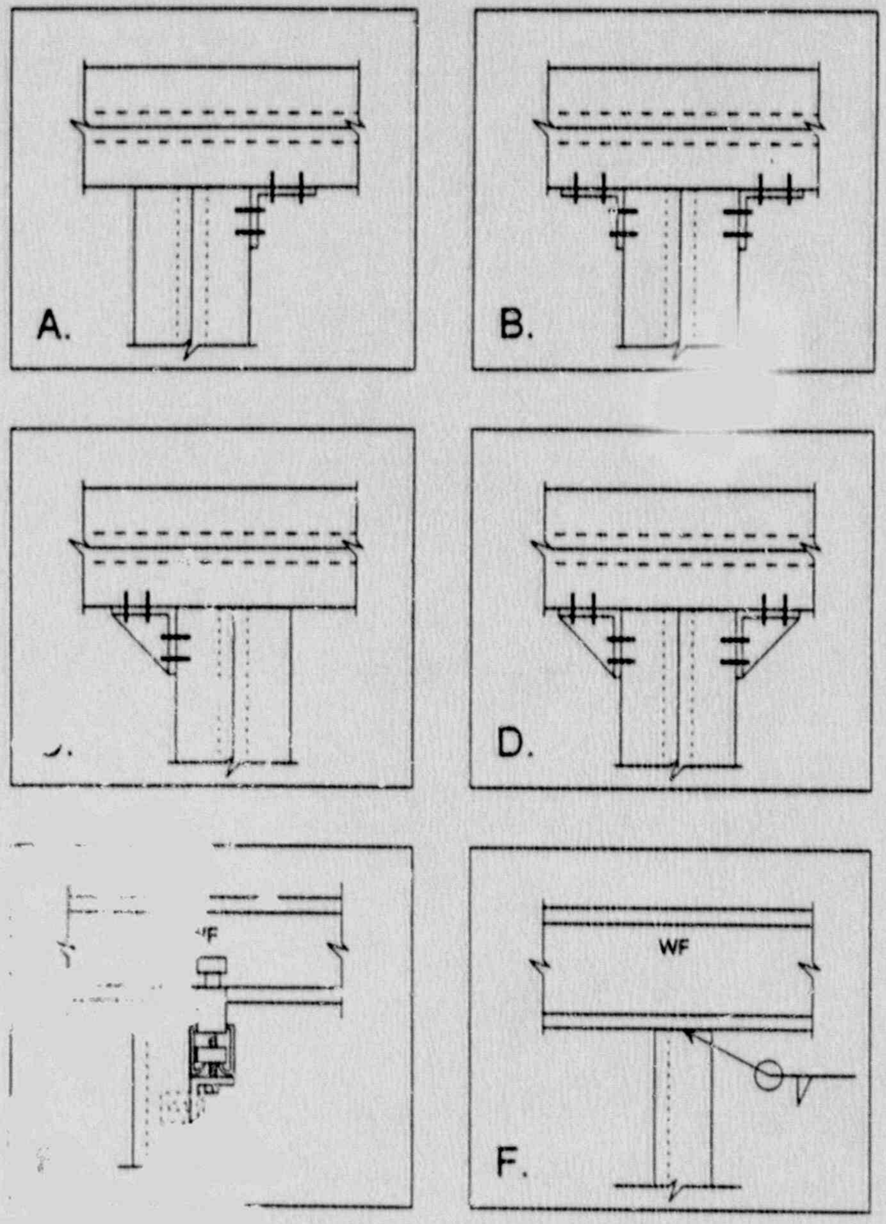


Figure 8-6. Logic Diagram for Limited Analytical Review of Suspended Raceway Supports.



Notes:

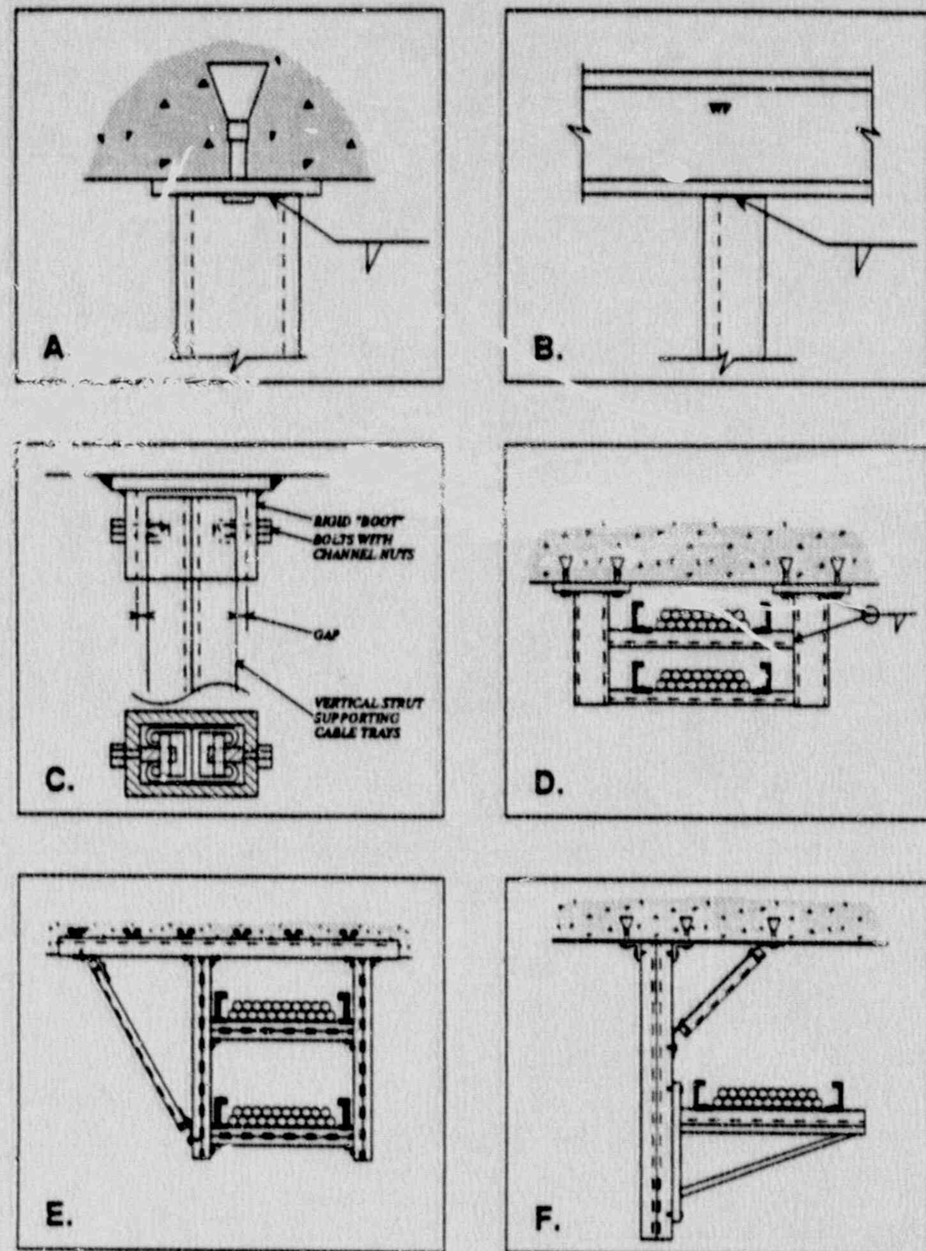
- ... and D are ductile connections of standard catalog, light metal, strut ...

- Connection is a properly oriented beam clamp, configured as a pin-ended connection. Pin-ended connections are considered ductile.

- Connection F is an all-around fillet weld on a structural steel angle section. If combined weld throat thickness is larger than the steel angle flange thickness, this may be considered a ductile connection.

- Connections and D are ductile if the vertical bolts are into steel members as shown. If the vertical bolts are into concrete, the connections may not be ductile and should be checked.

Figure 8-7. Examples of Inherently Ductile Raceway Support Connection Details and Configurations. (Source: Reference 9)



Notes:

- Connections A and B are partially welded connection details. Partial welds cannot develop the plastic moment capacity of the vertical member, and are considered non-ductile.
- Connection C is the non-ductile rigid boot connection
- Connection D is a rigid moment-resisting frame and should be checked for horizontal load.
- Connections E and F are diagonally braced, and should be checked for horizontal load.

Figure 8-8. Examples of Potentially Non-Ductile Connection Details and Configurations.
(Source: Reference 9)

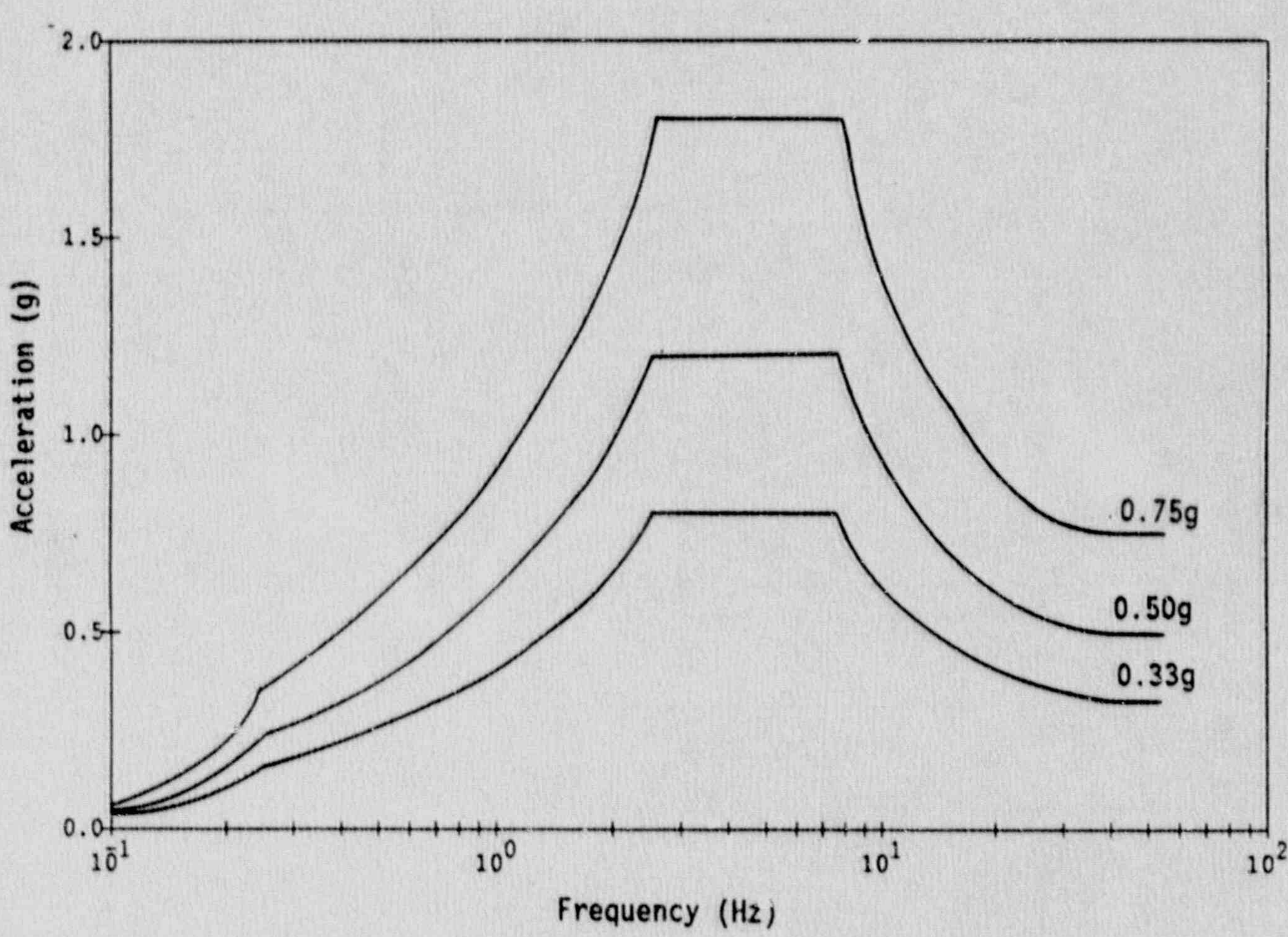
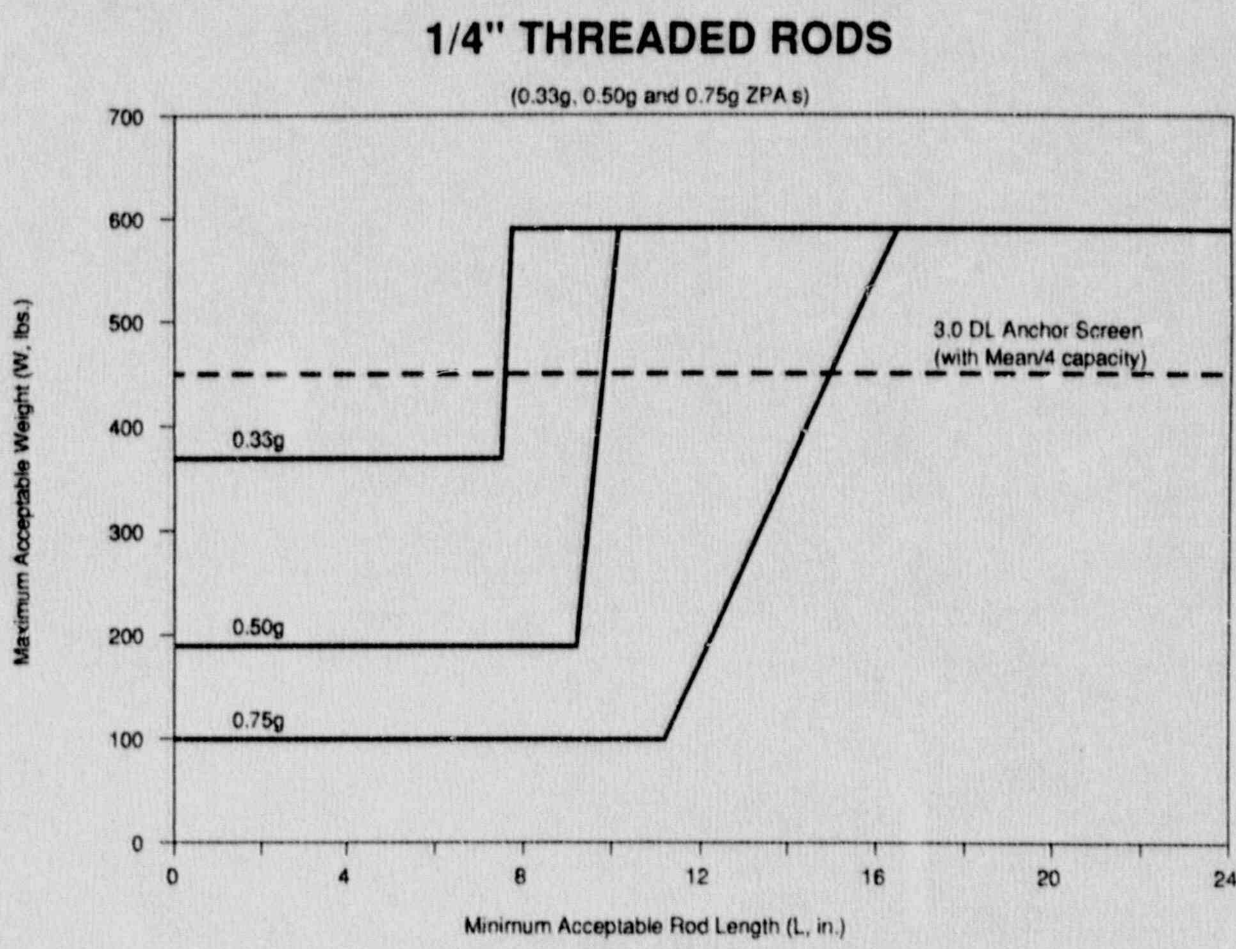
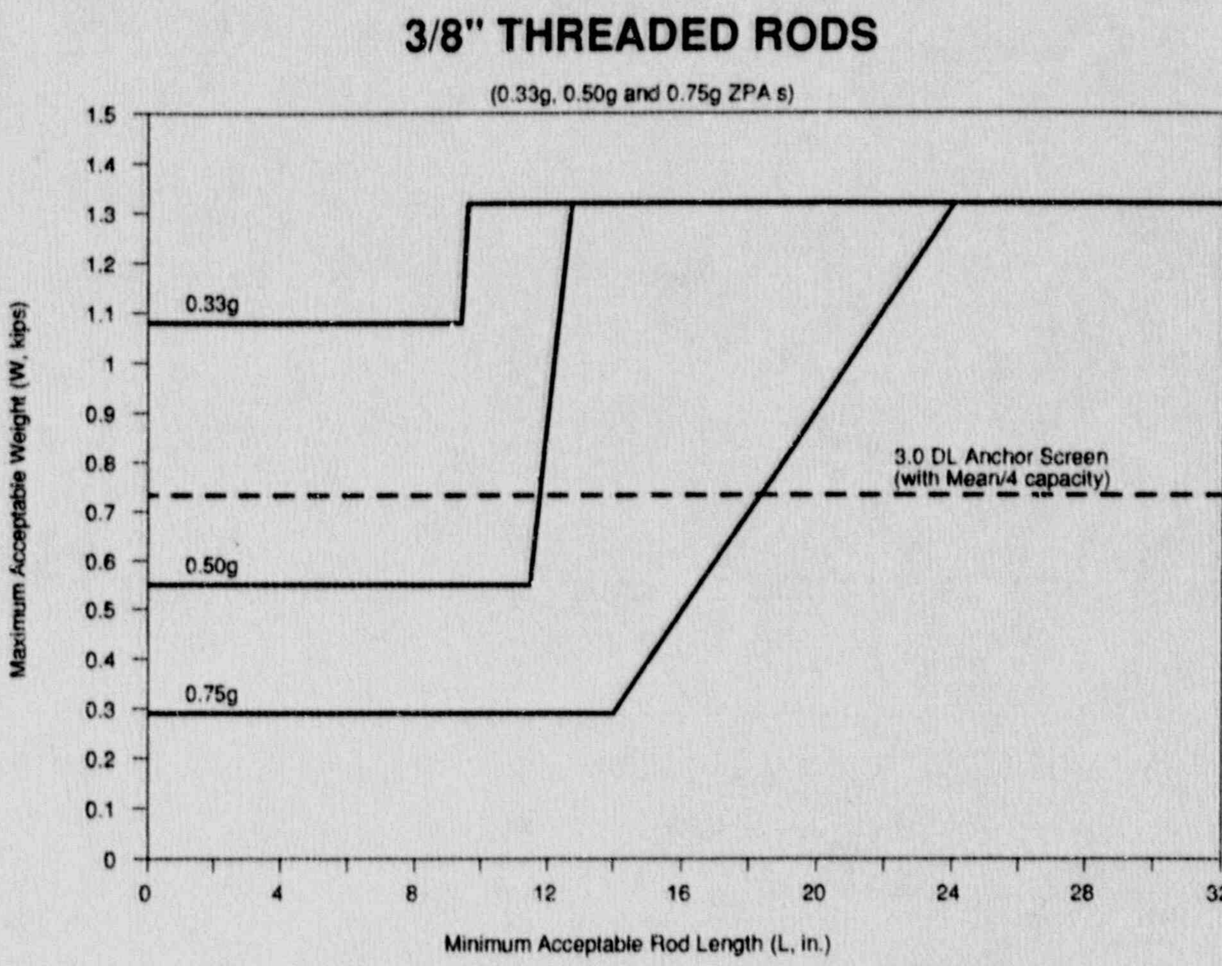


Figure 8-9. Rod Fatigue Bounding Spectrum
Anchored to 0.33g, 0.50g, and 0.75g.
(Source: Reference 9)



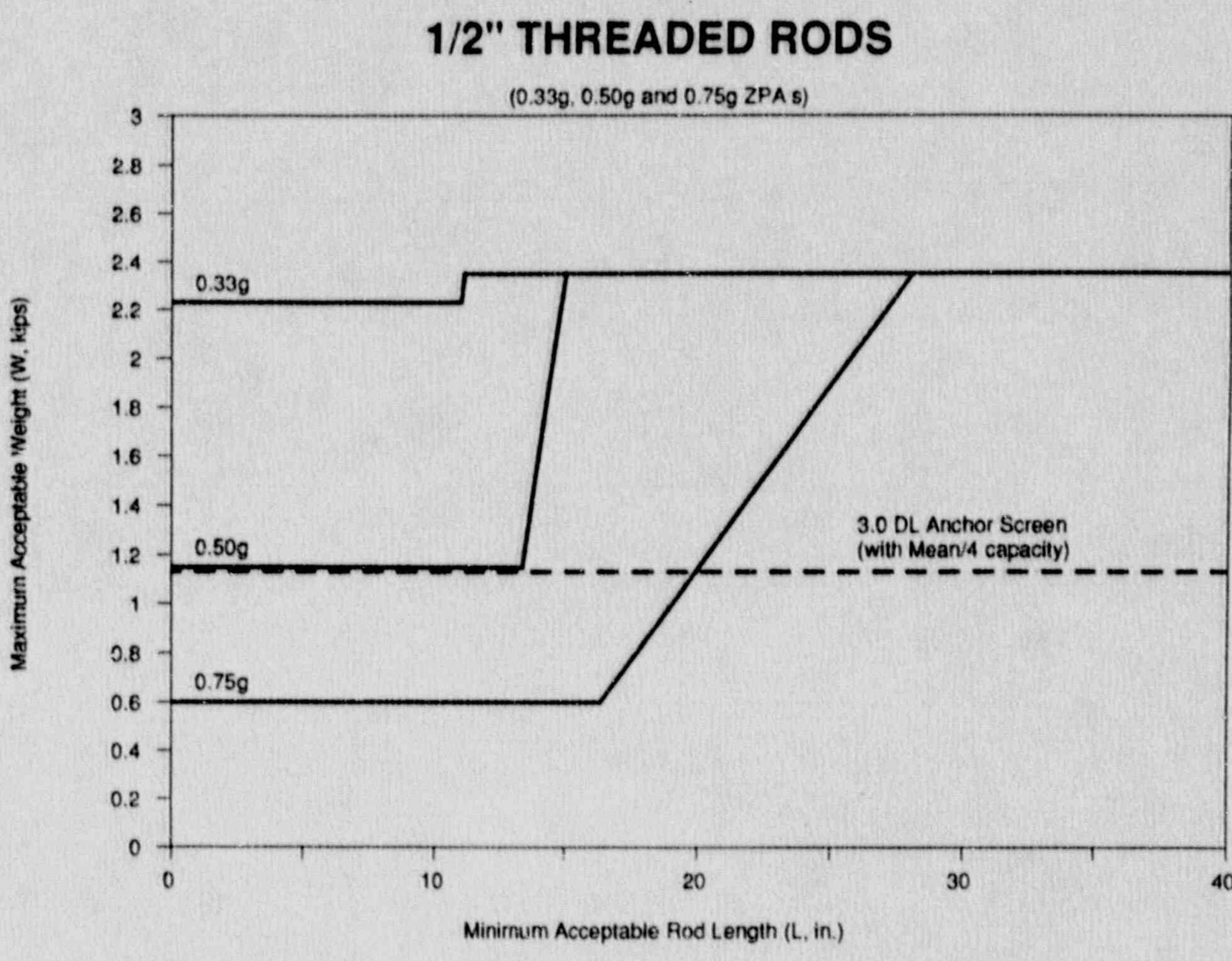
Notes:
- "W" corresponds to the total dead weight of the support (i.e., carried by both rods).
- "L" corresponds to the clear length above the top tier.

Figure 8-10. Fatigue Evaluation Screening Chart for 1/4-Inch Diameter Manufactured All-Thread Rods. (Source: Reference 9)



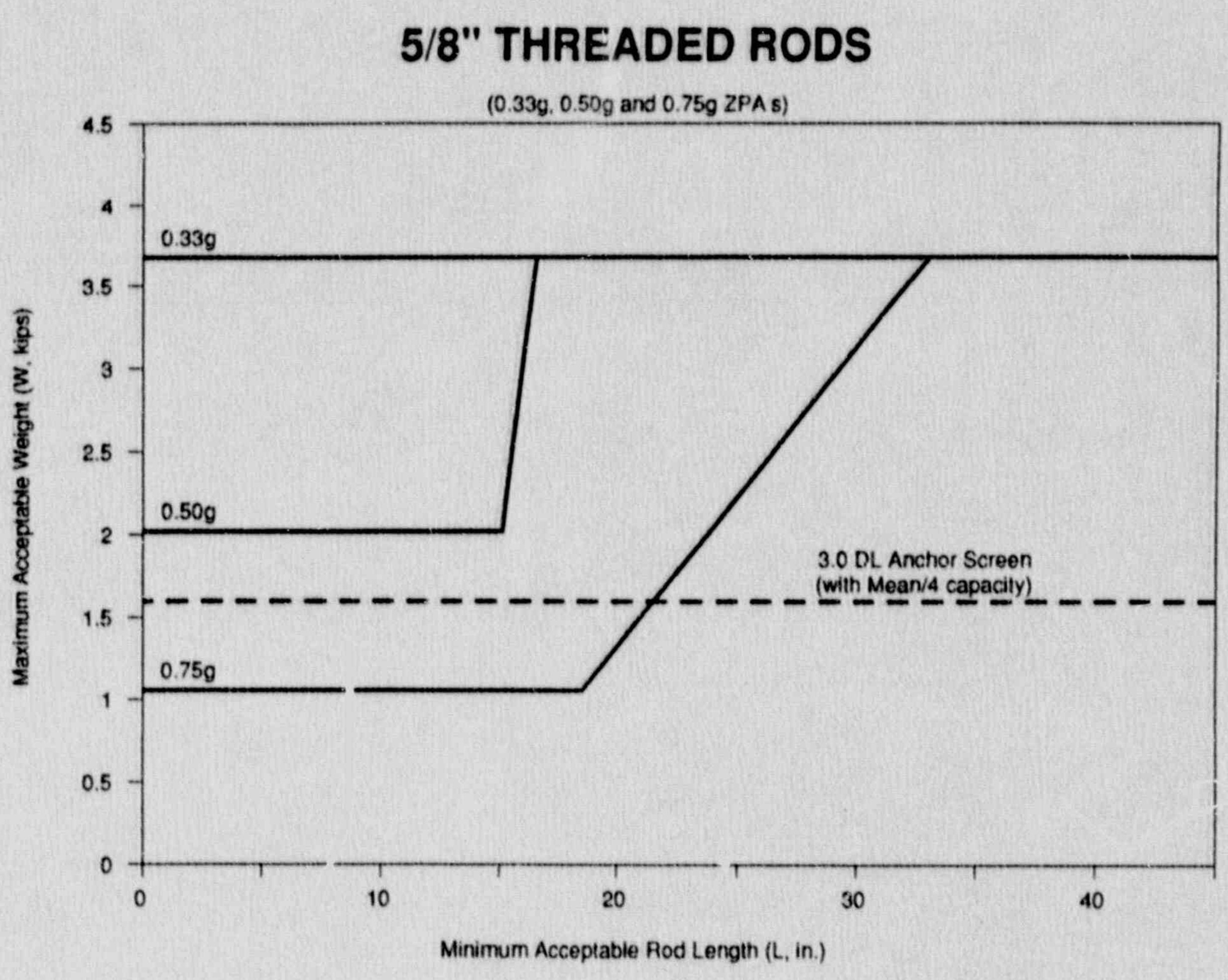
Notes:
- "W" corresponds to the total dead weight of the support (i.e., carried by both rods).
- "L" corresponds to the clear length above the top tier.

Figure 8-11. Fatigue Evaluation Screening Chart for 3/8-Inch Diameter Manufactured All-Thread Rods. (Source: Reference 9)



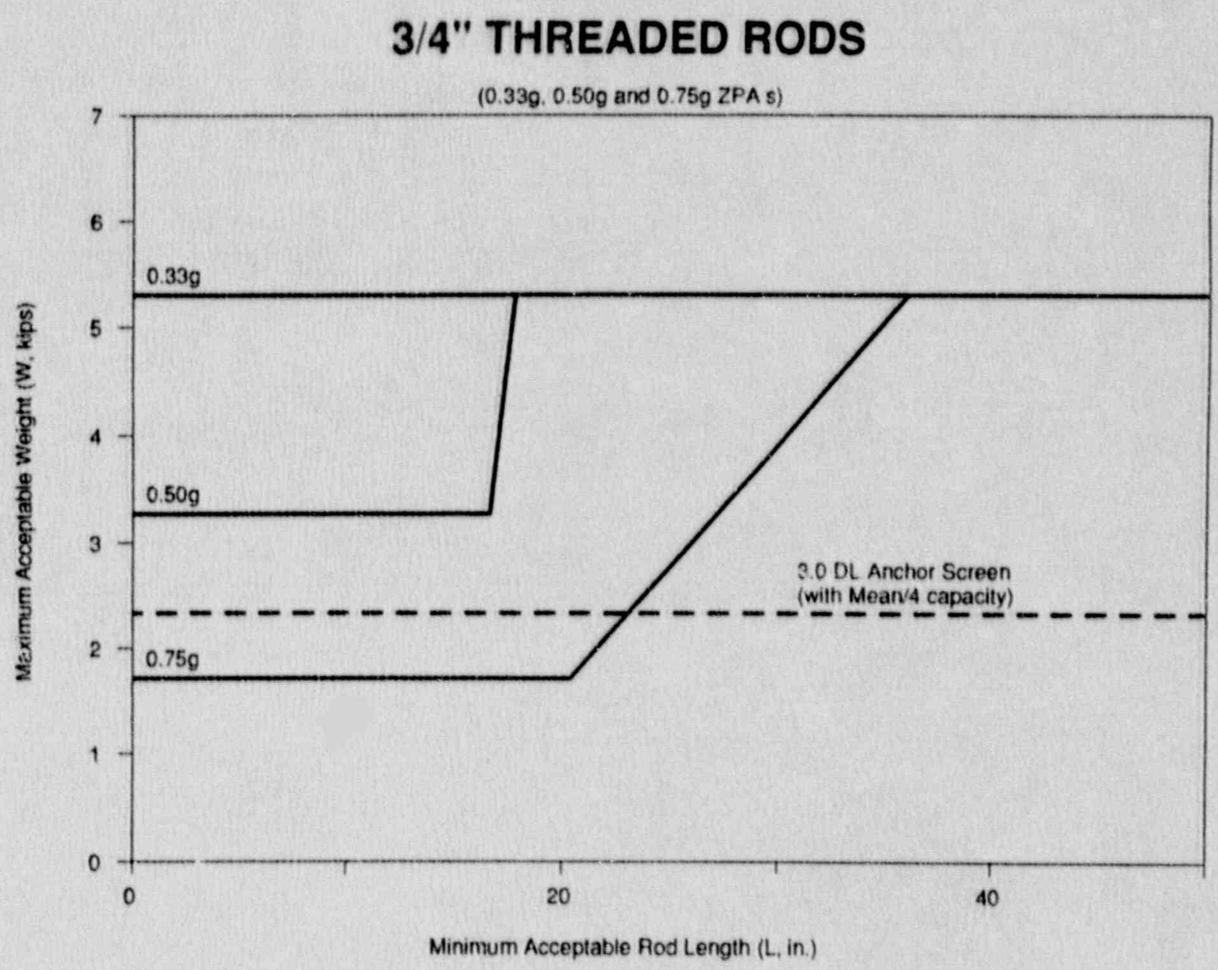
Notes:
- "W" corresponds to the total dead weight of the support (i.e., carried by both rods).
- "L" corresponds to the clear length above the top tier.

Figure 8-12. Fatigue Evaluation Screening Chart for 1/2-Inch Diameter Manufactured All-Thread Rods. (Source: Reference 9)



Notes:
- "W" corresponds to the total dead weight of the support (i.e., carried by both rods).
- "L" corresponds to the clear length above the top tier.

Figure 8-13. Fatigue Evaluation Screening Chart for 5/8-Inch Diameter Manufactured All-Thread Rods. (Source: Reference 9)



Notes:
- "W" corresponds to the total dead weight of the support (i.e., carried by both rods).
- "L" corresponds to the clear length above the top tier.

Figure 8-14. Fatigue Evaluation Screening Chart for 3/4-Inch Diameter Manufactured All-Thread Rods. (Source: Reference 9)

Section 9

DOCUMENTATION

9.0 INTRODUCTION

The purpose of this section is to describe the various types of documents which should be generated for the USI A-46 program and how they relate to each other. This section also describes the types of information which should be submitted to the NRC.

The following four major types of documents are described in this section.

- Safe Shutdown Equipment List (SSEL) Report
- Relay Evaluation Report
- Seismic Evaluation Report
- Completion Letter

The relationship between these documents and the time sequence for preparing them are illustrated in Figure 9-1. This figure also shows other minor documents which should be prepared to support the above four major documents.

The extent of documentation required in this section is limited. The underlying reason for this is that the seismic evaluations are to be done by highly-qualified individuals who have been trained in the use and application of the GIP. For example, Seismic Capability Engineers should have the background, experience, and training to make engineering judgments during the plant walkdown and thus avoid having to develop large quantities of backup documentation to record every decision made in applying this procedure. These Seismic Capability Engineers are then held accountable for the scope, accuracy, and completeness of the Screening Verification and Walkdown process by having all the engineers on the SRT certify that the

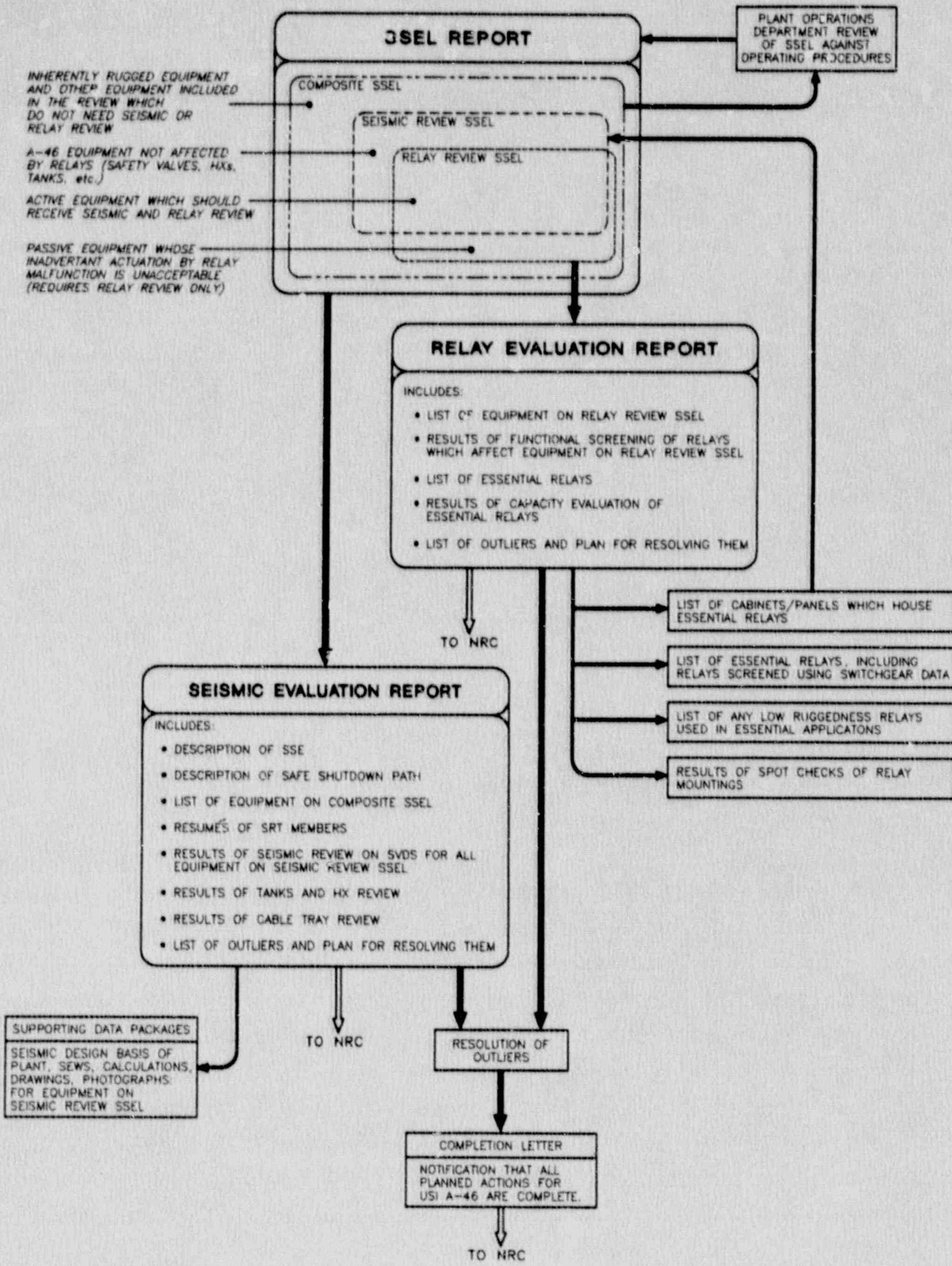


Figure 9-1. Documentation for USI A-46.

results of the Screening Verification and Walkdown are correct and accurate. One of these signatories should also be a licensed professional engineer.

9.1 SQUG COMMITMENTS

Members of SQUG adopting the Generic Implementation Procedure for USI A-46 resolution commit to the following in regard to documenting and reporting to the NRC the results of the safe shutdown equipment identification, the screening verification and walkdown, the relay evaluation, the tanks and heat exchangers review, the cable and conduit raceway review, and the outlier identification and resolution.

The licensee will submit to the NRC the following plant-specific information for resolution of USI A-46.

1. Description of the safe shutdown path(s) chosen for USI A-46.
2. A summary of the main steps in the plant operating procedures used to bring the plant to a safe shutdown condition.
3. List of the equipment on the Composite SSEL.
4. List of equipment on the Seismic Review SSEL.
5. List of equipment on the Relay Review SSEL.
6. Description of the SSE used in the USI A-46 program.
7. Qualifications of the Seismic Capability Engineers and the Lead Relay Reviewer.
8. Results of the Screening Verification and Walkdown for mechanical and electrical equipment.

9. List of essential relays, including their plant identification numbers, when available, the manufacturer's model number, and the floor elevations in the plant where the relays are mounted. The manufacturer's model number should include any submodel designation or other reference which can be used to uniquely identify the GERS or the vendor qualification analysis or test data which is used as the basis for the seismic capacity of the relay.

10. Results of the functional screening of relays which affect equipment on the Relay Review SSEL.

11. Results of the tanks and heat exchangers review.

12. Results of the cable and conduit raceway review.

13. Description of the outliers and any deficiencies.

14. Proposed schedule for complete resolution, future modifications and replacements, or a simple statement explaining why corrective modifications or replacements of outliers will not be made.

After all planned actions to resolve outliers are complete, the utility will inform the NRC of this fact by letter.

9.2 SSEL REPORT

The Safe Shutdown Equipment List (SSEL) Report and supporting documents should describe the overall approach used in the resolution of USI A-46 for shutting down the plant following a postulated safe shutdown earthquake (SSE). The systems selected for accomplishing each of the four safe shutdown functions, and the basis for selecting them should be summarized in this report.

The equipment selected within these systems should be identified and included on three types of SSELs which are described below.

- The Composite SSEL should contain all of the equipment needed during safe shutdown which could have an effect on accomplishing the four safe shutdown functions described in Section 3. This includes equipment which should be evaluated for seismic adequacy and equipment for which relay chatter could cause inappropriate operation. Other equipment in the safe shutdown systems may also be added to this SSEL at the option of the utility.

- The Seismic Review SSEL is a subset of the Composite SSEL and contains all of the mechanical and electrical equipment and the tanks and heat exchangers for which a seismic evaluation should be done as described in Sections 4 and 7, respectively.

- The Relay Review SSEL is a subset of the Composite SSEL and contains all of the mechanical and electrical equipment for which relay chatter could cause inappropriate operation. This list is the starting point for performing the Relay Functionality Review described in Section 6.

The SSEL Report should also describe the method used by the Operations Department for verifying the compatibility of the SSEL with the plant operating procedures.

The information from the SSEL Report which should be sent to the NRC is listed below. Note that it is not necessary to submit the SSEL Report itself. The information listed below may be included with the Relay Evaluation Report or the Seismic Evaluation Report.

- Description of the safe shutdown path(s) chosen for USI A-46.

- List of equipment included on the Composite SSEL.

- List of equipment included on the Seismic Review SSEL.

- List of equipment included on the Relay Review SSEL.

- A summary of the main steps in the plant operating procedures used to bring the plant to a safe shutdown condition and the results of the plant Operations Department review of the SSEL against the plant operating procedures.

9.3 RELAY EVALUATION REPORT

The information which should be documented for the Relay Functionality Review (Section 6) is listed below.

- Identification and listing of all the safe shutdown equipment for which a relay evaluation should be done.

- Résumé of Lead Relay Reviewer.

- Identification and listing of all relays or groups of relays which affect the operation of the safe shutdown equipment. The documentation should be sufficiently detailed such that a reviewer can trace the conclusions reached regarding the effect of relay malfunction on operation of any safe shutdown item of equipment. The relays (including all contact devices) which are screened out, because chatter is acceptable, or by use of the other screening approaches which do not require relay-specific evaluation, do not need to be identified individually. Only the essential relays which require relay-specific seismic capacity evaluations need to be individually identified.

- Identification of relays screened out using switchgear GERS.

- List of any low ruggedness relays used in essential applications.

- Functional screening and capacity evaluation results.

- Identification of cabinets, panels and other enclosures which house essential relays.

- Results of walkdown spot checks.

- Description of the outliers.

- Recommended corrective actions.

The Relay Evaluation Report to be submitted to the NRC should contain the following information. (Note: Some of the information from the SSEL Report may also be included in this report.)

- Results of the functional screening of relays which affect equipment on the Relay Review SSEL.

- List of essential relays including their plant identification number, the manufacturer's model number and the plant floor elevation where the relay is mounted. The manufacturer's model number should include any submodel designation or other reference which can be used to uniquely identify the GERS or the vendor qualification analysis or test data which is used as the basis for the seismic capacity of the relay.

- Results of seismic capacity evaluations of essential relays.

- Description of the relay outliers.

- Proposed schedule for complete resolution, future modifications and replacements, or justification for not performing corrective modifications or replacements of relay outliers.

After submitting this information to the NRC, the utility may use normal methods for implementing and tracking licensing commitments for resolving outliers.

9.4 SEISMIC EVALUATION REPORT

As a result of the screening evaluations described in Sections 4, 5, 7, and 8, the following information should be documented:

- Description of the seismic design basis of plant including SSE ground and floor response spectra, description of the earth on which the plant is founded; e.g., rock or soil; effective grade of plant, etc.

- List of the equipment on the Seismic Review SSEL.

- Résumés of Seismic Capability Engineers.

- Checklists (SEWS), notes, photographs, drawings, calculations, etc. used to back up the Screening Verification and Walkdown (optional).

- Results of the Screening Verification and Walkdown for mechanical and electrical equipment on SVDS forms.

- Results of the tanks and heat exchangers evaluation.

- Results of the cable and conduit raceway review including the basis for identifying which raceway systems support the electrical, control, and instrumentation cable for safe shutdown equipment.

- Description of the outliers on OSVS forms.
- Results of engineering evaluations, tests, calculations, and equipment modifications and replacements used to resolve outliers.

The Seismic Evaluation Report to be submitted to the NRC should contain the following information. (Note: Some of the information from the SSEL Report may also be included in this report)

- Description of the Safe Shutdown Earthquake (SSE) used in the USI A-46 program.
- Résumés of the Seismic Capability Engineers.
- Results of the Screening Verification and Walkdown for mechanical and electrical equipment.
- Results of the tanks and heat exchangers review.
- Results of the cable and conduit raceway review.
- Description of the equipment outliers.
- Proposed schedule for complete resolution, future modifications and replacements, or justification for not performing corrective modifications or replacements of equipment outliers.

After submitting this information to the NRC, the utility may use normal methods for implementing and tracking licensing commitments for resolving outliers.

9.5 COMPLETION LETTER

A completion letter should be sent to the NRC advising them that any corrective actions identified in the Relay Evaluation Report and the Seismic Evaluation Report or any corrective actions agreed to with the NRC Staff as a result of other related correspondence have been completed.

Section 10

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Appendix A

PROCEDURE FOR IDENTIFICATION OF SAFE SHUTDOWN EQUIPMENT

CONTENTS

Appendix A

PROCEDURE FOR IDENTIFICATION OF SAFE SHUTDOWN EQUIPMENT

A.1 INTRODUCTION

The purpose of this appendix is to amplify the method described in Section 3 for identifying safe shutdown equipment. This is done by: (1) describing typical alternative methods for accomplishing a safe shutdown for a pressurized water reactor (PWR) (Section A.2) and for a boiling water reactor (BWR) (Section A.3), and by (2) describing a step-by-step procedure for identifying the individual items of equipment and documenting the results (Section A.4).

A.2 DETAILED DESCRIPTION OF SAFE SHUTDOWN ALTERNATIVES FOR PWRs

Pressurized water reactors (PWRs) typically have several paths or methods which can be used to bring the plant to a safe shutdown condition. Typical alternative methods for accomplishing the four safe shutdown functions (reactor reactivity control, reactor coolant pressure control, reactor coolant inventory control, and decay heat removal) are described in detail for PWRs in this section.

A.2.1 Reactor Reactivity Control (PWR)

The safe shutdown alternatives for accomplishing the reactor reactivity control function for PWRs are illustrated in the block diagram shown in Figure A-1; these alternatives are described below.

Generally, nuclear plants have two methods for controlling reactivity. The primary method for shutting down the nuclear reaction (inserting negative reactivity) is by control rod insertion (SCRAM). A second method is the

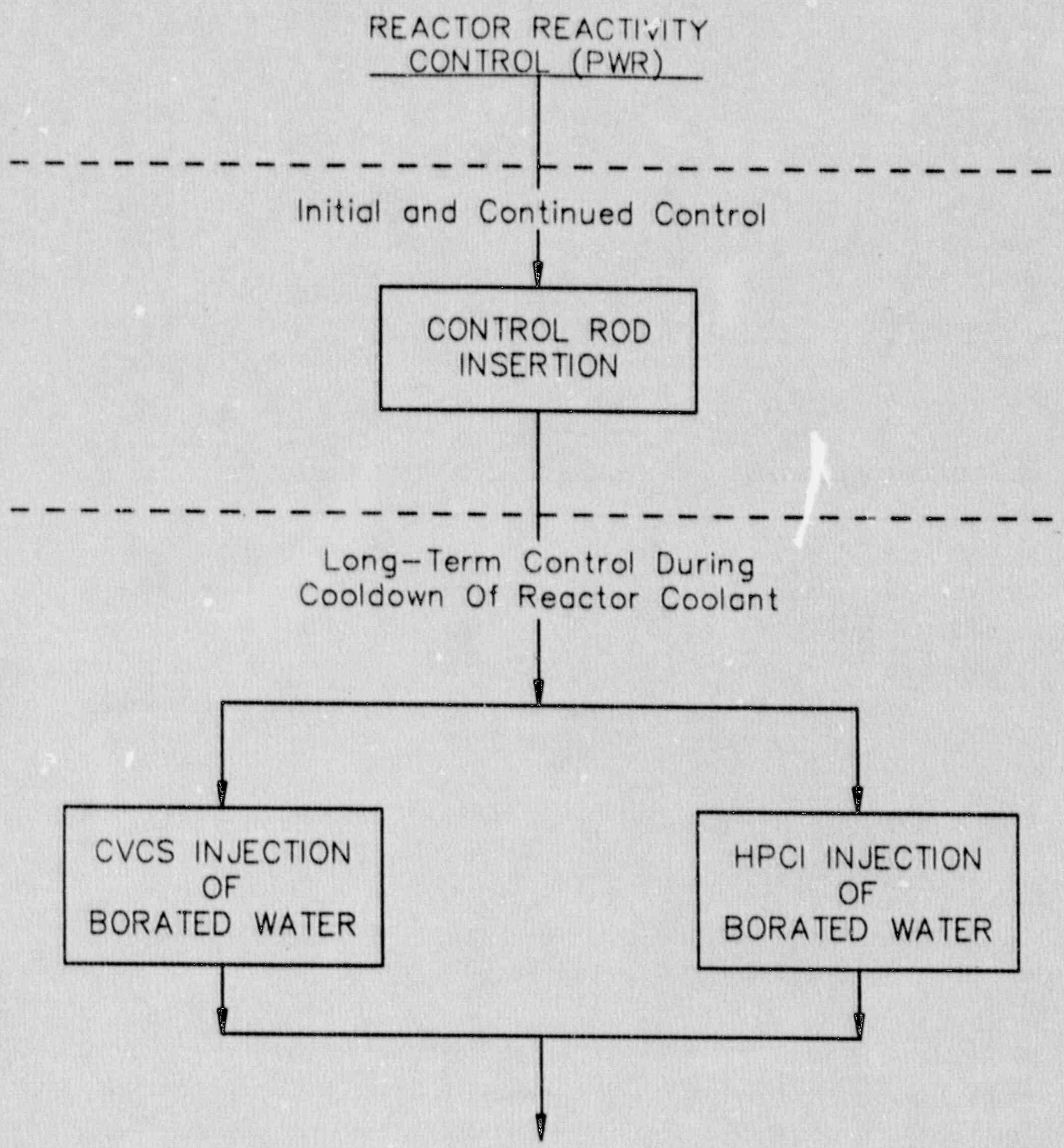

Figure A-1. Safe Shutdown Alternatives for Reactor Reactivity Control of PWRs.

rapid addition of liquid neutron poison, typically boron, to the reactor coolant; this method requires a minimum of 10 to 15 seconds to inject sufficient neutron poison into the reactor coolant system to make the core subcritical without control rod insertion. While both methods are available for emergency shutdown, it is considered that, from a practical standpoint, fast control rod insertion (SCRAM) should be available for initial reactor shutdown during and after an earthquake; therefore, the control rods and associated control rod insertion mechanisms and systems are considered essential for safe shutdown. Since reactors are designed to shut down with one control rod not inserted, this method meets the single failure criteria.

In addition to control rod insertion, reactors also typically require supplemental long-term reactivity control by the addition of liquid poison to the reactor coolant system. This long-term control is needed to compensate for the combined effects of positive reactivity increases resulting from Xenon-135 decay and reduction of the reactor coolant temperature. Note that some plants may need to compensate for significant reactor coolant temperature decreases to get to the hot shutdown mode. Two methods are typically available for injection of borated water into the reactor coolant system to compensate for these long-term, positive reactivity effects. These safe shutdown alternatives include injection via the:

- Chemical and Volume Control System (CVCS), or
- High Pressure Coolant Injection (HPCI) system.

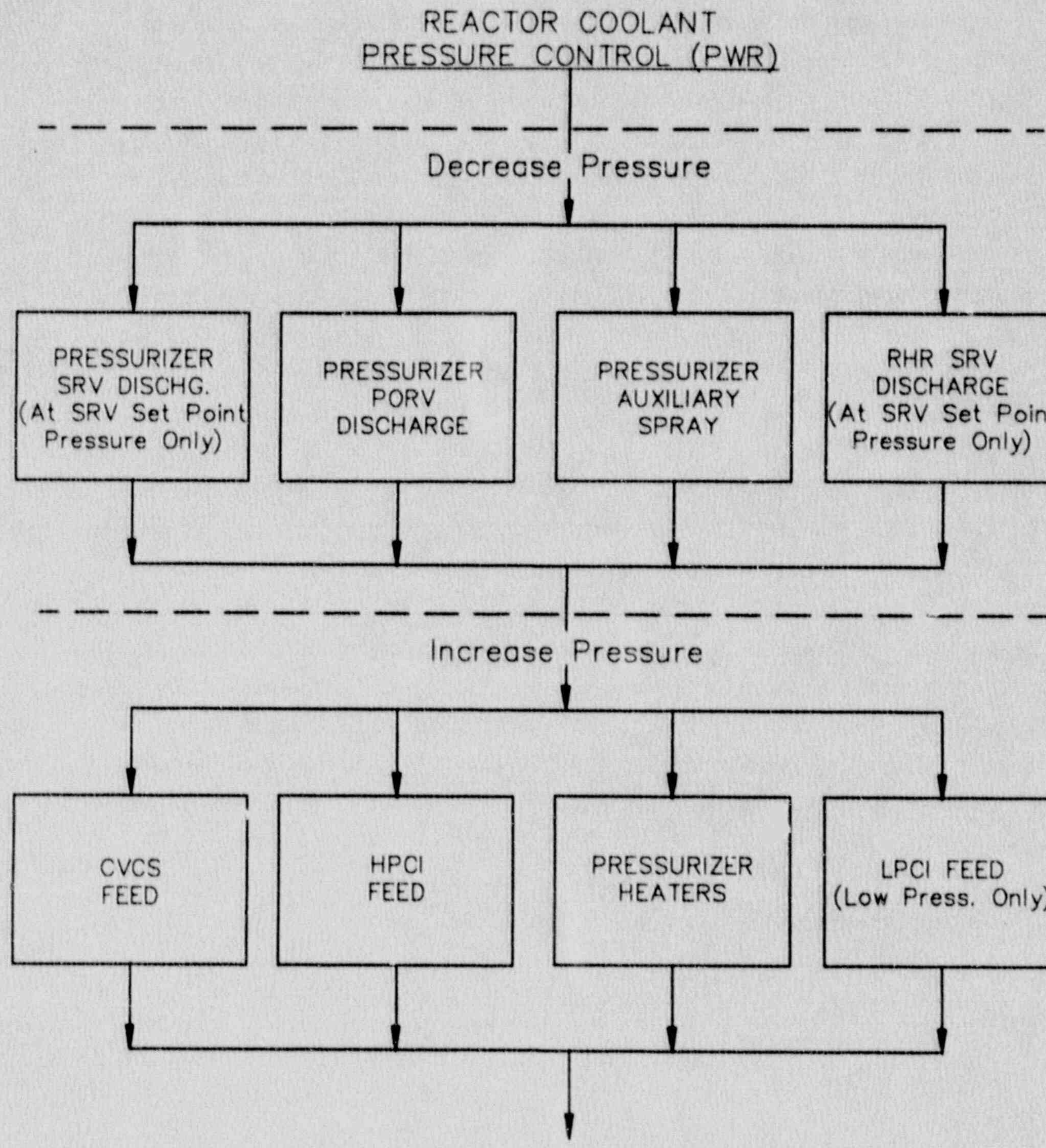

Figure A-2. Safe Shutdown Alternatives for Reactor Coolant Pressure Control of PWRs.

A.2.2 Reactor Coolant Pressure Control (PWR)

The safe shutdown alternatives for accomplishing the reactor coolant pressure control function for PWRs are illustrated in the block diagram shown in Figure A-2; these alternatives are described below along with the conditions under which they can be used. There are various pressure-temperature limits which should not be exceeded in the reactor coolant system of PWRs. These are illustrated in Figure A-3 where the unshaded area in the center of the figure is the Operating Region for the reactor coolant system during and following an earthquake while the reactor coolant pumps are not operating (loss of offsite power is assumed). The shape of the curves and the values of pressure and temperature are approximate. Actual plant limits may be different.

The methods which can be used to avoid exceeding the pressure-temperature limits are illustrated in Figure A-3 by arrows within the Operating Region. These arrows indicate the direction of change of the pressure and temperature when one of the indicated systems or methods is used to avoid exceeding the limits.

The discussion below explains the various pressure-temperature limits and the methods which can be used to avoid them:

The reactor coolant system design pressure (about 2500 psia) is the upper limit on pressure. The pressurizer safety relief valves (SRVs) have the capability to prevent this limit from being exceeded. Also, the power-operated relief valves (PORVs) on the pressurizer can be used to lower the pressure throughout the Operating Region from 2500 psia down to ambient pressure. In addition, reactor coolant system pressure can be reduced by spraying water into the steam space of the pressurizer using an

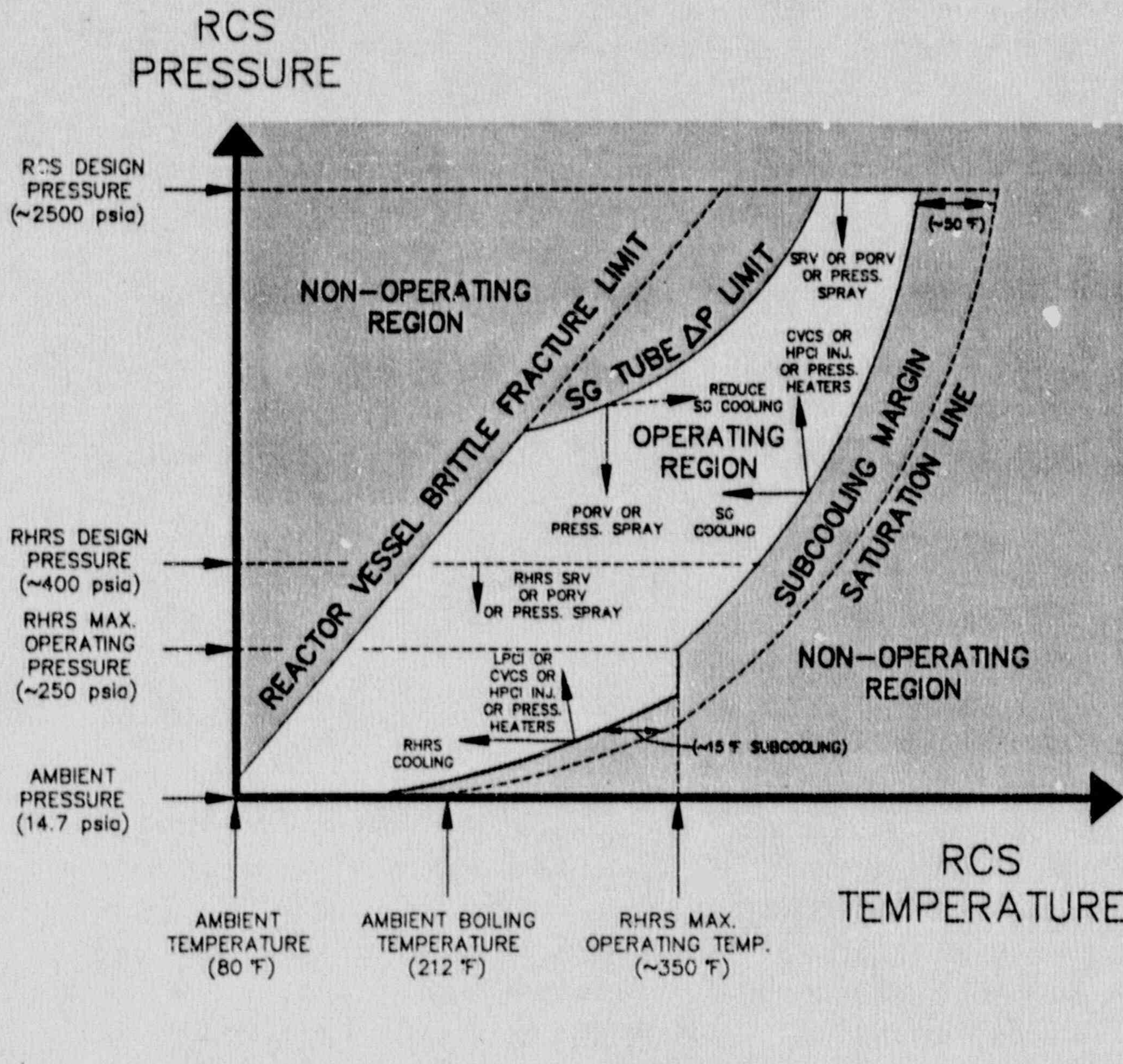

Figure A-3. Pressure-Temperature Limits For Typical PWR Reactor Coolant System Without Reactor Coolant Pumps Operating.

auxiliary spray system. (Normal spray is not available since the reactor coolant pumps are not running due to the assumed loss of offsite power.)

<u>The subcooling margin</u> is another limit on the reactor coolant system pressure (and temperature). It is required to avoid formation of a steam bubble within the reactor vessel. This limit, shown in Figure A-3, is typically about 50°F of subcooling from the saturation line; this amount of subcooling margin is used during natural circulation decay heat removal with the steam generators at secondary side pressures above about 250 psia. Less subcooling margin (about 15°F) is needed below this pressure to maintain sufficient net positive suction head (NPSH) on the low pressure residual heat removal pumps.

The subcooling margins can be maintained by increasing the pressure of the reactor coolant system. Above the maximum operating pressure of the residual heat removal system (RHRS) (about 250 psia), the chemical and volume control system (CVCS) or the high pressure coolant injection (HPCI) system can be used to inject water into the reactor coolant system and thereby compress the steam bubble in the pressurizer and increase the system pressure. As an alternative, the saturation temperature of the reactor coolant in the pressurizer can be increased via pressurizer heaters and thereby raise the pressure. At lower pressures, the low pressure coolant injection (LPCI) system also can be used. Note that injection of cool water into the reactor coolant system also slightly reduces the overall bulk temperature of the reactor coolant. As the water is cooled, it contracts slightly; this is shown by the leftward leaning arrows pointing upward from the subcooling margin line.

Another method of maintaining adequate subcooling margin is to decrease the temperature of the reactor coolant system by increasing the rate of decay heat removal as described in Section A.2.4, Decay Heat Removal (PWR). For pressures above about 250 psia, natural circulation decay heat removal via the steam generators (SGs) can be used. For pressures lower than this, the residual heat removal system (RHRS) can be used.

The reactor vessel brittle fracture limit is another limit on reactor coolant system pressure (and temperature). This limit can be avoided by lowering the reactor coolant system pressure by the same methods described earlier.

Steam generator (SG) tube differential pressure (delta P) limit is another limit on reactor coolant system pressure (and temperature). This limit can be exceeded by overpressurizing the ID of the SG tube with the reactor coolant system without sufficient balancing pressure on the OD of the tube for a given temperature. This limit can be avoided by lowering the reactor coolant system pressure using the same methods described in the previous paragraphs.

One other method of avoiding the reactor vessel brittle fracture limit and the SG tube delta P limit is to allow the temperature of the reactor coolant to rise by reducing the steam generator (SG) cooling. This method is illustrated by the dashed arrow pointing to the right in the operating region of Figure A-3; this arrow is sloping upward to show that as the reactor coolant gets hotter, it also expands and increases the system pressure slightly.

The residual heat removal system (RHRS) design pressure (about 400 psia) should not be exceeded after the residual heat removal system has been connected to the reactor coolant system. In addition to all of the methods described above for lowering the reactor coolant system pressure, the safety relief valves (SRVs) on the RHRS also can be used when the RHRS is connected to the reactor coolant system. Note that it is not necessary to use the RHRS unless the plant elects to go to cold shutdown.

A.2.3 Reactor Coolant Inventory Control (PWR)

The safe shutdown alternatives for accomplishing the reactor coolant inventory control function for PWRs are illustrated in the block diagram shown in Figure A-4; these alternatives are described below.

The inventory of the reactor coolant system is controlled by feeding water into the system and by minimizing the loss of water from the various openings in the system. Note that the alternatives for reactor coolant inventory control are directly related to some of the alternatives for reactor coolant pressure control, e.g., adding water to the reactor coolant system increases the system pressure while removing steam (decreasing inventory) decreases the pressure. Therefore many of the same alternatives are used for both of these safe shutdown functions.

Feed Into the Reactor Coolant System (PWR). Typically, there are three safe shutdown alternatives available for feeding the reactor coolant system:

- Chemical and Volume Control System (CVCS),
- High Pressure Coolant Injection (HPCI) system, or
- Low Pressure Coolant Injection (LPCI) system (at low pressure only).

The CVCS and HPCI systems can be used to control the reactor coolant inventory at both high and low system pressure. The HPCI system in some plants does not have the capability to inject reactor coolant at normal system pressure (about 2250 psia) but can do so at a somewhat lower pressure (about 1600 psia). The LPCI system can only inject reactor coolant into the system at pressures below about 250 psia, depending upon the plant-specific design.

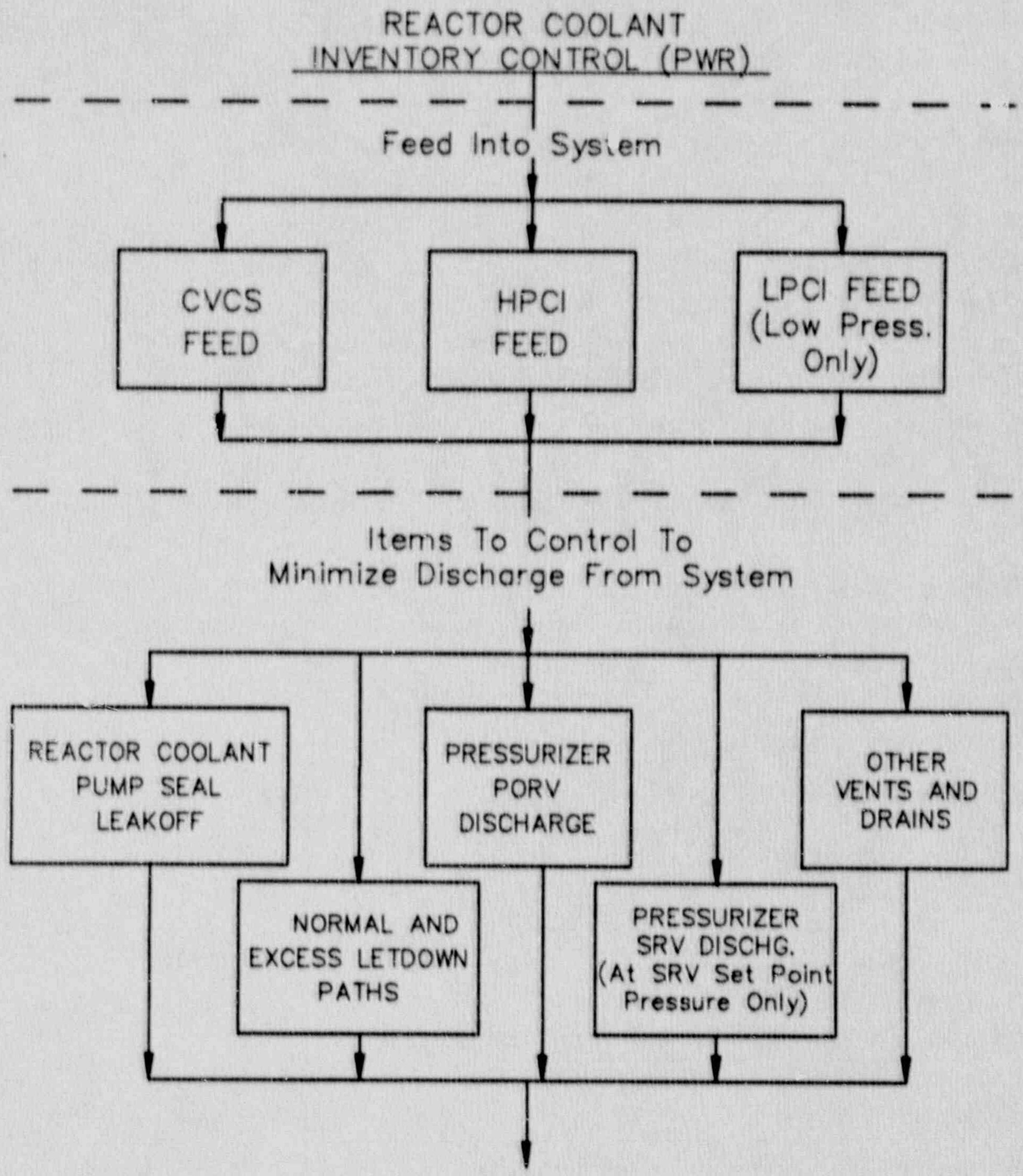

Figure A-4. Safe Shutdown Alternatives for Reactor Coolant Inventory Control of PWRs.

Discharge from the Reactor Coolant System (PWR). There are several paths through which reactor coolant can leave the reactor coolant system. Listed below are typical discharge paths which should be controlled to minimize loss of inventory:

- Reactor Coolant Pump Seal[1] Leakoff,
- Normal and Excess Letdown Paths,
- Pressurizer Power-Operated Relief Valves (PORVs),
- Pressurizer Safety Relief Valves (SRVs) (only at pressures at or above the SRV set point), and
- Other Vents and Drains.

A.2.4 Decay Heat Removal (PWR)

The safe shutdown alternatives for accomplishing the decay heat removal function for PWRs are illustrated in the block diagram shown in Figure A-5; these alternatives are described below.

While the reactor coolant system is at high pressure the steam generators can be used for removing decay heat from PWRs. After the reactor coolant system pressure is lowered sufficiently, the residual heat removal system can also be used.

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1 Note that the reactor coolant pump seals may need a supply of water for cooling (closed cooling, injection, or both) to maintain their integrity while the reactor coolant system is at elevated pressure. If these services are not included in the selected safe shutdown approach, the consequences of seal failure leakage should also be addressed with adequate makeup capacity.

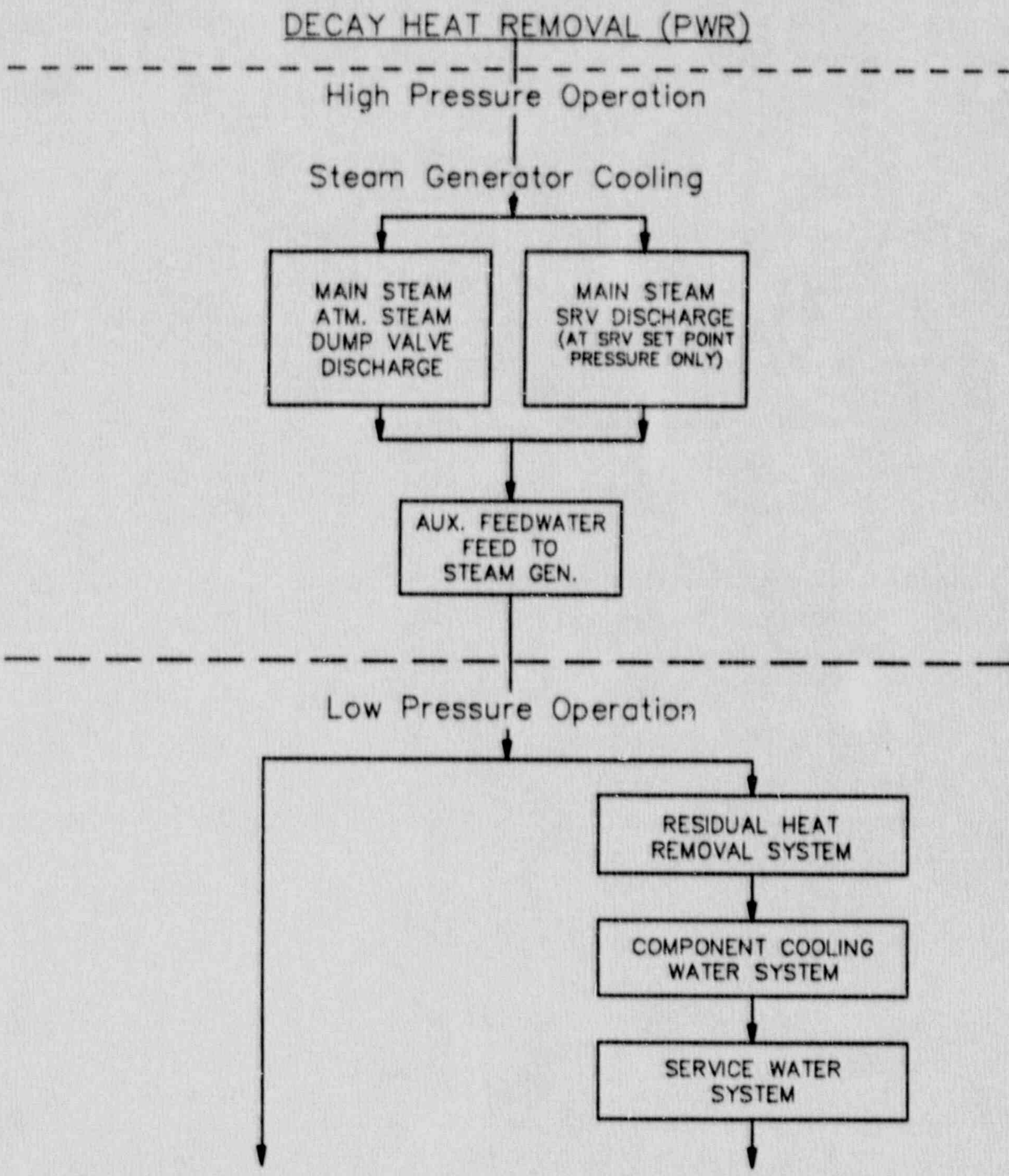

Figure A-5. Safe Shutdown Alternatives for Decay Heat Removal of PWRs.

To remove decay heat via the steam generators, it is necessary to establish natural circulation of reactor coolant between the core (heat source) and the steam generators (heat sink). It is assumed that the reactor coolant pumps are unavailable since they rely upon the use of offsite power. Natural circulation normally requires the reactor coolant to be subcooled to minimize void formation within the reactor vessel (as described in Section A.2.2, Reactor Coolant Pressure Control). After natural circulation is established, heat can be removed from the reactor coolant by boiling the feedwater on the secondary side of the steam generators. The steam generated from this boiling can be discharged to the atmosphere through the main steam atmospheric steam dump valves. The main steam safety valves (SRV) also can be used to discharge steam if the secondary side pressure is allowed to go up to the SRV set point. Condenser steam dumps are not available due to the assumed loss of condenser circulating water pumps, which are driven from offsite power.

Makeup feedwater can be supplied to the secondary side of the steam generator via the emergency/auxiliary feedwater (AFW) system. The condensate storage tank (CST) is the preferred source of auxiliary feedwater with the service water system (SW) typically available as a backup.

The reactor coolant temperature and pressure can be lowered by manually lowering the steam generator secondary side pressure using the atmospheric steam dump valve. In some plants, decay heat removal via the steam generators can continue at low reactor coolant system pressure and temperature; however, in other plants, it is difficult to continue this natural circulation mode of decay heat removal after the reactor coolant system pressure and temperature have dropped below about 250 psia and 350°F. In these cases a low pressure decay heat removal system can be used.

If it is preferred (or required due to certain plant limitations) to bring the plant to a cold shutdown condition, the residual heat removal system (RHRS) can be used to remove decay heat from the core after the reactor coolant system pressure and temperature are typically below about 250 psia and 350°F. There is considerable variation in the design of this system both among reactor vendors and as a result of evolution of each vendor's design; however, this system typically consists of pumps which take suction from the reactor coolant system, circulate the water through heat exchangers, and inject the water back into the reactor coolant system. Heat is transferred from the RHRS heat exchangers to the closed loop, component cooling water (CCW) system which has its own set of pumps for circulating water. Heat is transferred from the CCW system to the service water (SW) system in another heat exchanger and from there to the ultimate heat sink (lake, river, atmosphere).

A.3 DETAILED DESCRIPTION OF SAFE SHUTDOWN ALTERNATIVES FOR BWRs

Boiling water reactors (BWRs) typically have several paths or methods which can be used to bring the plant to a safe shutdown condition. Typical alternative methods for accomplishing the four safe shutdown functions (reactor reactivity control, reactor coolant pressure control, reactor coolant inventory control, and decay heat removal) are described in detail in this section for BWRs.

A.3.1 Reactor Reactivity Control (BWR)

The safe shutdown alternative for accomplishing the reactor reactivity control function for BWRs is illustrated in the block diagram shown in Figure A-6. Although two independent methods are available for reactivity

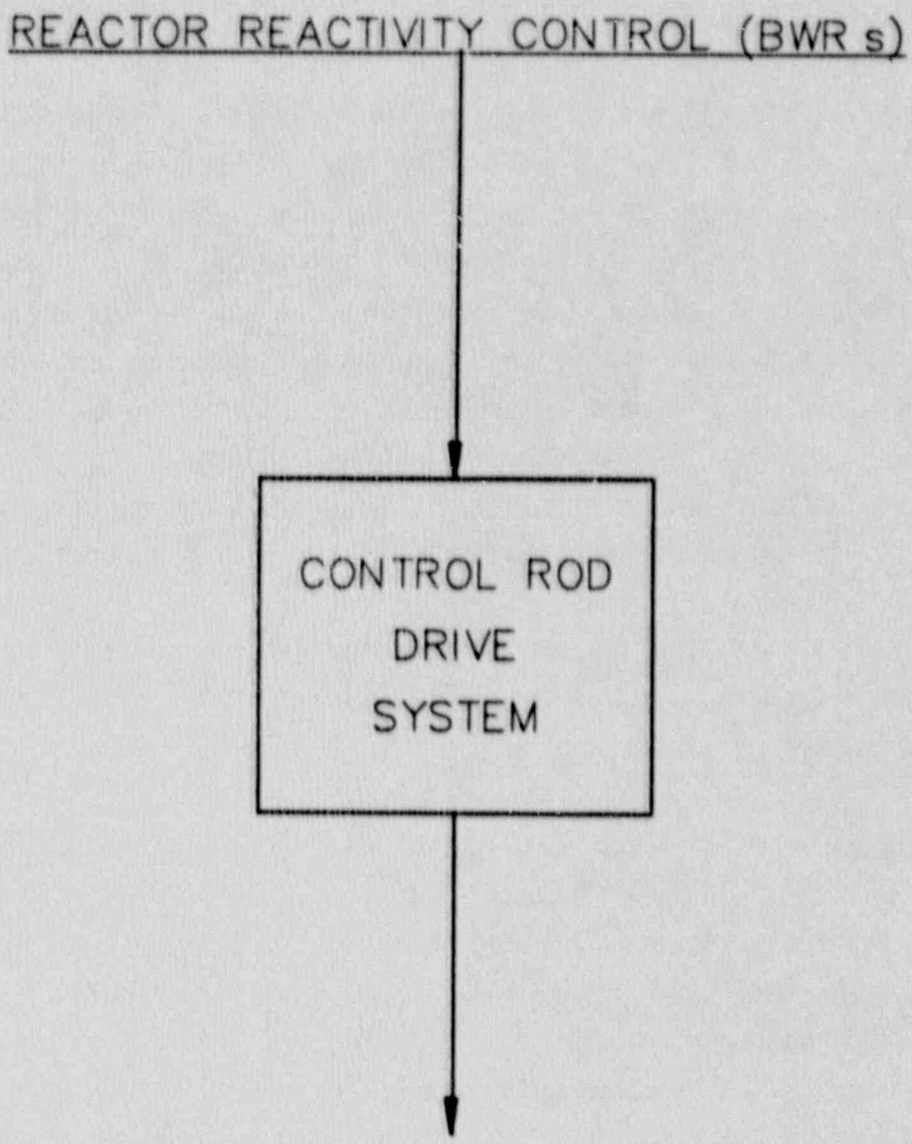

Figure A-6. Safe Shutdown Alternatives for Reactor Reactivity Control of BWRs.

control during reactor shutdown conditions, control rod drive system and standby liquid control system, the control rod drive system is the preferred method.

Control Rod Drive System (BWR). The control rod drive (CRD) system is the primary method of reactivity control and is the only method capable of rapid shutdown (SCRAM) of the reactor or operational control of fast reactivity transients. For this reason, the CRD system is considered an essential safe shutdown system. The CRD system is used to manually position neutron absorbing control rods in the reactor core and acts automatically to rapidly insert the control rods when required.

The CRD mechanism consists of a double-acting, mechanically-latched, hydraulic cylinder which uses demineralized water from the condensate storage tank or condenser hotwell as the operating fluid. A separate hydraulic control unit is provided for each individual control rod. The CRD hydraulic system supplies and controls the pressure and flow requirements to the drive mechanisms.

Each CRD drive mechanism is connected to a SCRAM accumulator tank pressurized with nitrogen. The SCRAM accumulator tank stores sufficient energy to fully insert the control rod independent of any other source of energy; i.e., pneumatic, AC, or DC power. During SCRAM, accumulator pressure is admitted below the drive piston and the volume over the drive piston is vented to the SCRAM discharge volume tank. The large differential pressure across the drive piston produces a large upward force on the control rod to insert the control rod into the core.

Standby Liquid Control System (BWR). The standby liquid control (SLC) system provides a backup method of reactivity control. The SLC system will shut down the reactor from full power to cold shutdown in the event the control rods are inoperable. The SLC system is manually initiated from the control room and pumps a neutron absorbing solution (sodium pentaborate) into the reactor vessel. The injection time is approximately 1 to 2 hours, depending on the pump capacity and the amount of solution in the tank. The SLC system is only required to shut down the reactor at a steady state within the capacity of the normal shutdown cooling systems. The SLC system is not capable of rapid shutdown (SCRAM) of the reactor or operational control of fast reactivity transients. Since the CRD system is required and is sufficient to achieve and maintain reactor shutdown in BWRs during and after an earthquake, the SLC system is not considered an essential safe shutdown system in BWRs.

A.3.2 Reactor Coolant Pressure Control (BWR)

The safe shutdown alternatives for accomplishing the reactor coolant pressure control function for BWRs are illustrated in the block diagram shown in Figure A-7; these alternatives are described below.

Overpressure protection of the reactor coolant system is provided by safety relief valves and safety valves located on the main steam lines in the drywell. The safety relief valves are self-actuated by the reactor coolant system pressure to open at their set relieving pressure. Typically, the safety relief valves are set to open at a lower pressure than the safety valves. The safety relief valves discharge steam directly to the suppression pool. Also, they may be actuated remotely from the control room to open at lower pressures to

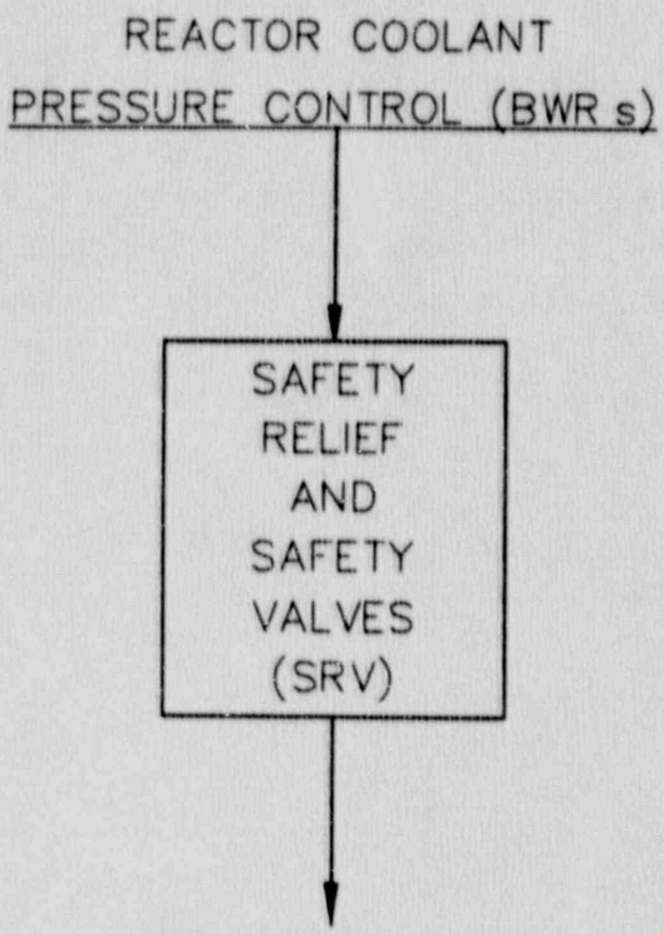

Figure A-7. Safe Shutdown Alternatives for Reactor Coolant Pressure Control of BWRs.

depressurize the reactor coolant system so that low pressure systems can be used for reactor coolant inventory control and decay heat removal. In addition, some of the safety relief valves open automatically during certain LOCAs in the event the high pressure core cooling systems are unavailable or are unable to maintain acceptable reactor water level above the core.

The safety valves are spring-loaded valves which are self-actuated by the reactor coolant system pressure to open at the set relieving pressure. The safety valves are set to open at a higher pressure than the safety relief valves, and, in conjuction with the safety relief valves, protect the reactor coolant system from severe pressure transients. The safety valves generally discharge to the drywell.

Safety valves on the low pressure residual heat removal system also can be used during low pressure decay heat removal to prevent the reactor coolant system pressure from exceeding the design pressure of the low pressure system.

A.3.3 Reactor Coolant Inventory Control (BWR)

The safe shutdown alternatives for accomplishing the reactor coolant inventory control function for BWRs are illustrated in the block diagram shown in Figure A-8; these alternatives are described below.

During reactor shutdown conditions, makeup water to the reactor coolant system is required to replace steam released through the safety relief valves and safety valves, to make up for leakage from the reactor coolant system (i.e., recirculation pump seals, normal unidentified leakage, etc.), and to compensate for the contraction of the reactor coolant system volume due to cooldown. The following high and low pressure systems are available for supplying makeup water to the reactor vessel.

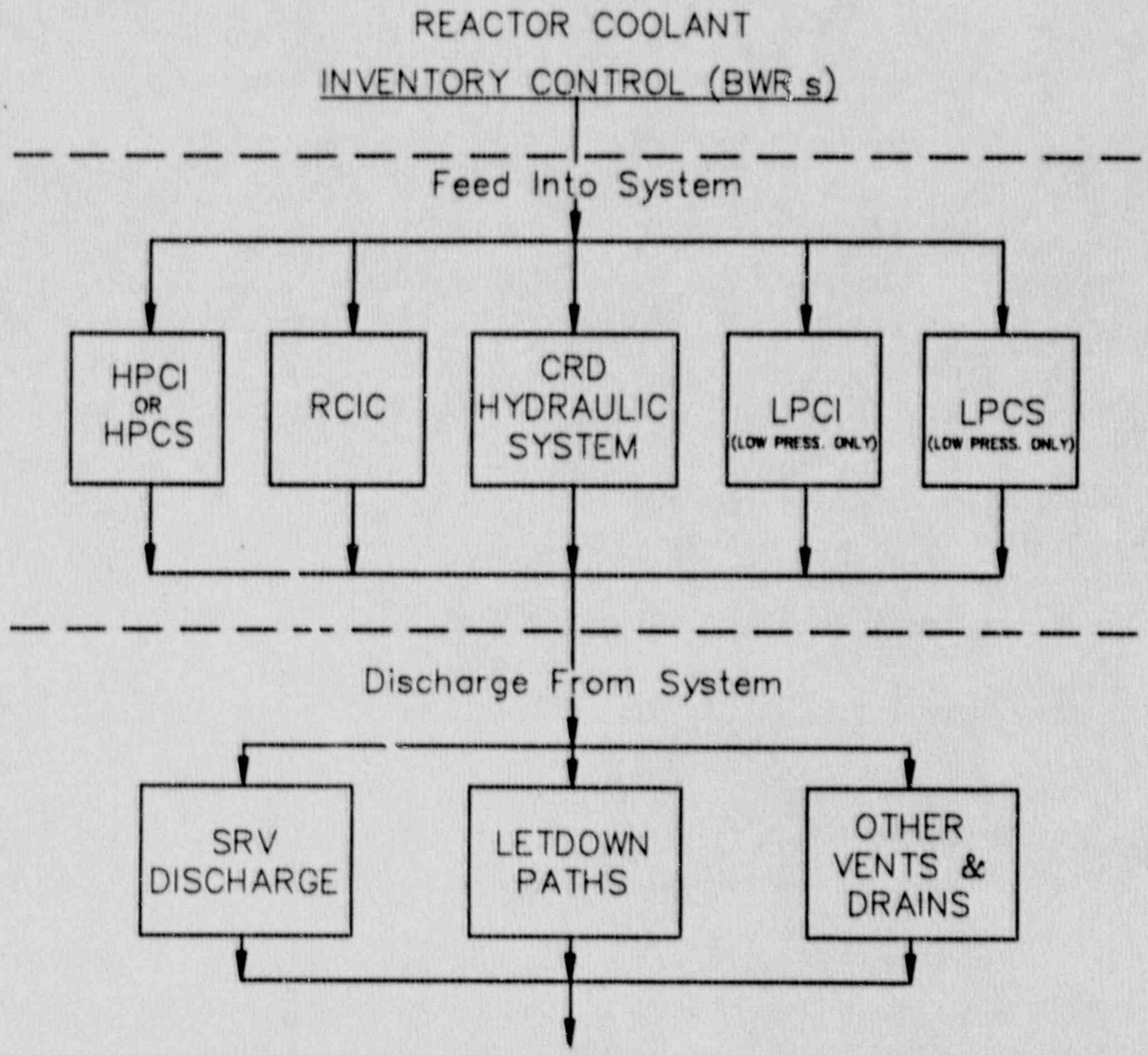

Figure A-8. Safe Shutdown Alternatives for Reactor Coolant Inventory Control of BWRs.

High Pressure Systems (BWR). Available high pressure systems consist of the following:

1. High Pressure Coolant Injection (HPCI) System, or High Pressure Core Spray (HPCS) System (BWR). BWRs will have only one of these two high pressure injection systems. Most older BWRs have HPCI systems while the newer BWRs have HPCS systems.

   The HPCI system uses a steam turbine-driven pump to pump water from the condensate storage tank into the feedwater system. Water is injected into the reactor vessel through the feedwater sparger. On low condensate storage tank level or high suppression pool level, the pump suction is automatically transferred to the suppression pool. Manual transfer may also be made from the control room.

   The HPCS system uses a motor-driven pump to pump water from the condensate storage tank into the reactor vessel through a spray header located inside the reactor vessel. On low condensate storage tank level or high suppression pool level, the pump suction is automatically transferred to the suppression pool. Manual transfer may also be made from the control room.

2. Reactor Core Isolation Cooling System (BWR). The reactor core isolation cooling (RCIC) system uses a steam turbine-driven pump to pump water from the condensate storage tank into the feedwater system. Water is injected into the reactor vessel through the feedwater sparger. Another source of water is the suppression pool in the event the condensate storage tank becomes depleted. The RCIC system is not provided on older BWRs with isolation condenser systems.

3. Control Rod Drive Hydraulic System (BWR). Another source of high pressure water is from the control rod drive (CRD) hydraulic system. The CRD hydraulic system is relatively limited in capacity (approximately 100 gpm), but can provide sufficient makeup to maintain reactor vessel water level after the reactor has been shutdown for several hours. In some plants, the CRD hydraulic system may not be available to perform safe shutdown functions due to reliance on offsite AC power to operate the electric-driven CRD pumps.

   The earliest BWRs (e.g., Oyster Creek, Nine Mile Point 1, and Millstone 1) have feedwater coolant injection (FWCI) systems instead of HPCI or HPCS systems. The FWCI system uses the electric-driven main feedwater pumps to pump water into the reactor vessel via the main feedwater system; however, the FWCI system is considered unavailable for performing safe shutdown functions due to its reliance on offsite AC power for the main feedwater pumps. Thus, these plants must use the CRD hydraulic system or the reactor coolant system must be depressurized so that low pressure systems can be used for reactor coolant inventory control.

Low Pressure Systems (BWR). The Automatic Depressurization System (ADS) may be used in conjunction with low pressure systems to supply makeup water to the reactor vessel. The ADS may be remotely manually-actuated from the control room. The ADS depressurizes the reactor vessel by releasing steam to the suppression pool through the safety relief valves. Available low pressure systems consist of the following:

1. Low Pressure Coolant Injection System (BWR). The low pressure coolant injection (LPCI) system uses the electric-driven residual heat removal (RHR) pumps to pump water from the suppression pool to the reactor vessel through a recirculation line. The LPCI system is not provided on some of the early BWRs.

2. Low Pressure Core Spray System (BWR). The low pressure core spray (LPCS) system uses electric-driven pumps to pump water from the suppression pool to the reactor vessel through a spray header located inside the reactor vessel.

Discharge From Reactor Coolant System (BWR). There are several paths through which reactor coolant can leave the reactor coolant system. Listed below are typical discharge paths which should be controlled to minimize loss of inventory:

- Safety Relief Valves (SRV);
- Letdown Paths; and
- Other Vents and Drains.

A.3.4 Decay Heat Removal (BWR)

The safe shutdown alternatives for accomplishing the decay heat removal function for BWRs are illustrated in the block diagram shown in Figure A-9; these alternatives are described below.

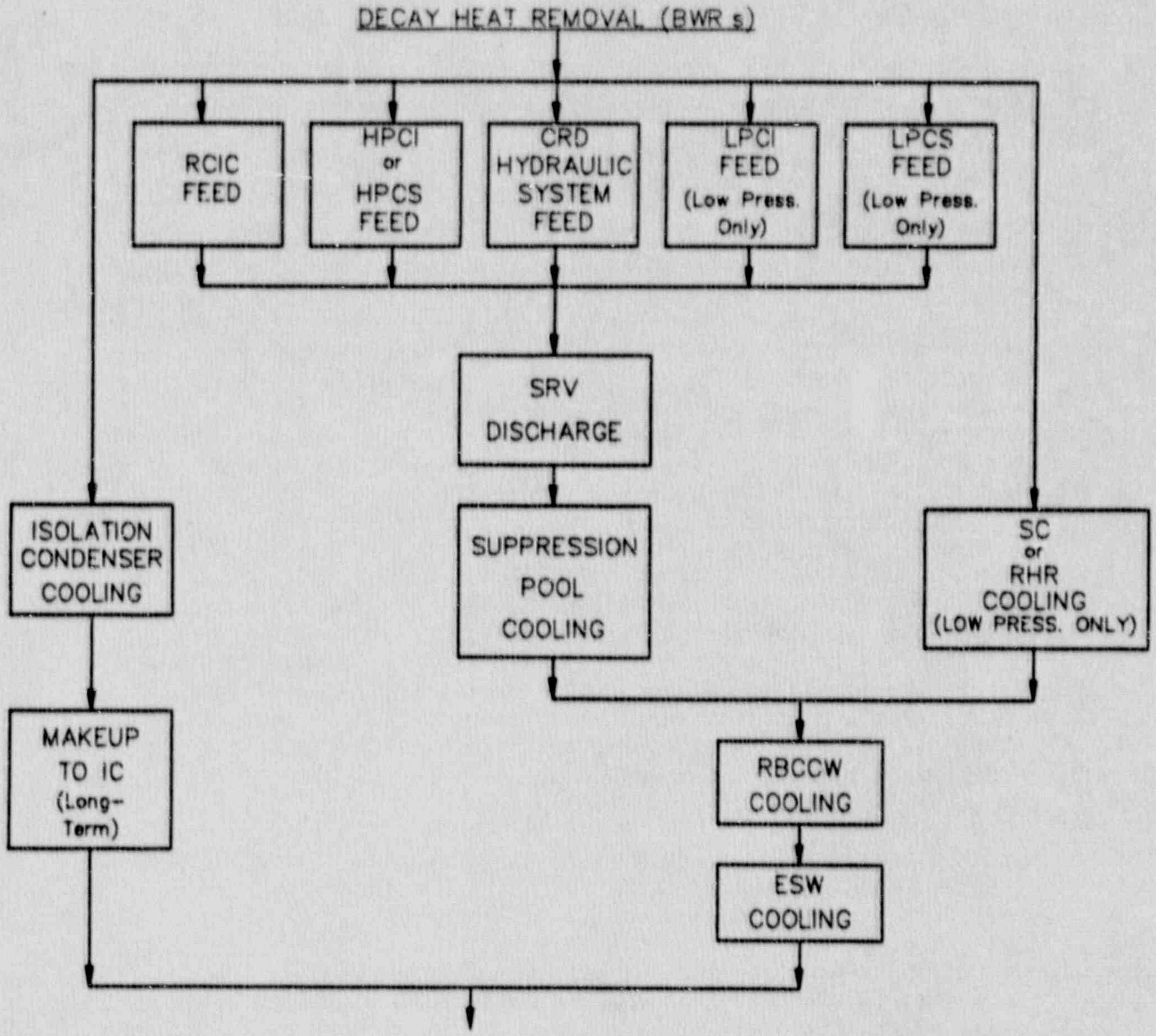

Figure A-9. Safe Shutdown Alternatives for Decay Heat Removal of BWRs.

The following high and low pressure systems are available to remove reactor core decay heat following reactor shutdown.

<u>High Pressure Systems (BWR)</u>. The high pressure systems typically available to remove reactor core decay heat are as follows:

1. <u>Isolation Condenser (IC) System or Reactor Core Isolation Cooling (RCIC) System (BWR)</u>. Early BWRs have an IC system to remove decay heat in the event the reactor becomes isolated from the main condenser. Later BWRs have the RCIC system.

   The IC system consists of a large vessel filled with water with an internal U-tube bundle which is connected by piping to the reactor vessel. Isolation valves (one AC powered and one DC powered) are provided on the steam supply and condensate return lines. Normally, the isolation valves on the steam supply lines are open so that the steam supply line, condenser tubes, and condensate return line are pressurized at reactor pressure. The AC isolation valve in the condensate return line normally is open and the DC valve normally is closed. The system is placed in operation by opening the normally closed DC isolation valve in the condensate return line. Thus, AC power is not required to place this system in operation. Steam flows by natural circulation from the reactor vessel to the isolation condenser where it is condensed and cooled by boil-off of water on the shell side of the condenser to the atmosphere. The condensate returns to the reactor vessel through the condensate return line which connects with the reactor recirculation system. Makeup to the shell side of the isolation condenser is normally from the condensate storage tank or a dedicated makeup storage tank. In addition, most plants can also supply makeup water to the shell side of the isolation condenser by alternate methods (e.g., from the fire protection system, suppression pool, etc.).

   The RCIC system consists of a steam turbine-driven injection pump and associated piping, valves, and controls. Core decay heat is removed by releasing steam through the safety relief valves to the suppression pool. Suppression pool cooling is provided via the residual heat removal (RHR) heat exchangers. The RHR heat exchangers are cooled by the reactor building closed cooling water (RBCCW) system which is cooled by the emergency service water (ESW) system. Makeup to the reactor vessel is provided by the RCIC pump which uses steam produced in the reactor vessel to pump demineralized water from the condensate storage tank to the feedwater system. The feedwater system provides a direct flow path to the reactor vessel. Another source of water is the suppression pool in the event the condensate storage tank becomes depleted.

   In newer BWRs, the steam condensing mode of the RHR system may be manually initiated approximately 1.5 hours after reactor shutdown. In this mode, steam is routed through one of the RHR heat exchangers where it is condensed and cooled, then returned to the reactor vessel by an interconnection with the RCIC pump, providing closed loop cooling.

2. High Pressure Coolant Injection (HPCI) System or High Pressure Core Spray (HPCS) System (BWR). Early BWRs used the HPCI system. In later BWRs, the HPCI system was replaced with the HPCS system. The HPCI and HPCS systems are designed to protect the core in the event of a LOCA. The HPCI and HPCS systems also may be used for long-term decay heat removal following reactor shutdown. Core decay heat is removed by releasing steam through the safety relief valves to the suppression pool. Suppression pool cooling is provided via the RHR heat exchangers. The RHR heat exchangers are cooled by the RBCCW system which is cooled by the ESW system. Makeup to the reactor vessel is provided by the HPCI or HPCS injection pumps. The HPCI pumps are steam turbine-driven and pump demineralized water from the condensate storage tank to the feedwater system. The feedwater system provides a direct flow path to the reactor vessel. The HPCS pumps are electric-driven and pump demineralized water from the condensate storage tank to a spray header located inside the reactor vessel. On low condensate storage tank level, the HPCI and HPCS pump suctions are automatically transferred to the suppression pool.

Low Pressure Systems (BWR). If desired, the reactor coolant system may be depressurized manually by using the Automatic Depressurization System (ADS) to release steam through the safety relief valves to the suppression pool. This will allow the use of the following low pressure systems for long-term decay heat removal.

1. Shutdown Cooling (SC) System or Residual Heat Removal (RHR) System (BWR). Early BWRs contained a separate low pressure SC system for removal of core decay heat following reactor shutdown. In later BWRs, the SC system was replaced with the RHR system which can be operated in several different modes to accomplish the following:

   - Shutdown cooling
   - Low pressure coolant injection
   - Vessel head spray cooling
   - Suppression pool cooling
   - Containment cooling

The SC system uses electric-driven pumps to circulate reactor coolant from the reactor recirculation system to the SC heat exchangers and back to the recirculation system. The shutdown cooling heat exchangers are cooled by the RBCCW system which is cooled by the ESW system.

The shutdown cooling mode of the RHR system operates in a similar manner; i.e., reactor coolant is circulated from the recirculation system through the RHR heat exchangers and back to the recirculation system using electric-driven RHR pumps. The RHR heat exchangers are cooled by the RBCCW system which is cooled by the ESW system.

2. Low Pressure Coolant Injection System (BWR). The low pressure coolant injection (LPCI) mode of the RHR system also can be used for long-term decay heat removal at low pressure following reactor shutdown. Core decay heat is removed by releasing steam through the safety relief valves to the suppression pool. Suppression pool cooling is via the RHR heat exchanger. The RHR heat exchangers are cooled by the RBCCW system which is cooled by the ESW system. Makeup to the reactor vessel is provided by the electric-driven LPCI injection pumps (which are actually RHR pumps). In the LPCI mode, water is pumped by the RHR pumps from the suppression pool to the reactor recirculation system.

3. Low Pressure Core Spray System (BWR). The low pressure core spray (LPCS) system provides another redundant method of removing core decay heat at low pressure following reactor shutdown. Core decay heat is removed by releasing steam through the safety relief valves to the suppression pool. On early BWRs with a separate shutdown cooling system instead of the multi-purpose RHR system, the suppression pool is cooled via the containment spray heat exchangers. The containment spray heat exchangers are cooled by the RBCCW system which is cooled by the ESW system. On later BWRs with the multi-purpose RHR system, the suppression pool is cooled via the RHR heat exchangers. The RHR heat exchangers are cooled by the RBCCW system which is cooled by the ESW system. Makeup to the reactor vessel is provided by the LPCS electric-driven pumps which pump water from the suppression pool to a spray header inside the reactor vessel.

A.4 STEP-BY-STEP PROCEDURE FOR IDENTIFYING SAFE SHUTDOWN EQUIPMENT

This section describes a step-by-step procedure for:

- Identifying the major system alternatives available for achieving and maintaining safe shutdown conditions at a nuclear power plant,
- Selecting preferred safe shutdown alternatives for the primary and backup means of safe shutdown, and

- Identifying all the equipment required by the preferred safe shutdown alternatives.

The approach taken in this procedure is to identify the major system alternatives and then select a preferred major system alternative or shutdown train for the primary and backup means of safe shutdown. Only the equipment in these preferred alternatives need to be identified prior to the seismic walkdown. The decision as to which alternatives should be selected can be made from a high-level engineering evaluation conducted by a team of engineers with experience in the mechanical and electrical systems of the plant and with background in seismic areas. Also, plant operations and management should review the selection of the preferred safe shutdown alternatives.

If desired, the equipment associated with other major system alternatives also can be identified prior to the walkdown. This would provide additional flexibility during the walkdown in case the seismic adequacy of certain equipment in the preferred paths cannot be easily verified.

The flow diagram in Figure A-10 (located at the end of this appendix) shows all the steps to be taken in identifying the safe shutdown equipment in the plant. It is suggested that this figure be referred to while reading this section. The steps in this procedure can be divided into three major tasks.

- Identification of the primary and backup safe shutdown alternatives for each of the four safe shutdown functions described in Section 3.4. The generic safe shutdown alternatives described in Sections A.2 and A.3 of this appendix can be used as a guide. This major task is shown in Steps 1 through 3 in Figure A-10.
- Identification of the equipment needed for each of the four safe shutdown functions and generation of a safe shutdown equipment list (SSEL) for each function. This major task is shown in Steps 4 through 16 in Figure A-10.

- Generation of a safe shutdown equipment list (SSEL) for the seismic evaluation and an SSEL for the relay evaluation from the SSELs generated above. This major task is shown in Steps 17 and 18 in Figure A-10.

The sequence of steps in this procedure is to: (1) select one of the safe shutdown functions, (2) identify the preferred safe shutdown alternative, and (3) identify the equipment in that alternative. However, the user may wish to identify all the preferred alternatives for all four functions prior to identifying the specific equipment in any of these alternatives; i.e., perform the first major task (Steps 1 through 3) for all four functions prior to performing the remainder of the procedure. Then, the results of this overall system selection process can be reviewed by utility operations and management before proceeding with the detailed (and time consuming) process of identifying the individual items of equipment.

The steps in this procedure include a description of how to document its implementation. Note that the purpose of documenting these steps is to provide a systematic method of identifying all the equipment needed for safe shutdown. The documentation identified by this procedure includes: (1) a description of the plant-specific, preferred safe shutdown alternative and the procedures which would be used for each safe shutdown function, (2) marked-up schematic diagrams (fluid system P&IDs, electrical one-line diagrams, instrumentation block diagrams, etc.), (3) safe shutdown equipment lists (SSELs) for each safe shutdown function and any other SSELs for support systems, (4) an SSEL for seismic evaluation, and (5) an SSEL for relay evaluation. Blank forms are provided in Exhibits A-1, A-3, and A-5 at the end of this appendix for documenting the identification of equipment on SSELs; the discussion below describes how to fill out these forms. Exhibits A-2, A-4, and A-6 show these forms filled out with a data base management system.

The details for performing each of the steps shown in Figure A-10 are provided below. The number and description within each box of the flow diagram in Figure A-10 correspond to the step number and section title in the description below.

Step 1 - Pick a Safe Shutdown Function

The four safe shutdown functions which should be accomplished during and following a safe shutdown earthquake are:

- Reactor Reactivity Control
- Reactor Coolant Pressure Control
- Reactor Coolant Inventory Control
- Decay Heat Removal

One of these four functions should be selected on the first pass through this procedure. Succeeding passes through this procedure should pick up the other three functions. A separate SSEL should be generated for each of these four functions. In some cases a separate SSEL can be generated for the primary and backup trains of equipment. Also, additional tables can be generated for supporting systems which are common to several functions so that the same equipment does not need to be duplicated or several tables. The form shown in Exhibit A-1 can be used for each of these SSELs.

Step 2 - Identify Paths Available

There are normally several alternatives for accomplishing each of the safe shutdown functions selected in Step 1, above. In this step, various major system alternatives should be identified and documented.

The description of each safe shutdown alternative should be similar to the descriptions of the generic safe shutdown alternatives contained in Section A.2 or A.3 of this appendix. Plant-unique equivalents to these generic alternatives also may be identified. These descriptions should address how the systems used for each alternative can be put into operation including any automatic controls and operator initiated actions using the plant procedures. Note that manual initiation and verification of operation at a local station is an acceptable alternative to automatic initiation and remote indication, provided time, manpower, and appropriate procedures are available to use the local station.

It should be noted that for each of the four safe shutdown functions, a backup or redundant item of equipment or alternate method should be available for each active item of equipment in the system being used.

Backup equipment need not necessarily be installed spares. Alternative means of providing backup capability can include manual operation of power-operated equipment, substitution of a temporary item of equipment (if enough time and procedures are available to bring it into operation), or use of another safe shutdown alternative.

Completion of this step should result in the following:

- Descriptions of the safe shutdown alternatives for accomplishing the safe shutdown function.
- Descriptions of how the alternatives can be put into operation using the plant procedures.

The above results should be documented in a format similar to the descriptions shown in Sections A.2 and A.3 of this appendix.

Step 3 - Pick A Primary/Backup Path

The purpose of this step is to review the various alternative methods for achieving safe shutdown defined in Step 2 and to select a preferred method for either the primary or backup means of shutdown. This selection can be based on one or a combination of the following considerations:

- The systems and equipment selected for shutting down the plant following a fire. It should be noted, however, that the safe shutdown equipment identified for this procedure will not necessarily be the same as equipment identified for 10 C.F.R. Part 50, Appendix R, for the same general shutdown method.
- The alternatives which rely on the systems and equipment to operate in their normal mode.
- The alternatives which are straightforward and present the least challenge to the operators.
- The status of the seismic classification, design, and documentation for the equipment in the safe shutdown alternative.
- The results of previous seismic reviews and walkdowns.
- The location (elevation) of the equipment within the plant (the lower the elevation, the lower the seismic excitation).
- The operating procedures (normal or emergency) used to achieve and maintain safe shutdown conditions.

In addition, the following factors may also be considered:

- The practicality/difficulty and cost of returning the plant to normal operation after an SSE.
- The alternatives which minimize the amount of effort, expense, and radiation exposure to verify the seismic adequacy of the equipment.

Selection of the preferred safe shutdown alternative requires a broad understanding of the systems, equipment, and procedures used in the plant. This high-level selection process should be reviewed by plant operations and management. Specific items of equipment within the selected systems can then be identified by the systems engineer in the remaining steps of this procedure.

Completion of this step will result in the following:

- Completed headings beneath the title on the SSEL (Exhibit A-1) with the following information:

  -- Name of safe shutdown function for which equipment will be identified, for example:

     FUNCTION: Decay Heat Removal

  -- Description of alternative for accomplishing the safe shutdown function, for example:

     ALTERNATIVE: SG Cooling/AFW and Steam Dump Valves

- Description of the safe shutdown alternatives selected for accomplishing each of the four safe shutdown functions. This summary should also identify the major steps in the procedures which would be used in bringing the selected safe shutdown equipment into operation and continuing to operate it.

Step 4 - Identify An Item of Equipment

The preferred safe shutdown alternative identified in Step 3, above, typically will require several different systems or parts of systems to operate. The purpose of this step is to trace the path of fluid (or power, or cooling, etc.) from its source to its destination and identify one item of equipment. The schematic diagram (fluid system P&ID, electrical system one-line diagram, instrument block diagram, etc.) can be marked up with see-through markers or highlighters to illustrate the path selected and to ensure that all branches and alternate paths are accounted for.

The equipment to be identfied for safe shutdown should be one of the Equipment Classes #0 through #21 described in Table 3-1 of Section 3. Equipment to be included in the safe shutdown equipment list are those items of active mechanical and electrical equipment which should operate or change state to accomplish the safe shutdown function selected in Step 1. It should also include electrical equipment which should not inadvertently operate or change state due to relay (contact) chatter. The equipment needed for supporting the safe shutdown equipment should also be identified, such as, electrical power and control, pneumatic power and control, cooling, lubrication, etc.; this is done in Steps 9, 10, 11, and 12.

The marked-up areas on the schematic diagram should extend up to, and includes the first closed or closeable isolation valve or open or operable circuit breaker in the main and branch lines. The configuration of the system used during normal operation of the plant should be used when marking the diagram and identifying the boundary.

If the identified system is used differently by another safe shutdown alternative, a separate SSEL should be generated and a separate schematic diagram should be marked up for that alternative.

Completion of this step should result in the following:

- Marked-up schematic diagrams (e.g., fluid system P&IDs, electrical system one-line diagrams, instrument block diagrams, etc.) for the identified system for one of the safe shutdown alternatives.
- Completed columns (1) through (6) and columns (10) and (11) of the SSEL with the following information for the item of equipment:

Column No.	Column Description
1	Table Line Number
2	Train or Backup Component Designation
3	Equipment Class (From Table 3-1)
4	Equipment Identification Number (Plant Unique)
5	System Designation and Equipment Description

Column No.	Column Description
6	Schematic Drawing Number and Zone. The schematic drawing number and zone is optional. It can be used to help re ace the steps used in identifying the safe shutdown equipment.
10	Type of Evaluation Needed, i.e., Seismic and/or Relay Review
11	Note Number. The note number is optional. Notes can be used to document the reason why certain equipment was or was not included in the safe shutdown equipment list.

Step 5 - Determine Location In Plant

The location of the item of equipment should be identified in this step. In some cases it may be necessary to walkdown the plant to find where the equipment is located. The floor elevation from which the equipment can be seen should be identified.

Completion of this step should result in the following:

- Completed columns (7) through (9) of the SSEL with the following information for the item of equipment.

Column No.	Column Description
7	Building in Which Equipment is Located
8	Floor Elevation in Building From Which Equipment Can Be Seen. It is suggested that the floor elevation from which the equipment can be seen be entered into this column for use in sorting equipment for later walkdown. The seismic review team should determine the actual plant elevation from which the equipment receives its seismic input (demand) during the plant walkdown (for input into the SVDS shown in Exhibit 4-1, Column 7, Base Elevation).
9	Room or Row and Column Number Designation Where Equipment is Located

Step 6 - Determine Normal State

The purpose of this step is to identify the normal operating state of the item of equipment identified in Step 4 during normal operation of the plant. This information is often given on the fluid system schematic diagrams (P&IDs); however, this information should be confirmed by an operator familiar with the specific plant being evaluated.

Completion of this step should result in the following:

- Completed column (12), "Normal State", of the SSEL with one of the following conditions:

OPEN	(Equipment is normally open)
CLOSED	(Equipment is normally closed)
OP/CL	(Equipment normally changes state from open to closed or from closed to open)
RUNNING	(Equipment is on and normally running)
OFF	(Equipment is off and normally not running)
N/A	(Not Applicable)

Step 7 - Determine Desired State

The purpose of this step is to identify the desired operating state of the equipment identified in Step 4 to accomplish the safe shutdown function selected in Step 1. This operating state should be confirmed by an operator familiar with the specific plant being evaluated.

Completion of this step should result in the following:

- Completed column (13), "Desired State," in the SSEL with one of the following conditions:

OPEN	(Equipment should be open)
CLOSED	(Equipment should be closed)
OP/CL	(Equipment should change state from open to closed or from closed to open)
ON	(Equipment should be on and operating)
OFF	(Equipment should be off and not operating)
N/A	(Not applicable)

Step 8 - Is Power Needed?

This step asks whether the equipment identified in Step 4 needs an external source of power (hydraulic, pneumatic, electrical) to operate, or if power is needed to control its operation so that it can accomplish the safe shutdown function selected in Step 1. This information is used in Step 9 to identify a power source and to decide whether a Seismic and/or Relay review is needed (Column 10).

The answer to whether power is needed depends upon which of the following four categories the equipment falls into. These categories depend upon whether the equipment is in the desired operating state while the plant is at normal operation and whether the equipment will achieve the desired operating state upon loss of operating or control power. These four categories and the answer as to whether operating or control power is needed are given below. The table at the end of this description summarizes these categories.

1. The equipment is in the desired state to achieve the safe shutdown function, and upon loss of operating and/or control power, the equipment stays in the desired state. This would include valves which normally are open and fail open, valves which normally are closed and fail closed, and other active equipment (e.g., pumps, compressors, M-G sets, etc.) which normally are not running and fail in the not running state. Equipment in this category does not need operating or control power to maintain the desired operating state; therefore, this equipment is not considered active and does not need to be seismically evaluated. However, to be sure that this equipment does not inadvertently become energized and change state, this equipment should be identified for Relay review (Column 10) and included as a line item on the SSEL if it is electrically-powered or -controlled so that it can later (Step 18) be included on the SSEL for relay evaluation. For this category of equipment, skip Step 9 and proceed to Step 10.

2. The equipment is in the desired state to achieve the safe shutdown function, but upon loss of operating and/or control power, the equipment does not stay in the desired state. This would include valves which normally are open and fail closed, valves which normally are closed and fail open, and other active equipment which normally is running and fails in the not running state. Equipment in this category does need operating power and perhaps also control power to maintain the desired operating state. This equipment is considered active and should be seismically evaluated. Also, this equipment should be identified for Relay review (Column 10) if it is electrically-powered or -controlled so that it can later (Step 18) be included on the SSEL for relay evaluation. For this category of equipment, proceed to Step 9.

3. The equipment is not in the desired state to achieve the safe shutdown function, but upon loss of operating and/or control power, the equipment will go to the desired state. This would include valves which normally are open and fail closed, valves which normally are closed and fail open, and other active equipment which normally is running and fails in the not running state. Equipment in this category does need control power to assure that operating power will be cut off from the equipment to obtain the desired operating state. This equipment is considered active and should be seismically evaluated. Also, this equipment should be identified for Relay review (Column 10) and included as a line item on the SSEL if it is electrically-powered or -controlled so that it can later (Step 18) be included on the SSEL for relay evaluation. For this category of equipment, proceed to Step 9.

4. The equipment is not in the desired state to achieve the safe shutdown function, and upon loss of operating and/or control power, the equipment will not go to the desired state. This would include valves which normally are open and fail open, valves which normally are closed and fail closed, and other active equipment which normally is

not running and fails in the not running state. Equipment in this category does need operating power and possibly also needs control power to obtain the desired operating state. This equipment is considered active and should be seismically evaluated. Also, this equipment should be identified for Relay review (Column 10) and included as a line item on the SSEL if it is electrically-powered or -controlled so that it can later (Step 18) be included on the SSEL for relay evaluation. For this category of equipment, proceed to Step 9.

The above categories of equipment are summarized in the following table. Substitute the following words in this table at each location where there is an asterisk (*) to determine what answer should be placed in Column (14) of the SSEL:

(*) = (the desired operating state to achieve safe shutdown function.)

During normal operation, the equipment	Upon loss of power, the equipment	Is power needed? (Answer for Column 14 in the SSEL)
is in (*)	stays in (*)	No (Go To Step 10)
is in (*)	does not stay in (*)	Yes (Go To Step 9)
is not in (*)	will go to (*)	Yes (Go To Step 9)
is not in (*)	will not go to (*)	Yes (Go To Step 9)

Completion of this step should result in the following:

- Completed column (14), "Power Required?", in the SSEL with one of the following answers to the question posed by this step:

  NO (For 1st Line in Above Table. Proceed to Step 10 of Procedure.)

  YES (For 2nd, 3rd, or 4th Line in Above Table Proceed to Step 9 of Procedure.)

Step 9 - Identify Power Sources

The purpose of this step is to identify the sources of power which are used to power and control the equipment identified in Step 4. The main motive source of power to operate the equipment or hold it in position and the control power for controlling this main motive force should be identified. It is necessary to identify only the immediate source of power for the subject item of equipment in this step. Subsequent passes through this section of the procedure will identify all the items of equipment included in these sources of power; each one of these individual power train items of equipment will later be included as a separate line item in the SSEL.

Completion of this step should result in the following:

- Completed column (15), "Supporting System Drawing Number," in the SSEL with any reference drawing number which identifies the power sources.
- Completed column (16) "Required Supporting Systems or Components," in the SSEL with the identification name and/or number of the power sources. For example, entries in this column could be:

  AC BUS 622

  DC BUS 212

  PNEUMATIC

  INSTR. BUS 211

  MANUAL

  -- (Equipment does not require power)

  N/A (Not applicable)

Step 10 - Identify Supporting Systems and Components

The purpose of this step is to identify the supporting systems or components needed by the equipment identified in Step 4 so that subsequent passes through this procedure can identify all the equipment in these supporting systems. Supporting systems include such services as cooling, lubrication, HVAC, etc.

It is only necessary to identify the systems or components supporting the equipment in this step; subsequent passes through this section of the procedure will identify all the equipment included in a supporting system. Each of these individual items of equipment in a supporting system will be included later as separate line items in the SSEL.

Completion of this step should result in the following:

- Completed column (15), "Supporting System Drawing Number," in the SSEL with any reference drawing number which identifies the supporting system.
- Completed column (16), "Required Supporting Systems or Components," in the SSEL with the name of each system or component supporting the equipment identified in Step 4. For example, entries in this column could be:

  PNEUMATIC

  INST.AIR

  SERV.AIR

  MANUAL

  CCW (Component Cooling Water System)

  HVAC (Heating, Ventilating and Air Conditioning System)

  -- (Equipment does not require any supporting system)

  N/A (Not Applicable)

Step 11 - Identify Instruments for Function

To assure that the safe shutdown function selected in Step 1 is being accomplished, a number of process variables should be measured. The purpose of this step is to identify the primary process variables and instruments associated with the safe shutdown function defined in Step 1. For example, to control the inventory in the reactor coolant system, the water level instrumentation for the pressurizer (PWR), or the reactor vessel (BWR), should be identified as an essential instrument. Note that other process variables and instruments, needed to control the individual items of equipment, are identified in Step 12 of this procedure.

For each process variable identified, a transmitter and its indicator (or recorder) should be listed as line items on the SSEL (Exhibit A-1). For example, transmitters can be identified as either Equipment Class 18 (Instrument Racks) or Class 19 (Temperature Sensors), while indicators (or recorders) can be identified as Equipment Class 20 (Instrumentation and Control Cabinets) on the SSEL.

Completion of this step should result in the following:

- Completed columns (1) through (11) and columns (14) through (16) of the SSEL with the following information for the transmitters and indicators (or recorders):

Column No.	Column Description
1	Table Line Number
2	Train or Backup Component Designation
3	Equipment Class (From Table 3-1)
4	Equipment Identification Number (Plant Unique)
5	System Designation and Equipment Description

Column No.	Column Description
6	Schematic Drawing Number and Zone. The schematic drawing and zone is optional. It can be used to help retrace the steps used in identifying the safe shutdown equipment.
7	Building in Which Equipment is Located
8	Floor Elevation in Building From Which Equipment Can Be Seen. It is suggested that the floor elevation from which the equipment can be seen be entered into this column for use in sorting equipment for later walkdown. The Seismic Review Team should determine, during the plant walkdown, the actual plant elevation from which the equipment receives its seismic input (demand).
9	Room or Row and Column Number Designation Where Equipment is Located.
10	Type of Evaluation Needed, i.e., Seismic and/or Relay Review.
11	Note Number. The note number is optional. Notes can be used to document the reason why certain items of equipment were or were not included in the safe shutdown equipment list.
14	Is Power Required to Attain or Maintain the Desired Operating State or Condition? (Yes or No)
15	Reference Drawing Number for Supporting Power
16	Power Source Identification Number for the Instrument

Step 12 - Identify Instruments For Control

The purpose of this step is to identify the essential process variables which should be measured to control the operation of the equipment identified in Step 4. It is necessary to measure these equipment-related process variables in addition to the primary process variables identified in Step 11 for the reactor and reactor coolant system.

Note that only those process variables needed for controlling the subject item of equipment need be identified. For example, it may be necessary to measure the level of water in a tank so that the operator (or an automatic control system) knows when the suction should be transferred to another tank. In this case, the tank level measurement is needed for the operation of a set of valves which connect the two tanks to the pump suction; tank level should be identified as an essential process variable for the operation of these valves.

Note that this step only identifies the process variables to be measured; identification of the transmitters and indicators (or recorders) will be done during subsequent passes through this procedure. It is necessary, however, to have an understanding of the available instruments in the plant so that appropriate process variables can be identified.

Completion of this step should result in the following:

- Completed column (15), "Supporting System Drawing Number," in the SSEL with any reference drawing number which identifies the instruments which can be used to measure the process variables.
- Completed column (16), "Supporting Systems or Components," in the SSEL with the name of each process variable to be measured for controlling the change in operating state of the equipment identified in Step 4. For example, entries in this column could be:

  RC P (Reactor coolant pressure)

  SG A LVL (Steam generator A level)

-- (Equipment does not require any process variables to be measured to control its operation)

N/A (Not Applicable)

Step 13 - Is All Equipment Identified?

This step asks whether all the equipment (mechanical equipment, electrical equipment, instrumentation, controls, tanks, and heat exchangers) have been identified which are needed to acccomplish the safe shutdown function selected in Step 1. To answer this question, the schematic diagrams, being marked up in Step 4, should be reviewed to determine whether all the equipment has been identified.

Step 14 - Are All Power/Support Systems Identified?

This step asks whether all the individual items of equipment for power, control, instrumentation, and other supporting systems have been identified which are needed to accomplish the safe shutdown function selected in Step 1.

One approach for systematically identifying all the equipment is to first identify all the equipment on the fluid system schematic diagrams and enter them as line items in the SSEL. Next, trace all the operating and control power equipment listed in column (16) using the electrical one-line diagrams and enter these as separate line items in the SSEL. Then, the transmitters and indicators (or recorders) should be identified from the list of process variables listed in column (16) of the SSEL. Finally, the equipment contained in any supporting systems listed in column (16) of the SSEL should be added as additional line entries in the SSEL. This process of adding equipment to the SSEL should continue until all the equipment contained in the systems listed in column (16) are entered as line items.

Note that it may be convenient to use separate tables for some of the supporting systems since they support several safe shutdown functions. For example, the emergency diesel generators could be needed for both the decay heat removal function and the inventory control function. Using a separate SSEL for the supporting systems would eliminate the need for repeating these entries in several different tables.

If additional equipment should be added to the SSEL, then go back to Step 4, identify another item of equipment, and add it to the list. However, if all equipment and instruments have been identified for accomplishing the safe shutdown function selected in Step 1, then continue on to Step 15.

Step 15 - Are Primary and Backup Paths Considered?

This step asks whether both the primary and the backup equipment or trains have been identified to accomplish the safe shutdown function selected in Step 1. To answer this question, each item of equipment in the primary SSEL should be reviewed to determine whether another backup item of equipment or another backup train of equipment has been identified.

If the backup equipment and instruments have not been identified, then go back to Step 3 and select a backup safe shutdown alternative. Note that it may be convenient to use a separate SSEL for the backup equipment or train and to mark the schematic drawings with a different color highlighter to distinguish between primary and backup.

If the backup equipment and instruments have been identified for each item of equipment in the primary safe shutdown alternative, then continue on to Step 16.

Step 16 - Are All Four Functions Evaluated?

This step asks whether all four of the safe shutdown functions have been evaluated for safe shutdown equipment. If they have not all been evaluated, then go back to Step 1 and select another safe shutdown function to evaluate. A new SSEL should be generated for this new function.

When the equipment for all four safe shutdown functions has been identified, then proceed to Step 17.

Step 17 - Develop Seismic Review SSEL

The purpose of this step is to combine the various safe shutdown equipment lists, generated by repeated application of Steps 1 through 16, into a single safe shutdown equipment list which can be used as the basis for the seismic evaluation to be done in Section 4. This seismic review SSEL should have only one line entry for each unique item of equipment. The SSELs generated in Steps 1 through 16 typically contain some of the same equipment; this seismic review SSEL should eliminate this duplication.

This seismic review SSEL should contain only equipment for which a Seismic review(s) or a Seismic and a Relay review (S, R) is identified in column (10).

The seismic review SSEL contains the following columns of information, as shown in Exhibit A-3:

Column No.	Column Description
1	Equipment Class (From Table 3-1)
2	Train or Backup Component Designation
3	Equipment Identification Number (Plant Unique)

Column No.	Column Description
4	System Designation and Equipment Description
5	Building In Which Equipment is Located
6	Floor Elevation in Building From Which Equipment Can Be Seen
7	Room or Row and Column Number Designation Where Equipment is Located

Generating this seismic review SSEL can be done rather easily by using a computerized data base management program. A data base program can also be used to generate subsets of this SSEL in which the equipment can be sorted by equipment class, by equipment ID number, by location in the plant, etc.

Step 18 - Develop Relay Review SSEL

The purpose of this step is to combine the various safe shutdown equipment lists (SSELs), generated by repeated application of Steps 1 through 16, into a single safe shutdown equipment list which can be used as the basis for the relay evaluation described in Section 6.

This relay review SSEL should contain the items of active equipment from the various earlier SSELs which use electricity for power, control, or instrumentation and passive equipment which, if they change state or inadvertently operate, could prevent one of the safe shutdown functions from being accomplished. This SSEL should contain only equipment for which a Relay review (R) or a Seismic and a Relay review (S, R) is identified in Column (10).

The relay review SSEL contains the following columns of information, as shown in Exhibit A-5:

Column No.	Column Description
1	Equipment Class (From Table 3-1)
2	Train or Backup Component Designation
3	Equipment Identification Number (Plant Unique)
4	System Designation and Equipment Description
5	Building In Which Equipment is Located
6	Floor Elevation in Building From Which Equipment Can Be Seen
7	Room or Row and Column Number Designation Where Equipment is Located

Generating the relay review SSEL can be done rather easily by using a computer-based data base management program. A data base program can also be used to generate subsets of this relay evaluation SSEL in which the equipment can be sorted by equipment class, by equipment ID number, by location in the plant, etc.

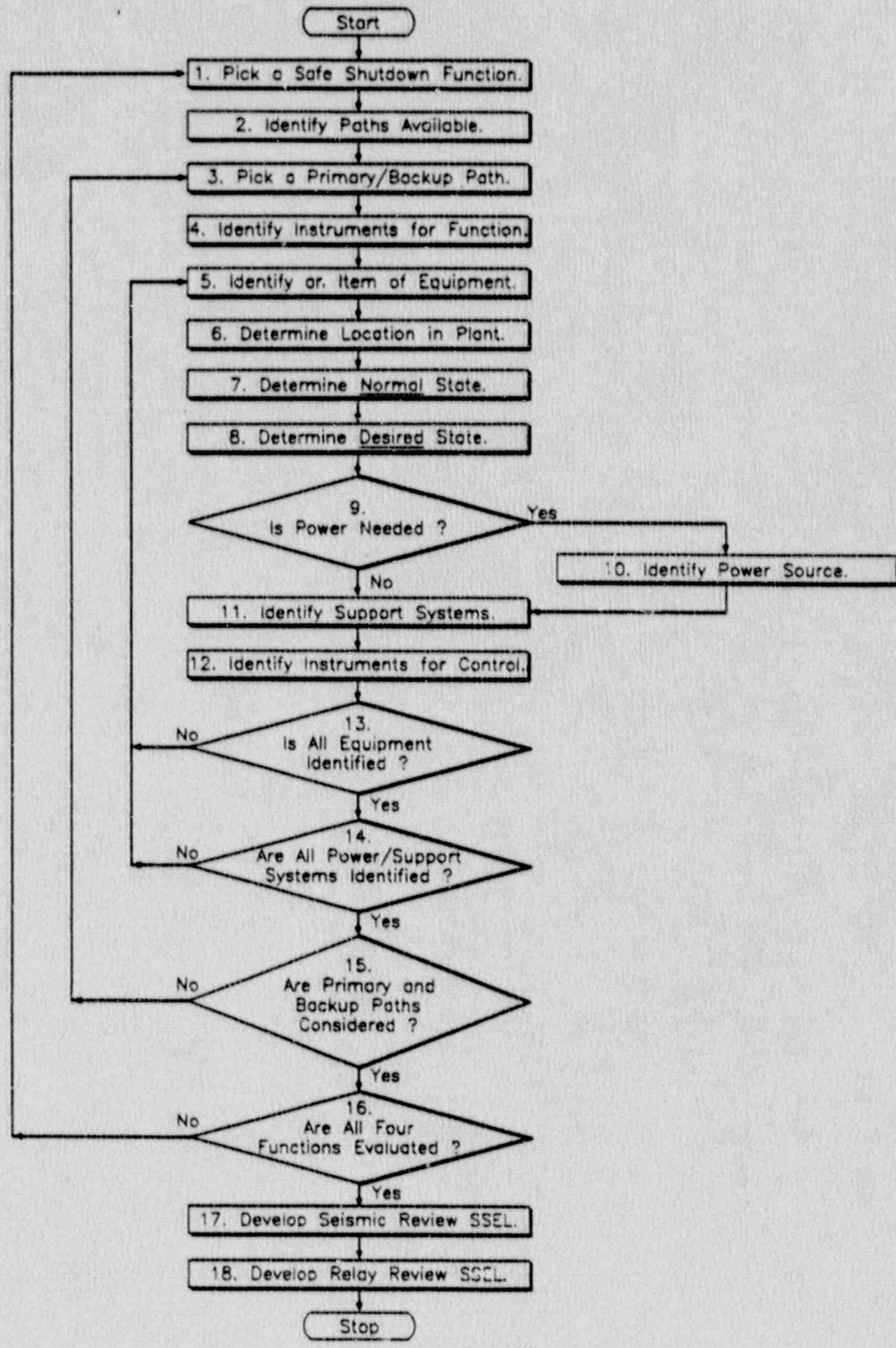

Figure A-10. Steps for Identifying Safe Shutdown Equipment.

Exhibit A-1

Page No. __
Report Date/Time: ________

SAFE SHUTDOWN EQUIPMENT LIST (SSEL)

FUNCTION: ____________________

ALTERNATIVE: ____________________

Line No. (1)	Train (2)	Eq. Cl. (3)	Equipment ID Number (4)	System/Equipment Description (5)	Drawing No. /Rev./Zone (6)	Bldg. (7)	Floor Elev. (8)	Room or Row/Col (9)	Eval Type (10)	Notes (11)	Normal State (12)	Desired State (13)	Power Req'd? (14)	Supporting Sys. Dwg. No./Rev. (15)	Required Supporting Systems or Components (16)

Certification:

The information identifying the equipment required to bring the plant to a safe shutdown condition on this Safe Shutdown Equipment List (SSEL) is, to the best of our knowledge and belief, correct and accurate. (One or more signatures of Systems or Operations Engineers)

Print or Type Name/Title ____________________ Signature ____________________ Date ____________

Print or Type Name/Title ____________________ Signature ____________________ Date ____________

Exhibit A-2

Page No. 2
Report Date/Time: 05-22-90 / 13:17:58

SAFE SHUTDOWN EQUIPMENT LIST (SSEL)
- CORE SPRAY SYSTEM -

Data Base File Name/Date/Time: NMP1EXP4.DBF / 05-22-90 / 08:47:42
Index File Name/Date/Time: LINE_NO4.NDX / 05-22-90 / 08:47:42
Index File Contents: VAL(NUMBER)
Program File Name & Version: Nmplprt v1.0

Line No.	Train	Min/ Opt	Eq. Cl.	Q- List	Equipment ID Number	System/Equipment Description	Drawing No. /Rev./Zone	Bldg.	Floor Elev.	Room or Row/Col	Sort	Notes	Normal State	Desired State	Power Req'd?	Supporting Sys. Dwg. No./Rev.	Required Interconnections and Supporting Components
4119	5	OPT	20	Q	ID59A#	RCS/RCS LEVEL INDICATOR	C-18015-C/20/B1	TB	277	CR PNL E	S R	--	N/A	N/A	YES	C-22004-C3/14	36-31, ID13A
4120	6	OPT	20	Q	ID59B#	RCS/RCS LEVEL INDICATOR	C-18015-C/20/M2	TB	277	CR PNL F	S R	--	N/A	N/A	YES	C-22004-C6/9	36-32, ID13B
4121	1OP1	OPT	8A	SR	40-10	CRS/CORE SPRAY INLET INNER ISO VLV	C-18007-C/34/F3	DW	261	N7	S R	31	CLOSED	OPEN	YES	C-19440-C2/27	171B, RMC 40-10A, RPS
4122	1	MIN	8A	SR	40-11	CRS/CORE SPRAY INLET INNER ISO VLV	C-18007-C/34/F4	DW	261	N7	S R	31	CLOSED	OPEN	YES	C-19437-C2/28	161B, RMC 40-11A, RPS
4123	2	MIN	8A	SR	40-09	CRS/CORE SPRAY INLET INNER ISO VLV	C-18007-C/34/G4	DW	261	N9	S R	31	CLOSED	OPEN	YES	C-19440-C2/27	171B, RMC 40-09A, RPS
4124	2OP1	OPT	8A	SR	40-01	CRS/CORE SPRAY INLET INNER ISO VLV	C-18007-C/34/G4	DW	261	N9	S R	31	CLOSED	OPEN	YES	C-19437-C2/28	161B, RMC 40-01A, RPS
4125	1	MIN	8A	SR	40-12	CRS/CORE SPRAY INLET OUT ISO VLV	C-18007-C/34/D4	RB	237	SE CORNER	R	5, 31	OPEN	OPEN	NO	C-19438-C2/13	167, PNL 167A, RMC 40-12A, RPS
4126	2	MIN	8A	SR	40-02	CRS/CORE SPRAY INLET OUT ISO VLV	C-18007-C/34/I4	RB	237	SE CORNER	R	5, 31	OPEN	OPEN	NO	C-19438-C1/17	167, RMC 40-02A, RPS
4127	1,2	MIN	7	SR	39-06	EC/LOOP #12 CONDENSER RETURN ISO VLV	C-18006-C1/21/G7	RB	281	IV ROOM	S	1	CLOSED	CLOSED	YES	C-19839-C18/4	39-06E, 39-06F, 39-06G, 39-06H
4128	1,2	MIN	7	SR	39-05	EC/LOOP #11 CONDENSER RETURN ISO VLV	C-18006-C1/21/N7	RB	281	IV ROOM	S	1	CLOSED	CLOSED	YES	--	39-05E, 39-05F, 39-05G, 39-05H
4129	1	MIN	5	SR	81-50	CRS/CORE SPRAY TOPPING PUMP #111	C-18007-C/34/B6	RB	237	SW CORNER	S R	--	OFF	RUNNING	YES	C-19839-C7/0	102, 81-58, 81-78
4130	1	MIN	7	SR	81-58	CRS/SEAL COOLING PRESS. REGULATOR	C-18007-C/34/12	RB	237	SW CORNER	S	--	OPEN	OP/CL	NO	--	--
4131	1	MIN	7	SR	81-78	CRS/SEAL COOLING PRESS. RELIEF VLV	C-18007-C/34/12	RB	237	SW CORNER	S	30	CLOSED	OP/CL	NO	--	--
4133	2OP1	OPT	5	SR	81-49	CRS/CORE SPRAY TOPPING PUMP #112	C-18007-C/34/A6	RB	237	SW CORNER	S R	--	OFF	RUNNING	YES	C-19839-C8/1	103, 81-57, 81-77
4134	2OP1	OPT	7	SR	81-57	CRS/SEAL COOLING PRESS. REGULATOR	C-18007-C/34/12	RB	237	SW CORNER	S	--	OPEN	OP/CL	NO	--	--
4135	2OP1	OPT	7	SR	81-77	CRS/SEAL COOLING PRESS. RELIEF VLV	C-18007-C/34/12	RB	237	SW CORNER	S	30	CLOSED	OP/CL	NO	--	--
4137	2	MIN	5	SR	81-52	CRS/CORE SPRAY TOPPING PUMP #122	C-18007-C/34/M6	RB	237	SE CORNER	S R	--	OFF	RUNNING	YES	C-19839-C8/1	103, 81-60, 81-80
4138	2	MIN	7	SR	81-60	CRS/SEAL COOLING PRESS. REGULATOR	C-18007-C/34/12	RB	237	SE CORNER	S	--	OPEN	OP/CL	NO	--	--
4139	2	MIN	7	SR	81-80	CRS/SEAL COOLING PRESS. RELIEF VLV	C-18007-C/34/12	RB	237	SE CORNER	S	30	CLOSED	OP/CL	NO	--	--

CERTIFICATION:

The information identifying the equipment required to bring the plant to a safe shutdown condition on this Safe Shutdown Equipment List (SSEL) is, to the best of our knowledge and belief, correct and accurate. (One or more signatures of Systems or Operations Engineers)

Print or Type Name/Title ____________ Signature ____________ Date ____________

Print or Type Name/Title ____________ Signature ____________ Date ____________

Exhibit A-3

Page No. ___

SAFE SHUTDOWN EQUIPMENT LIST (SSEL)
FOR SEISMIC WALKDOWN

Equip Class (1)	Train (2)	Equipment ID Number (3)	System/Equipment Description (4)	Bldg. (5)	Floor Elev. (6)	Room Or Row/Col. (7)

Prepared by: ______________________

Checked by : ______________________

Exhibit A-4

SAFE SHUTDOWN EQUIPMENT LIST (SSEL)
FOR SEISMIC WALKDOWN LISTING (UNIQUE)
(Minimum + Expanded List)
(Sorted By Equipment ID Number)

Equip Class	Min/ Opt	Equipment ID Number	Q-List	System/Equipment Description	Bldg.	Floor Elev.	Room Or Row/Col
7	MIN	39-06	SR	EC/LOOP #12 CONDENSER RETURN ISO VLV	RB	281	IV ROOM
8B	OPT	39-06E	SR	EC/LOOP #12 CONDENSER RETURN ISO VLV PILOT	RB	281	IV ROOM
8B	OPT	39-06F	SR	EC/LOOP #12 CONDENSER RETURN ISO VLV PILOT	RB	281	IV ROOM
8B	OPT	39-06G	SR	EC/LOOP #12 CONDENSER RETURN ISO VLV PILOT	RB	281	IV ROOM
8B	OPT	39-06H	SR	EC/LOOP #12 CONDENSER RETURN ISO VLV PILOT	RB	281	IV ROOM
7	MIN	39-11#	SR	EC/LOOP #11 EMERGENCY CONDENSER DRAIN ISO VLV #111	RB	298	IV ROOM
8B	MIN	39-11C	SR	EC/LOOP #11 EMERGENCY CONDENSER DRAIN ISO VLV PILOT	RB	298	39-11#
8B	MIN	39-11D	SR	EC/LOOP #11 EMERGENCY CONDENSER DRAIN ISO VLV PILOT	RB	298	39-11#
7	MIN	39-12#	SR	EC/LOOP #11 EMERGENCY CONDENSER DRAIN ISO VLV #112	RB	298	IV ROOM
8B	MIN	39-12C	SR	EC/LOOP #11 EMERGENCY CONDENSER DRAIN ISO VLV PILOT	RB	298	39-12#
8B	MIN	39-12D	SR	EC/LOOP #11 EMERGENCY CONDENSER DRAIN ISO VLV PILOT	RB	298	39-12#
7	MIN	39-13#	SR	EC/LOOP #12 EMERGENCY CONDENSER DRAIN ISO VLV #121	RB	298	IV ROOM
8B	MIN	39-13C	SR	EC/LOOP #12 EMERGENCY CONDENSER DRAIN ISO VLV PILOT	RB	298	39-13#
8B	MIN	39-13D	SR	EC/LOOP #12 EMERGENCY CONDENSER DRAIN ISO VLV PILOT	RB	298	39-13#
7	MIN	39-14#	SR	EC/LOOP #12 EMERGENCY CONDENSER DRAIN ISO VLV #122	RB	298	IV ROOM
8B	MIN	39-14C	SR	EC/LOOP #12 EMERGENCY CONDENSER DRAIN ISO VLV PILOT	RB	298	39-14#
8B	MIN	39-14D	SR	EC/LOOP #12 EMERGENCY CONDENSER DRAIN ISO VLV PILOT	RB	298	39-14#
8A	OPT	40-01	SR	CRS/CORE SPRAY INLET INNER ISO VLV	DW	261	M9
8A	OPT	40-02	SR	CRS/CORE SPRAY INLET OUT ISO VLV	RB	237	SE CORNER
8A	MIN	40-09	SR	CRS/CORE SPRAY INLET INNER ISO VLV	DW	261	M9
8A	OPT	40-10	SR	CRS/CORE SPRAY INLET INNER ISO VLV	DW	261	M7
8A	MIN	40-11	SR	CRS/CORE SPRAY INLET INNER ISO VLV	DW	261	M7
8A	OPT	40-12	SR	CRS/CORE SPRAY INLET OUT ISO VLV	RB	237	SE CORNER
19	OPT	41-23	NSR	LPS/LIQUID POISON TEMPERATURE SWITCH	RB	298	K8
19	OPT	41-24	NSR	LPS/LIQUID POISON TEMPERATURE SWITCH	RB	298	K8
19	OPT	41-25	NSR	LPS/LIQUID POISON TEMPERATURE SWITCH	RB	298	K8
19	OPT	41-26	NSR	LPS/LIQUID POISON TEMPERATURE SWITCH	RB	298	K8

Prepared by:______________________

Checked by :______________________

Report Date/Time: 05-23-90 / 09:29:54
Data Base File Name/Date/Time: NMP1WD4.DBF / 05-23-90 / 09:24:44
Index File Name/Date/Time: WD_UNIQ4.NDX / 05-23-90 / 09:27:50
Index File Contents: COMPID
Program File Name & Version Nmp1prt v1.0

Exhibit A-5

Page No. ____

SAFE SHUTDOWN EQUIPMENT LIST (SSEL)
FOR RELAY REVIEW

Equip Class (1)	Train (2)	Equipment ID Number (3)	System/Equipment Description (4)	Bldg. (5)	Floor Elev. (6)	Room Or Row/Col. (7)

Prepared by: ______________________

Checked by : ______________________

Exhibit A-6

SAFE SHUTDOWN EQUIPMENT LIST (SSEL)
RELAY REVIEW LISTING (UNIQUE)
(Minimum + Expanded List)
(Sorted By Equipment ID Number)

Equip Class	Min/ Opt	Equipment ID Number	Q-List	System/Equipment Description	Bldg.	Floor Elev.	Room Or Row/Col
8A	MIN	40-05	SR	CRS/CORE SPRAY TEST ISO VLV	RB	237	--
8A	MIN	40-06	SR	CRS/CORE SPRAY TEST ISO VLV	RB	237	--
8A	MIN	40-09	SR	CRS/CORE SPRAY INLET INNER ISO VLV	DW	261	M9
8A	OPT	40-10	SR	CRS/CORE SPRAY INLET INNER ISO VLV	DW	261	M7
8A	MIN	40-11	SR	CRS/CORE SPRAY INLET INNER ISO VLV	DW	261	M7
8A	MIN	40-12	SR	CRS/CORE SPRAY INLET OUT ISO VLV	RB	237	SE CORNER
8A	MIN	40-30	SR	CRS/CORE SPRAY VENT INSIDE ISO VLV	DW	--	--
8A	MIN	40-31	SR	CRS/CORE SPRAY VENT INSIDE ISO VLV	DW	--	--
8B	OPT	40-32B	SR	CRS/OUTSIDE IV #11-CORE SPRAY LOOP HI POINT VENT PILOT	RB	261	SD COOL RM
8B	OPT	40-32C	SR	CRS/OUTSIDE IV #11-CORE SPRAY LOOP HI POINT VENT PILOT	RB	261	SD COOL RM
8B	OPT	40-33B	SR	CRS/OUTSIDE IV #12-CORE SPRAY LOOP HI POINT VENT PILOT	RB	261	SD COOL RM
8B	OPT	40-33C	SR	CRS/OUTSIDE IV #12-CORE SPRAY LOOP HI POINT VENT PILOT	RB	261	SD COOL RM
19	OPT	41-23	NSR	LPS/LIQUID POISON TEMPERATURE SWITCH	RB	298	K8
19	OPT	41-24	NSR	LPS/LIQUID POISON TEMPERATURE SWITCH	RB	298	K8
19	OPT	41-25	NSR	LPS/LIQUID POISON TEMPERATURE SWITCH	RB	298	K8
19	OPT	41-26	NSR	LPS/LIQUID POISON TEMPERATURE SWITCH	RB	298	K8
8A	OPT	44-04	Q	CRDH/CRDH PRESSURE CONTROL VLV	RB	237	N4
8A	OPT	44-05	Q	CRDH/CRDH PRESSURE CONTROL VLV	RB	237	N4
7	OPT	55-05	Q	DMW/DEMIN WATER STORAGE TANKS BLOCK VLV	RB	261	M12
5	OPT	57-11	SR	CTS/CONDENSATE TRANSFER PUMP #12	TB	261	--
5	OPT	57-12	SR	CTS/CONDENSATE TRANSFER PUMP #11	TB	261	--
18	OPT	57-18	NSR	CTS/CONDENSATE STORAGE TANKS LEVEL TRANSMITTER	TB	250	LB14
20	OPT	57-18A	NSR	CTS/CONDENSATE STORAGE TANKS LEVEL INDICATOR	TB	277	CR PNL H
8B	OPT	60-03C*	SR	ECMU/EMER COND MAKEUP TANK 12 SUPPLY ISO VLV PILOT	TB	369	60-03
8B	OPT	60-04C*	SR	ECMU/EMER COND MAKEUP TANK 11 SUPPLY ISO VLV PILOT	TB	369	60-04
20	OPT	60-17A	SR	ECMU/EMER COND #111,112 LEVEL E/P CONVERTER	RB	340	60-17
20	OPT	60-17B	SR	ECMU/EMER COND #111,112 LEVEL CONTROLLER	TB	277	CR PNL K

Prepared by:____________________

Checked by :____________________

Report Date/Time: 05-22-90 / 14:46:55
Data Base File Name/Date/Time: NMP1RR4.DBF / 05-22-90 / 14:43:02
Index File Name/Date/Time: RR_UNIQ4.NDX / 05-22-90 / 14:43:02
Index File Contents: COMPID
Program File Name & Version Nmplprt v1.0

Appendix B

SUMMARY OF EQUIPMENT CLASS DESCRIPTIONS AND CAVEATS

CONTENTS

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* GERS are included for this equipment class

CONTENTS (Continued)

Appendix B

SUMMARY OF EQUIPMENT CLASS DESCRIPTIONS AND CAVEATS

INTRODUCTION

The purpose of this appendix is to summarize the descriptions of the equipment classes and the inclusion and exclusion rules, also called caveats, which apply to the classes of equipment covered by the earthquake experience data base and the generic seismic test data base. The equipment class descriptions summarize the general parameters of equipment representative of these data bases. The caveats identify the important characteristics and features which an item of equipment should have in order to verify seismic adequacy by use of these data bases.

The procedure for using these class descriptions and caveats is covered in Section 4. Note, however, that if equipment-specific seismic qualification data is used instead of the earthquake experience or generic seismic testing data bases, then the equipment should meet any specific restrictions applicable to that equipment-specific qualification data rather than the class descriptions and caveats in this appendix.

This appendix is organized by equipment class corresponding to the listing in Section 3, Table 3-1. For each equipment class, the class description and the caveats applicable to the Bounding Spectrum are given first. Next, the class description and the caveats applicable to the GERS are given when available. (Note: Some equipment classes have more than one GERS while other classes have none.) A plot of the GERS follows the caveats for each applicable equipment class.

The class descriptions and caveats summarized in this appendix are based on the information contained in References 4, 5, and 6. More details and photographs are given in References 4 and 6. Note that in some cases, clarifying remarks have been included in this appendix which are not contained in the above reference documents. These clarifying remarks include such things as the reason for including a particular caveat, the intent of the caveat, and recommended allowables for stress analysis. These clarifying remarks are based on experience gained during the SQUG trial plant reviews and serve to help guide the Seismic Capability Engineers in making judgment.

Note: The Seismic Capability Engineers should not use the summaries contained in this appendix unless they have thoroughly reviewed and understand the above reference documents.

Certain important caveats from the above reference documents are included in this appendix even though they are also covered in other sections of the GIP, such as:

- Equipment should be adequately anchored.
- Relays for which chatter is not acceptable should be specifically evaluated.
- Possible seismic interaction concerns should not adversely affect the equipment.

Past earthquake experience has shown that these three concerns are very important to equipment seismic adequacy. The anchorage evaluation guidelines are addressed in Section 4.4 and Appendix C of the GIP. The relay evaluation guidelines are addressed in Section 6. The seismic interaction evaluation guidelines are presented in Section 4.5 and Appendix D.

[illegible] although the primary responsibility for conducting [illegible] relay [illegible]ion described in Section 6 is the Lead Relay Reviewer, the Seismic [illegible]lity Engineers should be alert for any seismically induced systems effects which may lead to loss of function or malfunction of the equipment being evaluated.

B.1 MOTOR CONTROL CENTERS

B.1.1 Bounding Spectrum - Motor Control Centers

The earthquake experience data base equipment class of motor control centers (MCCs) includes control and electrical fault protection systems for motors powered at 600 volts or less (typically 480 volts). Motor controllers are mounted in sheet metal cubicles with controller cubicles typically assembled into stacks which are lined up side-by-side and bolted together to form a motor control center. This equipment class includes motor controllers mounted in individual cubicles on racks or walls as well as freestanding MCCs.

Individual motor controllers are normally mounted in a sheet metal box that can be removed from its cubicle in the motor control center. Motor controllers are arranged in vertical stacks or sections attached to each other within the MCC assembly. The individual components of the motor controller are attached to the sides and rear face of the box. Motor controller cubicles typically include the following types of components: molded case circuit breaker (or disconnect switch), magnetic contactors, a control transformer, fuses, push buttons, and pilot lights.

The motor controller cubicles are typically arranged in vertical stacks within an MCC assembly. Each stack is a separate sheet metal enclosure, usually reinforced at its corners by overlapped sheet metal or steel angle framework. Stacks are bolted together through adjacent sheet metal side walls or steel framework.

Motor control centers may be either single- or double-sided. Double-sided MCCs have controller cubicles on both the front and rear face of the cabinet, with vertical bus bars routed through a center compartment between the front and rear stacks of controller cubicles. Single-sided MCCs typically route electrical connections through vertical raceways along the sides of each stack section.

Motor control centers may be either freestanding units or form part of a more complex assembly. In many cases, MCCs are included in an assembly with switchgear, distribution panels, and/or transformers. Another alternative to the freestanding motor control center is the wall- or rack-mounted motor control cubicle. Within these cubicles, motor control components are bolted to the inner faces of the wall in the same manner as in a small control or instrument cabinet. Access to the cubicle is usually through a swinging door that forms the front face of the cubicle.

MCC cabinet dimensions are generally standardized. Most MCC sections (stacks) are 20 to 24 inches wide, and 90 inches tall. The depth of each section varies from 12 to 24 inches, with double-sided sections usually having depths of 20 or 24 inches. The weight of each section ranges from 500 to 800 pounds.

The construction of motor control centers is typically governed by industry standards such as those developed by the National Electrical Manufacturers Association (NEMA) and Underwriters' Laboratories (UL) (e.g., NEMA ICS-6, UL-508). These standards define minimum sheet metal thickness as a function of wall area between reinforcement.

Motor control center assemblies represented in the data base contain motor starters (contactors), disconnect switches, and, in some cases, over-current relays. They also contain distribution panels, automatic transfer switches, and relay/instrumentation compartments. Motor controllers are represented in a variety of mounting configurations ranging from individual mounted controllers to MCC assemblies in outdoor enclosures.

The Bounding Spectrum (BS) represents the seismic capacity of a Motor Control Center (MCC) if the MCC meets the intent of the following inclusion and exclusion rules.

<u>MCC/BS Caveat 1 - Earthquake Experience Data Base.</u> The MCC should be similar to and bounded by the MCC class of equipment of the earthquake experience data base. The discussion above briefly summarizes the class description of MCCs in the data base.

<u>MCC/BS Caveat 2 - Rating of 600 V or Less.</u> The MCC should have a 600 V rating or less. This is the upper limit voltage rating of MCCs in the earthquake experience data base.

<u>MCC/BS Caveat 3 - Adjacent Cabinets Bolted Together.</u> Adjacent cabinets which are close enough to impact each other and sections of a multi-bay cabinet assembly should be bolted together if any of these cabinets contains essential relays. The concern addressed in this caveat is that unbolted cabinets could respond out of phase to one another and impact each other during an earthquake. This would cause impact loadings and high frequency vibration loadings which could cause any essential, impact-sensitive relays to chatter.

<u>MCC/BS Caveat 4 - Attached Weight of 100 Pounds or Less.</u> Equipment and their enclosures (but not conduit) mounted externally to cabinets and supported by them should have a weight less than about 100 pounds per cabinet. The concern is that the center of gravity of the cabinet will be raised too high, the total weight of the cabinets will be too large, or large eccentric weights will introduce excessive torsion. This additional load may also reduce the natural frequency of the cabinet below 8 Hz. This concern is directed primari[illegible] [illegible]d equipment which is attached to the cabinet but is not normally supplied with the MCC and thereby possibly not included in the seismic experience data base equipment class. The load path for the attached component through the cabinet should be carefully examined. In addition, its attachment should be reviewed to ascertain whether the attached component may become a seismic interaction hazard source. Conduit was deleted from this caveat since conduit supported above an MCC is well represented by seismic experience data. Additional support of the cabinet and attached equipment will alleviate these concerns and satisfy the intent of this caveat.

For the purposes of anchorage checking, the effective weight of any attached conduit and equipment should be included in the cabinet weight.

MCC/BS Caveat 5 - Externally Attached Items Rigidly Anchored. Externally attached items should be rigidly attached to the cabinet. The concern addressed by this caveat is that these items could impact the cabinet and possibly lead to relay chatter, or impact other components of the MCC as a seismic interaction hazard. As an example, some electrical cabinets have small, externally attached panels mounted on hinges to the main cabinet frame. During seismic motion the externally attached panel may swing and cause significant impact loading to the electrical panel.

MCC/BS Caveat 6 - General Configuration Similar to NEMA Standards. The general configuration of the cabinets should be similar to those constructed to NEMA Standards. The MCC does not have to conform exactly to the NEMA standards but should be similar with regard to the gage of the steel, internal structure and support. This caveat is intended to preclude unusual designs not covered by the data base (thin gage material, flimsy internal structure, etc.). In general, cabinets manufactured by the major manufacturers of MCCs conform to this caveat if they have not been modified.

MCC/BS Caveat 7 - Cutouts Not Large. Cutouts in the lower half of the cabinet sheathing should be less than 6 inches wide and 12 inches high. One concern of this caveat is that these cutouts will reduce the natural frequency below 8 Hz. A second concern is that the shear load from the earthquake will not be able to be transferred through the shear walls to the anchorage. There are many standard MCCs that exceed this caveat; however, in many cases, the area around the cutout is reinforced with additional plate or steel members alleviating the concern of shear transfer. This caveat is of more concern for cutouts modifying the standard design that are not reinforced.

MCC/BS Caveat 8 - Doors/Buckets Secured. All doors and drawout buckets should be secured by a latch or fastener. The concern addressed by this caveat is that the doors and drawout buckets could open during an earthquake and repeatedly impact the housing, causing internal components such as relays and contactors to malfunction or chatter.

MCC/BS Caveat 9 - Natural Frequency Relative to 8 Hz Limit Considered. The lowest natural frequency of the cabinet should be estimated. For cabinets which have a natural frequency below about 8 Hz, the floor response spectrum should be compared to 1.5 times the Bounding Spectrum (see Table 4-1 of Section 4).

MCC/BS Caveat 10 - Adequate Anchorage. The unit should be properly anchored in accordance with the guidelines of Section 4.4.

MCC/BS Caveat 11 - Potential Chatter of Essential Relays Evaluated. If relays are mounted on the equipment, a relay functionality review in accordance with Section 6 should be performed.

MCC/BS Caveat 12 - No Other Concerns. There should not be any other concerns by the SRT with the seismic capacity of the MCC. The Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats.

B.1.2 GERS - Motor Control Centers

The generic seismic test data base equipment class of MCCs includes control and electrical fault protection systems for motors powered at 600 VAC (480 VAC nominal), 250 VDC, or less. MCCs in the test data base typically include several enclosure sections which are normally about 20 inches wide, 14 to 20 inches deep, and about 90 inches high. These sections are fabricated of 14 gage (0.0747 inches thick) or heavier steel sheets and are supported at the floor on base channels which are either integral with the MCC frame or are external members connected by internal bolts to the MCC frame. Multiple MCC sections may be grouped together to make widths to 120 inches or greater. The weight per section of these MCCs ranges from 200 to 800 pounds.

The types of components typically housed within MCCs in the test data base include contactors, overload relays, various types of other relays, circuit breakers, disconnect switches, control or distribution transformers, and panelboards. MCCs may also have indicator lamps and meters mounted on them.

The GERS represent the seismic capacity of a Motor Control Center (MCC) if the MCC meets the intent of the following inclusion and exclusion rules.

MCC/GERS Caveat 1 - Generic Seismic Test Data Base. The MCC should be similar to and bounded by the MCC class of equipment of the GERS data base. The discussion above briefly summarizes the generic seismic test data base MCC class description.

MCC/GERS Caveat 2 - Bounding Spectrum Caveats. The MCC should meet all the caveats given for the Bounding Spectrum. This caveat is included to cover the vulnerabilities identified in the earthquake experience data base. Those GERS caveats which are the same as the Bounding Spectrum caveats are not repeated below.

MCC/GERS Caveat 3 - Floor-Mounted Cabinet. The MCC should be floor-mounted. This is the mounting configuration for all MCCs in the generic seismic test data base.

MCC/GERS Caveat 4 - Weight Less Than 800 Pounds. The average weight per vertical section should be less than about 800 pounds. This is the upper bound weight of MCCs in the generic seismic test data base.

MCC/GERS Caveat 5 - Anchored Through Base Channel. The MCC should be anchored through an integral base channel or an external base channel which is connected to the MCC by internal bolts. The intent of this caveat is to avoid anchoring MCCs through flimsy or flexible sections in which significant bending of sheet metal could occur during an earthquake.

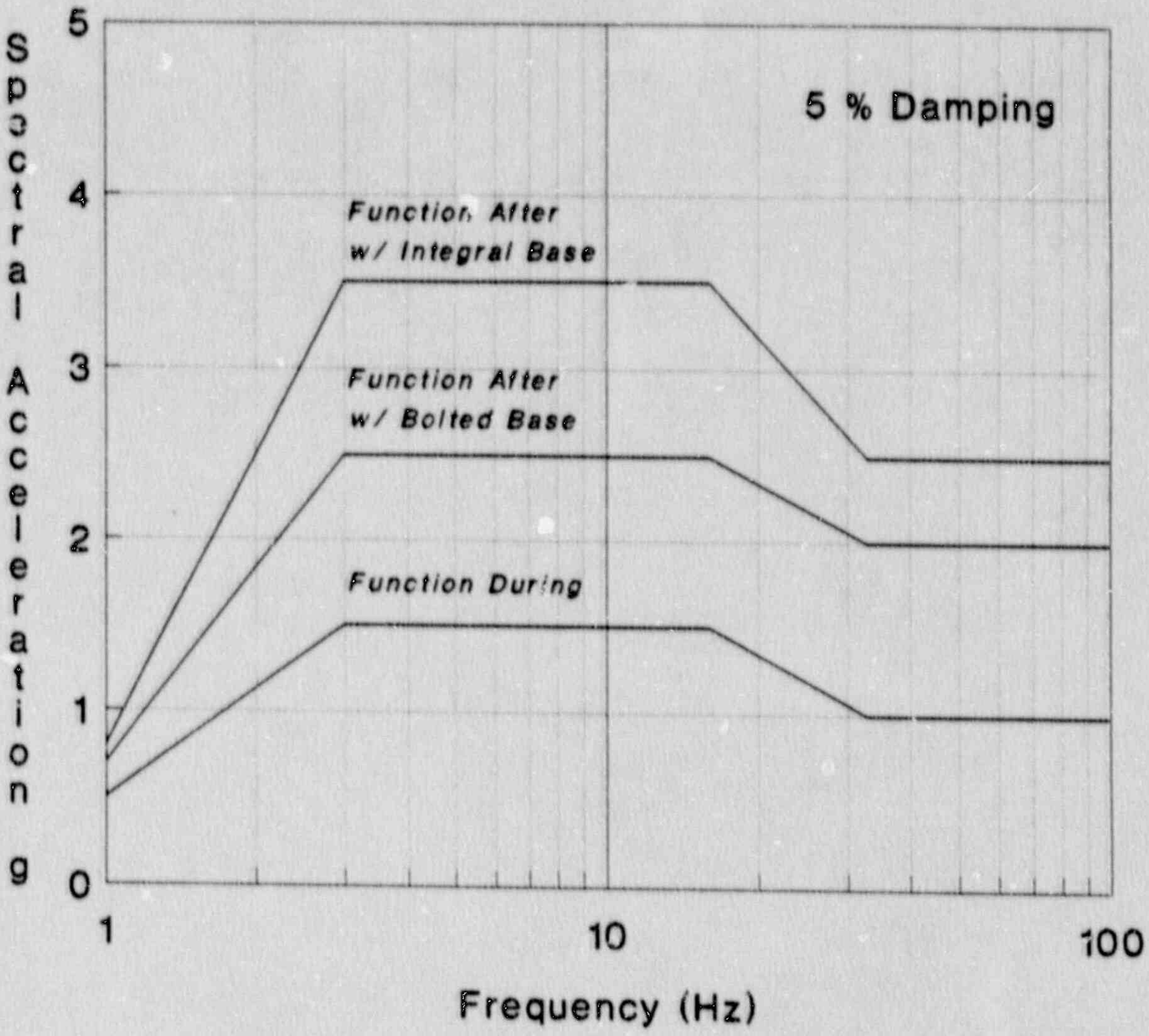
MCC/GERS Caveat 6 - Load Path Check. The load transfer path from the anchorage to base frame of the MCC should be checked for adequacy. If the MCC frame is connected to external base structural members with internal mounting bolts, then these bolts should be at least 3/8 inches in diameter. Any sheet metal cabinet components used for anchorage should have reinforcement. Excessive eccentricities in the internal load path which allow significant bending of sheet metal should be evaluated separately for adequacy and stiffness.

MCC/GERS Caveat 7 - "Function During" GERS. The "Function During" GERS can be used only if all the relays within the MCC have GERS greater than 4.5g within the amplified spectral region. For this caveat, the term "relays" does not include contactors and other starter components. Auxiliary contacts of contactors require a separate relay evaluation as described in Section 6 if they are used for external control or lockout signals.

<u>MCC/GERS Caveat 8 - "Function After" GERS.</u> The "Function After" GERS can be used if it can be demonstrated that the starters can be reset. The Relay Functionality Review in Section 6 describes the guidelines for evaluating the acceptability of resetting relays and starters. Note that, in general, both system tolerance of the changed state and operator availability for manual reset should be shown.

<u>MCC/GERS Caveat 9 - 3.5g "Function After" GERS for Integral Bases.</u> The 3.5g "Function After" GERS can be used only for MCCs with integral welded structural base members. This base framing configuration is typical of MCCs of the generic seismic test data base representative of the 3.5g "Function After" GERS.

GERS-MCC.7
11/1/89



Frequency (Hz)	1	3	16	33
Function After w/ Integral Base (g)	0.8	3.5	3.5	2.5
Function After w/ Bolted Base (g)	0.7	2.5	2.5	2.0
Function During (g)	0.5	1.5	1.5	1.0

Figure B.1-1. Generic Equipment Ruggedness Spectra (GERS) for Motor Control Centers. (Source: Reference 6)

B.2 LOW VOLTAGE SWITCHGEAR

B.2.1 Bounding Spectrum - Low Voltage Switchgear (LVS)

The earthquake experience data base equipment class of low voltage switchgear (LVS) assemblies consists of one or more circuit breakers and associated control relays, instrumentation, disconnect switches, and distribution buses mounted in a sheet metal enclosure. The term "low voltage switchgear" is associated with circuits of 600 volts or less, typically 440 to 480 volts in modern power plants and industrial facilities.

Switchgear assemblies are composed of vertical sections which normally contain stacks of two to four circuit breaker cubicles. The vertical section is a sheet metal enclosure welded to a framework of steel angles or channels. Each section includes a circuit breaker or other control devices in a forward compartment and bus connections for the primary circuits in the rear compartment.

A section of a switchgear assembly is typically 90 inches in height and 60 inches in depth. The width of each section ranges from 20 to 36 inches, depending on the size of the circuit breaker it contains. A typical section weighs about 2000 pounds. Individual sections are bolted together through adjoining walls to form an assembly. LVS assemblies normally include at least one cubicle that serves as a metering compartment. The compartment typically contains ammeters, voltmeters, relays, and transformers.

Most low voltage circuit breakers are the drawout type. They are mounted on a roller/rail support system that allows them to be disconnected from their primary contacts at the rear, and drawn forward out of their sheet metal enclosure for maintenance. While in operation, the circuit breaker clamps to bus bars in the rear of the switchgear assembly. Additional positive attachment of the breaker to its enclosure is made by a mechanical jack or racking mechanism which slides the breaker in or out of its operating position.

The circuit breaker can include the following types of components: spring-actuated electric contacts, a closing solenoid, various types of tripping devices (overcurrent, shunt, under voltage), fuses, and auxiliary switches.

Low voltage breakers may be combined in assemblies with transformers, distribution panels, medium voltage breakers, and motor controllers. Circuit breakers, relays, instrumentation, the switchgear assembly enclosure, internal transformers, attachments such as junction boxes, and attached conduit or cables are included in the Low Voltage Switchgear equipment class.

The Bounding Spectrum (BS) represents the seismic capacity of a Low Voltage Switchgear (LVS) if the switchgear meets the intent of the following inclusion and exclusion rules.

<u>LVS/BS Caveat 1 - Earthquake Experience Data Base.</u> The low voltage switchgear should be similar to and bounded by the LVS class of equipment of the earthquake experience data base. The discussion above briefly summarizes the class description of LVS in the data base.

<u>LVS/BS Caveat 2 - Rating of 600 V or Less.</u> The low voltage switchgear should have a 600 V rating or less. This is the upper bound voltage rating of LVS in the earthquake experience data base.

LVS/BS Caveat 3 - Adjacent Cabinets Bolted Together. Adjacent cabinets which are close enough to impact each other and sections of multi-bay cabinet assemblies should be bolted together if any of these cabinets contain essential relays. The concern addressed in this caveat is that unbolted cabinets could respond out of phase to one another and impact each other during an earthquake. This would cause additional impact loadings and high frequency vibration loadings which could cause any essential relays to chatter.

LVS/BS Caveat 4 - Attached Weight of 100 Pounds or Less. Equipment and their enclosures (but not conduit) mounted externally to cabinets and supported by them should have a weight less than about 100 pounds per cabinet. The concern is that the center of gravity of the cabinet will be raised too high, the total weight of the cabinets will be too large, or large eccentric weights will introduce excessive torsion. The concern is directed primarily for equipment not normally supplied with the switchgear and thereby possibly not included in the seismic experience data base equipment class. The load path of the attached component through the cabinet should be carefully examined. In addition, its attachment should be reviewed to ascertain whether the attached component may become a seismic interaction hazard source. Conduit was deleted from the caveat since conduit supported above switchgear is well represented in the seismic experience data. Additional support of the cabinet and attached equipment will alleviate these concerns and satisfy the intent of this caveat.

For the purposes of anchorage checking, the effective weight of any attached conduit and equipment should be included in the cabinet weight.

LVS/BS Caveat 5 - Externally Attached Items Rigidly Anchored. Externally attached items should be rigidly attached to the cabinet. The concern addressed by this caveat is that these items could impact the cabinet and possibly lead to relay chatter, or impact other components of the switchgear as a seismic interaction hazard. As an example, some electrical cabinets have small, externally attached panels mounted on hinges to the main cabinet frame. During seismic motion the externally attached panel may swing and cause significant impact loading to the electrical panel.

LVS/BS Caveat 6 - General Configuration Similar to ANSI C37.20 Standards. The general configuration of the cabinets should be similar to those constructed to ANSI C37.20 Standards. The switchgear does not have to conform exactly to ANSI standards but should be similar with regard to the gage of the steel, internal structure and support. This caveat is intended to preclude unusual designs not covered by the data base (thin gage material, flimsy internal structure, etc.) In general, cabinets manufactured by the major manufacturers of switchgear conform to this caveat if they have not been modified.

LVS/BS Caveat 7 - Cutouts Not Large. Cutouts in the lower half of cabinet sheathing should be less than 30% of the width of the side panel, and the height of the cutout should be less then 60% of the width of the side panel. This caveat also applies to side panels between multi-bay cabinets. Cutout restrictions do not apply to the bus transfer compartment if the remaining part of the enclosure conforms with the cutout limitation. The concern of this caveat is that the shear load from the earthquake will not be able to be transferred through the shear walls to the anchorage. Reinforcement around the cutout with additional plate or steel members may alleviate the concern of shear transfer.

LVS/BS Caveat 8 - Doors Secured. All doors should be secured by a latch or fastener. The concern addressed by this caveat is that loose doors could repeatedly impact the housing and be damaged or cause internal components such as relays to malfunction or chatter.

LVS/BS Caveat 9 - Adequate Anchorage. The unit should be properly anchored in accordance with the guidelines of Section 4.4.

LVS/BS Caveat 10 - Potential Chatter of Essential Relays Evaluated. If relays are mounted on the equipment, a relay functionality review in accordance with Section 6 should be performed.

LVS/BS Caveat 11 - No Other Concerns. There should not be any other concerns with the seismic capacity of the switchgear. Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats.

B.2.2 GERS - Low Voltage Switchgear

The generic seismic test data base equipment class of LVS includes steel enclosures containing several draw-out type circuit breakers, bus bars, protective/auxiliary relays, and meters. Units have a maximum rating of 600 VAC or 250 VDC. The metal enclosure sections are typically 20 to 30 inches wide, 60 inches deep, and 80 to 90 inches high. They are fabricated of 14 gage (0.0747 inches thick) or heavier steel sheets framed with angles, with anchorage provisions included in the base frame. The weight per section of the switchgear assembly ranges from 1000 to 1600 pounds. The units should be mounted within ANSI-type metal enclosures with either welded or bolted anchorage. To exclude specialty-type switchgear, the class is limited to the following four manufacturers: ITE/Brown Boveri, Westinghouse, General Electric, or Powell.

The GERS represent the seismic capacity of a Low Voltage Switchgear (LVS) if the switchgear meets the intent of the following inclusion and exclusion rules.

LVS/GERS Caveat 1 - Generic Seismic Test Data Base. The low voltage switchgear should be similar to and bounded by the LVS class of equipment of the GERS data base. The discussion above briefly summarizes the generic seismic test data base LVS class description.

LVS/GERS Caveat 2 - Bounding Spectrum Caveats Apply. The switchgear should meet all the caveats given for the Bounding Spectrum. This caveat is included to cover the vulnerabilities identified in the earthquake experience data base. Those GERS caveats which are the same as the Bounding Spectrum caveats are not repeated below.

LVS/GERS Caveat 3 - Floor-Mounted Switchgear. The low voltage switchgear must be housed within a floor-mounted ANSI-type enclosure. This ensures consistency with enclosures included in the generic seismic test data base.

LVS/GERS Caveat 4 - Manufactured by Major Vendors. The switchgear must be manufactured by either ITE/Brown Boveri, Westinghouse, General Electric, or Powell. These are the LVS manufacturers included in the generic seismic test data base.

LVS/GERS Caveat 5 - Weight Less than 1600 Pounds. The average weight per section should be less than 1600 pounds. This is the upper bound weight limit of LVS in the generic seismic test data base.

LVS/GERS Caveat 6 - Separate Evaluation of Racking Mechanism. Breaker positioning or racking mechanisms should be evaluated. There should be sufficient side-to-side constraints to prevent secondary/auxiliary breaker contacts from opening. The evaluation may consist of an inspection by the SRT. This caveat is intended to address potential damage or operational problems due to excessive relative motion between the drawout breaker and the switchgear cabinet frame as was observed in an example from the generic seismic test data base.

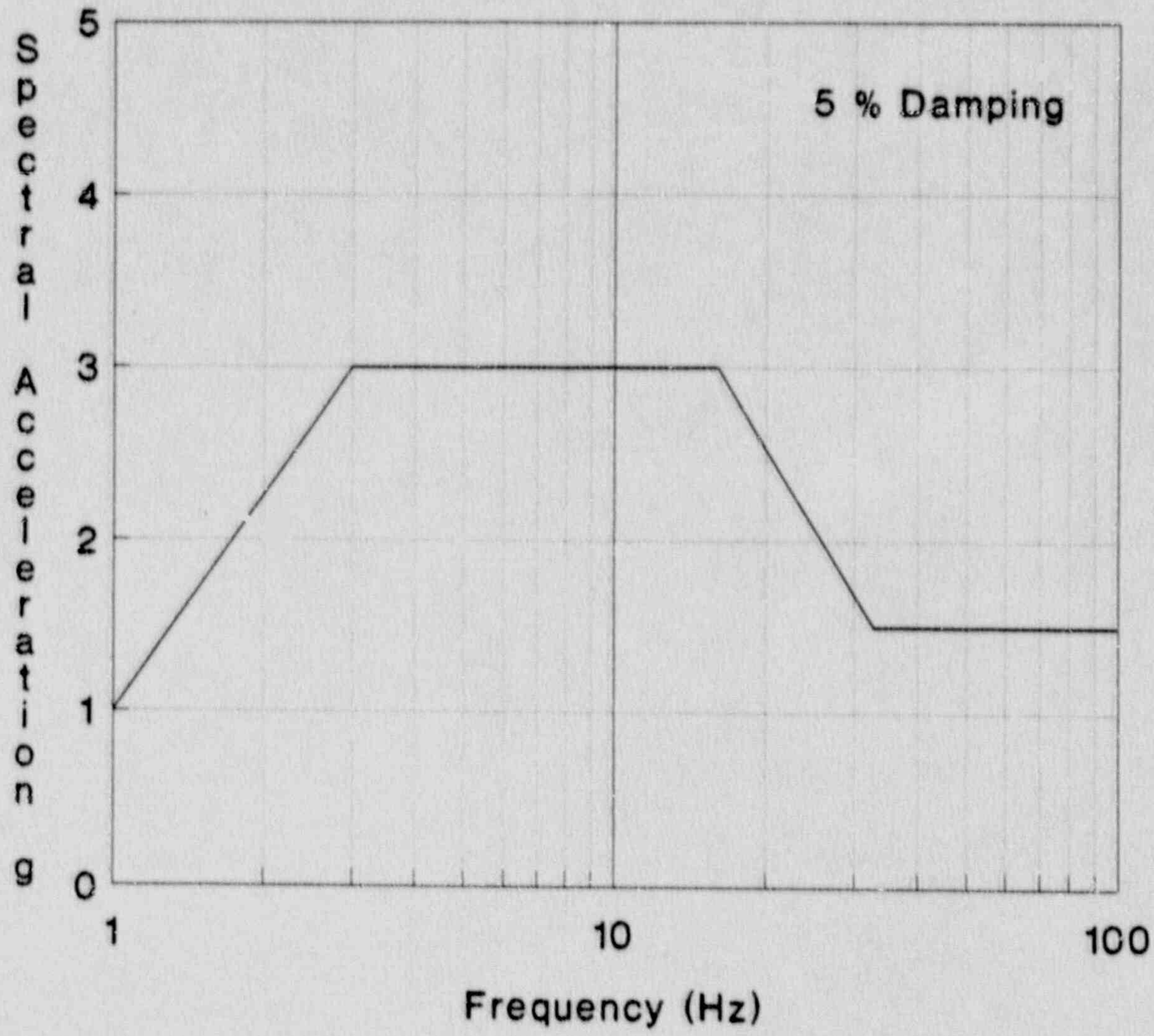
<u>LVS/GERS Caveat 7 - Base Anchorage Evaluation.</u> The switchgear should be base anchored and the installed anchorage should be evaluated as described in Section 4. This caveat ensures applicability of the generic seismic test data base.

<u>LVS/GERS Caveat 8 - No Special Purpose Switchgear.</u> Switchgear GERS do not apply to special purpose switchgear such as those used for reactor trip. Special purpose switchgear may be custom designed and manufactured, and not included in the generic seismic test data base.

<u>LVS/GERS Caveat 9 - Relay Screening Required.</u> Relays which control switchgear operation should not appear on the Low Ruggedness Relays list (given in Reference 32).

<u>LVS/GERS Caveat 10 - Additional Relay Screening Required.</u> Additional screening evaluation of relays is, in general, required (see Reference 8) only if the relay is essential to other equipment. The guidelines for identifying and evaluating switchgear relays are described in Section 6.

GERS-MVS/LVS.3 (Low Voltage)
11/1/89



Frequency (Hz)	1	3	16	33
Low Voltage Switchgear (g)	1.0	3.0	3.0	1.5

Figure B.2-1. Generic Equipment Ruggedness Spectra (GERS) for Low Voltage Switchgear. (Source: Reference 6)

B.3 MEDIUM VOLTAGE SWITCHGEAR

B.3.1 Bounding Spectrum - Medium Voltage Switchgear (MVS)

The earthquake experience data base equipment class of medium voltage switchgear (MVS) assemblies consists of one or more circuit breakers and associated control relays and instrumentation mounted in a sheet metal enclosure. The equipment class includes electrical switching and fault protection circuit breakers for systems powered between 2400 and 4160 volts. Medium voltage circuit breakers are mounted in sheet metal cabinets which are bolted together, side-by-side, to form a switchgear assembly.

Medium voltage circuit breakers or load interrupter switches are often integrated into unit substations that may include a transformer (typically 4160/480 volt), a set of low voltage switchgear, or a distribution switchboard. The switchgear assembly also may include internal transformers, junction boxes, and attached conduit and cables. The basic component of a medium voltage switchgear assembly is a metal-clad enclosure, typically containing a circuit breaker compartment in a lower section and a metering compartment in an upper section. The rear of the enclosure is a separate compartment for primary electrical connections. The enclosure consists of sheet metal panels welded to a supporting frame of steel angles or channels. Individual enclosures are typically 90 inches in height and approximately 90 inches in depth. The width of an enclosure typically varies from 24 to 36 inches, depending on the size of the circuit breaker within. The weight of a metal-clad enclosure ranges from 2000 to 3000 pounds, with the circuit breaker itself weighing from 600 to 1200 pounds.

Electro-mechanical relays are mounted either to the swinging doors at the front of the enclosure, or to the interior of the metering compartment. Relays are typically inserted through cutouts in the door and secured by screws through a mounting flange into the sheet metal. The metering compartment may also contain components such as ammeters, voltmeters, hand switches, and small transformers.

The medium voltage circuit breakers commonly used in power plant applications include the drawout-type air-magnetic circuit breakers, and stationary load interrupter switches. Each type is discussed in this section.

Drawout, air-magnetic circuit breakers are mounted on rollers to allow them to be wheeled in and out of their individual sheet metal enclosures. There are two general types of drawout circuit breakers: the horizontally-racked model and the vertically-racked model.

The horizontally-racked model has clamping bus connections at its rear. It is racked into operating position by a mechanical jack that rolls the circuit breaker into contact with the bus connections at the rear of its enclosure and secures it in place. The weight of the circuit breaker rests on the floor of its sheet metal enclosure.

Vertically-racked circuit breakers roll into position within their enclosure and are then engaged by a jack built into the walls of the enclosure. The jack lifts the circuit breaker several inches above the floor, until the clamping connections atop the circuit breaker contact the bus connections at the top of the enclosure. The weight of the circuit breaker is then supported on the framework of the sheet metal enclosure.

Air-magnetic circuit breakers typically include the following types of components: spring-actuated contacts, tripping devices, auxiliary switches, and fuses. Typical capacities for medium voltage circuit breakers range from 1200 to 3000 amperes.

Load interrupter switches perform the load connecting and interrupting function of circuit breakers, but do not include the same capabilities of electrical fault protection. Interrupter switches are bolted into sheet metal enclosures and are therefore designated as stationary devices. Like air-magnetic circuit breakers, interrupter switches usually operate with spring-actuated contacts to ensure quick opening of the primary circuit.

The Bounding Spectrum (BS) represents the seismic capacity of a Medium Voltage Switchgear (MVS) if the switchgear meets the intent of the following inclusion and exclusion rules.

<u>MVS/BS Caveat 1 - Earthquake Experience Data Base.</u> The switchgear should be similar to and bounded by the MVS class of equipment of the earthquake experience data base. The discussion above briefly summarizes the class description of MVS in the data base.

<u>MVS/BS Caveat 2 - Rating between 2.4 KV and 4.16 KV.</u> The switchgear should have a rating between 2.4 KV and 4.16 KV. This is the typical voltage range of MVS of this equipment class in the earthquake experience data base.

<u>MVS/BS Caveat 3 - Adjacent Cabinets Bolted Together.</u> Adjacent cabinets which are close enough to impact each other and sections of multi-bay cabinet assemblies should be bolted together if any of these cabinets contain essential relays. The concern addressed in this caveat is that unbolted cabinets could respond out of phase to one another and impact each other during an earthquake. This would cause additional impact loadings and high frequency vibration loadings which could cause the essential relays to chatter.

MVS/BS Caveat 4 - Attached Weight of 100 Pounds or Less. Equipment and their enclosures (but not conduit) mounted externally to cabinets and supported by them should have a weight less than about 100 pounds per cabinet. The concern is that the center of gravity of the cabinet will be raised too high, the total weight of the cabinets will be too large, or large eccentric weights will introduce excessive torsion. The concern is directed primarily for equipment not normally supplied with the switchgear and thereby possibly not included in the seismic experience data base equipment class. The load path for the attached component through the cabinet should be carefully examined. In addition, its attachment should be reviewed to ascertain whether the attached component may become a seismic interaction hazard source. Conduit was deleted from the caveat since conduit supported above switchgear is well represented in the seismic experience data base. Additional support of the cabinet and attached equipment will alleviate these concerns and satisfy the intent of this caveat.

For the purposes of anchorage checking, the effective weight of any attached conduit and equipment should be included in the cabinet weight.

MVS/BS Caveat 5 - Externally Attached Items Rigidly Anchored. Externally attached items should be rigidly attached to the cabinet. The concern addressed by this caveat is that these items could impact the cabinet and possibly lead to relay chatter or impact other components of the switchgear as a seismic interaction hazard. As an example, some electrical cabinets have small, externally attached panels mounted on hinges to the main cabinet frame. During seismic motion the externally attached panel may swing and cause significant impact loading to the electrical panel.

MVS/BS Caveat 6 - General Configuration Similar to ANSI C37.20 Standards. The general configuration of the cabinets should be similar to those constructed to ANSI C37.20 Standards. The switchgear does not have to conform exactly to ANSI standards but should be similar with regard to the gage of the steel, internal structure and support. This caveat is intended to preclude unusual designs not covered by the data base (thin gage material, flimsy internal structure, etc.). In general, cabinets manufactured by the major manufacturers of switchgear conform to this caveat if they have not been modified.

MVS/BS Caveat 7 - Cutouts Not Large. Cutouts in the lower half of cabinet sheathing should be less than 30% of the width of the side panel, and the height of the cutout should be less than 60% of the width of the side panel. This caveat also applies to side panels between multi-bay cabinets. Cutout restrictions do not apply to the bus transfer compartment if the remaining part of the enclosure conforms with the cutout limitations. The concern of this caveat is that the shear load from the earthquake will not be able to be transferred through the shear walls to the anchorage. Reinforcement around the cutout with additional plate or steel members may alleviate the concern of shear transfer.

MVS/BS Caveat 8 - Doors Secured. All doors should be secured by a latch or fastener. The concern addressed by this caveat is that the doors could open during an earthquake, and the loose door could repeatedly impact the housing and be damaged or cause internal components such as relays to malfunction or chatter.

MVS/BS Caveat 9 - Adequate Anchorage. The unit should be properly anchored in accordance with the guidelines of Section 4.4.

MVS/BS Caveat 10 - Potential Chatter of Essential Relays Evaluated. If relays are mounted on the equipment, a relay functionality review in accordance with Section 6 should be performed.

MVS/BS Caveat 11 - No Other Concerns. There should not be any other concerns with the seismic capacity of the switchgear. Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats.

B.3.2 GERS - Medium Voltage Switchgear

The generic seismic test data base equipment class of metal clad medium-voltage switchgear includes steel panel enclosures containing several wheel-mounted draw-out type circuit breakers, bus bars, auxiliary/protective relays, transformers, switches, and meters. Units are medium voltage rated at 5000 VAC. Circuit breakers which must be jacked up to engage (vertical lift) into the connected position are not included in this class. The equipment in the GERS data base include ANSI C37.20 enclosures whose nominal section sizes are 30 inches wide, 60 inches deep, and 90 inches high. They are fabricated of 12 gage (0.1046 inches thick) or heavier steel sheet metal and framed with angles, with anchorage provisions included in the base frame. Widths of MVS can range between 24 inches and 42 inches. Some cubicles can be essentially empty, while other cubicles can house very heavy circuit breaker units. In general, a single cubicle which houses a circuit breaker can typically weigh between 3000 and 5000 pounds. The MVS GERS equipment class covers most medium voltage switchgear used in power plants for overcurrent protection in primary voltage (normally 4160 VAC) distribution systems.

The GERS represent the seismic capacity of a Medium Voltage Switchgear (MVS) if the switchgear meets the intent of the following inclusion and exclusion rules.

<u>MVS/GERS Caveat 1 - Generic Seismic Test Data Base.</u> The switchgear should be similar to, and bounded by, the MVS class of equipment of the GERS data base. The discussion above briefly summarizes the generic seismic test data base MVS class description.

<u>MVS/GERS Caveat 2 - Bounding Spectrum Caveats Apply.</u> The switchgear should meet all the caveats given for the Bounding Spectrum. This caveat is included to cover the vulnerabilities identified in the earthquake experience data base. Those GERS caveats which are the same as the Bounding Spectrum caveats are not repeated below.

<u>MVS/GERS Caveat 3 - Floor-Mounted Switchgear.</u> The medium-voltage switchgear should be housed within a floor-mounted ANSI-type enclosure. This ensures consistency with the enclosures included in the generic seismic test data base.

<u>MVS/GERS Caveat 4 - No Jack-Up or Vertical-Lift Type Breakers.</u> The breakers should be the wheel-mounted type and not a jack-up or vertical-lift type. This is the only breaker configuration represented in the generic seismic test data base.

<u>MVS/GERS Caveat 5 - Weight Less than 5000 Pounds.</u> The average weight per vertical breaker section should be less than 5000 pounds (review of manufacturer's submittals is sufficient). This is the upper bound weight limit of sections included in the generic seismic test data base.

<u>MVS/GERS Caveat 6 - Separate Evaluation of Racking Mechanism.</u> Breaker positioning or racking mechanisms should be evaluated. There should be sufficient side-to-side constraints to prevent secondary/auxiliary breaker contacts from opening. The evaluation may consist of an inspection by the SRT. This caveat is intended to address potential damage or operational

problems due to excessive relative motion between the drawout breaker and the switchgear cabinet frame as was observed in an example from the generic seismic test data base.

MVS/GERS Caveat 7 - Inspection of Internal Component Mountings. To utilize 3.0g GERS level for medium voltage switchgear, an inspection of internal component mountings should be conducted. This inspection should include a general judgment of mounting adequacy for support brackets and attachments of items such as, but not limited to, current and potential transformers. Particular attention should be given to components supported upon other components. Past shake table test experience has shown that internal components such as small current transformers may loosen during seismic motion and break free from their attachments. The concern is that inadequately mounted internal components may impact and damage other sensitive switchgear components.

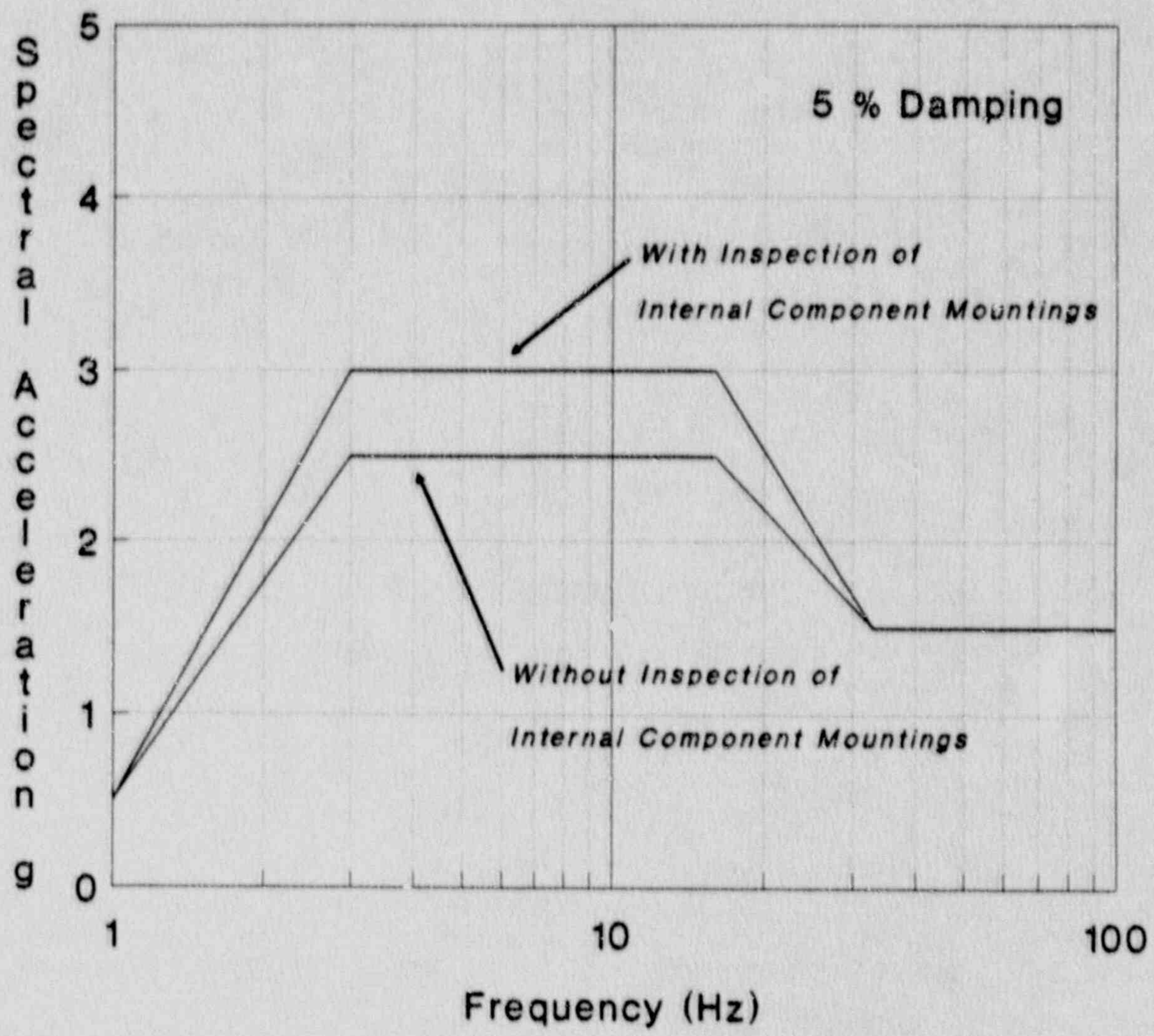
MVS/GERS Caveat 8 - Base Anchorage Evaluation. The switchgear should be base anchored and the installed anchorage should be evaluated as described in Section 4. This caveat ensures applicability of the generic seismic test data base.

MVS/GERS Caveat 9 - No Special Purpose Switchgear. Switchgear GERS do not apply to special purpose switchgear such as those used for reactor trip. Special purpose switchgear may be custom designed and manufactured, and not included in the generic seismic test data base.

MVS/GERS Caveat 10 - Relay Screening Required. Relays which control switchgear operation should not appear on the Low Ruggedness Relays list (given in Reference 32).

MVS/GERS Caveat 11 - Additional Relay Screening Required. Additional screening evaluation of relays is, in general, required (see Reference 8) only if a relay is essential to other equipment. The guidelines for identifying and evaluating switchgear relays are described in Section 6.

GERS-MVS/LVS.3 (Medium Voltage)
11/1/89



Frequency (Hz)	1	3	16	33
With Inspection (g)	0.5	3.0	3.0	1.5
Without Inspection (g)	0.5	2.5	2.5	1.5

Figure B.3-1. Generic Equipment Ruggedness Spectra (GERS) for Medium Voltage Switchgear. (Source: Reference 5)

B.4 TRANSFORMERS

B.4.1 Bounding Spectrum - Transformers (TRN)

The earthquake experience data base equipment class of transformers (TRN) includes the unit substation type, typically 4160/480 volts, and the distribution type, typically 480/120 volts. Main power transformers with primary voltages greater than about 13,800 volts are not included in this class. Small transformers that are components of electrical equipment, such as motor control centers or control panels, are also not included in this class but are addressed as components of other classes of electrical equipment.

Unit substation transformers step power down from the medium voltage levels (typically 4160 volts for use in large mechanical equipment) to lower voltage levels (typically 480 volts) for use in smaller equipment. Distribution transformers usually step power from the 480 volt level to the 120 to 240 volt level to operate small mechanical equipment, battery chargers, or lighting systems.

Unit substation transformers included in the equipment class can be freestanding or attached to motor control centers or switchgear assemblies. They typically have primary voltages of 2400 to 4160 volts, and secondary voltages of 480 volts. This transformer type may be either liquid- or air-cooled. Liquid-cooled units typically consist of a rectangular steel tank filled with oil or a similar insulating fluid. The transformer coils are submerged in a liquid bath which provides cooling and insulation within the steel tank casing. Most liquid-filled transformers have one or more radiator coils attached to the side of the transformer.

Air-cooled or dry-type unit substation transformers are similar in size and construction to liquid-cooled units, except the transformer coils are mounted in a ventilated steel enclosure, rather than a liquid bath. Larger air-cooled unit substation transformers may have small fans mounted to their enclosures for forced air cooling.

The casings of both liquid-cooled and air-cooled unit substation transformers have typical overall dimensions of 60 to 100 inches in height, and 40 to 100 inches in width and depth. The weights of these units range from 2000 to 15,000 pounds.

Distribution transformers typically have primary voltages of 480 volts stepping down to secondary voltages of 120 to 240 volts. This type of transformer is almost always air-cooled. The construction of distribution transformers is essentially the same as that of unit substation transformers, except for a difference in size. The sizes of typical distribution transformers range from small wall-mounted or cabinet-mounted units that have overall dimensions of about 10 inches in height, width, and depth, and weights of 50 to 100 pounds; to larger units that are typically floor-mounted with dimensions ranging up to the size of unit substation transformers and weights ranging up to 5000 pounds.

The transformer equipment class includes the enclosure along with the internals and attached cable and conduit.

The Bounding Spectrum (BS) represents the seismic capacity of a Transformer (TRN) if the transformer meets the intent of the following inclusion and exclusion rules.

TRN/BS Caveat 1 - Earthquake Experience Data Base. The transformer should be similar to and bounded by the TRN class of equipment of the earthquake experience data base. The discussion above briefly summarizes the class description of TRNs in the data base.

TRN/BS Caveat 2 - Rating of 4.16 KV or Less. The transformer should have a 4.16 KV rating or less. This is the upper bound voltage rating of transformers included in the experience data base equipment class.

TRN/BS Caveat 3 - Transformer Coils Restrained Within Cabinet. For floor-mounted dry and oil-type units, the transformer coils should be restrained within their cabinet so that relative sliding and rocking motions between the transformer coil and their cabinet is kept to an acceptable level. The concern is that excessive relative motions may damage the wiring yoke, or that the coils may come in contact with their cabinet which may result in a short circuit or damage to the electrical insulation. This caveat especially applies to transformers whose installation procedure recommends that bolts used to anchor the coils during shipping be removed. If the unit is factory-sealed or constructed so that removing shipping anchors is precluded, no internal inspection is necessary.

TRN/BS Caveat 4 - Wall-Mounted Units Anchored Close to Enclosure Support. The transformer coil contained in wall-mounted units should have engineered anchorage and be anchored to its enclosure near the enclosure support surface. The concern is that a well-engineered load path should exist for earthquake loadings from the transformer coil (which is relatively massive), through the enclosure, and to the enclosure support. If the transformer coil is not anchored to the enclosure near the enclosure support surface, a calculation can be performed to show that the earthquake loadings can be transferred to the anchorage.

TRN/BS Caveat 5 - Weak-Way Bending. The base assembly of floor-mounted units should be properly braced or stiffened such that lateral forces in any direction do not rely on weak-way bending of sheet metal or thin webs of structural steel shapes. If unbraced or unstiffened steel webs are used, they should be specially evaluated so that adequate strength and stiffness is ensured.

TRN/BS Caveat 6 - Adjacent Cabinets Bolted Together. Adjacent cabinets which are close enough to impact each other, and sections of multi-bay cabinet assemblies should be bolted together if any of these cabinets contains essential relays. The concern addressed in this caveat is that unbolted cabinets could respond out of phase to one another and cause impact loadings and high frequency vibration loadings which could cause any impact sensitive essential relays to chatter.

TRN/BS Caveat 7 - Doors Secured. All doors should be secured by a latch or fastener. The concern addressed by this caveat is that the doors could open during an earthquake, and the loose door could repeatedly impact the housing and be damaged or cause internal components such as relays to malfunction or chatter.

TRN/BS Caveat 8 - Adequate Anchorage. The unit should be properly anchored in accordance with the guidelines of Section 4.4.

TRN/BS Caveat 9 - Potential Chatter of Essential Relays Evaluated. If relays are mounted on the equipment, a relay functionality review in accordance with Section 6 should be performed.

TRN/BS Caveat 10 - No Other Concerns. There should not be any other concerns with the seismic capacity of the transformer. Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats.

B.4.2 GERS - Transformers

The generic seismic test data base equipment class of Transformers includes only dry-type transformers. The equipment in the GERS data base is limited to units which range from 7.5 to 225 KVA capacity with either single- or three-phase voltage ratings of 120-480 volts AC. These transformers are housed in NEMA-type metal enclosures which can be either wall-mounted or floor-mounted.

The GERS represent the seismic capacity of a Transformer (TRN) if the transformer meets the intent of the following inclusion and exclusion rules.

TRN/GERS Caveat 1 - Generic Seismic Test Data Base. The transformer should be similar to and bounded by the TRN class of equipment of the GERS data base. The discussion above briefly summarizes the generic seismic test data base TRN class description.

TRN/GERS Caveat 2 - Bounding Spectrum Caveats Apply. The transformer should meet all the caveats given for the Bounding Spectrum. This caveat is included to cover the vulnerabilities identified in the earthquake experience data base. Those GERS caveats which are the same as the Bounding Spectrum caveats are not repeated below.

TRN/GERS Caveat 3 - Only Dry-Type Transformer. The transformer should be a dry-type unit. Oil-filled units are excluded as they are not included in the generic seismic test data base.

TRN/GERS Caveat 4 - NEMA-Type Enclosure. The transformer should be housed within a wall- or floor-mounted NEMA-type enclosure (review of manufacturer's submittals is sufficient). This is the enclosure type represented by the generic seismic test data base.

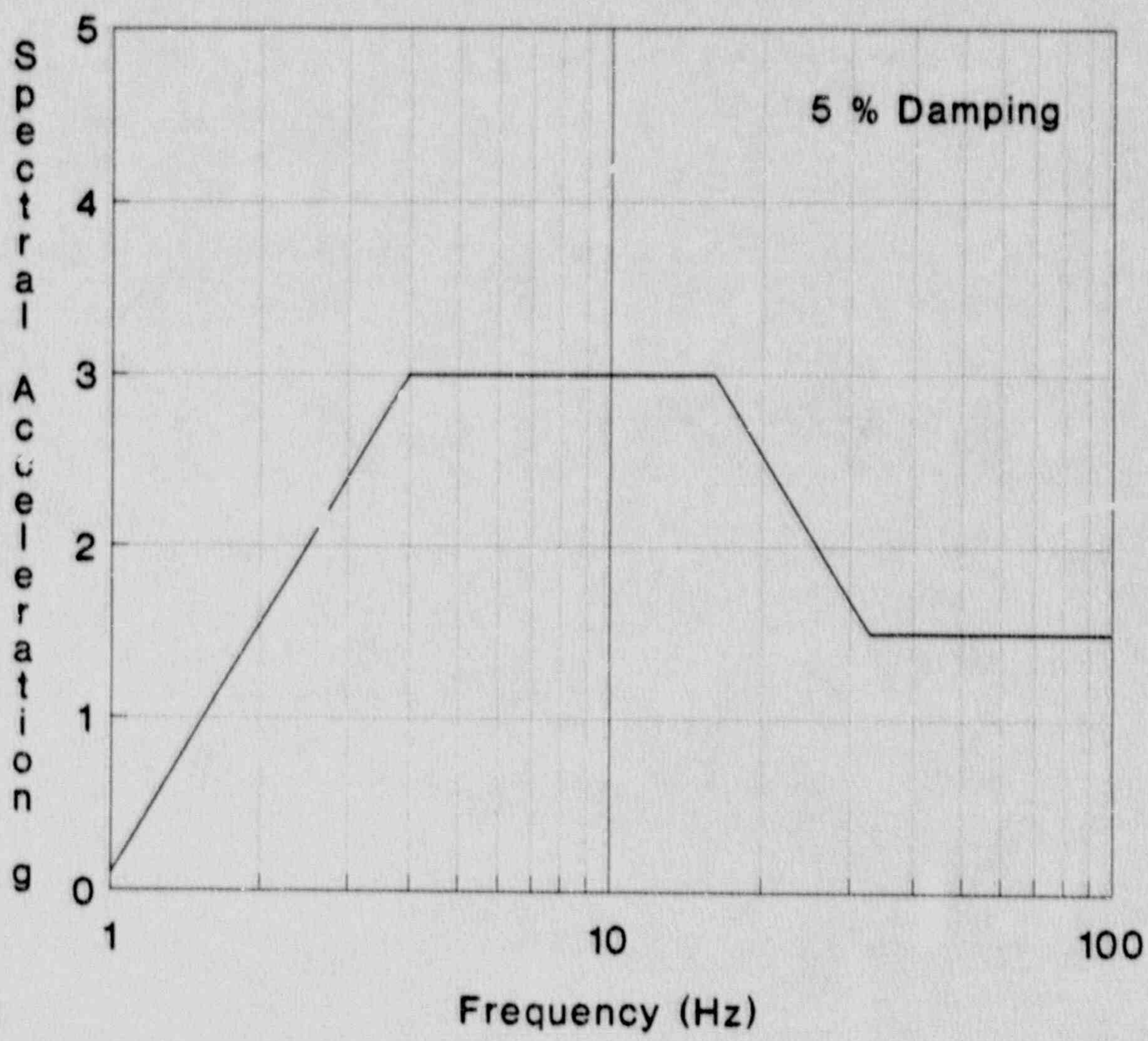
TRN/GERS Caveat 5 - Voltage Rating of 120-480 VAC. The transformer should have a single- or three-phase voltage rating of 120-480 volts AC (review of manufacturer's submittals or transformer name-plate is sufficient).

TRN/GERS Caveat 6 - Capacity of 7.5 to 225 KVA. The transformer should have a capacity of 7.5 to 225 KVA (review of manufacturer's submittals or transformer name-plate is sufficient).

TRN/GERS Caveat 7 - Weight of 180-2000 Pounds. The transformer should weigh between 180 and 2000 pounds (review of the manufacturer's submittals or transformer name-plate is sufficient).

TRN/GERS Caveat 8 - Transformer Internal Supports. The internal supports should provide positive attachment of the transformer components (a load transfer path for seismic loads is necessary). An adequate load path should exist for earthquake loadings of the transformer coil through the enclosure support. A calculation may be performed to show that the earthquake loadings can be transferred to the anchorage.

GERS-TR.3
12/1/86



Frequency (Hz)	1	4	16	33
Dry-Type Transformers (g)	0.1	3.0	3.0	1.5

Figure B.4-1. Generic Equipment Ruggedness Spectra (GERS) for Dry-Type Transformers. (Source: Reference 6)

B.5 HORIZONTAL PUMPS

B.5.1 Bounding Spectrum - Horizontal Pumps (HP)

The earthquake experience data base equipment class of Horizontal Pumps (HP) includes all pumps commonly found in power plant applications which have their axes aligned horizontally. The class includes pumps driven by electric motors, reciprocating piston engines, and steam turbines. The common peripheral components such as conduit, instrumentation, and suction and discharge lines up to their first structural anchor point are included in this equipment class.

Pumps can generally be categorized as either kinetic (rotary impeller) or positive displacement types. Kinetic pumps move fluid using the kinetic energy of a rotating impeller. Positive displacement pumps move fluid by volumetric displacement.

Single-stage kinetic pumps typically include a single impeller that moves fluid primarily by centrifugal force. The suction port is normally mounted along or near the impeller axis, and the discharge port is mounted near the periphery. Pumps may range in size from fractional horsepower units, with capacities of a few gallons per minute (gpm), to units requiring several thousand horsepower, with capacities of tens of thousands of gpm.

Multi-stage kinetic pumps include two or more impellers working in series on a single shaft. Depending on the impeller design, multi-stage pumps move fluid using either centrifugal force toward the periphery of the impeller, or propeller force along the axis of the impeller. The impeller is surrounded by a stationary casing or volute that directs the flow from the discharge of one impeller to the intake of the next.

Kinetic pumps are usually powered by electric motors with the pump and motor sharing the same shaft through a close-coupled connection. Larger multi-stage pumps sometimes couple the motor and pump through a gearbox, which allows the pump and motor to turn at different speeds. Single-stage pumps are occasionally belt-driven, with the motor mounted to the side, or even atop the pump casing. Smaller, single-stage pumps sometimes mount the motor and impeller within the same casing. Larger pumps, both single- and multi-stage, normally have the motor and pump in separate casings, with both casings anchored to the same steel skid. Kinetic pumps may also be powered by engines or steam turbines.

Reciprocating-piston positive displacement pumps are similar in design to reciprocating-piston air compressors. They include an electric motor that powers a set of piston impellers through a shaft or belt connection. The piston impellers are usually mounted within a cast block that also contains the piston crank shaft and valve mechanism.

Rotary-screw positive displacement pumps are somewhat similar to multi-stage kinetic pumps, except that the screw impeller moves fluid axially through volume displacement rather than through a transfer of kinetic energy from the impeller to the fluid. The screw impeller is normally powered by an electric motor through a close-coupled shaft.

Kinetic and positive displacement horizontal pumps driven by electric motors, engines, and turbines are represented in the range from 5 to 2300 hp and 45 to 36,000 gpm. Submersible pumps are not included in this equipment class.

The Bounding Spectrum (BS) represents the seismic capacity of a Horizontal Pump (HP) if the pump meets the intent of the following inclusion and exclusion rules.

<u>HP/BS Caveat 1 - Earthquake Experience Data Base.</u> The horizontal pump should be similar to and bounded by the HP class of equipment of the earthquake experience data base. The discussion above briefly summarizes the class description of HPs in the data base.

<u>HP/BS Caveat 2 - Driver and Pump on Rigid Skid.</u> The driver and pump should be connected by a rigid base or common skid. The concern is that differential displacement between the pump and driver may cause shaft misalignment. If they are not mounted on a rigid skid, the potential for differential displacement between the driver and pump should be specially evaluated.

<u>HP/BS Caveat 3 - Thrust Bearings in Both Axial Directions.</u> Thrust restraint of the shaft in both axial directions should exist. The concern arose from shake table testing on pumps without thrust bearings that performed poorly. In general, pumps from U.S. manufacturers have such axial thrust restraint so that explicit verification is not necessary; however, any indication to the contrary should be investigated.

<u>HP/BS Caveat 4 - Check of Long Unsupported Piping.</u> Brief consideration should be given to identify situations where the horizontal pump may be affected by gross pipe motion, differential displacement, and excessive nozzle loads. The concern is that excessive force on pump nozzles could potentially break the pump nozzle or cause sufficient pump case distortion to cause binding, or fail the anchorage. These excessive forces are uncommon and need only be considered if there is a long section of unsupported pipe or a heavy valve attached to the pipe near the pump.

<u>HP/BS Caveat 5 - Base Vibration Isolation System Checked.</u> If the unit is mounted on vibration isolators, the adequacy of the vibration isolators for seismic loads should be evaluated in accordance with Section 4.4.

<u>HP/BS Caveat 6 - Sufficient Slack and Flexibility of Attached Lines.</u> Sufficient slack and flexibility should be present in attached lines (e.g., cooling, air, electrical) to preclude a line breach due to differential seismic displacement of the equipment and the line's nearest support. Sufficient slack and flexibility of lines is also considered in the seismic interaction review (Section 4.5).

HP/BS Caveat 7 - Adequate Anchorage. The unit should be properly anchored in accordance with the guidelines of Section 4.4.

HP/BS Caveat 8 - Potential Chatter of Essential Relays Evaluated. If relays are mounted on the equipment, a relay functionality review in accordance with Section 6 should be performed.

HP/BS Caveat 9 - No Other Concerns. There should not be any other concerns with the seismic capacity of the pump. Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats.

B.5.2 GERS - Horizontal Pumps

There are no GERS for Horizontal Pumps.

B.6 VERTICAL PUMPS

B.6.1 Bounding Spectrum - Vertical Pumps

The earthquake experience data base equipment class of Vertical Pumps (VP) includes pumps with the impeller drive shaft mounted in a vertical (as opposed to horizontal) direction. Vertical pumps are typically powered by an electric drive motor, vertically aligned, and mounted atop a steel or cast-iron support frame that is anchored to a concrete base pad.

The two general types of vertical pumps represented by seismic experience data include deep-well pumps and centrifugal pumps. Motor sizes range from 5 to 7000 hp and flow rates range from 95 to 16,000 gpm.

Deep-well turbine type pumps have the pump impeller attached to the bottom of a long vertical drive shaft extending beneath the pump base plate. The pump drive shaft is enclosed in a steel or cast iron casing which extends below the pump base plate. The pump impeller is mounted in a contoured housing or bowl at the base of the casing. The casing or suction pipe is immersed in a well and opened at the bottom for fluid inlet.

A variation of the deep-well turbine pump is the can-type pump. The casing that encloses the impeller drive shaft is, in turn, enclosed by an outer casing or can. Fluid feed to the pump flows through an inlet line, usually mounted in the support frame above the pump base plate. The can forms an annular reservoir of fluid that is drawn into the impeller at the base of the inner casing.

Deep-well pumps range in size from fractional horsepower units to pumps of several thousand horsepower. The casings, cantilevered below the base plate, have typical lengths of 10 to 20 feet. The most massive component of the pump is normally the drive motor, which may weigh several tons.

Single-stage centrifugal pumps are configured with the impeller mounted above the base plate, directly beneath the drive motor. The impeller is housed in a casing that is usually part of the support frame for the drive motor. Instead of drawing fluid from a well or can beneath the pump base plate, the fluid inlet is a piping attachment aligned with a centerline of the impeller drive shaft. The discharge line is tangential to the periphery of the centrifugal impeller casing. Smaller centrifugal pumps are sometimes mounted directly on the piping system they serve.

The pump, drive motor, associated instrumentation and controls attached to the pump, and attached piping and conduit, are included in the vertical pump equipment class. The equipment class does not include submersible pumps.

The Bounding Spectrum (BS) represents the seismic capacity of a Vertical Pump (VP) if the pump meets the intent of the following inclusion and exclusion rules.

<u>VP/BS Caveat 1 - Earthquake Experience Data Base.</u> The vertical pump should be similar to and bounded by the VP class of equipment of the earthquake experience data base. The discussion above briefly summarizes the class description of VPs in the data base.

<u>VP/BS Caveat 2 - Cantilever Impeller Shaft Less Than 20 Feet Long.</u> The impeller shaft and casing should not be cantilevered more than 20 feet below the pump mounting flange. This type of cantilever vertical pump should have a radial bearing at the bottom of the casing to support the impeller shaft. Twenty (20) feet represents the upper bound length of cantilever shafts of vertical pumps in the earthquake experience data base. The concern is that pumps with longer lengths may be subject to misalignment and bearing damage due to excessive lateral loads, damage to the impeller due to excessive displacement, and damage due to interfloor

displacement on multi-floor supported pumps. Either individual analysis or use of another method as a means of evaluating vertical pumps should be used when the shaft cantilever length exceeds 20 feet. The evaluation should address the concerns of excessive shaft and casing stresses and deflection of the impeller drive shaft.

VP/BS Caveat 3 - Check of Long Unsupported Piping. Brief consideration should be given to identify situations where the vertical pump may be affected by gross pipe motion, differential displacement, and excessive nozzle loads. The concern is that excessive force on pump nozzles could potentially break the pump nozzle or cause sufficient pump case distortion to cause binding, or fail the anchorage. These excessive forces are uncommon and need only be considered if there is a long section of unsupported pipe or a heavy valve attached to the pipe near the pump.

VP/BS Caveat 4 - Sufficient Slack and Flexibility of Attached Lines. Sufficient slack and flexibility should be present in attached lines (e.g., cooling, air, electrical) to preclude a line breach due to differential seismic displacement of the equipment and the line's nearest support. Sufficient slack and flexibility of lines is also considered in the seismic interaction review (Section 4.5).

VP/BS Caveat 5 - Adequate Anchorage. The unit should be properly anchored in accordance with the requirements of Section 4.4.

VP/BS Caveat 6 - Potential Chatter of Essential Relays Evaluated. If relays are mounted on the equipment, a relay functionality review in accordance with Section 6 should be performed.

VP/BS Caveat 7 - No Other Concerns. There should not be any other concerns with the seismic capacity of the pump. Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats.

B.6.2 GERS - Vertical Pumps

There are no GERS for Vertical Pumps.

B.7 FLUID-OPERATED VALVES

B.7.1 Bounding Spectrum - Fluid-Operated Valves

The earthquake experience data base equipment class of Fluid-Operated Valves (FOV) includes a wide diversity of valve sizes, types, and applications, which are actuated by air, water, or oil. Liquid-operated (i.e., hydraulic) piston valves are not included in the FOV class of equipment because they have not been reviewed in sufficient detail to be included.

The main types of fluid-operated valves are diaphragm-operated, piston-operated, and pressure relief valves. The most common type of fluid-operated valve found in power plant applications is a spring-opposed, diaphragm-operated pneumatic valve. The bell housing contains a diaphragm (usually a thin, steel membrane) which forms a pressure barrier between the top and bottom sections of the housing. The position of the actuated rod (or valve stem) is controlled by a return spring and the differential pressure across the diaphragm. The actuated rod position, in turn, controls the position of the valve. A yoke supports the bell housing and connects it to the valve body. A solenoid valve or, on larger valves, a pneumatic relay controls the air pressure difference across the diaphragm. This solenoid valve or pneumatic relay is often mounted directly to the operator yoke.

Piston-operated valves are similar to diaphragm-operated valves, with a piston replacing the diaphragm as the valve actuator. The piston typically acts in opposition to a spring to control the position of the valve.

Pressure relief valves are also included in this equipment class. Pressure relief valves balance confined fluid pressure against the force of a spring. The actuating force in a pressure relief valve is supplied by the fluid that is confined by the valve. Fluid-operators are typically cantilevered either above or to the side of the valves they serve. The length from the cantilevered actuator to the valve body is typically 1 to 4 feet, with operator weights ranging up to several hundred pounds. The valve and actuator can form a continuous body, or the actuator can be attached to the valve through a flanged, threaded, or ring clamp connection.

The valve, the operator, and peripheral attachments (air lines, pneumatic relays, control solenoids, and conduit) are included in the Fluid-Operated Valve equipment class. The valve may be of any type, size, or orientation.

The Bounding Spectrum (BS) represents the seismic capacity of a Fluid-Operated Valve (FOV) if the valve meets the intent of the following inclusion and exclusion rules.

<u>FOV/BS Caveat 1 - Earthquake Experience Data Base.</u> The valve should be similar to and bounded by the FOV class of equipment of the earthquake experience data base. The discussion above briefly summarizes the class description of FOVs in the data base.

<u>FOV/BS Caveat 2 - Valve Body Not of Cast Iron.</u> The valve body should not be made of cast iron. The intent of this caveat is to avoid the brittle failure mode of cast iron as evidenced by the poor performance of some cast iron components in past earthquakes. Cast iron is not common in such applications in nuclear plants; therefore, it is not necessary to determine the material of the valve body unless it appears to the Seismic Capability Engineers that the body is made of cast iron. In such cases, if the valve is indeed cast iron, the intent of this caveat is satisfied if seismic stresses in the valve body due to piping loads are low (for example, less than 20% of specified minimum ultimate tensile strength).

FOV/BS Caveat 3 - Valve Yoke Not of Cast Iron for Piston-Operated Valves and Spring-Operated Pressure Relief Valves. The yoke of piston-operated valves and spring-operated pressure relief valves should not be made of cast iron. The intent of this caveat is to avoid the brittle failure mode of cast iron as evidenced by the poor performance of some cast iron components in past earthquakes. Cast iron is not common in such applications in nuclear plants; therefore, it is not necessary to determine the material of the valve yoke unless it appears to the Seismic Capability Engineers that the yoke is made of cast iron. In such cases, if the yoke is indeed cast iron, this caveat may be satisfied by performing a stress analysis of the valve for a 3g load applied at the center of gravity of the operator in the yoke's weakest direction. If the yoke stress is low (for example, less than 20% of specified minimum ultimate strength), then the intent of the caveat is satisfied.

FOV/BS Caveat 4 - Mounted on 1-Inch Diameter Pipe Line or Greater. The valve should be mounted on a pipe line of at least 1-inch diameter. This is the lower bound pipe size supporting FOVs in the earthquake experience data base. The concern is that valves with heavy operators on small lines may cause an overstressed condition in the adjacent piping. To satisfy the intent of this caveat a stress analysis (that accounts for the valve operator eccentricity) may be used to show that the pipe stress adjacent to the valve is low. There is no concern if the valve, the operator, and the line (if smaller than 1 inch) are well-supported and anchored to the same support structure.

FOV/BS Caveat 5 - Valve Operator Cantilever Length for Air-Operated Diaphragm Valves, Spring-Operated Pressure Relief Valves, and Light Weight Piston-Operated Valves. The distance from the centerline of the pipe to the top of the operator or cylinder should not exceed the distance given in Figure B.7-1 corresponding to the diameter of the pipe. This figure bounds the pipe diameter and operator length combinations included in the earthquake experience data base. The concern is that longer operator lengths may lead to excessive valve yoke stress.

As a second screen to evaluate the operator weight and length, Figure B.7-2 may be used instead of the limits given in Figure B.7-1 provided: (1) the yoke is not of cast iron (Caveat 3 applies), and (2) the operator length does not exceed about 30% beyond the limits of Figure B.7-1.

As a third option, this caveat may also be satisfied by performing a stress analysis consisting of applying a 3g load at the center of gravity of the operator in the yoke's weakest direction. If the yoke stresses are low and the relative deflections are small (to ensure that shaft binding will not occur) then the caveat is satisfied.

Alternately, an in-situ static test may be conducted to demonstrate seismic adequacy. In these tests, a static force equal to three times the operator weight should be applied approximately at the center of gravity of the operator, in each of the three orthogonal principal axes of the yoke (non-concurrently). Such tests should include demonstration of operability following the application of the static loads. Note that all of the other limitations still apply.

A mockup test stand may be used provided that the details are similar to those in the plant. If there are numerous valves, a rational test program may be developed to envelop the valve configurations in the plant.

<u>FOV/BS Caveat 6 - Valve Operator Cantilever Length for Substantial Piston-Operated Valves.</u> For piston-operated valves which are of substantial weight, the distance from the centerline of the pipe to the top of the operator or cylinder and the weight of the operator should not exceed the values given in Figure B.7-2 corresponding to the diameter of the pipe. This figure represents the pipe diameter and operator weight/length combinations included in the earthquake experience data base. The concern is that longer operator lengths or heavier operator weights may lead to excessive valve yoke stress.

To meet the intent of this caveat the operator length or weight may be extrapolated by as much as 30% beyond that given in Figure B.7-2 provided the product of the weight times the lever arm does not exceed the limits of Figure B.7-2.

If the ground motion spectra for the site is below the Bounding Spectrum, given in Figure 4-2, over the entire frequency range possible for the piping and valve network, the operator weight or distance to the top of the operator can be increased by the ratio of the spectra [illegible]e cantilever length or the operator weight should not be increased by more than about 30% beyond the limits of Figure B.7-2.

Another option for satisfying this caveat is to perform a stress analysis that consists of applying a 3g load at the center of gravity of the operator in the yoke's weakest direction. If the yoke stresses are low and the relative deflections are small (to ensure that shaft binding will not occur) then the caveat is satisfied. Alternately, as discussed in FOV/BS Caveat 5 above, a static test may be performed.

<u>FOV/BS Caveat 7 - Actuator and Yoke Not Independently Braced.</u> The valve actuator and yoke should not be independently braced to the structure or supported by the structure unless the pipe is also braced to the same structure immediately adjacent to the valve. The concern is that if the operator is independently supported from the valve and attached piping,

then the operator may act as a pipe support during seismic motion and attract considerable load through the yoke and possibly fail the yoke or bind the shaft. In addition, if both the operator and the valve/pipe are restrained, and if they are both not tied back to the same structure, then differential motion of support points may lead to high seismic loads and possible binding of the shaft. If either of these concerns are noted, then a special evaluation should be conducted to demonstrate low stress and small deflections.

FOV/BS Caveat 8 - Sufficient Slack and Flexibility of Attached Lines. Sufficient slack and flexibility should be present in attached lines (e.g., cooling, air, electrical) to preclude a line breach due to differential seismic displacement of the equipment and the line's nearest support. Sufficient slack and flexibility of lines is also considered in the seismic interaction review (Section 4.5).

FOV/BS Caveat 9 - No Other Concerns. There should not be any other concerns with the seismic capacity of the valve. Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats.

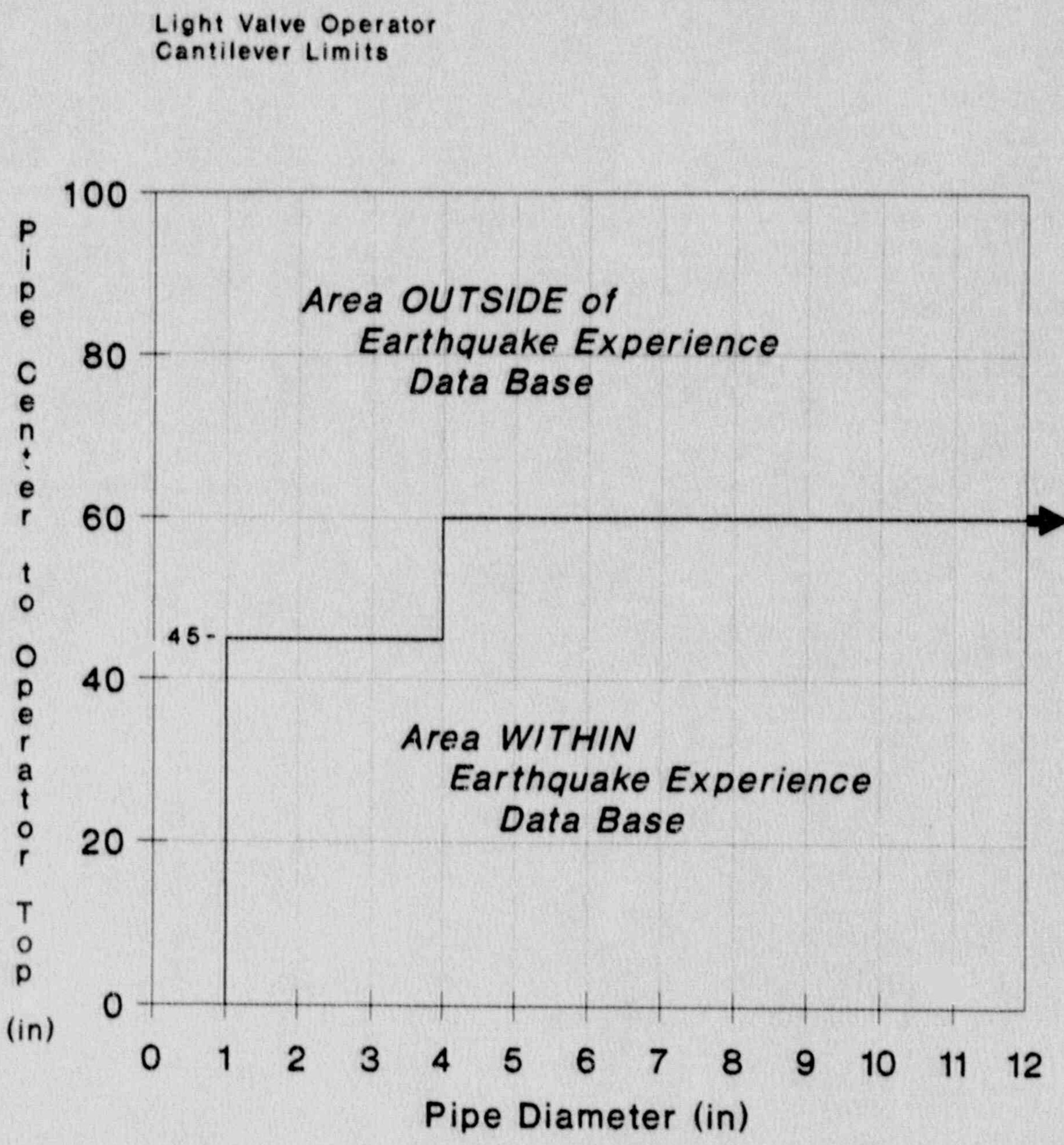
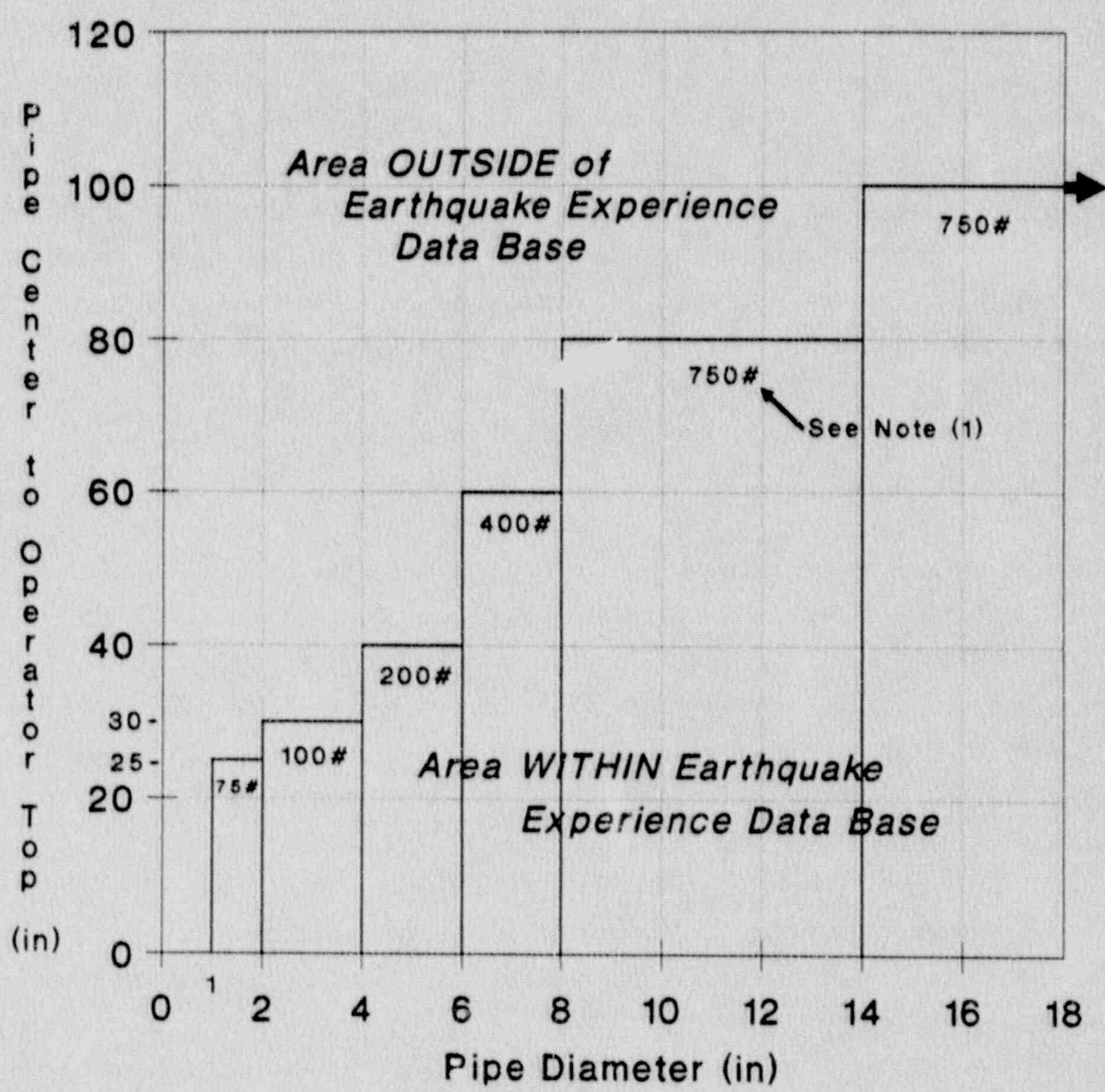


Figure B.7-1. Valve Operator Cantilever Length Limits for Air-Operated Diaphragm Valves, Spring-Operated Pressure Relief Valves and Piston-Operated Valves of Light-Weight Construction. (Source: Reference 5)

Heavy Valve Operator
Cantilever Limits



(1) Approximate Maximum Operator Weights Given for Various Ranges of Pipe Diameter

Figure B.7-2. Valve Operator Cantilever Length Limits for Piston-Operated Valves of Substantial Weight and Construction. (Source: Reference 5)

B.7.2 GERS - Air-Operated Valves (AOV)

The generic seismic test data base equipment class of air-operated valves consists of spring-opposed, diaphragm-type pneumatic actuators which are designed to operate both gate and globe valves. They range in size from 12 to 40 inches in height (pipe centerline is reference position) with weights up to 500 pounds. The valves within this class are for 3-inch and smaller pipe sizes with design pressures less than 2,500 psi. A pneumatic actuator generally consists of a reinforced rubber diaphragm enclosed in a steel housing. The valve stem and diaphragm are attached so that any diaphragm movement results in valve movement. A solenoid valve controls the admission of high pressure air (100 to 150 psi) to the diaphragm housing. A return spring supplies sufficient counter force to close or open the valve when air pressure is not pushing on the diaphragm. The yoke of this class of pneumatic actuator is an integral part of the unit which is directly bolted to the valve bonnet. The valve body, bonnet, and yoke material should be carbon steel. The active components of the actuator are the solenoid valve, limit switches, and a pressure regulator, all of which are yoke-mounted appurtenances. This equipment class covers virtually all air-operated diaphragm valves used in small bore power plant piping systems.

The GERS represent the seismic capacity of an Air-Operated Valve (AOV) if the valve meets the intent of the following inclusion and exclusion rules.

AOV/GERS Caveat 1 - Generic Seismic Test Data Base. The valve should be similar to and bounded by the AOV class of equipment of the GERS data base. The discussion above briefly summarizes the generic seismic test data base AOV class description.

AOV/GERS Caveat 2 - Bounding Spectrum Caveats Apply. The valve should meet all the caveats given for the Bounding Spectrum. This caveat is included to cover the vulnerabilities identified in the earthquake experience data base. Those GERS caveats which are the same as the Bounding Spectrum caveats are not repeated below.

AOV/GERS Caveat 3 - Only Diaphragm-Type Air Operated Valves. The air-operated gate or globe valve should have a spring-opposed, diaphragm-type pneumatic actuator. This equipment class does not include piston-operated, pressure relief valves, or other diaphragm-type valves powered by fluids other than air. These valve types are the only types included in the generic seismic test data base.

AOV/GERS Caveat 4 - Evaluation of Amplified Response. The valves and operators were tested with the valve fixed to the shake table. Therefore realistic amplification through the piping system should be included when determining the amplified response of the valve-to-pipe interface for comparison to the GERS.

AOV/GERS Caveat 5 - No Impact Allowed. A separate evaluation should be done to assure that the valve and operator will not impact surrounding structures and components as a result of pipe flexibility. The concern is that impact may damage the valve, operator, yoke, stem, or attached components. This type of damage has occurred in past earthquakes and is also identified as a seismic interaction concern (Section 4.5).

AOV/GERS Caveat 6 - Nominal Pipe Size 1 to 3 Inches. The nominal pipe size of the valve should be within the range of 1 to 3 inches. This is the pipe size range included in the generic seismic test data base.

AOV/GERS Caveat 7 - Carbon Steel Valve Body, Bonnet and Yoke. The valve body, bonnet, and yoke should all be carbon steel. Cast iron components are not covered by the GERS. Since cast iron is not commonly used in safe shutdown systems of nuclear plants, it is not necessary to determine the material used for the valve body, bonnet, or yoke unless it appears to the Seismic Capability Engineers that cast iron may have been used.

GERS-AOV.3
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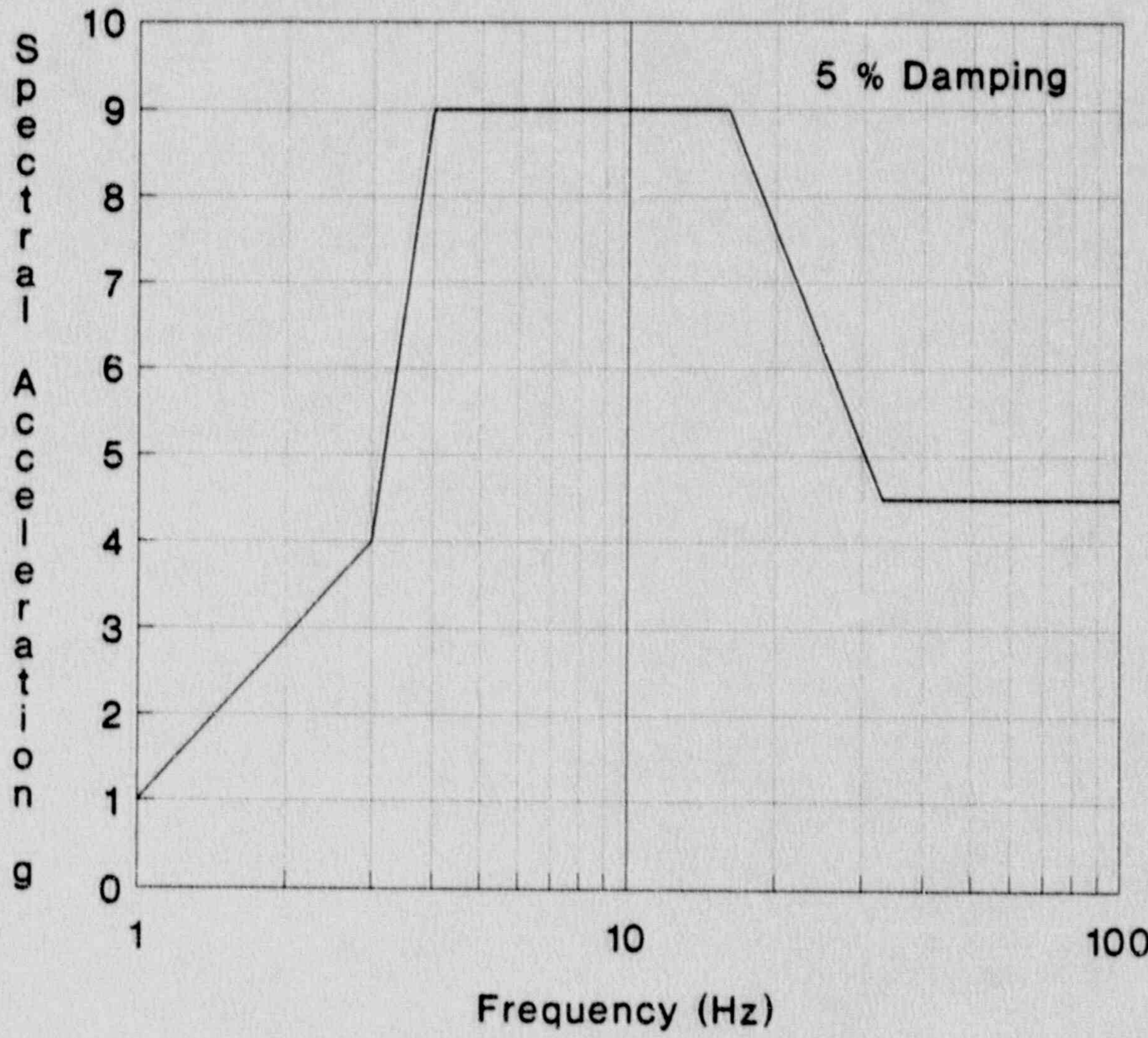


Frequency (Hz)	1	3	4	16	33
Air-Operated Valves (g)	1.0	4.0	9.0	9.0	4.5

Figure B.7-3. Generic Equipment Ruggedness Spectra (GERS) for Air-Operated Valves. (Source: Reference 6)

B.8 MOTOR-OPERATED AND SOLENOID-OPERATED VALVES

B.8.1 Bounding Spectrum - Motor-Operated and Solenoid-Operated Valves

The earthquake experience data base equipment class of Motor-Operated Valves (MOV) and Solenoid-Operated Valves (SOV) includes a wide diversity of sizes, types, and applications. This equipment class includes all valves actuated by either an electric motor or a solenoid.

Components of a motor-operated valve include a motor operator with a control box, gear box, and drive motor. The gear box includes the gears which link the valve actuation to the drive motor shaft. Local controls typically include a relay for actuating the primary circuit to the motor, and torque and limit switches for coordinating the drive motor and the valve position. Modern valve operators may have a local motor controller built into the operator housing. The valve actuator shaft typically passes through the steel support frame or yoke. The valve which is actuated by a motor operator may be of any type, size, or orientation.

Motor operators may be mounted in any position (e.g., cantilevered vertically above, below, or to the side of the valve). The yoke, which connects the operator to the valve body, may take the form of a steel pipe enclosing the actuator shaft or a frame of welded beams. The attachments of the motor-gearbox to the yoke and the yoke to the valve are typically bolted flange connections, threaded connections, or ring clamps. In some applications, motor operators are mounted at a remote location above the valve. Typical motor operators weigh about 300 pounds and have a moment arm length of two to three feet.

Solenoid operators are smaller and lighter than motor operators. Solenoid-operated valves are actuated by passing an electrical current through a coil, thereby creating a magnetic field which opens or closes the valve. Solenoid operators are generally more compact than motor operators with less of a cantilevered mass supported from the valve body. In addition, solenoid-operated valves are typically mounted on smaller diameter lines than MOVs.

The equipment class of motor-operated and solenoid-operated valves includes all valves actuated by either an electric motor or a solenoid. The valve, the operator, and the attached conduit are included in the Motor-Operated and Solenoid-Operated Valve equipment class.

The Bounding Spectrum (BS) represents the seismic capacity of a Motor-Operated Valve (MOV) or a Solenoid-Operated Valve (SOV) if the valve meets the intent of the following inclusion and exclusion rules.

<u>MOV/BS Caveat 1 - Earthquake Experience Data Base.</u> The valve should be similar to and bounded by the MOV class of equipment of the earthquake experience data base. The discussion above briefly summarizes the class description of MOVs and SOVs in the data base.

<u>MOV/BS Caveat 2 - Valve Body Not of Cast Iron.</u> The valve body should not be made of cast iron. The intent of this caveat is to avoid the brittle failure mode of cast iron as evidenced by the poor performance of some cast iron components in past earthquakes. Cast iron is not common in such applications in nuclear plants; therefore, it is not necessary to determine the material of the valve body unless it appears to the Seismic Capability Engineers to be made of cast iron. In such cases, if the valve is indeed cast iron, the intent of this caveat is satisfied if seismic stresses in the valve body due to piping loads are low (for example, less than 20% of specified minimum ultimate tensile strength).

<u>MOV/BS Caveat 3 - Valve Yoke Not of Cast Iron.</u> The yoke of the motor-operated valve should not be made of cast iron. The intent of this caveat is to avoid the brittle failure mode of cast iron as evidenced by the poor performance of some cast iron components in past earthquakes. Cast iron is

not common in such applications in nuclear plants; therefore, it is not necessary to determine the material of the valve yoke unless it appears to be cast iron to the Seismic Capability Engineers. In such cases, if the yoke is indeed cast iron, this caveat may be satisfied by performing a stress analysis of the valve for a 3g load applied at the center of gravity of the operator in the yoke's weakest direction. If the yoke stress is low (for example, less than 20% of specified minimum ultimate strength), then the intent of the caveat is satisfied.

MOV/BS Caveat 4 - Mounted on 1-Inch Diameter Pipe Line or Greater. The valve should be mounted on a pipe line of at least 1-inch diameter. This is the lower bound pipe size supporting MOVs in the earthquake experience data base. The concern is that valves with heavy operators on small lines may cause an overstressed condition in the adjacent piping. To satisfy the intent of this caveat a stress analysis (that accounts for the valve operator eccentricity) may be used to show that the pipe stress adjacent to the valve is low. There is no concern if the valve, the operator, and the line (if smaller than 1 inch) are well supported and anchored to the same support structure. This caveat does not apply to SOVs, which typically are installed on air lines smaller than 1 inch.

MOV/BS Caveat 5 - Valve Operator Cantilever Length for Motor-Operated Valves. The distance from the centerline of the pipe to the top of the operator or cylinder and the weight of the operator should not exceed the values given in Figure B.8-1 corresponding to the diameter of the pipe. This bounds the earthquake experience data base. The concern is that longer operator lengths may lead to excessive valve yoke stress.

As an option, this caveat may also be satisfied by performing a stress analysis consisting of applying a 3g load at the center of gravity of the operator in the yoke's weakest direction. If the yoke stresses are low and the relative deflections are small (to ensure that shaft binding will not occur) then the caveat may be shown to be satisfied.

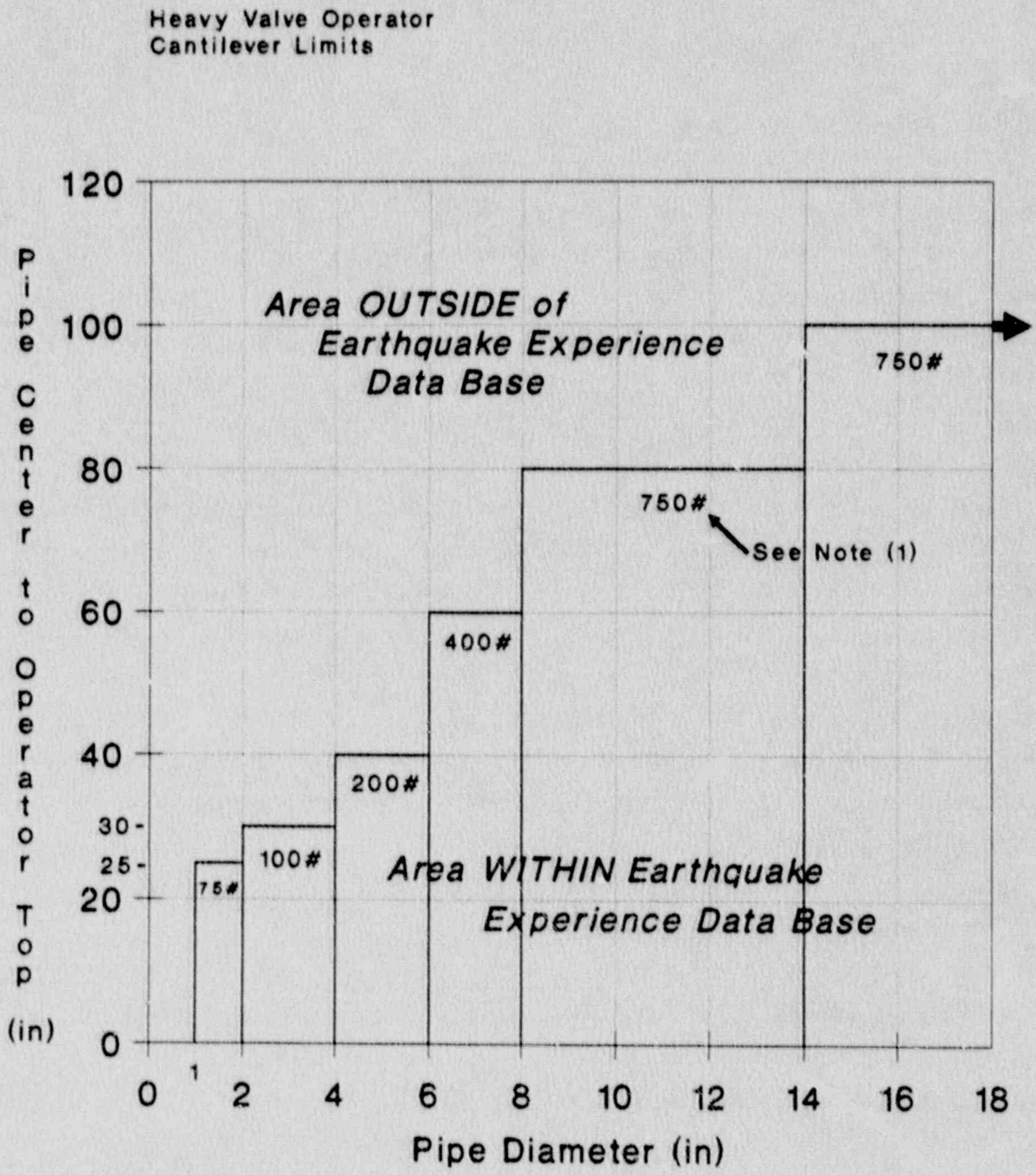
Alternatively, an in-situ static test may be conducted to demonstrate seismic adequacy. In these tests, a static force equal to three times the operator weight should be applied approximately at the center of gravity of the operator, non-concurrently in each of the three orthogonal principal axes of the yoke. Such tests should include demonstration of operability following the application of the static loads. Note that all of the other limitations still apply.

A mockup test stand may be used provided that the details are similar to those in the plant. If there are numerous valves, a rational test program may be developed to envelop the valve configurations in the plant.

<u>MOV/BS Caveat 6 - Actuator and Yoke Not Independently Braced.</u> The valve actuator and yoke should not be independently braced to the structure or supported by the structure unless the pipe is also braced to the same structure immediately adjacent to the valve. The concern is that if the operator is independently supported from the valve and attached piping, then the operator may act as a pipe support during seismic motion and attract considerable load through the yoke and possibly fail the yoke or bind the shaft. In addition, if both the operator and the valve/pipe are restrained, and if they are both not tied back to the same structure, then differential motion of support points may lead to high seismic loads and possible binding of the shaft. If either of these concerns are noted, then a special evaluation should be conducted to demonstrate low stress and small deflections.

<u>MOV/BS Caveat 7 - Sufficient Slack and Flexibility of Attached Lines.</u> Sufficient slack and flexibility should be present in attached lines (e.g., cooling, air, electrical) to preclude a line breach due to differential seismic displacement of the equipment and the line's nearest support. Sufficient slack and flexibility of lines is also considered in the seismic interaction review (Section 4.5).

<u>MOV/BS Caveat 8 - No Other Concerns.</u> There should not be any other concerns with the seismic capacity of the valve. Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats.



(1) Approximate Maximum Operator Weights Given for Various Ranges of Pipe Diameter

Figure B.8-1. Valve Operator Cantilever Length Limits for Motor-Operated Valves (Source: Reference 5)

B.8.2 GERS - Motor-Driven Valve Operators

The generic seismic test data base equipment class of electric motor-driven valve operators (MVO) includes operators designed to control the five major types of valves (gate, globe, plug, ball, and butterfly). They range in weight from 150 pounds up to 3,500 pounds. A valve operator consists of a metal housing which connects to the valve body by a flange or yoke and contains limit switches, a torque switch, an electric motor, a clutch, gears, and bearings. For this class of equipment, the motor controls (reversing starter, overload relays, and push-button station) should be located in a remote location (usually a motor control center). For some valve configurations, the valve actuators are mounted on secondary reducers resulting in the actuator being eccentric and cantilevered from the valve body. For these configurations, a special seismic bracket supplied by the manufacturer is required. The mounting position of the valve operator is with the motor horizontal and the limit switch compartment horizontal or vertical as specified by the manufacturer. These positions will insure the proper distribution of lubricants through the internal working component of the units. This equipment class covers virtually all motor-driven valve operators used in power plants.

The MVO GERS represent the seismic capacity of an electric Motor-Driven Valve Operator (MVO) if the operator meets the intent of the following inclusion and exclusion rules.

MVO/GERS Caveat 1 - Generic Seismic Test Data Base. The electric motor-driven valve operator should be similar to and bounded by the MVO class of equipment of the GERS data base. The discussion above briefly summarizes the generic seismic test data base MVO class description.

MVO/GERS Caveat 2 - Bounding Spectrum Caveats Apply. The operator should meet all the caveats given for the Bounding Spectrum for the MOV class of equipment of the earthquake experience data base. This caveat is included to cover the vulnerabilities identified in the earthquake experience data base. Those GERS caveats which are the same as the Bounding Spectrum caveats are not repeated below.

MVO/GERS Caveat 3 - Evaluation of Amplified Response. Most of the operators tested were mounted directly to the shake table and not on a valve yoke structure or a valve. Therefore realistic amplification through the piping system and valve should be included when determining the amplified response of the operator-to-valve interface for comparison to the GERS.

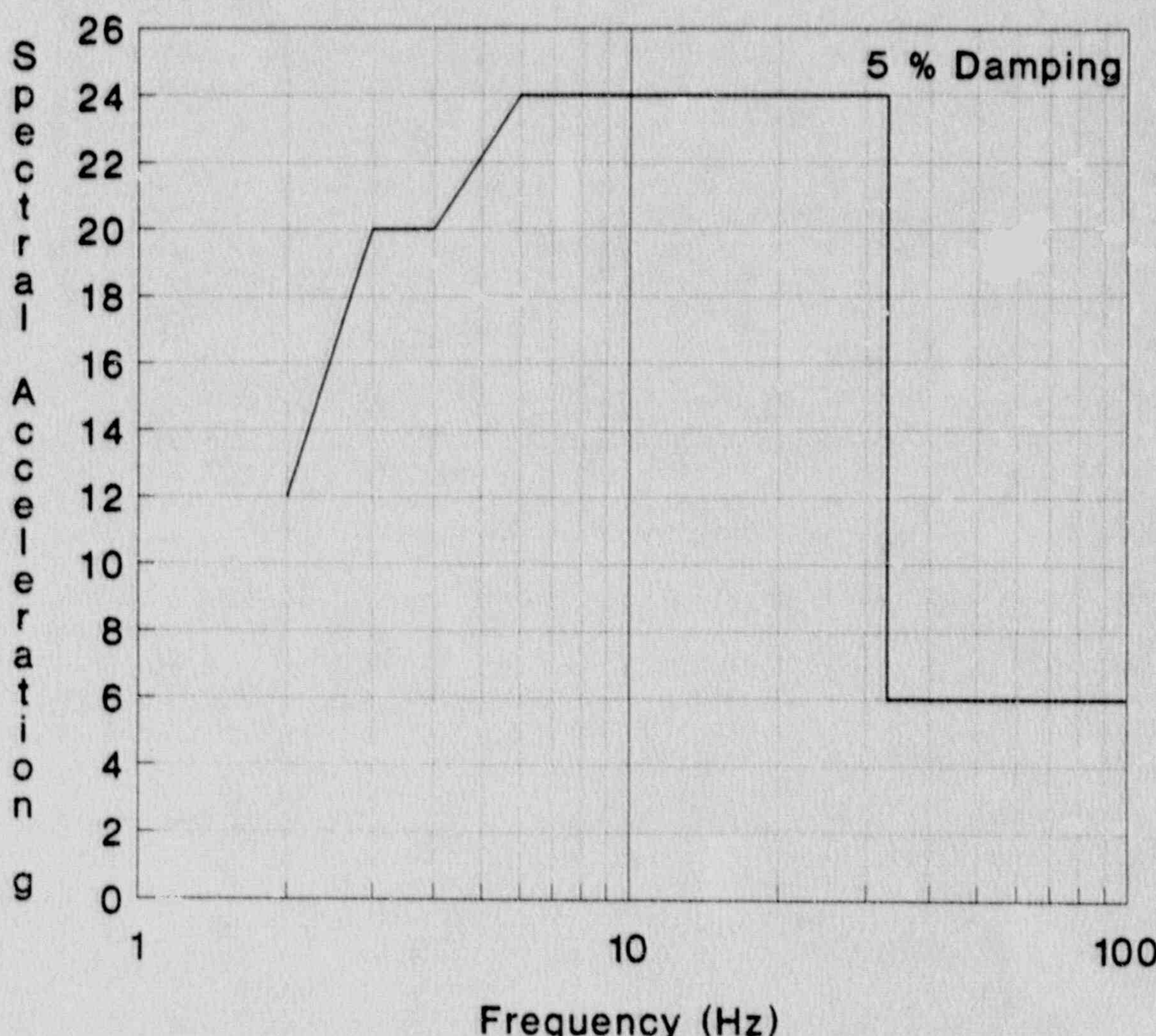
MVO/GERS Caveat 4 - Motor Axis Horizontal. The motor axis should be horizontal and the limit switch compartment should be horizontal or vertical (definition of orientation directions provided in manufacturer's submittals). These were the positions of the motor axis and limit switch compartment in the shake table tests of the generic seismic test data base.

MVO/GERS Caveat 5 - No Impact Allowed. A separate evaluation should be done to assure that the operator will not impact surrounding structures and components as a result of pipe flexibility. The concern is that impact may damage the operator, yoke, stem, or attached components. This type of damage has occurred in past earthquakes and is also identified as a seismic interaction concern (Section 4.5).

MVO/GERS Caveat 6 - Motor Controls Remotely Located. The motor controls (reversing starter, overload relays, and push-button station) should be remotely located and separately evaluated. The motor controls were not located on the valve operators during the GERS testing and are therefore not included in the generic seismic test data base.

MVO/GERS Caveat 7 - Seismic Brackets for Side-Mounted Actuators. Side-mounted valve actuators attached to secondary reducers should have seismic brackets as supplied by the manufacturer (review of manufacturer's submittals is sufficient). The actuators of the generic seismic test data base that were tested in this orientation had seismic brackets.

GERS-MOV.3
9/10/86



Frequency (Hz)	2	3	4	6	33	33
Motor Valve Operators (g)	12	20	20	24	24	6

Figure B.8-2. Generic Equipment Ruggedness Spectra (GERS) for Motor Valve Operators. (Source: Reference 6)

B.8.3 GERS - Solenoid-Operated Valves

The generic seismic test data base equipment class of solenoid-operated valves (SOV) consists of a combination of two basic functional units: 1) a solenoid actuator (electro-magnet) with its plunger (or core), and 2) a valve body containing an orifice in which a disc or plug is positioned to stop or allow flow. The valve is opened or closed by movement of the magnetic plunger which is drawn into the solenoid when the coil is energized. Solenoid valves can be either two-way, three-way or four-way valves. In the direct acting two-way solenoid valve, the solenoid acts directly on the valve stem to open or close the valve. Three-way solenoid valves are principally used in power plants as pilot valves to alternately apply pressure to and exhaust pressure from a diaphragm valve actuator. Four-way solenoid valves are often used for controlling double-acting pneumatic or hydraulic cylinders. The valves range in weight from a few pounds to 45 pounds and are made of either forged brass or steel. The valves within this class are for pipe sizes which are 1 inch or less in diameter and for design pressures less than 600 psi. This equipment class covers virtually all solenoid-operated valves used in small bore power plant piping or process air systems.

The SOV GERS represent the seismic capacity of a Solenoid-Operated Valve if the valve meets the intent of the following inclusion and exclusion rules.

SOV/GERS Caveat 1 - Generic Seismic Test Data Base. The valve should be similar to and bounded by the SOV class of equipment of the GERS data base. The discussion above briefly summarizes the generic seismic test data base SOV class description.

SOV/GERS Caveat 2 - Bounding Spectrum Caveats Apply. The valve should meet all the caveats given for the Bounding Spectrum for the MOV class of equipment of the earthquake experience data base. This caveat is included to cover the vulnerabilities identified in the earthquake experience data base. Those GERS caveats which are the same as the Bounding Spectrum caveats are not repeated below.

SOV/GERS Caveat 3 - Evaluation of Amplified Response. The valves and operators were tested with the valve fixed to the shake table. Therefore realistic amplification through the piping system should be included when determining the amplified response of the valve-to-pipe interface for comparison to the GERS.

SOV/GERS Caveat 4 - No Impact Allowed. A separate evaluation should be done to assure that the valve and operator will not impact surrounding structures and components as a result of pipe flexibility. The concern is that impact may damage the valve, operator, yoke, stem, or attached components. This type of damage has occurred in past earthquakes and is also identified as a seismic interaction action concern (Section 4.5).

SOV/GERS Caveat 5 - Nominal Pipe Size 1 Inch or Less. The nominal pipe size of the valve should be 1 inch or less. This is the upper bound pipe size included in the generic seismic test data base.

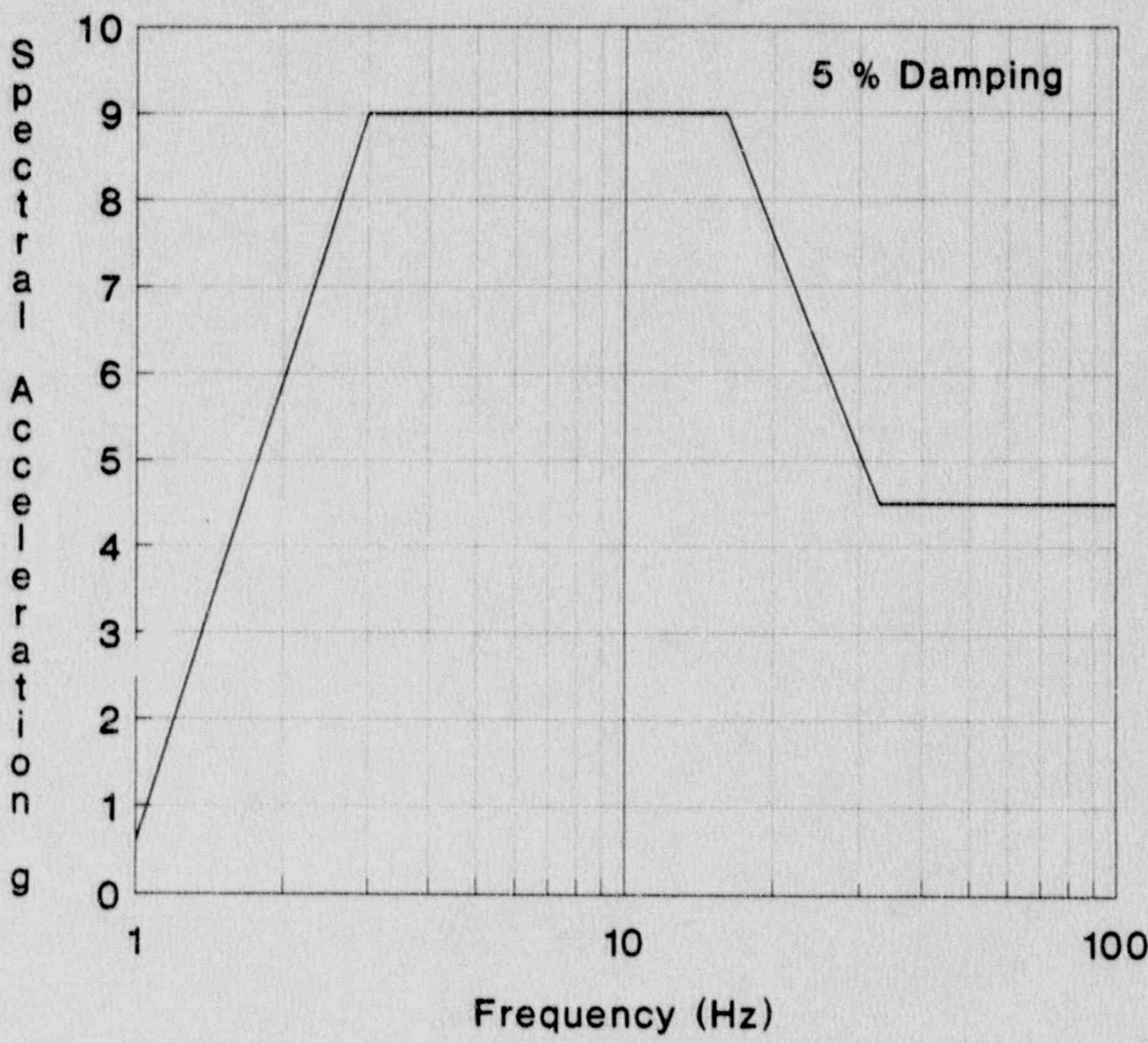
SOV/GERS Caveat 6 - Forged Brass or Steel Valve Body. The valve body should be made of either forged brass or steel. Other materials are not covered by the generic seismic test data base.

SOV/GERS Caveat 7 - Orientation of Solenoid Housing. The solenoid housing should be oriented in accordance with the manufacturer's recommendations for the specific model (review of manufacturer's submittals is sufficient). Testing was performed with the solenoid housing in the recommended orientation in the generic seismic test data base.

SOV/GERS Caveat 8 - Overall Height Not to Exceed 12 Inches. The overall height of the valve (pipe centerline to top of solenoid housing) should not exceed 12 inches. This is the upper bound height limit included in the generic seismic test data base.

SOV/GERS Caveat 9 - Separate Evaluation of Main Valve Controlled By SOV. When the Solenoid-Operated Valve is a pilot valve in a valve assembly, the main valve should be evaluated separately. Note that the amplified response spectra at the attachment point of the SOV should be used in the SOV evaluation as discussed in SOV/GERS Caveat 3.

GERS-SV.2
12/1/86



Frequency (Hz)	1	3	16	33
Solenoid Valves (g)	0.6	9.0	9.0	4.5

Figure B.8-3. Generic Equipment Ruggedness Spectra (GERS) for Solenoid-Operated Valves. (Source: Reference 6)

B.9 FANS

B.9.1 Bounding Spectrum - Fans

The earthquake experience data base equipment class of Fans (FAN) includes both freestanding and duct-mounted fans. Fans that are components of other classes of equipment such as air handlers are handled by other respective equipment classes and need not be specifically evaluated here. Blowers and exhausters are included in this equipment class.

Typical differential pressures for fans range from 1/2 inch to 5 inches of water. Some centrifugal fans can have differential pressures ranging up to 12 inches of water. Air flow rates typically range from less than 1000 cubic feet per minute (cfm) to flows on the order of 50,000 cfm. Corresponding fan drive motors typically range from 1 hp to 200 hp. Typical weights of fan units range from 100 to 1000 pounds, depending on capacity and design details. The two basic types of fans in this equipment class include axial fans and centrifugal fans.

Axial fans are used in relatively low pressure applications such as building HVAC systems or cooling towers. Propeller fans and vane-axial fans are the two major types of axial fans. Propeller axial fans consist of two or more blades assembled on a central shaft and revolving within a narrow mounting-ring. Propeller fans are often mounted to a wall or ceiling. Vane-axial fans have an impeller wheel, typically with four to eight blades, mounted to a central shaft within a cylindrical casing. Vane-axial fans are generally used in higher pressure, higher flow applications than propeller fans. Vane-axial fans include a set of guide vanes mounted either before or after the impeller that streamline the air flow for greater efficiency. A variation of vane-axial design is the tube-axial fan, which includes the higher pressure impeller wheel mounted within a cylindrical casing, but without the provision of vanes.

Certain axial fan designs include multiple impellers for increased pressure boost. Axial-flow fans are normally mounted inside cylindrical ducting, supported by radial struts running from the duct wall to the duct centerline. Electric drive motors are usually mounted along the duct centerline immediately upstream of the impeller. The impeller and drive shaft are normally cantilevered from the motor. Alternate designs mount the motor on the outside of the duct with a belt connection between the motor and the impeller drive shaft.

Centrifugal fans are divided into three major categories depending upon the position of their blades. The three blade positions are: forward-curved, radial, and backward-inclined. Forward-curved centrifugals have blades inclined toward the direction of rotation at the tip. These fans produce high flow volumes at low static pressures. Radial-blade centrifugals have their blades positioned on the radii extending from their axis of rotation. Backward-inclined fans are a type of centrifugal fan and have their blades inclined opposite to the direction of rotation at the tip.

Centrifugal fans typically have a cylindrical intake duct centered on the fan shaft and a square discharge duct directed tangentially from the periphery of the fan. A variation of the centrifugal fan is the tubular centrifugal fan which redirects the discharged air in the axial direction. As with axial-flow fans, centrifugal fans can have the electrical drive motor mounted either directly on the fan shaft, or outside of the fan casing with a belt drive to the fan. The impeller and drive shaft may have either a single-point support, where they are cantilevered from the motor, or a two-point support, where the shaft is supported both at the motor and at an end bearing.

The fan impeller and its enclosure, drive motor, attached ducting, mounted louvers, and attached conduit and instrumentation lines are included in the Fan equipment class.

The Bounding Spectrum (BS) represents the seismic capacity of a Fan (FAN) if the fan meets the intent of the following inclusion and exclusion rules.

FAN/BS Caveat 1 - Earthquake Experience Data Base. The fan should be similar to and bounded by the FAN class of equipment of the earthquake experience data base. The discussion above briefly summarizes the class description of FANs in the data base.

FAN/BS Caveat 2 - Drive Motor and Fan Mounted on Common Base. The driver and fan should be connected by a common base or attached in a way to limit differential displacement. The concern is that differential displacement between the driver motor and fan may cause shaft misalignment. If the driver motor and fan are not mounted on a common base, then the potential for differential displacement should be specially evaluated.

FAN/BS Caveat 3 - Long Shafts Should be Supported at Fan and at Motor. Axial fans with long shafts between the motor and fan should have the shaft supported at the fan and at the motor. The concern is shaft misalignment. If the shaft is not supported in both locations, then a special evaluation should be conducted. The potential earthquake displacement of the shaft should be determined and compared to the operability displacement limits of the fan.

FAN/BS Caveat 4 - No Possibility of Excessive Duct Distortion Causing Binding or Misalignment of Fan. The possibility of excessive duct distortion during an earthquake should be considered for its effect on binding or misalignment of the fan. This need only be considered in cases of long unsupported ducts near the fan or relatively stiff ducts subjected to significant relative support motion. A special evaluation should be conducted to evaluate for this failure mode if these conditions are considered to be significant by the Seismic Capability Engineers.

<u>FAN/BS Caveat 5 - Base Vibration Isolation System Checked.</u> If the unit is mounted on vibration isolators, the adequacy of the vibration isolators for seismic loads should be evaluated in accordance with Section 4.4.

<u>FAN/BS Caveat 6 - Sufficient Slack and Flexibility of Attached Lines.</u> Sufficient slack and flexibility should be present in attached lines (e.g., cooling, air, electrical) to preclude a line breach due to differential seismic displacement of the equipment and the line's nearest support. Sufficient slack and flexibility of lines is also considered in the seismic interaction review (Section 4.5).

<u>FAN/BS Caveat 7 - Adequate Anchorage.</u> The unit should be properly anchored in accordance with the guidelines of Section 4.4.

<u>FAN/BS Caveat 8 - No Other Concerns.</u> There should not be any other concerns with the seismic capacity of the fan. Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats.

B.9.2 <u>GERS - Fans</u>

There are no GERS for Fans.

B.10 AIR HANDLERS

B.10.1 Bounding Spectrum - Air Handlers

The earthquake experience data base equipment class of Air Handlers (AH) includes sheet metal enclosures containing (as a minimum) a fan and a heat exchanger. Air handlers are used for heating, dehumidifying or chilling, and distributing air.

The basic components of an air handler include a fan and a coil section. Small capacity, simple air handlers are often referred to as fan-coil units. Additional components such as filters, air-mixing boxes, and dampers are included in more elaborate air handlers. Fans (normally centrifugal) produce air flow across the coil for heat transfer. Coils act as heat exchangers in an air handler. Cooling coils are typically rectangular arrays of tubing with fins attached. Filters are either a strainer type or the electronic type, and are typically mounted in steel frames which are bolted together as part of a modular system. Mixing boxes are used as a plenum for combining two airstreams before channeling the resulting blend into the air handler unit. Dampers are rotating flaps provided in the inlet or outlet sides of the air handler to control the flow of air into or out of the fan.

Air handlers are typically classified as being either a draw-through or a blow-through type. Draw-through air handlers have the heat exchanger (coil) upstream of the fan, whereas the blow-through design locates the coil downstream. Air handler enclosures normally consist of sheet metal welded to a framework of steel angles or channels. Typical enclosures range in size from two feet to over ten feet on a side, with weights ranging from a few hundred pounds to several thousand pounds. Large components, such as fans and coils, are typically bolted to internal frames which are welded to the enclosure framing. Fans may be located in a variety of orientations with respect to the coil unit.

Air handlers typically include a system of attached ducts which provide for the intake and discharge of air. Additional attachments to air handlers include piping and cooling water or refrigerant, electrical conduit, and instrumentation lines. Self-contained air conditioning units are a variation of air handlers, in which the sheet metal enclosure includes a small refrigeration unit. Note that large centralized chillers are addressed as a separate equipment class (B.11).

Air handler configurations range from large floor-mounted units to smaller units suspended on rod hangers from ceilings. The sheet metal enclosure, fans and motors, heat exchanger coils, air filters, mixing boxes, dampers, attached ducts, instrument lines, and conduit are included in the Air Handler equipment class.

The Bounding Spectrum (BS) represents the seismic capacity of an Air Handler (AH) if the air handler meets the intent of the following inclusion and exclusion rules.

<u>AH/BS Caveat 1 - Earthquake Experience Data Base.</u> The air handler should be similar to and bounded by the AH class of equipment of the earthquake experience data base. The discussion above briefly summarizes the class description of AHs in the data base.

<u>AH/BS Caveat 2 - Anchorage of Internal Component.</u> In addition to reviewing the adequacy of the unit's base anchorage, the attachment of heavy internal equipment of the air handler must be assessed. Seismic Capability Engineers may exercise considerable engineering judgment when performing this review. Internal vibration isolators should meet the requirements for base isolators in Section 4.

<u>AH/BS Caveat 3 - Doors Secured.</u> All doors should be secured by a latch or fastener. The concern addressed by this caveat is that the doors could open during an earthquake, and the loose door could repeatedly impact the housing and be damaged or cause internal components such as relays to malfunction or chatter. In addition, the door may act as an integral structural member and may need to be latched to provide both stiffness and strength to the unit.

<u>AH/BS Caveat 4 - Base Vibration Isolation System Checked.</u> If the unit is mounted on vibration isolators, the adequacy of the vibration isolators for seismic loads should be evaluated in accordance with Section 4.4.

<u>AH/BS Caveat 5 - Sufficient Slack and Flexibility of Attached Lines.</u> Sufficient slack and flexibility should be present in attached lines (e.g., cooling, air, electrical) to preclude a line breach due to differential seismic displacement of the equipment and the line's nearest support. Sufficient slack and flexibility of lines is also considered in the seismic interaction review (Section 4.5).

<u>AH/BS Caveat 6 - Adequate Anchorage.</u> The unit should be properly anchored in accordance with the guidelines of Section 4.4.

<u>AH/BS Caveat 7 - Potential Chatter of Essential Relays Evaluated.</u> If relays are mounted on the equipment, a relay functionality review in accordance with Section 6 should be performed.

<u>AH/BS Caveat 8 - No Other Concerns.</u> There should not be any other concerns with the seismic capacity of the air handler. Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats.

B.10.2 <u>GERS - Air Handlers</u>

There are no GERS for Air Handlers.

B.11 CHILLERS

B.11.1 Bounding Spectrum - Chillers

The earthquake experience data base equipment class of Chillers (CHL) includes skid-mounted units comprised of components such as a compressor, a condenser, an evaporator, and a control and instrumentation panel. Chillers condense refrigerant or chill water for indoor climate-control systems which supply conditioned air for equipment operating environments and for personnel comfort.

Compressors draw vaporized refrigerant from the evaporator and force it into the condenser. The compressor of a chiller unit may be either the centrifugal or the reciprocating piston type. Condensers are heat exchangers which reduce the refrigerant from a vapor to a liquid state. Chiller condensers are usually shell- and tube-type heat exchangers, with refrigerant on the shell side. Evaporators are tube bundles over which refrigerant is sprayed and evaporated, the inverse function of the condenser. Evaporator tubes can have either finned or plain surfaces. Control panels provide local chiller system monitoring and control functions. Typical components include: oil level switches/gauges, temperature switches/gauges, pressure switches/gauges, undervoltage and phase protection relays, and compressor motor circuit breakers.

Chiller components may be arranged in a variety of configurations. Typically the evaporator and condenser are mounted in a stacked configuration, one above the other, with the compressor and the control panel mounted on the side. Variations of this arrangement include the side-by-side configuration, with the compressor usually mounted above the condenser and evaporator, or a configuration with all components mounted side by side on the skid. Components are usually bolted to a supporting steel skid, which is, in turn, bolted to a concrete pad. Attachments to chillers include piping for routing cooling water or refrigerant to the unit, electrical conduit, and instrumentation and control lines. Chiller weights range up to about 40,000 lbs.

The compressor, condenser, evaporator, local control panel, support framing, and attached piping, instrument lines, and conduit are included in the Chiller equipment class.

The Bounding Spectrum (BS) represents the seismic capacity of a Chiller (CHL) if the chiller meets the intent of the following inclusion and exclusion rules.

<u>CHL/BS Caveat 1 - Earthquake Experience Data Base.</u> The chiller should be similar to and bounded by the CHL class of equipment of the earthquake experience data base. The discussion above briefly summarizes the class description of CHLs in the data base.

<u>CHL/BS Caveat 2 - No Reliance on Weak-Way Bending of Steel Plate or Structural Steel Shapes.</u> The evaporator and condenser tanks should be reasonably braced between themselves for lateral forces parallel to the axis of the tanks without relying on weak-way bending of steel plate or webs of structural steel shapes. The concern is that in weak-way bending the structure will not be capable of transferring the lateral earthquake loads. If weak-way steel plate bending must be relied on to brace the upper tank, then the adequacy of the steel components should be specially evaluated for adequate strength and stiffness.

<u>CHL/BS Caveat 3 - Check Vibration Isolation Systems.</u> Some chiller units are mounted on base vibration isolation systems and/or are equipped with vibration isolators in the mountings of the compressors and/or motors to the evaporators or condensers. The adequacy of these vibration isolators for seismic loads should be evaluated in accordance with Section 4.4.

<u>CHL/BS Caveat 4 - Adequate Anchorage.</u> The unit should be properly anchored in accordance with the guidelines of Section 4.4.

CHL/BS Caveat 5 - Potential Chatter of Essential Relays Evaluated. If relays are mounted on the equipment, a relay functionality review in accordance with Section 6 should be performed.

CHL/BS Caveat 6 - No Other Concerns. There should not be any other concerns with the seismic capacity of the chiller. Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats.

B.11.2 GERS - Chillers

There are no GERS for Chiller units.

B.12 AIR COMPRESSORS

B.12.1 Bounding Spectrum - Air Compressors

The earthquake experience data base equipment class of Air Compressor (AC) includes freestanding air compressors together with attached components such as air intakes, air receiver tanks, local control panels, conduit, and discharge lines. Air compressors can be generally categorized as reciprocating piston or rotary screw. The equipment class of air compressors encompasses a wide range of sizes, configurations, and applications. Air compressors typically include as components: electric drive motor, piston- or impeller-driven compressor, air receiver tank, air intake filter, air aftercooler, moisture separator, lubrication system, and the control and instrument panel. Large compressors typically include water jackets to cool the compressor casing and the air aftercoolers, while smaller units are typically cooled by natural or fan-assisted convection to the surrounding air.

Air compressors supply operating pressure to pneumatic instrumentation and control systems, in particular to diaphragm-operated valves. Air compressors also charge pressurized air receiver tanks that serve the pneumatic starting systems for emergency engine-generators.

Compressor configurations in the equipment class include air receiver tank-mounted reciprocating piston or rotary screw compressors, skid-mounted reciprocating piston or rotary screw compressors, and freestanding reciprocating piston compressors.

Reciprocating piston compressors are constructed much like an automobile engine, with pistons encased in cast steel cylinders compressing the gas, and a system of timed valves controlling the inlet and discharge. Piston air compressors generally have one or two cylinders but may include more. Cylinders are normally supported on a cast iron crankcase, which encloses the rotating crankshaft, linked either directly to the electric motor through a drive shaft, or indirectly through a belt linkage. Reciprocating piston compressors are commonly mounted atop an air receiver tank, and have drive motor sizes which typically range from fractional horsepower to over 100 horsepower.

Rotary screw compressors replace the reciprocating piston with a set of helical screws, typically encased in a cast iron block. The components and attachments of the air compressor are similar to reciprocating piston units except that the system of timed intake and discharge valves are not required. The most common configuration has the air compressor mounted on top of its air receiver tank. The units are usually not large, ranging in capacity from about 1 to 100 cfm (cubic feet per minute of discharge air), with drive motors typically ranging from fractional horsepower up to 30 hp. Tank-mounted rotary screw compressors typically range in weight from about 200 to 2500 pounds.

Reciprocating piston and rotary screw compressors may also be mounted on a steel skid. The skid may be either open or enclosed in a sheet metal housing. The skid is normally constructed of a welded steel frame with the compressor, drive motor, receiver tank, control panel, and other components bolted to the frame in some convenient configuration. Skid-mounted compressors typically range in capacity up to about 2000 cfm, with drive motors of up to about 300 hp. Skid-mounted compressors typically range in weight from about 2000 to 8000 pounds.

Freestanding compressors are usually the reciprocating piston type with one or two cylinders normally cantilevered from a crankcase. The crankcase may form the primary support for all components, or it may be mounted on a steel or cast iron pedestal. Freestanding compressors include the largest units typically found in power plant applications, ranging in capacity up to about 4000 cfm, with drive motors up to about 1000 hp. Freestanding compressors range in weight from small units on the order of about 500 pounds to units as large as 10 tons.

The Air Compressor equipment class includes the piston- or impeller-driven compressor, drive motor, air receiver tank, and attached cooling coils and air intakes, attached air discharge lines, instrument lines, and attached conduit (up to the first support away from the unit).

The Bounding Spectrum (BS) represents the seismic capacity of an Air Compressor (AC) if the compressor meets the intent of the following inclusion and exclusion rules.

AC/BS Caveat 1 - Earthquake Experience Data Base. The air compressor should be similar to and bounded by the AC class of equipment of the earthquake experience data base. The discussion above briefly summarizes the class description of ACs in the data base.

AC/BS Caveat 2 - Check Vibration Isolation Systems. Some compressor units are mounted on base vibration isolation systems and/or are equipped with vibration isolators in the compressor or drive motor mountings (e.g., if the compressor is mounted atop an air receiver tank). The adequacy of these vibration isolators for seismic loads should be evaluated in accordance with Section 4.4.

AC/BS Caveat 3 - Sufficient Slack and Flexibility of Attached Lines. Sufficient slack and flexibility should be present in attached lines (e.g., cooling, air, electrical) to preclude a line breach due to differential seismic displacement of the equipment and the line's nearest support. Sufficient slack and flexibility of lines is also considered in the seismic interaction review (Section 4.5).

AC/BS Caveat 4 - Adequate Anchorage. The unit should be properly anchored in accordance with the guidelines of Section 4.4.

AC/BS Caveat 5 - Potential Chatter of Essential Relays Evaluated. If relays are mounted on the equipment, a relay functionality review in accordance with Section 6 should be performed.

AC/BS Caveat 6 - No Other Concerns. There should not be any other concerns with the seismic capacity of the compressor. Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats.

B.12.2 GERS - Air Compressors

There are no GERS for Air Compressors.

B.13 MOTOR-GENERATORS

B.13.1 Bounding Spectrum - Motor-Generators

The earthquake experience data base equipment class of Motor-Generators (MG) includes motors and generators that are coupled into a motor-generator set (M-G set). Motor-generator sets are structurally similar to horizontal pumps, which consist of an electric motor connected to a pump through a shaft. Motor-generators are basically two motors connected through a common shaft. M-G sets normally include either an AC or DC motor attached through a direct drive shaft to an AC or DC generator. A large flywheel is often mounted at one end of the shaft for storage of rotational inertia, to prevent transient fluctuations in generator output. Usually, both the motor and generator in an M-G set are mounted to a common drive shaft and bolted to a steel skid. Smaller sets sometimes house the motor and generator within the same casing. Motor-generator sets typically range in weight from about 50 to 5000 pounds.

The motor, generator, flywheel, and attached conduit are included in the Motor-Generator equipment class.

The Bounding Spectrum (BS) represents the seismic capacity of a Motor-Generator (MG) if the motor-generator meets the intent of the following inclusion and exclusion rules.

MG/BS Caveat 1 - Earthquake Experience Data Base. The motor-generator should be similar to and bounded by the MG class of equipment of the earthquake experience data base. The discussion above briefly summarizes the class description of MGs in the data base.

MG/BS Caveat 2 - Driver and Driven Component on Rigid Skid. The main driver and the driven component should be connected by a rigid base or common skid. The concern is that differential displacement between the driver and the driven component may bind the shaft or lead to excessive bearing wear. If they are not mounted on a rigid skid, the potential for differential displacement between the main driver and the driven component should be specially evaluated.

MG/BS Caveat 3 - Base Vibration Isolation System Checked. If the unit is mounted on vibration isolators, the adequacy of the vibration isolators for seismic loads should be evaluated in accordance with Section 4.4.

MG/BS Caveat 4 - Sufficient Slack and Flexibility of Attached Lines. Sufficient slack and flexibility should be present in attached lines (e.g., cooling, air, electrical) to preclude a line breach due to differential seismic displacement of the equipment and the line's nearest support. Sufficient slack and flexibility of lines is also considered in the seismic interaction review (Section 4.5).

MG/BS Caveat 5 - Adequate Anchorage. The unit should be properly anchored in accordance with the guidelines of Section 4.4.

MG/BS Caveat 6 - Potential Chatter of Essential Relays Evaluated. If relays are mounted on the equipment, a relay functionality review in accordance with Section 6 should be performed.

MG/BS Caveat 7 - No Other Concerns. There should not be any other concerns with the seismic capacity of the motor-generator. Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats.

B.13.2 GERS - Motor-Generators

There are no GERS for Motor-Generator sets.

B.14 DISTRIBUTION PANELS

B.14.1 Bounding Spectrum - Distribution Panels

The earthquake experience data base equipment class of Distribution Panels (DP) consists of circuit breakers or fused switches mounted in vertical stacks within sheet metal cabinets. The function of distribution panels is to distribute low voltage AC or DC power from a main circuit to branch circuits, and to provide overcurrent protection. Distribution panels typically serve AC power systems ranging up to 600 volts and DC power systems ranging up to 250 volts.

Two types of distribution panels are found in power plant electrical systems: switchboards and panelboards. Although switchboards and panelboards perform the same function, they differ in construction and application. Switchboards are typically floor-mounted assemblies, while panelboards are usually wall-mounted. Switchboards usually distribute larger quantities of power than panelboards.

Distribution switchboards are freestanding cabinets containing stacks of circuit breakers or fusible switches. They have assemblies of circuit breakers or switches mounted into shelf-like cubicles. Electrical connections are normally routed through enclosed cable compartments in the rear of the cabinet. A switchboard will sometimes include a main circuit breaker and a power metering section mounted in separate compartments within the cabinet. Switchboards are often incorporated into substation assemblies that include motor control centers, transformers, and switchgear. In modern power plant applications, the completely enclosed (safety) switchboard is almost exclusively used. These switchboards are completely enclosed in a sheet metal casing. Switchboard dimensions are standardized with individual sections ranging from 20 to 40 inches in depth and width. The height is generally 90 inches. Switchboard sections can weigh up to 500 pounds.

Distribution panelboards are defined by the National Electric Code (NEC) as panels which include buses, switches, and automatic protective devices designed for the control or distribution of power circuits. Panelboards are placed in a cabinet or cutout box which is mounted in or against a wall and accessible only from the front. The assembly of circuit breakers contained in a panelboard is normally bolted to a steel frame, which is in turn mounted to the rear or sides of the panelboard enclosure. Individual circuit breakers are either bolted or plugged into the steel chassis. A cable gutter typically runs along the side of the circuit breaker chassis. Panelboards have a wide range of cabinet sizes. Typical dimensions for wall-mounted units are 20 to 40 inches in height and width, and 6 to 12 inches in depth. Weights for wall-mounted panelboards typically range from 30 to 200 pounds.

Industry standards developed by the National Electrical Manufacturers Association and the Underwriters Laboratories (e.g., NEMA ICS-6, UL-508), are maintained for the construction of distribution panel enclosures. These standards determine the minimum structural framing and sheet metal thickness for distribution panel enclosures as a function of sheet metal area between supports or reinforcing.

The Distribution Panel equipment class includes the circuit breakers, fusible switches, metering compartments, switchboard/panelboard enclosure and internals, and attached conduit.

The Bounding Spectrum (BS) represents the seismic capacity of a Distribution Panel (DP) if the panel meets the intent of the following inclusion and exclusion rules.

DP/BS Caveat 1 - Earthquake Experience Data Base. The distribution panel should be similar to and bounded by the DP class of equipment of the earthquake experience data base. The discussion above briefly summarizes the class description of DPs in the data base.

DP/BS Caveat 2 - Contains only Circuit Breakers and Switches. The distribution panel should only contain circuit breakers and switches. This ensures consistency with the equipment class defined by the earthquake experience data base. The concern is that other seismically vulnerable components not normally associated with a distribution panel may have been added. Other components contained within the panel should be evaluated on a case-by-case basis. This case-by-case evaluation may include use of earthquake experience, test data or component specific qualification data as discussed in Section 5, Outlier Evaluation.

DP/BS Caveat 3 - Doors Secured. All doors, latches or screwdriver-operated door fasteners should be secured. The concern addressed by this caveat is that the doors could open during an earthquake and the loose door could repeatedly impact the housing and be damaged or cause internal components to malfunction or chatter.

DP/BS Caveat 4 - Adjacent Cabinets Bolted Together. Adjacent cabinets which are close enough to impact each other and sections of multi-bay cabinet assemblies should be bolted together if any of these cabinets contain essential relays. The concern addressed in this caveat is that unbolted cabinets could respond out of phase to one another and impact each other during an earthquake. This would cause additional impact loadings and high frequency vibration loadings which may result in malfunction or chatter of internal components.

DP/BS Caveat 5 - General Configuration Similar to NEMA Standards. The general configuration of the distribution panel should be similar to those constructed to NEMA Standards. The unit does not have to conform exactly to NEMA Standards, but should be similar with regard to the gage of steel, internal structure and support. This caveat is intended to preclude unusual designs not covered by the data base (thin gage material, flimsy internal structure, etc.). In general, units manufactured by the major manufacturers of distribution panels conform to this caveat if they have not been modified.

DP/BS Caveat 6 - Adequate Anchorage. The unit should be properly anchored in accordance with the guidelines of Section 4.4.

DP/BS Caveat 7 - Potential Chatter of Essential Relays Evaluated. If relays are mounted on the equipment, a relay functionality review in accordance with Section 6 should be performed.

DP/BS Caveat 8 - No Other Concerns. There should not be any other concerns with the seismic capacity of the panel. Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats.

B.14.2 GERS - Distribution Panels

The generic seismic test data base equipment class of Distribution Panels (or load centers) consists of individual molded-case circuit breakers and fused disconnect switches housed in NEMA-type floor and wall enclosures. Units are low voltage rated at 600 VAC (480 VAC nominal) or 250 VDC. A distribution panel receives its electrical power from the plant distribution system and distributes this power to each of the circuit breakers and fused disconnect switches by an internal arrangement of vertical and horizontal bus bars. The units in this equipment class should not contain motor starters or relays.

Floor-mounted (freestanding) distribution panels are denoted as Switchboards (NEMA Standard Publication No. PB2). The typical floor enclosure is 90 inches high, 36 inches wide, and 20 inches deep.

Wall-mounted (either flush or surface mount) distribution panels are denoted as Panelboards (National Electrical Code NFPA/ANSI No. 70). Wall-mounted enclosures vary in size, with a nominal dimension being 48 inches high, 24 inches wide, and 20 inches deep.

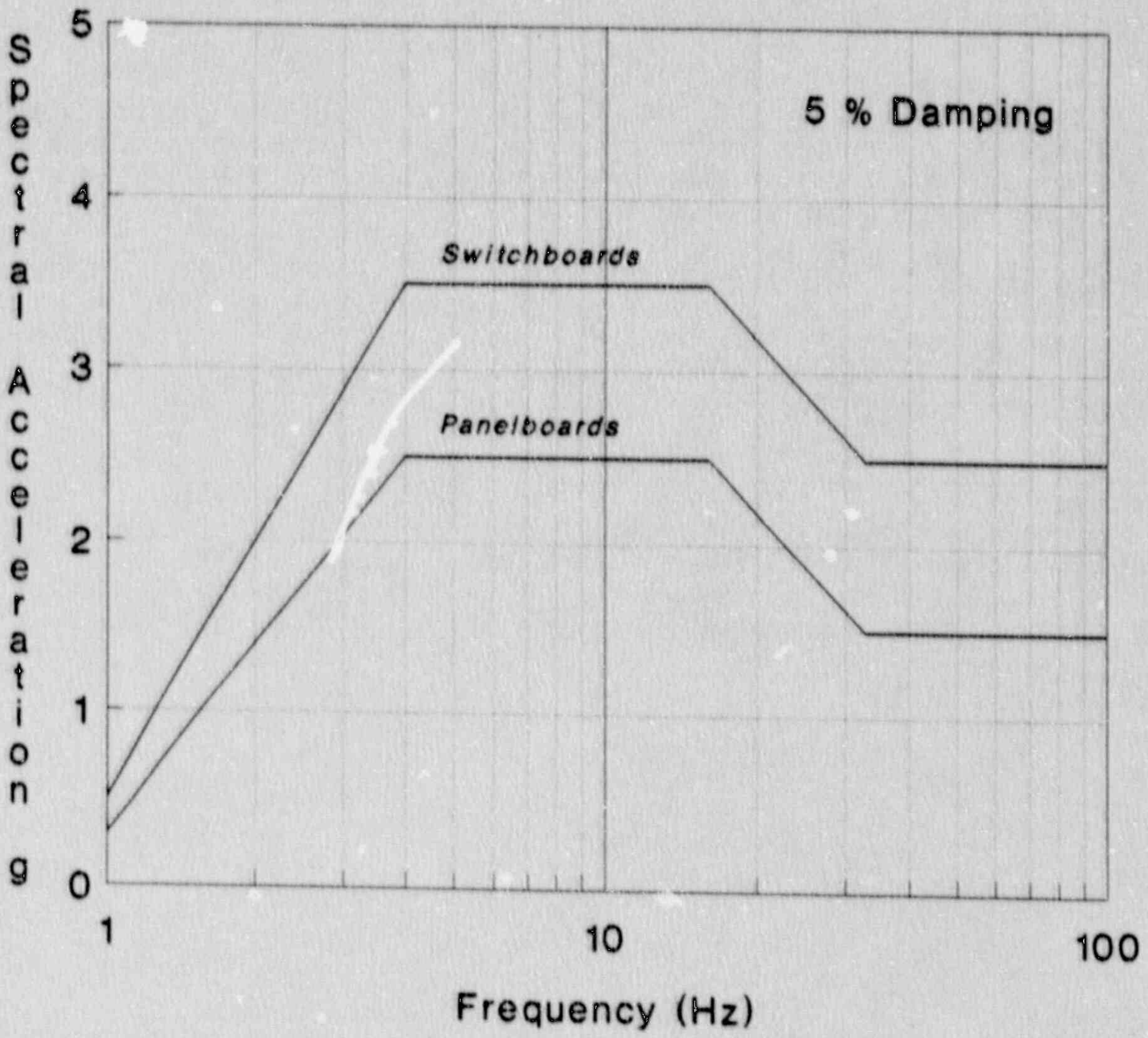
The GERS represent the seismic capacity of a Distribution Panel (DP) (Switchboard or Panelboard) if the panel meets the intent of the following inclusion and exclusion rules.

<u>DP/GERS Caveat 1 - Generic Seismic Test Data Base.</u> The distribution panel should be similar to and bounded by the DP class of equipment of the GERS data base. The discussion above briefly summarizes the generic seismic test data base DP class description.

<u>DP/GERS Caveat 2 - Bounding Spectrum Caveats Apply.</u> The panel should meet all the caveats given for the Bounding Spectrum. This caveat is included to cover the vulnerabilities identified in the earthquake experience data base. Those GERS caveats which are the same as the Bounding Spectrum caveats are not repeated below.

<u>DP/GERS Caveat 3 - Freestanding, Designated Switchboard.</u> The Switchboard GERS can be used only if the unit is freestanding and designated as a switchboard by the manufacturer; otherwise the Panelboard GERS should be used. A review of manufacturer's submittals and parts list is sufficient. These two subclasses (Switchboard and Panelboard) are specifically handled as different equipment classes in the generic seismic test data base.

GERS-DSP.6
11/1/89



Frequency (Hz)	1	4	16	33
Switchboards (g)	0.5	3.5	3.5	2.5
Panelboards (g)	0.3	2.5	2.5	1.5

Figure B.14-1. Generic Equipment Ruggedness Spectra (GERS) for Distribution Panelboards and Switchboards. (Source: Reference 6)

B.15 BATTERIES ON RACKS

B.15.1 Bounding Spectrum - Batteries on Racks

The earthquake experience data base equipment class of Batteries on Racks (BAT) includes both storage batteries and their supporting structures. Most battery systems consist of lead-acid storage batteries mounted in series on steel-frame racks or wooden racks.

A battery is a group of electro-chemical cells interconnected to supply a specified voltage of DC power. Individual battery weights typically range from about 50 to 450 pounds. Batteries are used to supply a steady source of DC power for circuits in control and instrumentation systems, to power DC starter motors for emergency engine-generators, and to provide DC power to inverters for uninterruptible power systems.

Lead-acid storage batteries are the most prevalent type of battery and are the subject of this equipment class. The basic components of a lead-acid battery cell are the electrode element, cell cover, cell jar, electrolyte, and flame arrestor. The electrode elements are the key components of the battery system.

There are four basic types of lead-acid storage batteries which are distinguished by the construction of their positive plates. These four types are: calcium flat plate, Planté or Manchex, antimony flat plate, and tubular. Since there are few experience data base examples of antimony flat plate and tubular batteries, they are excluded from the equipment class. The Planté or Manchex battery is one of the older designs of batteries but still has limited use in the power industry. It is constructed of heavy lead plate with either a series of horizontal cross-ribs attached to the plate (Planté plate design), or a matrix of spiral buttons inserted into the plate (Manchex design).

Battery racks are normally frames of steel channels, angles, and struts that support the batteries above the floor. Wooden members are also used for the frames. Racks can be multi-rowed, multi-tiered, or multi-stepped. Multi-rowed racks are adjacent rows of batteries all at the same level. Multi-tiered racks are vertical rows of batteries mounted directly above each other. Multi-stepped racks have each succeeding row of batteries located above and to the rear of the previous row.

The shelf that supports the batteries typically consists of steel channels running longitudinally that are, in turn, supported by transverse rectangular frames of steel angles. The racks are usually braced by diagonal struts along either the front or rear face for longitudinal support. The rack members are connected by a combination of welds and bolts.

Well-designed battery racks include a restraining rail running longitudinally along the front and the rear of the row of batteries and wrapping around the ends of the row. The rails are located at about mid-height of the battery, and can prevent accidental overturning of the batteries, or overturning from earthquake loadings.

The battery (including the cell jar and enclosed plates, the supporting rack, electrical connections between batteries (bus bar), and attached electrical cable) are included in the Batteries on Racks equipment class.

The Bounding Spectrum (BS) represents the seismic capacity of Batteries on Racks (BAT) if the batteries and racks meet the intent of the following inclusion and exclusion rules.

<u>BAT/BS Caveat 1 - Earthquake Experience Data Base.</u> The batteries and racks should be similar to and bounded by the BAT class of equipment of the earthquake experience data base. The discussion above briefly summarizes the class description of BATs in the data base.

<u>BAT/BS Caveat 2 - Plates of the Battery Cells Are Lead-Calcium Flat-Plate or They Are of Planté or Manchex Design.</u> The plates of the battery must be of the lead-calcium flat-plate or the Planté or Manchex design. These are the only battery cell types included in the earthquake experience data base.

<u>BAT/BS Caveat 3 - Each Individual Battery Weighs Less Than 450 Pounds.</u> Individual battery cells should weigh less than about 450 pounds. This is the upper bound weight of the battery cells included in the earthquake experience data base.

<u>BAT/BS Caveat 4 - Close-Fitting, Crush-Resistant Spacers Between Cells.</u> There should be close-fitting, crush-resistant spacers between the cells, which fill about two-thirds of the vertical space between the cells. The concern is that the batteries without spacers can rock and collide during the earthquake causing malfunction and damage.

<u>BAT/BS Caveat 5 - Batteries Restrained by Side and End Rails.</u> The battery racks should have end and side rails incorporated in the design. The end and side rails should also be close fitting against the cells (with shims, if needed). The concern is that batteries on racks without end and side rails may tip or slide off the rack.

<u>BAT/BS Caveat 6 - Battery Racks Have Longitudinal Cross Bracing.</u> The racks should have longitudinal cross bracing unless engineering judgment or analysis shows that such bracing is not needed. The concern is that racks without cross bracing may not be able to transfer the lateral seismic loads to the base support. Simple bounding hand calculations may be performed to show that the structural components of the rack are capable of transferring these loads. The capacity of rack steel members may be calculated following AISC Part 2 allowable stresses.

<u>BAT/BS Caveat 7 - Racks Constructed of Wood To Be Evaluated.</u> Battery racks constructed of wood should be specially evaluated. The concern is that racks constructed of wood may be more vulnerable to seismic loads than steel racks. Evaluation of the rack should consider industry accepted structural design standards for wood construction, using extreme load allowable stresses as appropriate.

<u>BAT/BS Caveat 8 - Batteries Greater Than 10 Years Old To Be Evaluated.</u> Batteries that are more than 10 years old should be specially evaluated. The concern with the aging of batteries is that some models have been shown by shake table testing to be susceptible to structural and or metallurgical changes with time that result in either structural failure or reduced capacity after vibration.

<u>BAT/BS Caveat 9 - Adequate Anchorage.</u> The unit should be properly anchored in accordance with the guidelines of Section 4.4.

<u>BAT/BS Caveat 10 - No Other Concerns.</u> There should not be any other concerns with the seismic capacity of the batteries on racks. Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats.

B.15.2 GERS - Batteries on Racks

The generic seismic test data base equipment class of Batteries on Racks (BAT) includes storage battery sets of the lead-calcium type supported on racks with rail restraints. Each battery set consists of multiple lead-acid cells (nominal 2 volts each) interconnected by rigid bus connectors. Rows or groups of cells are connected by flexible bus connectors. The racks have either a two-step or single-tier configuration with longitudinal cross-braces. The racks have rail restraints to keep the batteries in place. There are snug-fitting spacers between the cells and, if needed, shims between the cells and rails. This equipment class covers virtually all stationary lead-acid battery cells used in power plants.

The GERS represent the seismic capacity of Batteries on Racks (BAT) if the batteries and racks meet the intent of the following inclusion and exclusion rules.

BAT/GERS Caveat 1 - Generic Seismic Test Data Base. The batteries and racks should be similar to and bounded by the BAT class of equipment of the GERS data base. The discussion above briefly summarizes the generic seismic test data base BAT class description.

BAT/GERS Caveat 2 - Bounding Spectrum Caveats Apply. The batteries on racks should meet all the caveats given for the Bounding Spectrum. This caveat is included to cover the vulnerabilities identified in the earthquake experience data base. Those GERS caveats which are the same as the Bounding Spectrum caveats are not repeated below.

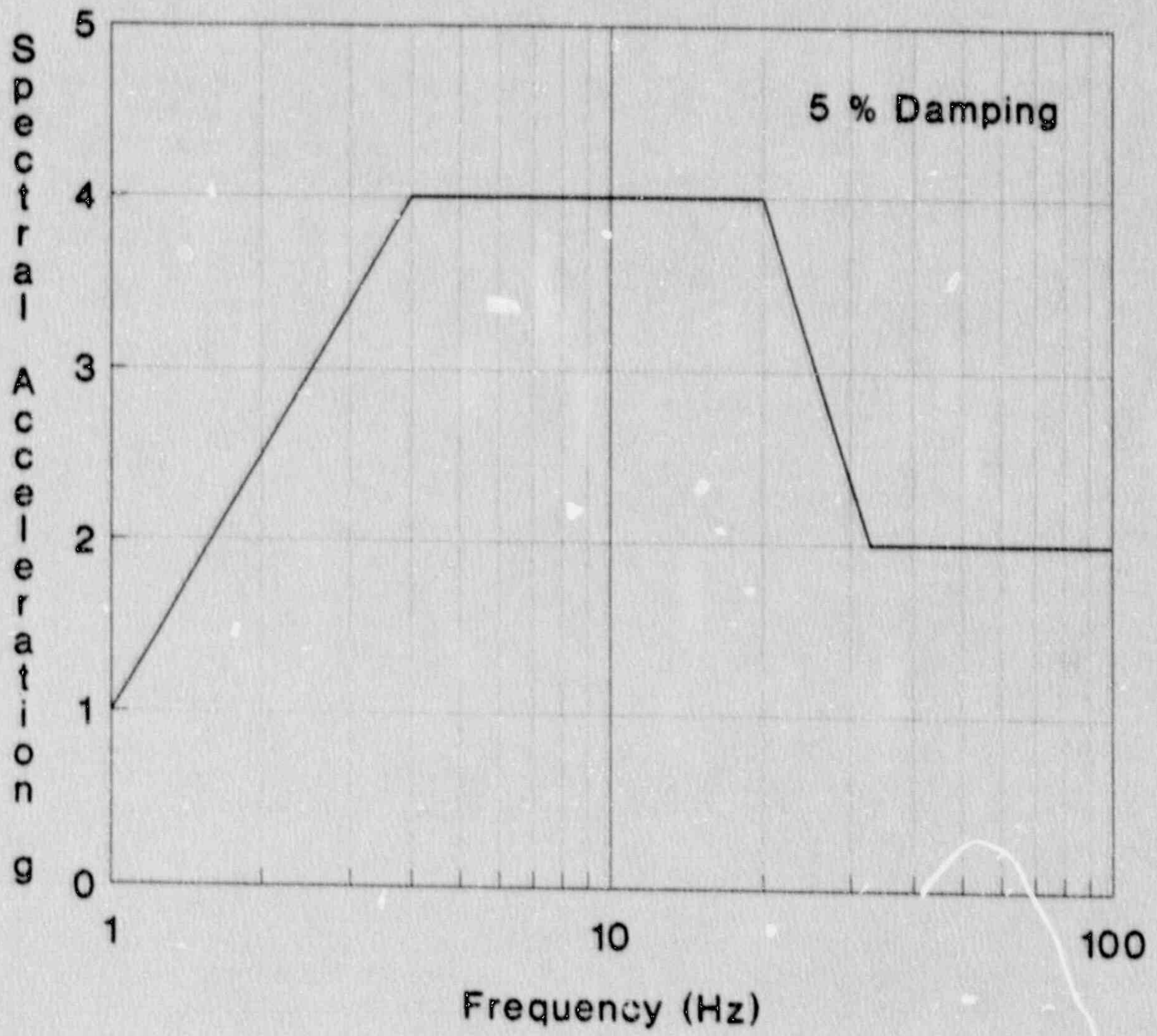
BAT/GERS Caveat 3 - Lead-Calcium Plates. The plates of the battery cell should be lead-calcium. Lead-calcium battery cells are the only type included in the generic seismic test data base.

BAT/GERS Caveat 4 - Supported on Two-Step or Single-Tiered Racks with Longitudinal Cross-Braces. The batteries should be supported on two-step racks or single-tier racks which have longitudinal cross-braces as supplied by the battery manufacturer (review of manufacturer's submittals is sufficient). A row of batteries should be restrained by double rails in front, back and on the ends, symmetrically placed with respect to the cell center of gravity. The concerns addressed by this caveat are that racks may not be able to transfer the lateral seismic loads to the base support, and that the natural frequencies of the rack may be lower than those in the testing data base.

If the battery rack is custom made and/or does not have longitudinal cross-braces supplied by the manufacturer, then the intent of this caveat can be satisfied by showing that the racks have adequate strength (i.e., within 1.6 times normal AISC allowable stress limits) and have natural frequencies above about 8 Hz horizontal and 20 Hz vertical. If the natural frequency of the rack is below these values, then a realistic amplification through the rack to the center of gravity of the batteries should be included when determining the amplified response of the batteries for comparison to the GERS (for this case the GERS represents the battery capacity).

If the racks only have a single rail, then this rail should be evaluated to determine whether it will hold the cells in place and prevent significant relative motion between cells.

GERS-BAT.4
8/1/86



Frequency (Hz)	1	4	20	33
Batteries on Racks (g)	1.0	4.0	4.0	2.0

Figure B.15-1. Generic Equipment Ruggedness Spectra (GERS) for Batteries on Racks. (Source: Reference 6)

B.16 BATTERY CHARGERS AND INVERTERS

B.16.1 Bounding Spectrum - Battery Chargers and Inverters

The earthquake experience data base equipment types of Battery Chargers and Inverters (BCI) are grouped into a single equipment class together because they perform similar (although electrically inverse) functions, contain similar components, and are packaged in similar cabinets. Solid-state battery chargers are assemblies of electronic components whose function is to convert AC input into DC output. Inverters are assemblies whose function is to convert DC input into AC output. Battery chargers and inverters are normally housed in floor- or wall-mounted cabinets.

The most common applications for both battery chargers and inverters are as components of an uninterruptible power supply (UPS). A typical UPS consists of a solid-state inverter, a battery charger, a set of lead-acid storage batteries, and an automatic transfer switch. Chargers serve the station batteries which provide a DC power source to controls, instrumentation and switchgear. A portion of the DC power from the batteries is routed through inverters which provide a source of AC power to critical equipment.

The primary electrical function of a battery charger is accomplished using a rectifier. Most modern battery chargers are based on solid-state rectifiers consisting of semiconductors. Solid-state battery chargers are the focus of this equipment class.

The primary components of battery chargers include solid-state diodes, transformer coils, capacitors, electronic filters, and resistors. In addition, the primary components are usually protected from electrical faults by molded case circuit breakers and fuses. The internal components are normally bolted either to the rear panel or walls of a cabinet, or to interior panels or steel frames mounted within a cabinet. The front panel of the cabinet typically contains instrumentation and controls, including ammeters, voltmeters, switches, alarms, and control relays. Inverters contain primary components similar to those found in battery chargers. Virtually all inverters use solid state components.

Battery chargers and inverters are typically mounted in separate cabinets, but they are sometimes supplied as an assembly of two adjoining cabinets. The smallest units are wall-mounted or rack-mounted with typical dimensions of 10 to 20 inches in height, width, and depth, and typical weights of 50 to 200 pounds. Typical cabinet dimensions for larger floor-mounted units are 20 to 40 inches in width and depth, and 60 to 80 inches in height. The weights of the floor-mounted chargers and inverters range from several hundred to several thousand pounds. Typical AC voltages to battery chargers and from inverters range from 120 to 480 volts. Voltages in DC power typically range from 24 to 240 volts.

Industry standards are maintained for the construction of cabinets by the National Electrical Manufacturers Association standard (NEMA ICS-6 1978) and Underwriters Laboratories standard (UL-1236 1984). These standards determine the minimum structural framing and sheet metal thickness for charger and inverter cabinetry as a function of size.

Solid-state inverters and battery chargers are included in the equipment class in freestanding, rack-mounted, and wall-mounted configurations. The Battery Charger and Inverter equipment class includes the sheet metal enclosure, all internal components, junction boxes, and attached cable or conduit.

The Bounding Spectrum (BS) represents the seismic capacity of a Battery Charger or Inverter (BCI) if the equipment meets the intent of the following inclusion and exclusion rules.

<u>BCI/BS Caveat 1 - Earthquake Experience Data Base.</u> The battery charger or inverter should be similar to and bounded by the BCI class of equipment of the earthquake experience data base. The discussion above briefly summarizes the class description of BCIs in the data base.

<u>BCI/BS Caveat 2 - Solid State Type.</u> The battery charger or static inverter should be a solid-state type. The solid-state electrical construction is the primary type included in the earthquake experience data base. The concern is that electronics which are not of the solid state variety (glass tubes, etc.) are vulnerable to earthquake damage.

<u>BCI/BS Caveat 3 - Transformer Mounted Near Base of Floor-Mounted Units.</u> For floor-mounted units, the transformer, which is the heaviest component of this equipment, should be positively anchored and mounted near the base of the cabinet. If not mounted near the base, then the load path should be specially evaluated. The concern is that the lateral earthquake loads on the transformer will not be properly transferred to the equipment base. The load path evaluation may use judgment or simple calculations to ensure that the structure can transfer these loads.

<u>BCI/BS Caveat 4 - No Reliance on Weak-Way Bending of Steel Plate or Structural Steel Shapes.</u> The base assembly of floor-mounted units should be properly braced or stiffened such that lateral forces in any direction do not rely on weak-way bending of sheet metal or thin webs of structural steel shapes. If such unbraced or unstiffened s[illegible] webs exist, they should be investigated and verified for adequacy by the Seismic Capability Engineers to check the strength and stiffness.

<u>BCI/BS Caveat 5 - Load Path Check for Wall-Mounted Units.</u> If the battery charger or inverter is a wall-mounted unit, the transformer supports and bracing should be visually reviewed for a proper load path to the rear cabinet wall. Lateral earthquake loads on the heavy transformer need to be properly transferred to the anchorage.

<u>BCI/BS Caveat 6 - Doors Secured.</u> All doors should be secured by a latch or fastener. The concern addressed by this caveat is that the doors could open during an earthquake and the loose door could impact the housing and be damaged or cause internal components to malfunction.

BCI/BS Caveat 7 - Adequate Anchorage. The unit should be properly anchored in accordance with the guidelines of Section 4.4.

BCI/BS Caveat 8 - Potential Chatter of Essential Relays Evaluated. If relays are mounted on the equipment, a relay functionality review in accordance with Section 6 should be performed.

BCI/BS Caveat 9 - No Other Concerns. There should not be any other concerns with the seismic capacity of the battery charger or inverter. Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats.

B.16.2 GERS - Battery Chargers and Inverters

The generic seismic test data base equipment class includes both Battery Chargers and Inverters. Battery charger units range from 25 to 600 amp capacity with either single- or three-phase voltage ratings of 24 to 250 volts DC and 120 to 480 Volts AC. The units utilize solid-state technology (silicon-controlled rectifier, SCR) in both the main circuits and the power controls. Major components include protective circuit breakers, transformers, power supply, SCR, filter, and various alarm relays, and control circuits. The units are housed in NEMA-type floor- or wall-mounted enclosures. Virtually all battery chargers used in power plants for float charging of lead-acid storage battery sets are included within this equipment class.

DC to AC inverter units included in the GERS data base range from 0.5 to 15 KVA capacity with either single- or three-phase voltage ratings of 120 volts DC and 120 to 480 volts AC. The units utilize solid-state technology (silicon-controlled rectifier, SCR), and have protective circuit breakers, transformers, frequency control circuitry, various alarm relays and SCR power control circuits as major components. The units are housed in NEMA-type floor-mounted enclosures. This equipment class covers virtually all 120 VDC inverters used in power plants for critical power supply.

The GERS represents the seismic capacity of a Battery Charger or Inverter (BCI) if the equipment meets the intent of the following inclusion and exclusion rules.

BCI/GERS Caveat 1 - Generic Seismic Test Data Base. The battery charger or inverter should be similar to and bounded by the BCI class of equipment of the GERS data base. The discussion above briefly summarizes the generic seismic test data base BCI class description.

BCI/GERS Caveat 2 - Bounding Spectrum Caveats Apply. The battery charger or inverter should meet all the caveats given for the Bounding Spectrum. This caveat is included to cover the vulnerabilities identified in the earthquake experience data base. Those GERS caveats which are the same as the Bounding Spectrum caveats are not repeated below.

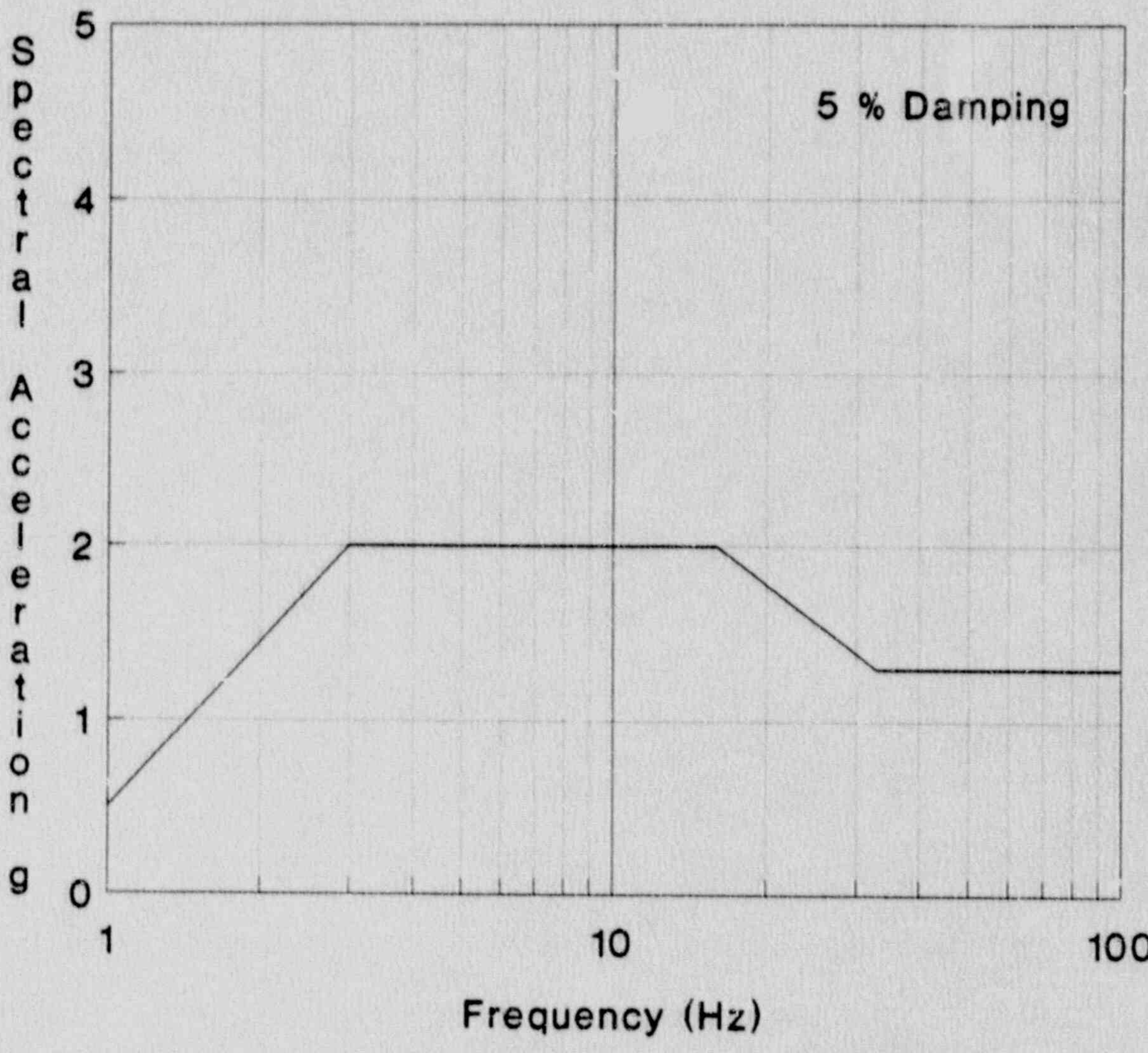
BCI/GERS Caveat 3 - SCR Power Controls Within NEMA-Type Enclosure. The battery charger or inverter should be a solid-state unit with SCR power controls (C&D, PCP, or Exide for battery chargers) (Elgar, Solid State Controls, Staticon for inverters). The unit should be wall- or floor-mounted within a NEMA-type enclosure (review of manufacturer's submittals is sufficient). The enclosure does not have to conform exactly to NEMA standards but should be similar with regard to the gage of the steel, internal structure and support. The purpose of this caveat is to ensure similarity with the power controls and enclosure type of the generic seismic test data base.

BCI/GERS Caveat 4 - Battery Charger Size and Capacity Range. Battery Charger size and capacity should be within the following range: 24 to 250 VDC, 120 to 480 VAC, 25 to 600 amps; and weight in the range of 150 to 2,850 pounds (review of manufacturer's submittals or Battery Charger nameplate is sufficient). This represents the size and capacity limits of the generic seismic test data base.

BCI/GERS Caveat 5 - Inverter Size and Capacity Range. Inverter size and capacity should be within the following range: 120 VDC, 120 to 480 VAC. 0.5 to 15 KVA; and weight in the range of 300 to 2,000 pounds. (Review of manufacturer's submittals or inverter nameplate is sufficient.) This represents the size and capacity range of the generic seismic test data base.

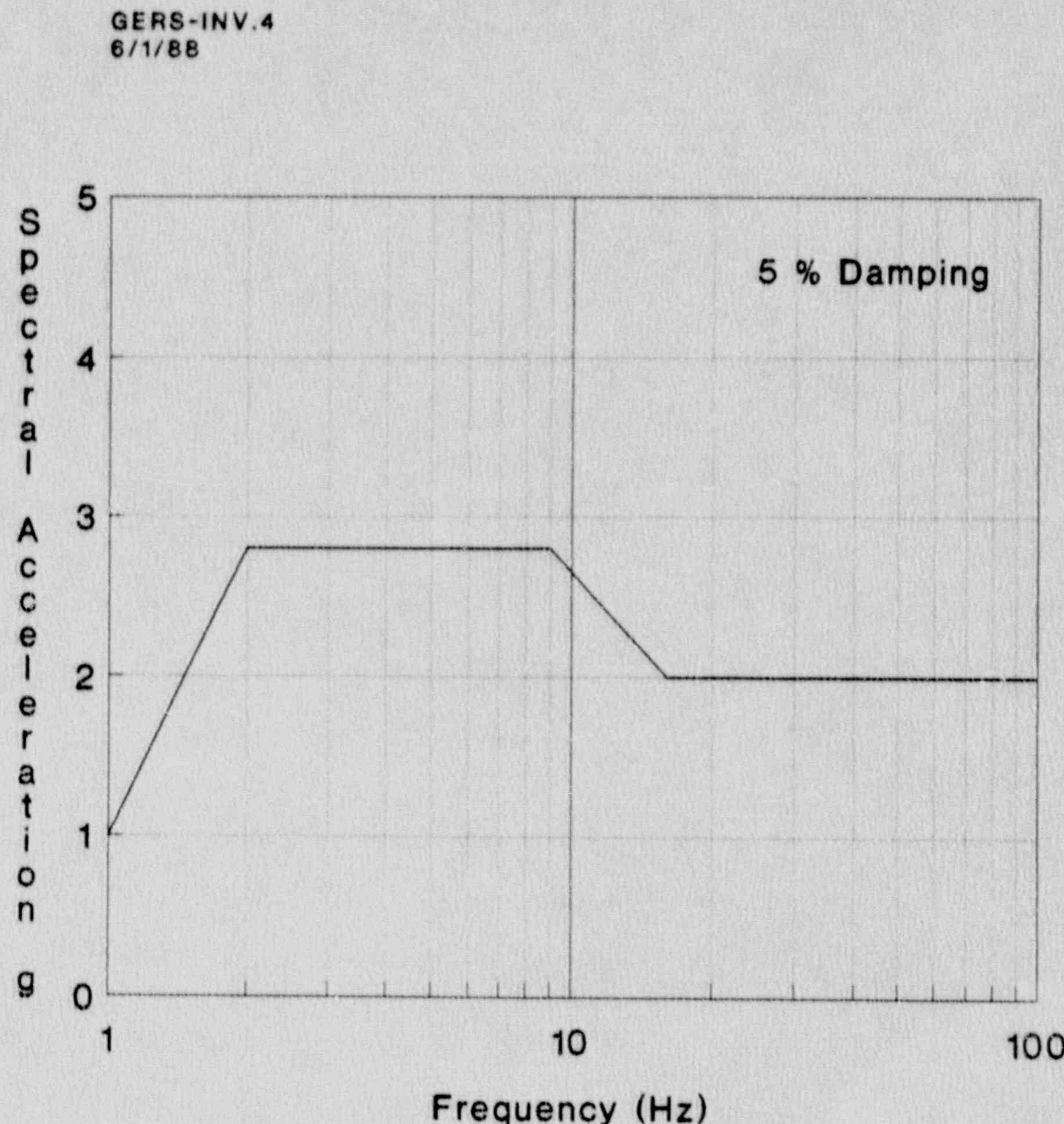
BCI/GERS Caveat 6 - Cutouts Require Separate Evaluation. Heavy components should, in general, be located in the lower half of the enclosure height and either supported from the base or rear panel. If cutouts are adjacent to support points for heavy internal components, a separate evaluation is required. The concern is that the seismic load will not be able to be transferred through the shear panels to the anchorage.

GERS-BC.3
6/1/88



Frequency (Hz)	1	3	16	33
Battery Chargers (g)	0.5	2.0	2.0	1.3

Figure B.16-1. Generic Equipment Ruggedness Spectra (GERS) for Battery Chargers. (Source: Reference 6)



Frequency (Hz)	1	2	9	16	33
Inverters (g)	1.0	2.8	2.8	2.0	2.0

Figure B.16-2. Generic Equipment Ruggedness Spectra (GERS) for Inverters. (Source: Reference 6)

B.17 ENGINE-GENERATORS

B.17.1 Bounding Spectrum - Engine-Generators

The earthquake experience data base equipment class of Engine-Generators (EG) includes a wide range of sizes and types of generators driven by piston engines. Engine-Generators are emergency power sources that provide bulk AC power in the event of loss of off-site power.

In typical power plant applications, generators range from 200 KVA to 5000 KVA; electrical output is normally at 480, 2400, or 4160 volts. Generators are typically the brushless rotating-field type with either a rotating rectifier exciter or a solid-state exciter and voltage regulator. Reciprocating-piston engines are normally diesel-fueled, although engines may operate on natural gas or oil. In typical applications piston engines range from tractor-size to locomotive-size, with corresponding horsepower ratings ranging from about 400 to 4000 horsepower.

Engine-generators normally include the piston engine and generator in a direct shaft connection, bolted to a common steel skid. The skid or the engine block also supports peripheral attachments such as conduit, piping, and a local control and instrumentation panel.

The engine-generator system also includes peripheral components for cooling, heating, starting, and monitoring operation, as well as supplying fuel, lubrication, and air. The peripheral components may or may not be mounted on or attached directly to the engine-generator skid. If they are not mounted on the skid, they should be evaluated separately.

The Bounding Spectrum (BS) represents the seismic capacity of an Engine-Generator (EG) if the generator meets the intent of the following inclusion and exclusion rules.

EG/BS Caveat 1 - Earthquake Experience Data Base. The engine-generator should be similar to and bounded by the EG class of equipment of the earthquake experience data base. The discussion above briefly summarizes the class description of EGs in the data base.

EG/BS Caveat 2 - Driver and Driven Component on Rigid Skid. The driver and the driven component should be connected by a rigid support or common skid. The concern is that differential displacement between the driver and the driven component may bind the shaft or lead to excessive bearing wear. If they are not mounted on a rigid skid, the potential for differential displacement between the driver motor and driven component should be evaluated.

EG/BS Caveat 3 - Base Vibration Isolation System Checked. If the unit is mounted on vibration isolators, the adequacy of the vibration isolators for seismic loads should be evaluated in accordance with Section 4.4.

EG/BS Caveat 4 - Sufficient Slack and Flexibility of Attached Lines. Sufficient slack and flexibility should be present in attached lines (e.g., cooling, air, electrical) to preclude a line breach due to differential seismic displacement of the equipment and the line's nearest support. Sufficient slack and flexibility of lines is also considered in the seismic interaction review (Section 4.5).

EG/BS Caveat 5 - Adequate Anchorage. The unit should be properly anchored in accordance with the guidelines of Section 4.4.

EG/BS Caveat 6 - Potential Chatter of Essential Relays Evaluated. If relays are mounted on the equipment, a relay functionality review in accordance with Section 6 should be performed.

EG/BS Caveat 7 - No Other Concerns. There should not be any other concerns with the seismic capacity of the generator. Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats.

B.17.2 GERS - Engine-Generators

There are no GERS for Engine-Generators.

B.18 INSTRUMENTS ON RACKS

B.18.1 Bounding Spectrum - Instruments on Racks

The earthquake experience data base equipment class of Instruments on Racks (IR) consists of steel frames that provide mounting for local controls and instrumentation, such as signal transmitters to remote control panels. Instrument racks typically consolidate transducer or control signals from several equipment items in their immediate vicinity.

Instrument racks usually consist of steel members (typically steel angle, pipe, channel, or Unistrut) bolted or welded together into a frame. Components are attached either directly to the rack members or to metal panels that are welded or bolted to the rack. Floor-mounted instrument racks typically range from 4 to 8 feet in height, with widths varying from 3 to 10 feet, depending on the number of components supported on the rack. A simpler configuration of an instrument rack is a single floor-mounted post supporting one or two components. Wall-mounted and structural column-mounted racks are often used for supporting only a few components.

Control system components mounted on instrument racks may include electronic systems used for functions such as temperature monitoring, starting, stopping, and throttling electric motors, and monitoring electric power. Pneumatic system components mounted on instrument racks may be used for monitoring fluid pressure, liquid level, fluid flow, and for adjusting pneumatically-actuated control valves. Electronic control and instrumentation system components mounted on instrument racks include transmitters that convert a pneumatic signal from the transducer to an electric signal for transmission to the main control panel.

Typical components supported on instrument racks include: pressure switches, transmitters, gauges, recorders, hand switches, manifold valves, and solenoid valves. Attachments to instrument racks include steel or plastic tubing, conduit, and junction boxes.

Freestanding, wall-mounted, and structural column-mounted instrument racks of bolted and welded steel construction are included in the equipment class along with the components mounted on them. Both pneumatic and electronic components, as well as associated tubing, wiring, and junction boxes, are included in the Instruments on Racks equipment class.

The Bounding Spectrum (BS) represents the seismic capacity of Instruments on Racks (IR) if the instruments and racks meet the intent of the following inclusion and exclusion rules.

<u>IR/BS Caveat 1 - Earthquake Experience Data Base.</u> The instruments and racks should be similar to and bounded by the IR class of equipment of the earthquake experience data base. The discussion above briefly summarizes the class description of IRs in the data base.

<u>IR/BS Caveat 2 - Evaluate Computers and Programmable Controllers Separately.</u> Computers and programmable controllers should be evaluated separately. The concern is that the subclass of computers and programmable controllers is so diverse that they may not be adequately represented by the experience data base. Computers and programmable controllers should therefore be evaluated on a case-by-case basis. Component specific test data for computers and programmable controllers may be used to resolve this concern.

<u>IR/BS Caveat 3 - Structure Adequate.</u> The steel frame and sheet metal structure should be evaluated in the walkdown for adequacy. Engineering judgment may be used to determine that an adequate load path exists to transfer the lateral earthquake loads to the foundation.

<u>IR/BS Caveat 4 - Adjacent Racks Bolted Together.</u> Adjacent racks which are close enough to impact each other and sections of multi-bay assemblies should be bolted together if any of these assemblies contain essential relays. The concern addressed in this caveat is that adjacent, unbolted

racks could respond out of phase to one another and impact each other during an earthquake. This would cause additional impact loadings and high frequency vibration loadings which could cause essential relays to chatter.

IR/BS Caveat 5 - Natural Frequency Relative to 8 Hz Limit Considered. For slender unbraced racks, the lowest natural frequency should be estimated. For racks which have a natural frequency below about 8 Hz, the floor response spectrum should be compared to 1.5 times the Bounding Spectrum (see Table 4-1 of Section 4).

IR/BS Caveat 6 - Sufficient Slack and Flexibility of Attached Lines. Sufficient slack and flexibility should be present in attached lines (e.g., cooling, air, electrical) to preclude a line breach due to differential seismic displacement of the equipment and the line's nearest support. Sufficient slack and flexibility of lines is also considered in the seismic interaction review (Section 4.5).

IR/BS Caveat 7 - Adequate Anchorage. The unit should be properly anchored in accordance with the guidelines of Section 4.4.

IR/BS Caveat 8 - Potential Chatter of Essential Relays Evaluated. If relays are mounted on the equipment, a relay functionality review in accordance with Section 6 should be performed.

IR/BS Caveat 9 - No Other Concerns. There should not be any other concerns with the seismic capacity of the instrument rack. Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats.

B.18.2 GERS - Instruments on Racks

The generic seismic test data base equipment class of Instruments on Racks includes four kinds of transmitters: pressure, temperature, level, and flow. The racks for these instruments are not covered in the seismic testing data base. Transmitters are used in power plants to transmit signals received from transducers which monitor plant operating conditions. The transmitters send electric signals to control panels for use by safety systems, plant control systems, alarm systems and operator displays. Some transmitters are designed for remote rack or control panel mounting while others are mounted adjacent to the transducer. The term "transmitter" is also used for the transducer/signal conditioner combination when the transducer and signal conditioner are integral. This is the usual case for flow, pressure, and level transmitters. Temperature transmitters are usually remote from the transducer. In general, transmitters range in size from a few pounds to about 40 pounds; however, the majority of the transmitters weigh only a few pounds. The largest physical dimension of a transmitter is usually less than about 12 inches.

The GERS represent the seismic capacity of a pressure, temperature, level, or flow transmitter if the transmitter meets the intent of the following inclusion and exclusion rules.

IR/GERS Caveat 1 - Generic Seismic Test Data Base. The transmitter should be similar to and bounded by the IR class of equipment of the GERS data base. The discussion above briefly summarizes the generic seismic test data base IR class description.

IR/GERS Caveat 2 - Bounding Spectrum Caveats Apply. The transmitter and its supporting rack, when present, should meet all the caveats given for the Bounding Spectrum. This caveat is included to cover the vulnerabilities identified in the earthquake experience data base. Those GERS caveats which are the same as the Bounding Spectrum caveats are not repeated below.

IR/GERS Caveat 3 - Component is a Pressure, Temperature, Level, or Flow Transmitter. The component should be a pressure, temperature, level, or flow transmitter. These are the components included in the generic seismic test data base.

IR/GERS Caveat 4 - Specific Transmitter Models Included. There is a wide diversity of transmitter types and mechanical properties. Specific manufacturer/models were tested for function during an earthquake. The tested transmitters of the generic seismic test data base include: Foxboro E96, E13, E916; Devar 18-119; Rosemount 1151, 1152, 442; Robertshaw 161; Love 48, 54, 8100, 1106; Kepco PCX; Travis P8, P24.

This caveat may be satisfied for other models of transmitters by performing a case-by-case evaluation of similarity to one of the above models.

<u>IR/GERS Caveat 5 - Seismic Induced System Changes Should be Evaluated.</u> Transmitters are sometimes sensitive to system perturbations. The concern is that the earthquake may induce system changes (i.e., pressure, flow, and level variation) which may have the same effect on the system being controlled as if the transmitter malfunctioned. For example, a level switch used to measure the oil level in the crank case of an emergency diesel-generator (EDG) may be tripped during an earthquake when the oil is sloshing. This reading may inadvertently cause the EDG to trip off line. This caveat is also addressed in the Relay Functionality Review in Section 6.

<u>IR/GERS Caveat 6 - No Vacuum Tubes.</u> Vacuum tubes should not be used as internal electrical components. The concern is that glass tubes are especially vulnerable to earthquake damage. Glass vacuum tubes are not included in the generic seismic test data base.

<u>IR/GERS Caveat 7 - All Mounting Bolts in Place.</u> All external mounting bolts (transmitter to bracket and bracket to support) should be in place. This is the condition under which the transmitters were tested in the generic seismic test data base.

<u>IR/GERS Caveat 8 - Evaluation of Amplified Response.</u> The transmitters were tested attached directly to the shake table. Therefore realistic amplification through the rack (or other supporting structure) to the transmitter should be included when determining the amplified response of the transmitter-to-rack interface for comparison to the GERS.

<u>IR/GERS Caveat 9 - Rack Requires Separate Evaluation.</u> The transmitters were tested separately from the rack, therefore in order use the GERS capacity curves which are higher than the Bounding Spectrum, an evaluation of the rack should be made. The evaluation should show that the structural components of the rack are capable of transferring the earthquake loads to the anchorage. This evaluation may depend upon the engineering judgment of the Seismic Capability Engineers and may not require a formal calculation.

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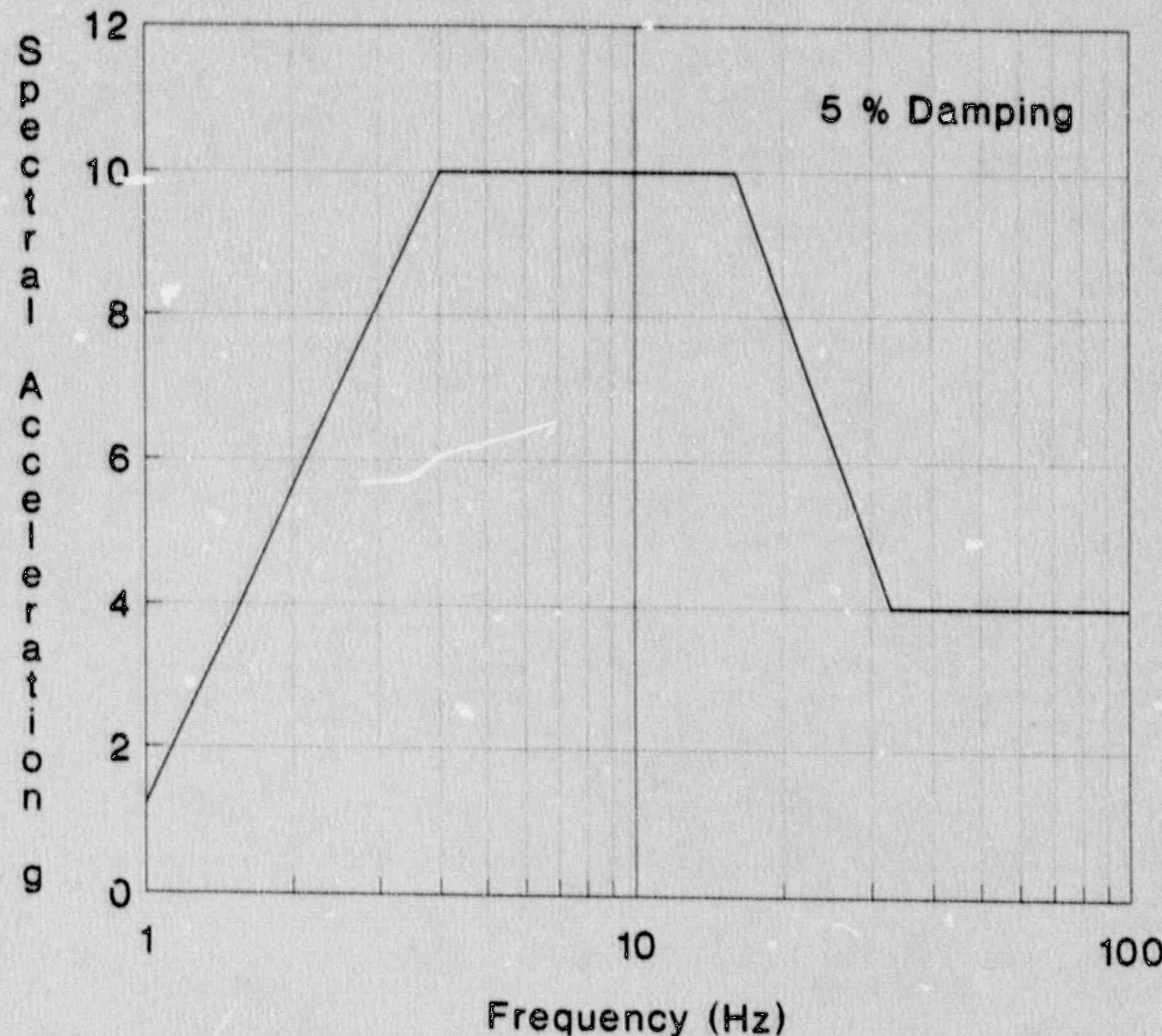


Frequency (Hz)	1	4	16	33
Transmitters (g)	1.2	10	10	4

Figure B.18-1. Generic Equipment Ruggedness Spectra (GERS) for Transmitters. (Source: Reference 6)

B.19 TEMPERATURE SENSORS

B.19.1 Bounding Spectrum - Temperature Sensors

The earthquake experience data base equipment class of Temperature Sensors (TS) includes thermocouples and resistance temperature detectors (RTDs) that measure fluid temperature and typically are mounted within or on piping or tanks. Thermocouples are probes consisting of two dissimilar metal wires routed through a protective sleeve that produce a voltage output proportional to the difference in temperature between the hot junction and the lead wires (cold junction). RTDs are similar in construction to thermocouples, but their operation is based on variation in electrical resistance with temperature. RTDs and thermocouples are connected to pressure vessel boundaries (piping, tanks, heat exchangers, etc.) using threaded joints. The sensor's sheath will often be inserted into a thermowell or outer protective tube that is permanently mounted in the pipe or tank. A thermowell allows the thermocouple or RTD to be removed without breaking the pressure boundary of the pipe or tank.

Sensors are typically linked to transmitters mounted on nearby instrument racks, which amplify the electronic signal generated in the sensors, and transmit the signal to a remote instrument readout.

The Temperature Sensors equipment class includes the connection head, threaded fitting, sheath or protective tube, thermowell, and attached wires.

The Bounding Spectrum (BS) represents the seismic capacity of a Temperature Sensor (TS) if the sensor meets the intent of the following inclusion and exclusion rules.

TS/BS Caveat 1 - Earthquake Experience Data Base. The temperature sensor should be similar to and bounded by the TS class of equipment of the earthquake experience data base. The discussion above briefly summarizes the class description of TSs in the data base.

TS/BS Caveat 2 - No Possibility of Detrimental Differential Displacement. Detrimental differential displacement between the mounting of the connection head and the mounting of the temperature sensor should not occur. The concern is that the differential displacement may cause the wiring to be pulled out of the sensor.

TS/BS Caveat 3 - Solid State Electronics. The electronics associated with the temperature sensor should be solid state (i.e., no vacuum tubes). The earthquake experience data base only applies to solid-state electronics for temperature sensors. The concern is that electronics that are not of the solid-state variety (glass tubes, etc.) are vulnerable to earthquake damage.

TS/BS Caveat 4 - Sufficient Slack and Flexibility of Attached Lines. Sufficient slack and flexibility should be present in attached lines (e.g., cooling, air, electrical) to preclude a line breach due to differential seismic displacement of the equipment and the line's nearest support. Sufficient slack and flexibility of lines is also considered in the seismic interaction review (Section 4.5).

TS/BS Caveat 5 - No Other Concerns. There should not be any other concerns with the seismic capacity of the temperature sensor. Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats.

B.19.2 GERS - Temperature Sensors

There are no GERS for Temperature Sensors.

B.20 INSTRUMENTATION AND CONTROL PANELS AND CABINETS

B.20.1 Bounding Spectrum - Instrumentation and Control Panels and Cabinets

The earthquake experience data base equipment class of Instrumentation and Control Panels and Cabinets (I&C) includes all types of electrical panels that support instrumentation and controls. This equipment class includes both the sheet metal enclosure and typical control and instrumentation components mounted on or inside the enclosure. Instrumentation and control panels and cabinets create a centralized location for the control and monitoring of electrical and mechanical systems. In addition to main control panels, local instrumentation and control panels are sometimes distributed throughout the facilities, close to the systems they serve.

Instrumentation and control panels and cabinets have a wide diversity of sizes, types, functions, and components. Panel and cabinet structures generally consist of a steel frame supporting sheet metal panels to which instrumentation and control components are bolted or clamped. Cabinet structures range from a single panel, braced against or built into a wall, to a freestanding cabinet enclosure. Enclosures are generally categorized as either switchboards or benchboards, described as follows.

A vertical switchboard is a single reinforced sheet metal instrument panel, which is either braced against an adjacent wall or built into it. An enclosed switchboard is a freestanding enclosed sheet metal cabinet with components mounted on the front face, and possibly on the interior walls. The front or rear panel is usually hinged as a single or double swinging door to allow access to the interior. A dual switchboard consists of two vertical panels braced against each other to form a freestanding structure, with components mounted to both front and rear panels. The sides are usually open, and the two panels are joined by cross members spanning between their tops. A duplex switchboard is similar to a dual switchboard, except that it consists of a panel fully enclosed by sheet metal on all sides, with access through doors in the two side panels.

A control desk has components mounted on the desk top, and interior access through swinging doors in the rear. A benchboard consists of a control desk with an attached vertical panel. The single panel is similar to a vertical switchboard and is normally braced against or built into a wall. A dual benchboard is similar to a dual switchboard, but the lower half of the front panel is a desk console. A duplex benchboard is similar to a duplex switchboard, a totally enclosed panel, but with a desk console in the lower half of the front panel.

Panel and cabinet enclosures normally consist of steel angles, channels, or square tubes welded together, with sheet metal siding attached by spot welds. Large panels are typically made of individual sections bolted together through adjoining framing. The cabinet may or may not include a sheet metal floor or ceiling.

Electronic or pneumatic instrumentation or control devices attached to sheet metal panels or within sheet metal cabinets are included in the equipment class. The Instrumentation and Control Panels and Cabinets equipment class includes the sheet metal enclosure, switches, push buttons, panel lights, indicators, annunciators, gauges, meters, recorders, rela (provided they meet relay requirements), controllers, solid-state circu boards, power supplies, tubing, wiring, and terminal blocks.

The Bounding Spectrum (BS) represents the seismic capacity of Instrumentation and Control Panels and Cabinets (I&C) if the panel or cabinet meets the intent of the following inclusion and exclusion rules.

I&C/BS Caveat 1 - Earthquake Experience Data Base. The panel or cabinet should be similar to and bounded by the I&C class of equipment of the earthquake experience data base. The discussion above briefly summarizes the class description of I&Cs in the data base.

I&C/BS Caveat 2 - Evaluate Computers and Programmable Controllers Separately. Computers and programmable controllers should be evaluated separately. The concern is that the subclass of computers and programmable controllers is so diverse that they may not be adequately represented by the experience data base. Computers and programmable controllers should therefore be evaluated on a case-by-case basis.

I&C/BS Caveat 3 - Evaluate Strip Chart Recorders Separately. Strip chart recorders should be evaluated separately. The concern is that long, narrow recorders which are cantilevered off the panel may not have adequate structural support. Strip chart recorders are commonly supported on compression-type mounting brackets supplied by the manufacturer. These types of support brackets are inherently rugged and generally adequate for transfer of seismic loads. If there are no support brackets, or the support system appears to be a custom design, or the Seismic Capability Engineers have any concerns regarding the adequacy of the bracket, then the support system should be subject to further evaluation.

I&C/BS Caveat 4 - Structural Adequacy. The steel frame and sheet metal should be evaluated for adequacy. Engineering judgment may be used to determine that an adequate load path exists to transfer the lateral earthquake loads to the foundation.

I&C/BS Caveat 5 - Adjacent Cabinets or Panels Bolted Together. Adjacent cabinets or panels which are close enough to impact each other and sections of multi-bay assemblies should be bolted together if any of these assemblies contain essential relays. The concern addressed in this caveat is that unbolted cabinets or panels could respond out of phase to one another and impact each other during an earthquake. This would cause additional impact loadings and high frequency vibration loadings which could cause any essential relays to chatter.

<u>I&C/BS Caveat 6 - Drawers or Equipment on Slides Restrained.</u> Drawers or equipment on slides should be restrained to prevent them from falling out during seismic motion. The concern is that the components in the drawer could slide and become damaged, or slide out and fall onto some other fragile essential component in the vicinity. A latch or fastener should secure these sliding components.

<u>I&C/BS Caveat 7 - Doors Secured.</u> All doors should be secured by a latch or fastener. The concern addressed by this caveat is that loose doors could repeatedly impact the housing and be damaged or cause internal components such as relays to malfunction or chatter.

<u>I&C/BS Caveat 8 - Sufficient Slack and Flexibility of Attached Lines.</u> Sufficient slack and flexibility should be present in attached lines (e.g., cooling, air, electrical) to preclude a line breach due to differential seismic displacement of the equipment and the line's nearest support. Sufficient slack and flexibility of lines is also considered in the seismic interaction review (Section 4.5).

<u>I&C/BS Caveat 9 - Adequate Anchorage.</u> The unit should be properly anchored in accordance with the guidelines of Section 4.4.

<u>I&C/BS Caveat 10 - Potential Chatter of Essential Relays Evaluated.</u> If relays are mounted on the equipment, a relay functionality review in accordance with Section 6 should be performed.

<u>I&C/BS Caveat 11 - No Other Concerns.</u> There should not be any other concerns with the seismic capacity of the cabinet or panel. Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats.

B.20.2 GERS - Instrumentation and Control Panels and Cabinets

There are no GERS for Instrumentation and Control Panels and Cabinets.

Appendix C

ANCHORAGE DATA

CONTENTS

CONTENTS (Continued)

Appendix C

ANCHORAGE DATA

INTRODUCTION

The purpose of this appendix is to:

- Provide generic information on the various equipment classes for use in anchorage evaluations,
- Provide nominal allowable capacities for certain types of anchors, and
- Describe anchor-specific inspection checks and capacity reduction factors.

A general description of the anchorage evaluation procedure is included in Section 4.4. Only those specific inspection checks or evaluations which apply to a particular type of anchor are described in this appendix.

This appendix is organized with the generic equipment characteristics for anchorage evaluations given first and the remaining information grouped by anchor type as follows:

C.1 Generic Equipment Characteristics for Anchorage Evaluations

C.2 Expansion Anchors - Shell and Nonshell Types

C.3 Cast-In-Place Bolts and Headed Studs

C.4 Cast-In-Place J-Bolts

C.5 Grouted-In-Place Bolts

C.6. Welds to Embedded or Exposed Steel

The first section in this appendix contains generic equipment characteristics for anchorage evaluations for use when equipment-specific data is not available for equipment mass, natural frequency, or damping.

The remaining sections of this appendix contain a table of nominal allowable load capacities along with anchor-specific inspections which should be performed. In some cases a capacity reduction factor is given which may be used to lower the nominal allowable load capacities if the inspection check reveals that the installation does not meet the minimum guidelines.

The material in this appendix is based on the information contained in Reference 7.

Note: The Seismic Capability Engineers should not use the material contained in this appendix unless they have thoroughly reviewed and understand Reference 7.

C.1 GENERIC EQUIPMENT CHARACTERISTICS FOR ANCHORAGE EVALUATIONS

This section of the appendix contains estimates of equipment mass, natural frequency, and damping for various classes of equipment for anchorage evaluations. These generic characteristics may be used during anchorage evaluations in place of equipment-specific data. These generic characteristics are typically conservative; i.e., they result in larger than actual loadings on the anchorages. However, for unusual items of equipment, an independent check should be made of the reasonableness of the values contained in Table C.1-1.

The equipment mass contained in Table C.1-1 is based on the heaviest item found in each of the classes covered during a survey of equipment.

Equipment natural frequency is given a relative rigidity of either rigid or flexible in Table C.1-1. Equipment with natural frequencies greater than about 20 Hz are considered rigid. Equipment with natural frequencies below about 20 Hz are considered flexible. [Note that the "rigid" and "flexible" categories of equipment in Table C.1-1 apply only to anchorage evaluations. These categories are different than the 8 Hz natural frequency limitation discussed in Section 4.2 and Table 4-1. The 8 Hz limitation applies to comparison of equipment seismic capacity to ground response spectra.]

The relative rigidities given in Table C.1-1 are for "typical" equipment in nuclear power plants. These generic categories of rigid or flexible should be checked when performing the seismic evaluation, noting particularly the rigidity or flexibility of the base support system for the equipment and the rigidity of the anchorage itself. In particular, the estimate for natural frequency of equipment secured with expansion anchors should take into account the potential for shippage of these types of anchors. This would be necessa[illegible]r example, when natural frequency estimates of equipment secure[illegible]th expansion anchors are based on analytical models which used fixed anchor points or when shake table test results are used in which the equipment was welded to the table.

For rigid equipment, the seismic demand on the equipment can be determined by using the Zero Period Acceleration (ZPA) of the appropriate floor response spectrum. For flexible equipment, the peak of the floor response spectrum (for the damping value given in Table C.1-1) should be used.

Table C.1-1

GENERIC EQUIPMENT CHARACTERISTICS FOR ANCHORAGE EVALUATIONS

Equipment Class Number and Name	Typical Maximum Mass		Typical Natural Frequency[2] and Damping
#1 Motor Control Centers	625 lb per cabinet		Flexible 5% Damping
#2 Low Voltage Switchgear	35 lb/ft^3		Flexible 5% Damping
#3 Medium Voltage Switchgear[1]	31 lb/ft^3		Flexible 5% Damping
#4 Transformers	Rating (KVA)	Mass (lb)	Flexible 5% Damping
	3,000	15,000	
	2,500	11,050	
	2,000	9,400	
	1,000	6,300	
	100	975	
#5 Horizontal Pumps with Motors	Power (HP)	Mass (lb)	Rigid 5% Damping[3]
	1,000	20,000	
	600	16,500	
	500	12,000	
	400	8,600	
	200	6,000	
	100	3,600	

1 Medium voltage switchgear are called "Metal-Clad Switchgear" in Reference 7.

2 Natural frequencies are given as either Rigid (> about 20 Hz) or Flexible (< about 20 Hz) and apply only to anchorage evaluations. (Note that the 8 Hz natural frequency limitation discussed in Section 4.2 applies to comparison of equipment seismic capacity to ground response spectra.)

3 A damping valve of 5% can be used for rigid equipment since the seismic accelerations can be taken from the ZPA which is not affected significantly by damping level.

Table C.1-1 (Lont'd)

GENERIC EQUIPMENT CHARACTERISTICS FOR ANCHORAGE EVALUATIONS

Equipment Class Number and Name	Typical Maximum Mass		Typical Natural Frequency[2] and Damping
#6 Vertical Pumps with Motors	Power (HP)	Mass (lb)	
a. Vertical Immersion	150	4,[illegible]	Flexible 3% Damping
b. Centrifugal	500	9,000	Rigid 5% Damping[3]
	2,000	48,000	
c. Deep-Well	500	9,000 (motor)	Flexible 3% Damping
		14,000 (pump)	
#12 Air Compressors	Power (HP)	Mass (lb)	
	50	4,000	Rigid 5% Damping[3]
	200	10,000	
#13 Motor-Generators	(Not Available)		Rigid 5% Damping[3]
#15 Batteries on Racks	$0.11\ lb/in^3$ for batteries, plus weight of racks		Flexible 5% Damping
#16 Battery Chargers and Inverters	$45\ lb/ft^3$		Flexible 5% Damping
#17 Engine-Generators	(Not Available)		Rigid 5% Damping[3]
#18 Instrument Racks	$20\ lb/ft^2$ of vertical face		Flexible 3% Damping
#14 & #20 Generic Equipment Cabinets	3 times the weight of cabinet housing		Flexible 5% Damping
#14 & #20 Walk-Through Control Panels	Determine and use weight per foot of length		Flexible 5% Damping

C.2 EXPANSION ANCHORS

The topics covered in this section of the appendix for expansion anchors are as follows. The subsection number of each of these topics is also given.

The specific checks described in this section should be performed in conjunction with the generic anchorage installation inspection checks described in Section 4.4.1. (See Table 4-2 for the checks which are applicable for this anchor type.)

The nominal allowable capacities and capacity reduction factors provided in this section should be used in the anchorage capacity equations given in Section 4.4.2.

C.2.1 Nominal Allowable Capacities

The nominal allowable load capacities which can be used for the types of expansion anchors covered by this procedure (i.e., those listed in Table C.2-2) are given in Table C.2-1 below.

Table C.2-1

NOMINAL ALLOWABLE CAPACITIES
FOR EXPANSION ANCHORS
($f'_c \geq 4000$ psi for pullout and $f'_c \geq 3500$ psi for shear)[1]

Bolt/Stud Diameter (D, in.)	Pullout Capacity (P_{nom}, kip)	Shear Capacity (V_{nom}, kip)	Minimum Embedment[2] (L_{min}, in.)	Minimum Spacing[3] (S_{min}, in.)	Min. Edge Distance[3] (E_{min}, in.)
3/8	1.46	1.42	2.16	3.75	3.75
1/2	2.29	2.38	2.81	5.00	5.00
5/8	3.17	3.79	3.31	6.25	6.25
3/4	4.69	5.48	4.25	7.50	7.50
7/8	6.09	7.70	4.72	8.75	8.75
1	6.95	9.53	5.56	10.00	10.00

---

1 The pullout and shear capacities shown here are for the expansion anchor types included in Section C.2.2 installed in the sound, uncracked concrete (i.e., no cracks passing through the anchor bolt installation) with a compressive strength (f'_c) of at least 4000 psi for pullout and 3500 psi for shear.

2 These are the largest minimum embedments for all makes and models of expansion anchors covered by this procedure. The minimum embedments shown in Section C.2.4, for specific makes and models of expansion anchors, may be used in place of the minimum embedment given above.

3 Minimum spacings and edge distances are measured from bolt center to bolt center. Smaller spacings and edge distances less than the minimums given here can be used with the reduction factors given in Sections C.2.5 and C.2.6.

C.2.2 Check for Anchor Type

The specific manufacturers and product names of expansion anchors covered by this procedure are listed in Table C.2-2 below. This table also lists capacity reduction factors (RT_p for pullout and RT_s for shear) which should be multiplied by the nominal pullout and shear capacities (P_{nom}, V_{nom}) given in Table C.2-1 to obtain the allowable pullout and shear capacities (P_{all}, V_{all}) as follows:

$$P_{all} = P_{nom}\,RT_p$$
$$V_{all} = V_{nom}\,RT_s$$

Note that, generally, expansion anchors should not be used for securing vibratory equipment such as pumps and air compressors. If such equipment is secured with expansion anchors, then there should be a large margin between the pullout loads and the pullout capacities; i.e., the loads on these expansion anchors should be primarily shear.

The principal differences between shell- and nonshell-type expansion anchors are explained below.

Shell-type expansion anchors are expanded into the concrete by application of a setting force independent of the load later applied to the bolt or nut by the equipment being anchored. The key feature of this type of expansion anchor is that it relies upon its initial preset for holding it in place. Figure C.2-1 shows the features of several types of shell-type expansion anchors.

Figure C.2-1a shows a "Self-Drilling Type" of shell-type expansion anchor. This type of anchor is set in place by driving the shell down over the cone expander which is resting against the bottom of the hole.

Table C.2-2

TYPE OF EXPANSION ANCHORS
COVERED BY THIS PROCEDURE AND
ASSOCIATED CAPACITY REDUCTION FACTORS

Manufacturer	Product Name	Type	Capacity Reduction Factors (RT_p, RT_s)
Hilti	Kwik-Bolt	Nonshell	1.0
	HDI	Shell	1.0
	Sleeve	Nonshell	0.6
ITW/Ramset	Dynaset	Shell	1.0
	Dynabolt	Nonshell	1.0
	Trubolt	Nonshell	0.75
ITW/Ramset/ Redhead	Multiset Drop-In	Shell	1.0
	Self Drilling	Shell	1.0
	Dynabolt Sleeve	Nonshell	1.0
	Nondrill	Shell	1.0
	Stud	Shell	0.75
	TRUBOLT	Nonshell	0.75
Molly	Parasleeve	Nonshell	1.0
	MDI	Shell	1.0
	Parabolt	Nonshell	0.75
Phillips	Self-Drilling	Shell	1.0
	Wedge	Nonshell	1.0
	Sleeve	Nonshell	1.0
	Multi-Set	Shell	1.0
	Stud	Shell	1.0
	Non-Drilling	Shell	1.0
Rawl	Drop-In	Shell	1.0
	Stud	Shell	0.75
	Saber-Tooth	Shell	0.75
	Bolt	Nonshell	0.75
Star	Selfdrill	Shell	0.75
	Steel	Shell	0.6
	Stud	Shell	0.6
USE Diamond	Sup-R-Drop	Shell	1.0
	Sup-R-Stud	Shell	1.0
	Sup-R-Sleeve	Nonshell	1.0
	Sup-R-Drill	Shell	0.75
WEJ-IT	Drop-In	Shell	1.0
	Sleeve	Nonshell	1.0
	Wedge	Nonshell	0.75
	Stud	Shell	0.6

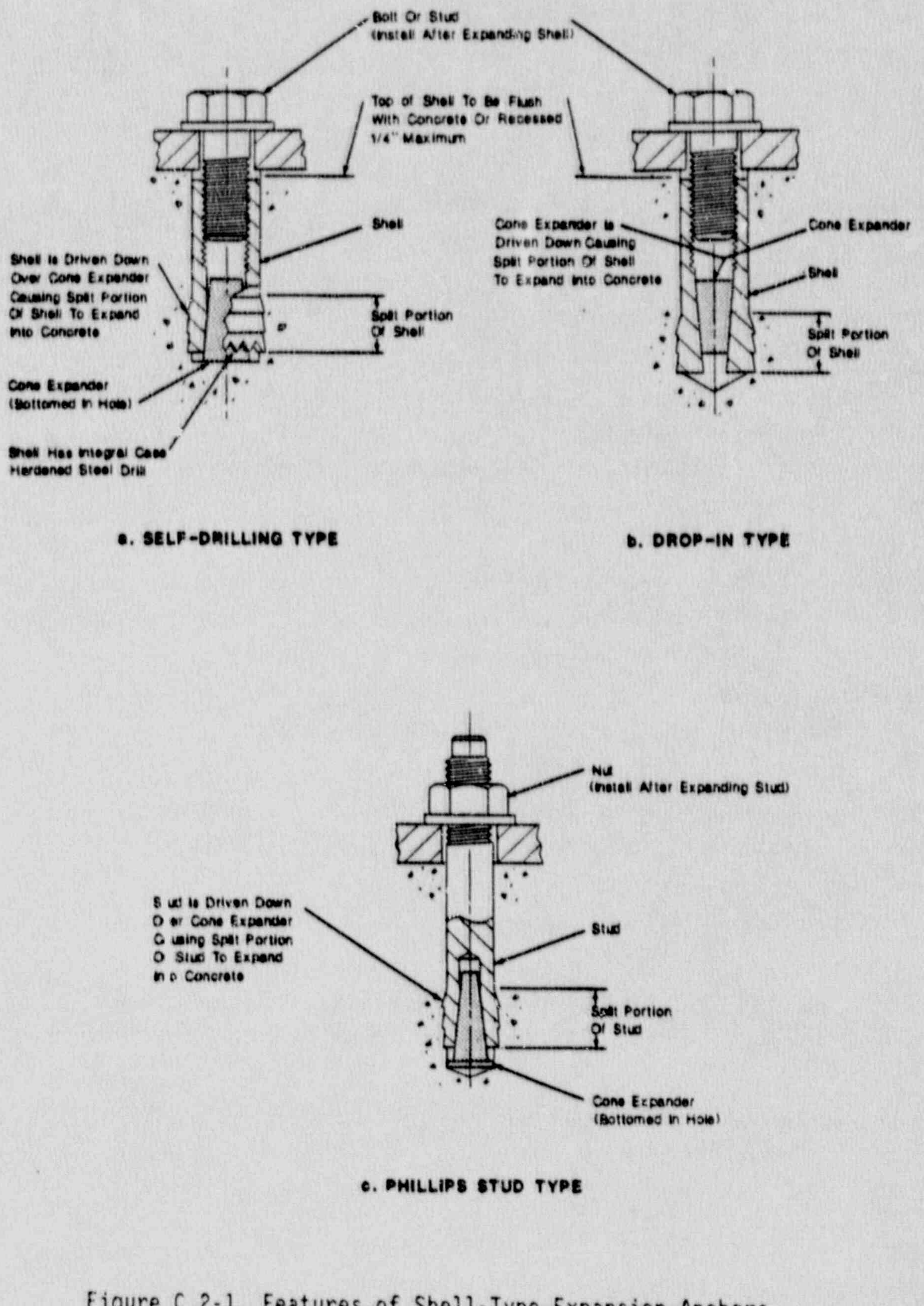


Figure C.2-1. Features of Shell-Type Expansion Anchors.
(Source: Reference 7)

Figure C.2-1b shows a "Drop-In Type" which is set in place by driving a cone expander down through the center of the shell thereby causing the lower portion of the shell to expand into the concrete.

Figure C.2-1c shows a "Phillips Stud Type" which is set in place by driving the stud down over the cone expander which is resting against the bottom of the hole.

<u>Nonshell-type</u> expansion anchors are expanded into the concrete by pulling the stud up out of the hole which causes a sleeve or a split ring to be forced into the concrete. The key feature of this type of expansion anchor is that the more the stud is loaded in tension, the greater the expansion setting force becomes. Figure C.2-2 shows the features of two types of nonshell-type expansion anchors.

Figure C.2-2a shows a "Sleeve Type" which is set in place by pulling the stud, with its integral cone expander on the bottom, up into the sleeve thereby forcing the lower split portion of the sleeve into the concrete. The sleeve is held in place during this setting process by butting up against the lower surface of the washer.

Figure C.2-2b shows a "Wedge Type" which is set in place by pulling the stud, with its integral cone expander on the bottom, up though a split ring. Note that the split ring relies on friction against the concrete to stay in place during the setting operation.

<u>Distinguishing characteristics</u> of shell- and nonshell-type expansion anchors in their <u>as-installed</u> condition are shown in Figure C.2-3.

Figure C.2-3a shows a nonshell-type expansion anchor in which the visible portion is characterized by a smoothly cut or mechanically finished threaded stud with a nut holding the base of the equipment in place.

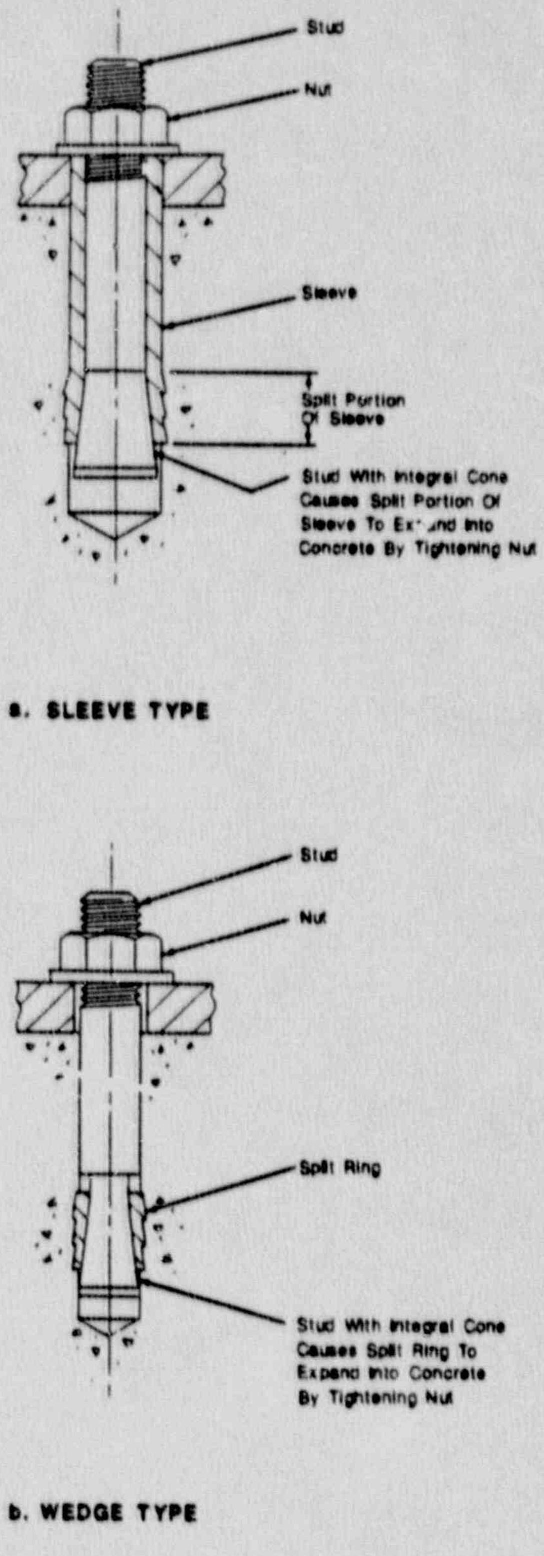


Figure C.2-2. Features of Nonshell-Type Expansion Anchors. (Source: Reference 7)

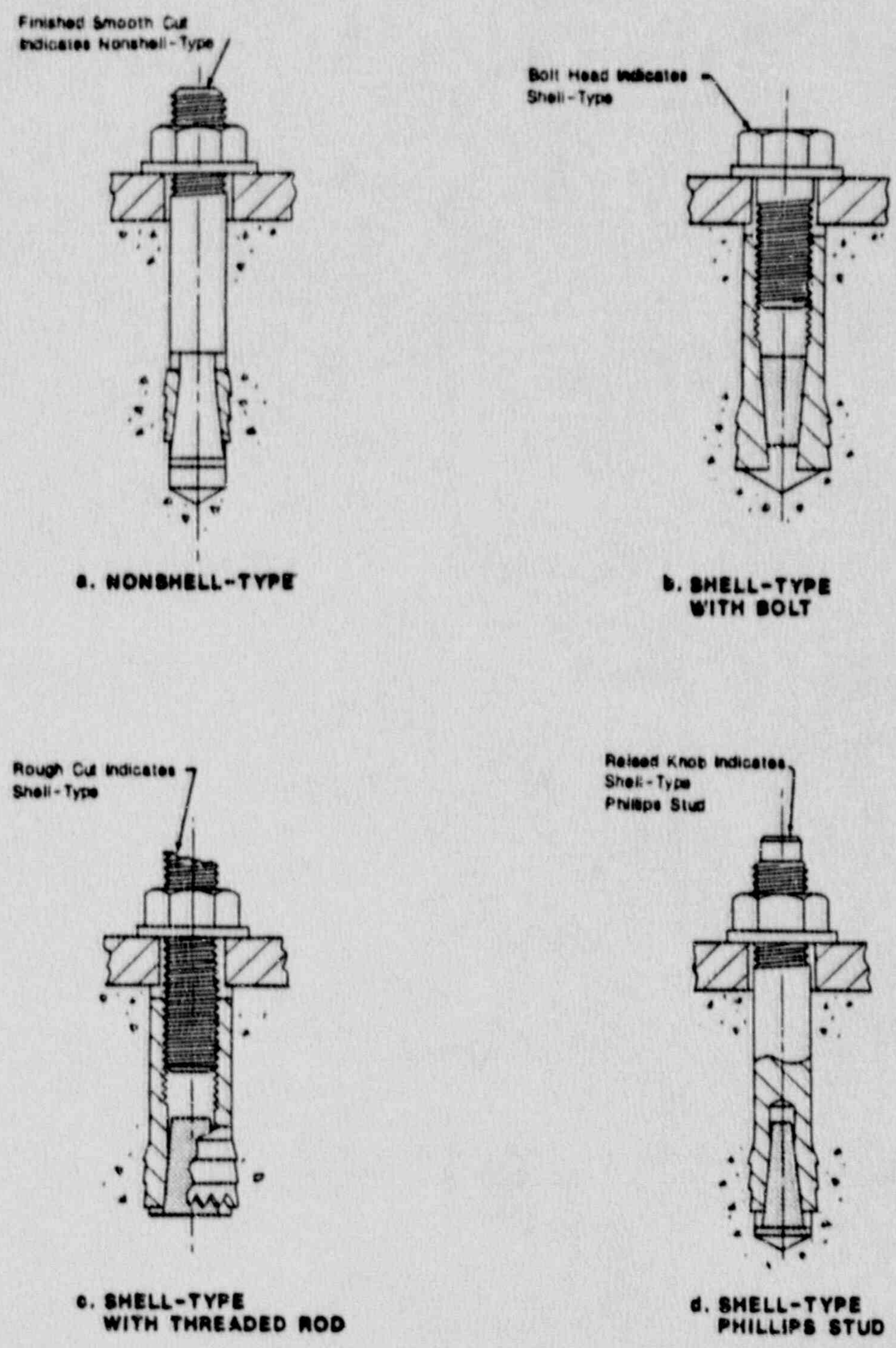


Figure C.2-3. Distinguishing Characteristics of Installed Shell- and Nonshell-Type Expansion Anchors. (Source: Reference 7)

Figure C.2-3b shows the most common type of shell-type expansion anchor in which the visible portion is characterized by a head of a bolt.

Figures C.2-3c and C.2-3d show other types of shell-type expansion anchors in which the visible portion is characterized by a rough cut or a raised knob on the end of the threaded rod. Careful inspection is necessary to distinguish these two types of shell expansion anchors from the nonshell-type shown in Figure C.2-3a.

C.2.3 Tightness Check

(Note: This inspection check is not needed if the Reduced Inspection Alternative is chosen, as described in Section C.2.10.)

The tightness check can be performed by using a standard size box or open-end wrench on the bolt head or nut and applying a torque by hand until the bolt or nut is "wrench tight"; i.e., tightened without excessive exertion. For those cases where specific torque values must be used (e.g., for maintenance work orders), the "Tightness Check Torque" values given in Table C.2-3, below, can be used for this expansion anchor tightness check. These values correspond to about 20% of the normal installation torques.

Table C.2-3

RECOMMENDED TORQUE VALUES FOR
EXPANSION ANCHOR TIGHTNESS CHECK

Anchor Diameter (in.)	Installation Torque (ft-lbs)	Tightness Check Torque (ft-lbs)
3/8	25-35	5-7
1/2	45-65	9-13
5/8	80-90	16-18
3/4	125-175	25-35
7/8	200-250	40-50
1	250-300	50-60

A well-installed expansion anchor should not rotate under this applied torque. A small amount of initial rotation (about 1/4 turn) is acceptable provided the nut or bolt will tighten and resist the applied torque. If a bolt turns more than about 1/4 turn, but does eventually resist the torque, it should be re-torqued to the manufacturer's recommended installation torque and then considered acceptable.

A sampling program can be used to check the tightness of expansion anchors provided it achieves 95% confidence that no more than 5% of the expansion anchors fail to meet the tightness guidelines given above. This 95/5 criterion can be met using the guidelines given below for sample size, homogeneous population, allowable number of nonconforming anchors, and use of initial tightness test results.

- <u>Sample Size</u>. The number of expansion anchors selected for tightness checking should be at least as large as given in Table C.2-4 below for "Sample Size".

Table C.2-4

SAMPLE SIZE FOR
EXPANSION ANCHOR TIGHTNESS CHECK

Condition	Sample Size
Expansion Anchors Securing Equipment Which Contains Essential Relays	100%
Total Size of Homogeneous Anchor Population Is Less Than 40 Anchors	100%
Total Size of Homogeneous Anchor Population Is Between 40 and 160 Anchors	40 Anchors
Total Size of Homogeneous Anchor Population Is More Than 160 Anchors	25%

- Homogeneous Population. The sample size is based on the total population of expansion anchors being homogeneous. Factors such as installation specifications, quality assurance procedures used in the installation specifications, quality assurance procedures used during installation, bolt manufacturer, installation contractor, etc., should be considered when judging whether or not the total population is homogeneous. If there is more than one homogeneous set of expansion anchors, then the sample size limitations given above and the allowable number of nonconforming anchors given below apply to each individual population.

- Allowable Number of Nonconforming Anchors. The criterion of 95% confidence that there are no more than 5% nonconforming anchors can be met if the number of expansion anchors which fails the tightness check does not exceed the limitations given in Table C.2-5 below. If more than these number of anchors fail the tightness check, then the sample size should be increased until the failure rate does not exceed the limitations in this table.

- Use of Initial Tightness Test Results. The results of the initial torque tightness check on each expansion anchor should be used to establish the failure rate for the purposes of the sampling program. For example, if out of a total population of 400 expansion anchors 100 were tightness checked and 4 of these failed the initial check, then the sample size should be expanded. (Table C.2-5 only allows 3 anchors to fail for 100 tests on a population of 400.) The sample size should be expanded even if all 4 of the failed anchors were able to be fully tightened up to their installation torque requirements.

Table C.2-5

ALLOWABLE NUMBER OF EXPANSION ANCHORS
WHICH NEED NOT PASS TIGHTNESS CHECK

Total Population Size (N)	Number of Anchors Which Need Not Pass Tightness Check for Test Sample Size, (n):											
	40	60	80	100	150	200	250	300	350	400	450	500
100	1	2	3	5	--	--	--	--	--	--	--	--
200	N/A	1	2	3	6	10	--	--	--	--	--	--
300	N/A	N/A	2	3	5	7	10	15	--	--	--	--
400	N/A	N/A	N/A	3	5	7	9	12	15	20	--	--
500	N/A	N/A	N/A	N/A	5	7	9	12	14	17	20	25
600	N/A	N/A	N/A	N/A	5	7	9	11	14	16	19	22
700	N/A	N/A	N/A	N/A	N/A	7	9	11	13	16	18	21
800	N/A	N/A	N/A	N/A	N/A	6	9	11	13	16	18	21
900	N/A	N/A	N/A	N/A	N/A	N/A	8	11	13	15	18	20
1000	N/A	N/A	N/A	N/A	N/A	N/A	8	11	13	15	17	20

If certain expansion anchors are not accessible due to such things as high radiation, concrete poured over the anchorages, equipment disassembly or removal being required, etc., then other methods may be used to assess the tightness of the expansion anchors as follows:

- Use the Reduced Inspection Alternative (Section C.2.10) to verify the anchorage adequacy (the reduced inspection does not require a tightness check).
- Delay the tightness checks until a later refueling outage when radiation hazards are less.
- Use engineering judgment to assess the anchorage adequacy based on other considerations, e.g., tightness checks on similar anchors elsewhere in the plant which show that installation practices produced consistently tight installation. This method should be used as a last resort. The basis for the engineering judgment should be documented.

C.2.4 Embedment Check

(Note: This inspection check is not needed if the Reduced Inspection Alternative is chosen, as described in Section C.2.10.)

The manufacturer's recommended minimum embedments are listed in Table C.2-6 below.

Table C.2-6

MANUFACTURER'S RECOMMENDED MINIMUM EMBEDMENT FOR EXPANSION ANCHORS COVERED BY THIS PROCEDURE

Manufacturer	Product Name (S=Shell, N=Nonshell)	Minimum Embedment (L) [in.] for Bolt/Stud Diameter: 3/8"	1/2"	5/8"	3/4"	7/8"	1"
Hilti	Kwik-Bolt (N)	1.50	2.25	2.75	3.25	--	4.50
	HDI (S)	1.75	2.00	2.53	3.19	--	--
	Sleeve (N)	1.50	2.00	2.00	--	--	--
ITW/Ramset	Dynaset (S)	1.63	2.00	2.63	3.25	--	--
	Dynabolt (N)	2.00	2.25	2.25	--	--	--
	Trubolt (N)	1.50	2.25	2.75	3.38	4.00	4.50
ITW/Ramset/ Redhead	Multiset Drop-In (S)	1.63	2.00	2.50	3.19	--	--
	Self Drilling (S)	1.53	2.03	2.47	3.25	--	--
	Dynabolt Sleeve (N)	1.88	2.00	2.25	--	--	--
	Nondrill (S)	1.56	2.06	2.56	3.19	--	--
	Stud (S)	1.63	1.88	2.38	2.88	--	--
	TRUBOLT (N)	1.50	2.25	2.75	3.25	3.75	4.50
Molly	Parasleeve (N)	1.25	1.50	2.00	2.00	--	--
	MDI (S)	1.56	2.00	2.50	3.19	--	--
	Parabolt (N)	1.50	2.25	2.75	3.25	4.00	4.50

Table C.2-6 (Continued)

MANUFACTURER'S RECOMMENDED MINIMUM EMBEDMENT
FOR EXPANSION ANCHORS COVERED BY THIS PROCEDURE

Manufacturer	Product Name (S=Shell, N=Nonshell)	Minimum Embedment (L) [in.] for Bolt/Stud Diameter: 3/8"	1/2"	5/8"	3/4"	7/8"	1"
Phillips	Self-Drilling (S)	1.53	2.03	2.47	3.25	3.69	--
	Wedge (N)	1.75	2.13	2.63	3.25	3.75	4.50
	Sleeve (N)	1.88	2.00	2.25	--	--	--
	Multi-Set (S)	1.38	1.75	2.25	2.50	--	--
	Stud (S)	1.63	1.88	2.38	2.88	--	--
	Non-Drilling (S)	1.56	2.06	2.56	3.19	--	--
Rawl	Drop-In (S)	1.88	2.38	3.00	3.50	--	--
	Stud (S)	1.75	2.25	2.88	3.38	4.00	4.50
	Saber-Tooth (S)	1.53	2.03	2.47	3.25	3.69	--
	Bolt (N)	2.00	2.50	2.75	3.00	--	--
Star	Selfdrill (S)	1.53	2.03	2.47	3.25	3.69	--
	Steel (S)	1.44	1.94	2.38	3.00	--	--
	Stud (S)	1.63	1.75	2.38	2.88	--	--
USE Diamond	Sup-R-Drop (S)	1.56	2.00	2.53	3.19	--	--
	Sup-R-Stud (S)	2.16	2.81	3.31	4.25	4.72	5.56
	Sup-R-Sleeve (N)	1.25	1.50	2.00	2.00	--	--
	Sup-R-Drill (S)	1.53	2.03	2.47	3.27	--	--
WEJ-IT	Drop-In (S)	1.63	2.00	2.50	3.25	--	--
	Sleeve (N)	1.50	1.88	2.00	2.25	--	--
	Wedge (N)	1.50	2.00	3.00	3.00	4.50	5.50
	Stud (S)	1.75	2.13	2.63	3.25	--	4.50
Largest of the Minimum Embedments Given Above:		2.16	2.81	3.31	4.25	4.72	5.56

These minimum embedments can be verified by performing the following inspection checks for shell- and nonshell-type expansion anchors. Note that these checks should be performed <u>after</u> the tightness check (described in Section C.2.3) has been performed.

Shell-Type Expansion Anchors. The embedment length of shell-type expansion anchors is predetermined by the length of the shell and how it is installed in the concrete. The appropriate shell length is assured if the expansion anchor is one of the types listed in Table C.2-6. An appropriate installation is assured if the shell of these anchors does not protrude above the surface of the concrete.

When making this embedment check, a check should also be made (as described in Section 4.4.1, Check #4) to confirm that the top of the shell is not touching the bottom of the base plate of the item of equipment being anchored. This check should be performed after the tightness check has been done. This will assure that the expansion anchor is tight in the hole and not just tight up against the base of the equipment.

If it is necessary to remove the bolt or nut from the anchorage to make the above two checks, then it is only necessary to spot check the embedment of a few anchors. If this spot check indicates that these types of bolts may not be properly installed, then this inspection check should be expanded accordingly. When re-installing the anchor, it should be re-tightened to a "wrench tight" condition or to the recommended tightness check torque values using the guidelines given in Section C.2.3 above.

Nonshell-Type Expansion Anchors. The embedment length of nonshell-type expansion anchors is predetermined by the length of the stud and the installation of the anchor. The appropriate overall length of nonshell studs is dependent upon the manufacturer, the model, and the thickness of the equipment base plate for which the anchor is designed. Table C.2-7, below, can be used as a generic screen for assessing whether a nonshell expansion anchor has adequate embedment. This table lists a range of maximum stud projections above the surface of the concrete for the makes and product names of nonshell expansion anchors listed in Table C.2-2. A range of projections is given in Table C.2-7 since there are differences in acceptable projections depending upon the make and model of the anchor. If a nonshell stud projects more than the lower value of this range, then anchor-specific information should be used to determine the embedment length of the anchor.

Table C.2-7

MAXIMUM STUD PROJECTIONS ABOVE CONCRETE
FOR NONSHELL-TYPE EXPANSION ANCHORS

Stud Diameter (in.)	Maximum Stud Projections Above Concrete (in.)
3/8	1/2 - 3/4
1/2	1/2 - 3/4
5/8	1/2 - 7/8
3/4	7/8 - 1-1/2
7/8	1-1/2 - 3-1/2
1	1-1/2 - 3-1/2

Note that some judgment is needed when checking the projections since larger projections than those given above may be needed if the base plate is relatively thick. Thus, while this check need only be visual, careful judgment should be made in determining whether the stud projection is reasonable, given the bolt diameter and base plate thickness. One other way to check embedment length is to use ultrasonic inspection techniques and compare the measured bolt/stud length to the manufacturer's recommended minimum embedment given in Table C.2-6.

This embedment check should be performed on wedge- and sleeve-type, nonshell expansion anchors <u>after</u> the tightness check has been done as described in Section C.2.3. This is to ensure that the tightness check does not pull the expansion anchor partially out of the hole beyond the required minimum embedment.

For bolts with deeper embedments than the minimum values given in Table C.2-6, manufacturer's catalog data may be used, if it is available, to establish the nominal allowable capacities instead of those given in Table C.2-1. As an alternative, plant specific testing may be performed to establish the strength of the more deeply embedded expansion anchors.

C.2.5 Spacing Check

If the spacing (S) between an expansion anchor and another anchor is less than the minimum value (S_{min}) given in Table C.2-1, then a pullout capacity reduction factor (RS_p) and a shear capacity reduction factor (RS_s) should be multiplied by the nominal pullout and shear capacities (P_{nom}, V_{nom}) given in Table C.2-1 to obtain the allowable pullout and shear capacities (P_{all}, V_{all}) as follows:

$$P_{all} = P_{nom} \, RS_p$$

$$V_{all} = V_{nom} \, RS_s$$

Where:

P_{all} = Allowable pullout capacity of anchor

P_{nom} = Nominal pullout capacity of anchor from Table C.2-1

V_{all} = Allowable shear capacity of anchor

V_{nom} = Nominal shear capacity of anchor from Table C.2-1

RS_p = Pullout capacity reduction factor for closely spaced expansion anchors

$= 1.0 \qquad \text{for } S \geq 10D$

$= \dfrac{S}{10} \qquad \text{for } 10D > S \geq 5D$

$= 0.5 \qquad \text{for } S < 5D$

RS_s = Shear capacity reduction factor for closely spaced expansion anchors

= 1.0 for $S \geq 2D$

= 0.5 for $S < 2D$

A reduction factor should be applied for each nearby anchor, whether it is another expansion anchor or a different type of anchor. The spacings (S) given above are defined in terms of multiples of the anchor bolt/stud diameter (D), measured from anchor centerline to centerline.

C.2.6 Edge Distance Check

If the distance (E) from an expansion anchor to a free edge of concrete is less than the minimum value (E_{min}) given in Table C.2-1, then a pullout capacity reduction factor (RE_p) and a shear capacity reduction factor (RE_s) should be multiplied by the nominal pullout and shear capacities (P_{nom}, V_{nom}) given in Table C.2-1 to obtain the allowable pullout and shear capacities (P_{all}, V_{all}) as follows:

$$P_{all} = P_{nom}\, RE_p$$

$$V_{all} = V_{nom}\, RE_s$$

Where:

P_{all} = Allowable pullout capacity of anchor

P_{nom} = Nominal pullout capacity of anchor from Table C.2-1

V_{all} = Allowable shear capacity of anchor

V_{nom} = Nominal shear capacity of anchor from Table C.2-1

RE_p = Pullout capacity reduction factor for near edge expansion anchors

= 1.0 for $E \geq 10D$

$$= \frac{E}{10} \qquad \text{for } 10D > E \geq 2D$$

$$= 0.0 \qquad \text{for } E < 2D$$

RE_s = Shear capacity reduction factor for near edge expansion anchors

$$= 1.0 \qquad \text{for } E \geq 10D$$

$$= \left[\frac{E}{10}\right]^{1.5} \qquad \text{for } 10D > E \geq 2D$$

$$= 0.0 \qquad \text{for } E < 2D$$

A reduction factor should be applied for <u>each</u> nearby edge; e.g., if an anchor is near a corner, then two reduction factors apply. The edge distance (E) given in the tables above are in terms of multiples of the anchor bolt/stud diameter (D), measured from the anchor centerline to the edge.

C.2.7 <u>Concrete Strength Check</u>

If the concrete compressive strength (f'_c) is less than 4000 psi for pullout loads or 3500 psi for shear loads, then a pullout capacity reduction factor (RF_p) and a shear capacity reduction factor (RF_s) should be multiplied by the nominal pullout and shear capacities (P_{nom}, V_{nom}), given in Table C.2-1, to obtain the allowable pullout and shear capacities (P_{all}, V_{all}) as follows:

$$P_{all} = P_{nom}\, RF_p$$

$$V_{all} = V_{nom}\, RF_s$$

Where:

P_{all} = Allowable pullout capacity of anchor

P_{nom} = Nominal pullout capacity of anchor from Table C.2-1

V_{all} = Allowable shear capacity of anchor

V_{nom} = Nominal shear capacity of anchor from Table C.2-1

RF_p = Pullout capacity reduction factor for expansion anchors in low strength concrete

= 1.0 for $f'_c \geq 4000$ psi

= $\frac{f'_c}{4000}$ for 4000 psi > $f'_c \geq 2000$ psi

= Outlier for $f'_c < 2000$ psi

RF_s = Shear capacity reduction factor for expansion anchors in low strength concrete

= 1.0 for $f'_c \geq 3500$ psi

= $\frac{f'_c}{10,000} + 0.65$ for 3500 psi > f'_c 2000 psi

= Outlier for $f'_c < 2000$ psi

f'_c = Concrete compression strength (psi)

C.2.8 <u>Check for Concrete Cracks</u>

If there are significant structural cracks in the concrete where expansion anchors are installed, then a pullout capacity reduction factor (RC_p) should be multiplied by the nominal pullout capacity (P_{nom}), given in Table C.2-1, to obtain the allowable pullout capacities (P_{all}) as follows.

The shear capacity of expansion anchors is not significantly affected by cracks in the concrete.

$$P_{all} = P_{nom} RC_p$$

Where:

P_{all} = Allowable capacity of anchor

P_{nom} = Nominal pullout capacity of anchor from Table C.2-1

RC_p = Pullout capacity reduction factor for expansion anchors in cracked concrete

= See Table C.2-8 for values

The pullout capacity reduction factor applies only to significant structural cracks which penetrate the concrete mass and pass through the vicinity of the anchor installation. Concrete with surface (craze) cracks or shrinkage cracks which only affect the surface of the concrete should be considered uncracked. It may be necessary to exercise judgment to establish whether cracks in the vicinity of an anchor actually pass through the installation. Inspections for crack width should be visual (i.e., detailed measurement of crack widths is not necessary).

C.2.9 Check for Essential Relays

If there are essential relays mounted in the item of equipment, then the following pullout capacity reduction factor (RR_p) and shear capacity reduction factor (RR_s) should be multiplied by the nominal pullout and shear capacity (P_{nom}) given in Table C.2-1 to obtain the allowable pullout and shear capacities (P_{all}, V_{all}) as follows:

$$P_{all} = P_{nom} RR_p$$

$$V_{all} = V_{nom} RR_s$$

Table C.2-8

PULLOUT CAPACITY REDUCTION FACTORS FOR
EXPANSION ANCHORS IN CRACKED CONCRETE

Conditions	Reduction Factor for Pullout Capacity (RC_p)
• No Cracks	1.0
• Crack Size < 0.01 in. and the Number of Anchors Securing the Equipment Which Are Affected by These Cracks Is:	
≤ 50%	1.0
> 50%	0.75*
• 0.01 in. ≤ Crack Size ≤ 0.02 in.	0.75*
• Crack Size > 0.02 in.	Outlier

* Capacity reduction factor applies to <u>all</u> anchors securing the item of equipment, not just anchors which are affected by the cracks.

Where: P_{all} = Allowable pullout capacity of anchor

P_{nom} = Nominal pullout capacity of anchor from Table C.2-1

V_{all} = Allowable shear capacity of anchor

V_{nom} = Nominal shear capacity of anchor from Table C.2-1

RR_p = Pullout capacity reduction factor for expansion anchors securing equipment in which essential relays are mounted

= 0.75

RR_s = Shear capacity reduction factor for expansion anchors securing equipment in which essential relays are mounted

= 0.75

The Relay Functionality Review described in Section 6 of the GIP identifies which cabinets and items of equipment contain essential relays.

C.2.10 Reduced Inspection Alternative

A reduced level of inspection can be performed for expansion anchors if additional conservatism is included in the anchorage evaluation. The two inspections which can be deleted for this reduced inspection are:

- Tightness Check (Section C.2.3)
- Embedment Check (Section C.2.4)

However to use this Reduced Inspection Alternative, the following conditions should be met:

- Capacity Reduction Factor Applied. If the Reduced Inspection Alternative is used, then a pullout capacity reduction factor (RI_p) and shear capacity reduction factor (RI_s) should be multiplied by the nominal pullout and shear capacities (P_{nom}, V_{nom}) given in Table C.2-1 to obtain the allowable pullout and shear capacities (P_{all}, V_{all}) as follows:

$$P_{all} = P_{nom} \, RI_p$$

$$V_{all} = V_{nom} \, RI_s$$

Where:

P_{all} = Allowable pullout capacity of anchor

P_{nom} = Nominal pullout capacity of anchor from Table C.2-1

V_{all} = Allowable shear capacity of anchor

V_{nom} = Nominal shear capacity of anchor from Table C.2-1

RI_p = Pullout capacity reduction factor for use with Reduced Inspection Alternative

= 0.75

RI_s = Shear capacity reduction factor for use with Reduced Inspection Alternative

= 0.75

- <u>Other Effects Do Not Reduce Anchor Capacity</u>. None of the other effects which could lower the capacity of the anchor are present. The following anchorage inspection checks, from Section 4.4.1, should show that the anchors have full capacity. The checks and the full capacity values are listed in Section 4.4.1 and in Sections C.2.5 through C.2.9:

Check 6 - Gap Size:	None	(Section 4.4.1)
Check 7 - Spacing:	$S \geq 10D$	(Section C.2.5)
Check 8 - Edge Distance:	$E \geq 10D$	(Section C.2.6)

Check 9 - Concrete Strength:

- For Pullout: $f'_c \geq 4000$ psi (Section C.2.7)
- For Shear: $f'_c \geq 3500$ psi (Section C.2.7)

Check 10 - Concrete Cracks: None

Check 11 - Essential Relays: None

- <u>One Third of Anchors Not Available</u>. The applied seismic and dead loads should be less than the allowable anchor pullout and shear capacities given above when a third of the anchors securing the item of equipment are assumed to be unavailable for carrying loads, i.e., 50% more bolts are used to secure the item of equipment than necessary to meet the allowable loads. There should be at least 6 anchors securing the equipment; 4 assumed to be carrying the load and 2 not.

C.2.11 <u>Shear-Tension Interaction</u>

When expansion anchors are subjected to simultaneous shear and tension, one of the following shear-tension interaction formulations should be used. The linear formulation is conservative. The bi-linear formulation is more realistic. Figure C.2-4 illustrates these formulations.

- <u>Linear Formulation</u> (conservative)

$$\frac{V}{V_{all}} + \frac{P}{P_{all}} \leq 1.0$$

- <u>Bilinear Formulation</u> (more realistic)

$$\frac{P}{P_{all}} \leq 1.0 \qquad \text{for } \frac{V}{V_{all}} \leq 0.3$$

$$0.7\,\frac{P}{P_{all}} + \frac{V}{V_{all}} \leq 1.0 \qquad \text{for } 0.3 < \frac{V}{V_{all}} \leq 1.0$$

Where: P = Applied pullout loads due to earthquake plus dead loads.

V = Applied shear loads due to earthquake plus dead loads.

P_{all} = Allowable pullout capacity load for the anchor.

V_{all} = Allowable shear capacity load for the anchor.

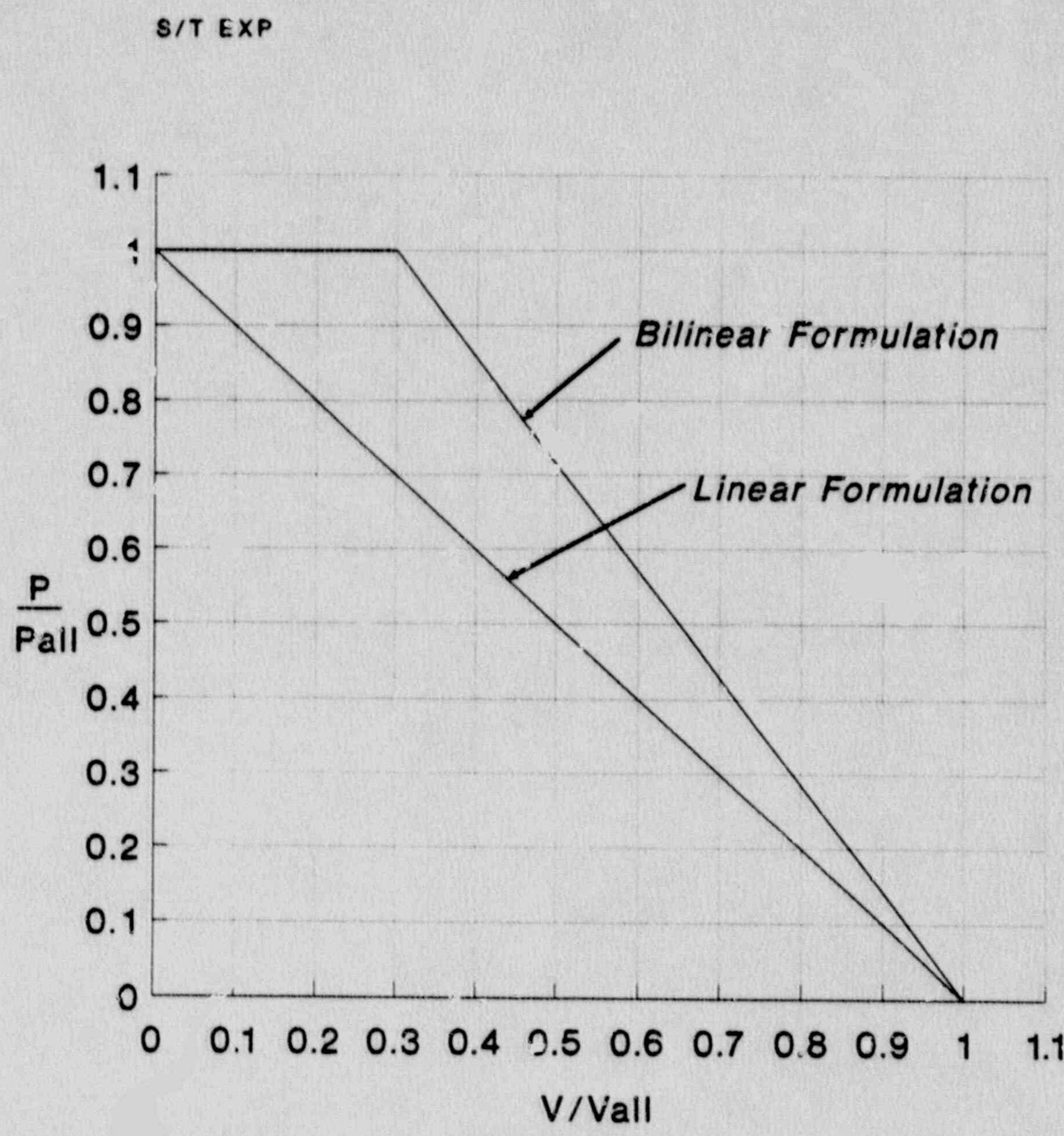


Figure C.2-4. Shear-Tension Interaction Limitations for Expansion Anchors (Source: Reference 7)

C.3 CAST-IN-PLACE BOLTS AND HEADED STUDS

The topics covered in this section of the appendix for cast-in-place bolts and headed studs are as follows. The number of each of these topics corresponds to the subsection number.

The specific checks described in this section should be performed in conjunction with the generic anchorage installation inspection checks described in Section 4.4.1 (See Table 4-2 for the checks which are applicable for this anchor type.)

The nominal allowable capacities and capacity reduction factors provided in this section should be used in the anchorage capacity equations given in Section 4.4.2.

C.3.1 Nominal Allowable Capacities

The nominal allowable load capacities which can be used for cast-in-place bolts and headed studs are listed in Table C.3-1 below.

Table C.3-1

NOMINAL ALLOWABLE CAPACITIES FOR CAST-IN-PLACE BOLTS AND HEADED STUDS ($f'_c \geq 3500$ psi)[1]

Bolt/Stud Diameter (D, in.)	Pullout Capacity (P_{nom}, kip)	Shear Capacity (V_{nom}, kip)	Minimum Embedment[2] (L_{min}, in.)	Minimum Spacing[3] (S_{min}, in.)	Min. Edge Distance[3] (E_{min}, in.)
3/8	3.74	1.87	3-3/4	4-3/4	3-3/8
1/2	6.66	3.33	5	6-1/4	4-3/8
5/8	10.44	5.22	6-1/4	7-7/8	5-1/2
3/4	15.03	7.51	7-1/2	9-1/2	6-5/8
7/8	20.44	10.22	8-3/4	11	7-3/4
1	26.69	13.35	10	12-5/8	8-3/4
1-1/8	33.80	16.90	11-1/4	14-1/4	9-7/8
1-1/4	41.72	20.86	12-1/2	15-3/4	11
1-3/8	50.40	25.25	13-3/4	17-3/8	12-1/8

---

1 The pullout and shear capacities shown here are for ASTM A-307 or equivalent strength bolts installed in sound, uncracked concrete (i.e., no cracks passing through the anchor bolt installation) with a compressive strength of 3500 psi or greater. For bolt capacities in lower strength concrete see Section C.3.5. For bolt capacities in cracked concrete see Section C.3.6.

2 See Figure C.3-1 for definition of embedment length (L). Smaller embedments than the minimum given here can be used with the reduction factor given in Section C.3.2.

3 Minimum spacings and edge distances are measured from bolt center to bolt center. Spacings and edge distances less than the minimums given here can be used with the reduction factors given in Sections C.3.3 and C.3.4.

C.3.2 Embedment Check

The nominal pullout and shear capacities (P_{nom}, V_{nom}) given in Table C.3-1 are based on the assumption that the embedment length is sufficiently long to preclude failure in the concrete. The minimum embedments (L_{min}) given in Table C.3-1 are equal to 10 times the bolt diameter (D). Figure C.3-1 shows the embedment length (L) for a cast-in-place bolt and a headed stud.

The embedment length should be verified by consulting existing drawings to ensure that the actual embedment length (L) is more than the minimum (L_{min}). If the construction drawings are not available, ultrasonic means or other appropriate methods may be used to verify the actual embedments.

If the embedment length (L) is less than the minimum value (L_{min}) given in Table C.3-1, then a pullout capacity reduction factor (RL_p) and a shear capacity reduction factor (RL_s) should be multiplied by the nominal pullout and shear capacities (P_{nom}, V_{nom}) given in Table C.3-1 to obtain the allowable pullout and shear capacities (P_{all}, V_{all}) as follows:

$$P_{all} = P_{nom} \, RL_p$$

$$V_{all} = V_{nom} \, RL_s$$

Where:

P_{all} = Allowable pullout capacity of anchor

P_{nom} = Nominal pullout capacity of anchor from Table C.3-1

V_{all} = Allowable shear capacity of anchor

V_{nom} = Nominal shear capacity of anchor from Table C.3-1

RL_p = Pullout capacity reduction factor for cast-in-place anchors with shallow embedment

RL_s = Shear capacity reduction factor for cast-in-place anchors with shallow embedment

= 1.0 for $L \geq 10D$

$$= \frac{(L + D)L}{(L_{min} + D)L_{min}} \quad \text{for } 4D < L < 10D \text{ and } L > 3 \text{ inches}$$

= Outlier for L < Greater of: 4D or 3 inches

C.3.3 <u>Spacing Check</u>

If the spacing (S) between a cast-in-place anchor and another anchor is less than the minimum value (S_{min}) given in Table C.3-1, then a pullout capacity reduction factor (RS_p) and a shear capacity reduction factor (RS_s) should be multiplied by the nominal pullout and shear capacities (P_{nom}, V_{nom}) given in Table C.3-1 to obtain the allowable pullout and shear capacities (P_{all}, V_{all}) as follows.

Note that a reduction factor should be applied for <u>each</u> nearby anchor, whether it is another cast-in-place anchor or a different type of anchor. For example, for 4 bolts in a line, the interior bolts would be subject to 2 reductions, while the exterior bolts would be subject to only 1 reduction.

$$P_{all} = P_{nom}\, RS_p$$

$$V_{all} = V_{nom}\, RS_s$$

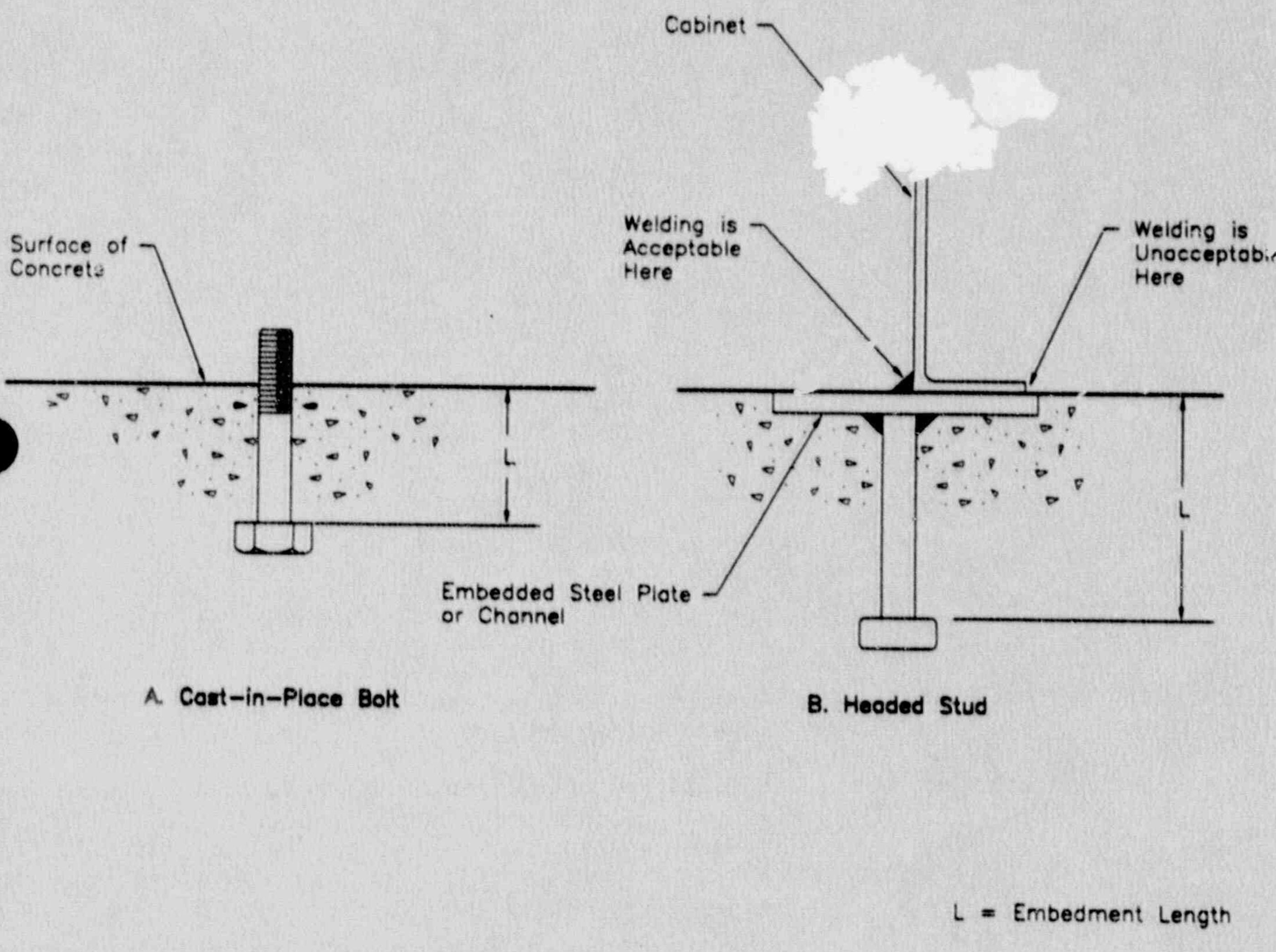


Figure C.3-1. Typical Installations of Cast-in-Place Bolt and Headed Stud

Where: P_{all} = Allowable pullout capacity of anchor

P_{nom} = Nominal pullout capacity of anchor from Table C.3-1

V_{all} = Allowable shear capacity of anchor

V_{nom} = Nominal shear capacity of anchor from Table C.3-1

RS_p = Pullout capacity reduction factor for closely spaced cast-in-place anchors

= 1.0 for $S \geq S_{min}$

= $\dfrac{A_{s,red}}{A_{s,nom}}$ for $S < S_{min}$

RS_s = Shear capacity reduction factor for closely spaced cast-in place anchors.

= 1.0 for $S \geq 2D$

= 0.5 for $S < 2D$

S = Spacing from the bolt being evaluated to an adjacent bolt measured center to center

S_{min} = Minimum spacing to develop full pullout strength from Table C.3-1

$A_{s,nom}$ = Nominal projected area of the nonoverlapping shear cone of a single bolt located <u>at</u> the minimum spacing distance (S_{min}) from another bolt. The values of A_{nom} are given in Table C.3-2 are about 13 percent less than the full shear cone projected area.

Table C.3-2

NONOVERLAPPING PROJECTED SHEAR CONE AREAS FOR BOLTS MEETING MINIMUM SPACING REQUIREMENTS

Bolt Diameter (D, in.)	Nonoverlapping Shear Cone Area ($A_{s,nom}$, in.^{2})
3/8	41.9
1/2	74.1
5/8	116.0
3/4	167.4
7/8	228.2
1	297.3
1-1/8	376.7
1-1/4	464.1
1-3/8	546.3

$A_{s,red}$ = Reduced projected area of the nonoverlapping shear cone of a single bolt located <u>less</u> than the minimum spacing (S_{min}) from another bolt. The values of A_{red} are calculated from the following equation:

$$= \pi r^2 - \frac{1}{2}\left[r^2 \theta - r\,S \sin\left(\frac{\theta}{2}\right)\right]$$

$$r = \frac{2L + D}{2}$$

$$\theta = 2\cos^{-1}\left[\frac{S}{2L + D}\right]$$

S = Actual spacing between bolt being evaluated and adjacent bolt measured center to center

L = Actual embedment of bolt being evaluated

D = Bolt diameter

C.3.4 Edge Distance Check

If the distance (E) from a cast-in-place bolt or a headed stud to a free edge of concrete is less than the minimum value (E_{min}), given in Table C.3-1, then a pullout capacity reduction factor (RE_p) and a shear capacity reduction factor (RE_s) should be multiplied by the nominal pullout and shear capacities (P_{nom}, V_{nom}), given in Table C.3-1, to obtain the allowable pullout and shear capacities (P_{all}, V_{all}) as follows. A reduction factor should be applied for <u>each</u> nearby edge; e.g., if an anchor is near a corner, then two reduction factors apply.

$$P_{all} = P_{nom}\, RE_p$$

$$V_{all} = V_{nom}\, RE_s$$

Where: P_{all} = Allowable pullout capacity of anchor

P_{nom} = Nominal pullout capacity of anchor from Table C.3-1

V_{all} = Allowable shear capacity of anchor

V_{nom} = Nominal shear capacity of anchor from Table C.3-1

RE_p = Pullout capacity reduction factor for near edge cast-in-place bolts and headed studs

$= 1.0$ for $E \geq E_{min}$ (From Table C.3-1)

$= \dfrac{A_{e,red}}{A_{e,nom}}$ for $E_{min} > E \geq 4D$

$= 0.0$ for $E < 4D$

RE_s = Shear capacity reduction factor for near edge cast-in-place bolts and headed studs

$= 1.0$ for $E \geq 8.75D$

$= 0.0131 \left[\dfrac{E}{D}\right]^2$ for $8.75D > E \geq 4D$

$= 0.0$ for $E < 4D$

$A_{e,nom}$ = Nominal projected shear cone area of a bolt which is located adjacent to a free concrete edge at the minimum edge distance given in Table C.3-1

$$= 0.96 \frac{\pi}{4} (2L + D)^2$$

$A_{e,red}$ = Reduced projected shear cone area of a bolt located at less than the minimum edge distance from a concrete edge

$$= \pi r^2 - \frac{1}{2}\left[r^2\theta - 2r\,E \sin\left(\frac{\theta}{2}\right)\right]$$

$$\theta = 2\cos^{-1}\left[\frac{2E}{2L + D}\right]$$

$$r = \frac{2L + D}{2}$$

E = Actual distance from centerline of bolt being evaluated to edge

L = Actual embedment length of bolt being evaluated

D = Bolt diameter

C.3.5 Concrete Strength Check

If the concrete compressive strength (f'_c) is less than 3500 psi, then a pullout capacity reduction factor (RF_p) and a shear capacity reduction factor (RF_s) should be multiplied by the nominal pullout and shear capacities (P_{nom}, V_{nom}) given in Table C.3-1, to obtain the allowable pullout and shear capacities (P_{all}, V_{all}) as follows:

$$P_{all} = P_{nom}\ RF_p$$

$$V_{all} = V_{nom}\ RF_s$$

Where:

P_{all} = Allowable pullout capacity of anchor

P_{nom} = Nominal pullout capacity of anchor from Table C.3-1

V_{all} = Allowable shear capacity of anchor

V_{nom} = Nominal shear capacity of anchor from Table C.3-1

$RF_p = RF_s$ = Pullout and shear capacity reduction factors for cast-in-place bolts and headed studs in low strength concrete

= 1.0 for $f'_c \geq 3500$ psi

= $\sqrt{\dfrac{f'_c}{3500}}$ for $3500 \text{ psi} \geq f'_c \geq 2500$ psi

= Outlier for $f'_c < 2500$ psi

f'_c = Concrete compressive strength (psi)

C.3.6 Check for Concrete Cracks

If there are significant structural cracks in the concrete where the cast-in-place bolts and headed studs are installed, then a pullout capacity reduction factor (RC_p) should be multiplied by the nominal pullout capacity (P_{nom}) given in Table C.3-1 to obtain the allowable pullout capacity (P_{all}) as follows. The shear capacity of the cast-in-place bolts and headed stud anchors is not significantly affected by cracks in the concrete.

The pullout capacity reduction factor applies only to significant structural cracks which penetrate the concrete mass and pass through the vicinity of the anchor installation. Concrete with surface (craze) cracks or shrinkage cracks which only affect the surface of the concrete should be considered uncracked. It may be necessary to exercise judgment to establish whether cracks in the vicinity of an anchor actually pass through the installation. Inspections for crack width should be visual (i.e., detailed measurement of crack widths is not necessary).

$$P_{all} = P_{nom} \, RC_p$$

Where:

P_{all} = Allowable pullout capacity of anchor

P_{nom} = Nominal pullout capacity of anchor from Table C.3-1

RC_p = Pullout capacity reduction factor for cast-in-place anchors in cracked concrete

= 1.0 for no cracks and for CS < 0.01 in.

= 1.08 - 8CS for 0.01 in. ≤ CS ≤ 0.06 in.

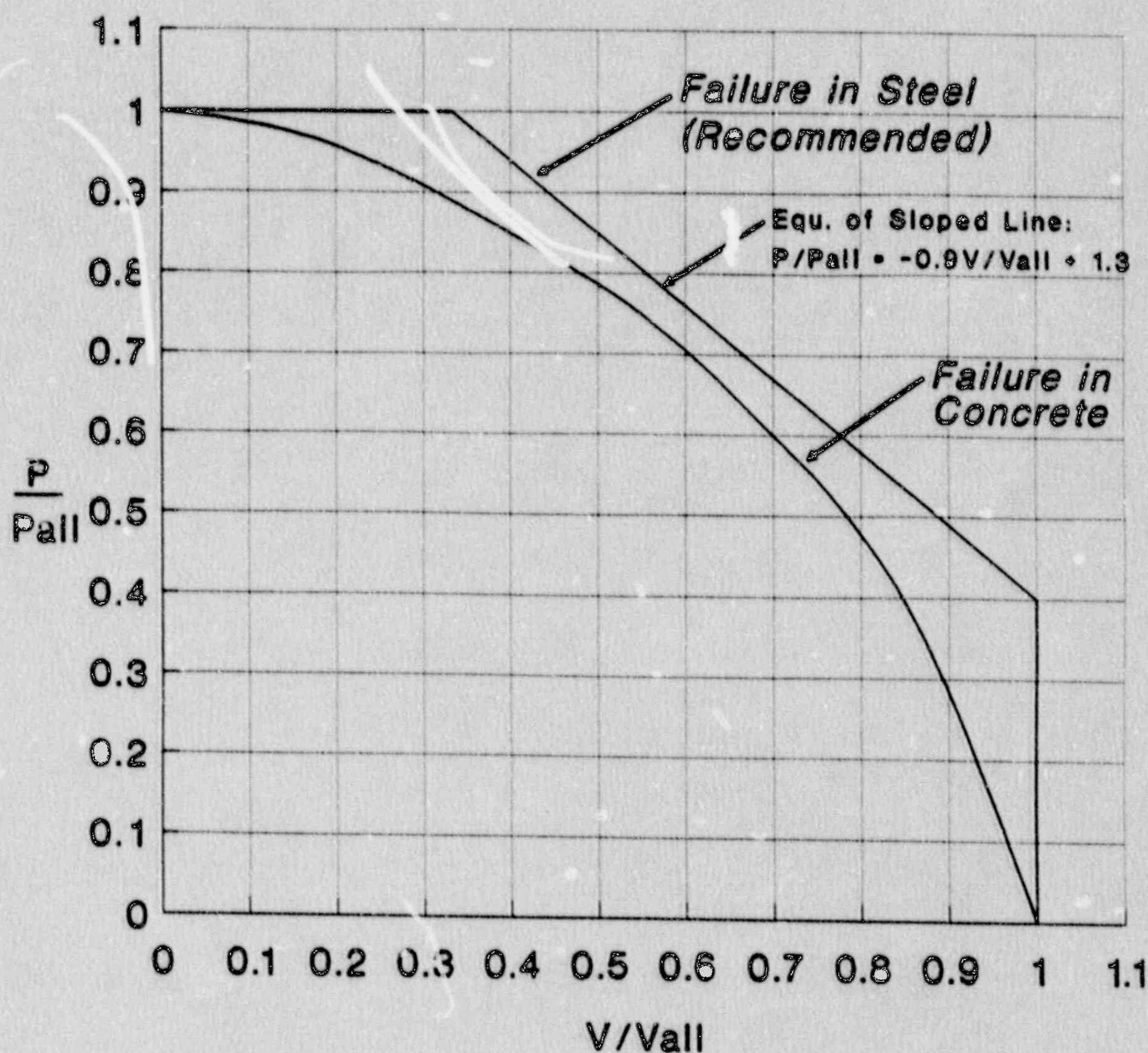
= Outlier for CS > 0.06 in.

CS = Crack size (approximate size based on visual observation)

C.3.7 Shear-Tension Interaction

For existing cast-in-place bolts subjected to simultaneous shear and tension, the shear-tension interaction depends on the anticipated failure mode. Figure C.3-2 presents the interaction curves for cast-in-place bolts for failure in the bolt steel or failure in the concrete. Since the anchorage criteria in this procedure (and Reference 7) for cast-in-place bolts and headed studs ensure that failure does not occur in the concrete, it is recommended that the interaction formulation for steel failure be used.

S/T CIP



V/Vall	0.0	0.2	1/3	0.5	0.7	0.9	1.0
P/Pall - Steel	1.0	1.0	1.0	.85	.67	.49	0.4
P/Pall - Concrete	1.0	.96	.89	.79	.60	.31	0.0

Figure C.3-2. Shear-Tension Interaction Limitations for Cast-In-Place Bolts and Headed Studs (Source: Reference 7)

C.4 CAST-IN-PLACE J-BOLTS

The term J-Bolt refers to a plain steel bar with a hook formed at the embedded end, and threaded at the other end. A typical J-bolt is shown in Figure C.4-1. The following topics are covered in this section of the appendix. The number of each of these topics corresponds to the subsection number.

C.4.1 Nominal Allowable Capacities

C.4.2 Embedment Check

C.4.3 Spacing Check

C.4.4 Edge Distance Check

C.4.5 Concrete Strength Check

C.4.6 Check for Concrete Cracks

The specific checks described in this section should be performed in conjunction with the generic anchorage installation inspection checks described in Section 4.4.1. (See Table 4-2 for the checks which are applicable for this anchor type.)

The nominal allowable capacities and capacity reduction factors provided in this section should be used in the anchorage capacity equations given in Section 4.4.2.

C.4.1 <u>Nominal Allowable Capacities</u>

The nominal allowable load capacities which can be used for cast-in-place J-bolts are listed in Table C.4-1 below. An embedded bar can be considered as a J-bolt only if it has a hook on the embedded end meeting the minimum dimensions shown in Figure C.4-1.

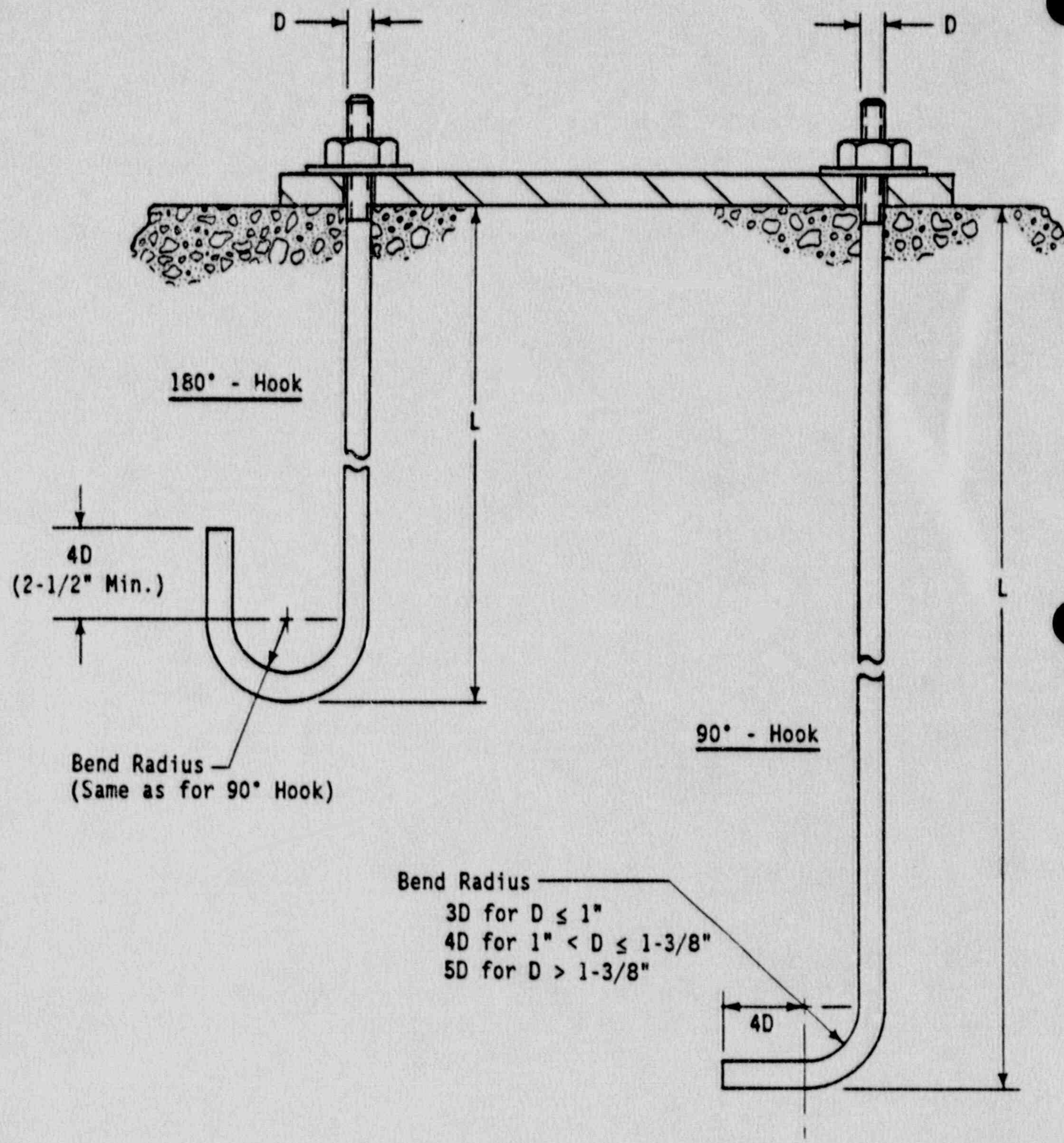


Figure C.4-1. Typical J-Bolt Installations
(Source: Reference 7)

Table C.4-1

NOMINAL ALLOWABLE CAPACITIES FOR
J-BOLTS CAST-IN-PLACE

($f'_c \geq 3500$ psi)

Bar Diameter (D, in.)	Pullout Capacity (P_{nom}, kip)	Shear Capacity (V_{nom}, kip)	Minimum Embedment (L_{min}, in.) 180° Hook	90° Hook	Minimum Spacing (S_{min}, in.)	Minimum Edge Distance (E_{min}, in.)
3/8	3.74	1.87	16	20-1/2	1-1/8	3-3/8
1/2	6.66	3.33	21-1/4	27-1/4	1-1/2	4-3/8
5/8	10.44	5.22	26-5/8	34-1/8	1-7/8	5-1/2
3/4	15.03	7.51	31-7/8	40-7/8	2-1/4	6-5/8
7/8	20.44	10.22	37-1/4	47-3/4	2-5/8	7-3/4
1	26.69	13.35	42-1/2	54-1/2	3	8-3/4
1-1/8	33.80	16.90	47-7/8	61-3/8	3-3/8	9-7/8
1-1/4	41.72	20.86	53-1/8	68-1/8	3-3/4	11
1-3/8	50.40	25.25	58-1/2	75	4-1/8	12-1/8

C.4.2 Embedment Check

The nominal pullout capacities (P_{nom}) given in Table C.4-1 are based on the assumption that the embedded length is at least as long as the minimum embedment lengths (L_{min}) given in Table C.4-1.

If the embedment length (L) is less than the minimum value (L_{min}), then a pullout capacity reduction factor (RL_p) should be multiplied by the nominal pullout capacity (P_{nom}) to obtain the allowable pullout capacity (P_{all}). A capacity reduction factor for shear is not needed since J-bolts develop their full shear strength even when the embedment is so small that the J-bolt becomes an outlier due to insufficient embedment for pullout (at L = 16D).

$$P_{all} = P_{nom} \, RL_p$$

P_{all} = Allowable pullout capacity of anchor

P_{nom} = Nominal pullout capacity of anchor from Table C.4-1

Where: RL_p = Pullout capacity reduction factor for cast-in-place J-bolts

$= 1.0$ for $L \geq L_{min}$ from Table C.4-1

$$= \frac{L + 20D}{62.5D} \quad \text{for 180° hook when } L_{min} > L \geq 16D$$

$$= \frac{L + 8D}{62.5D} \quad \text{for 90° hook when } L_{min} > L \geq 16D$$

= Outlier when $L < 16D$

L = Actual embedment length (in.)

D = Rod diameter (in.)

C.4.3 Spacing Check

The nominal shear capacities (V_{nom}) for J-bolts given in Table C.4-1 are based on a minimum spacing of 3D, where D is the diameter of the J-bolt.

For spacings less than 3D, the J-bolt is an outlier.

C.4.4 Edge Distance Check

The minimum edge distances given in Table C.4-1 for J-bolts are the same as those for cast-in-place bolts and headed studs. Likewise the capacity reduction factors for J-bolts installed near an edge are also the same as discussed in Section C.3.4 for cast-in-place bolts and headed studs.

C.4.5 Concrete Strength Check

If the concrete compressive strength (f'_c) is less than 3500 psi, then a pullout capacity reduction factor (RF_p) and a shear capacity reduction factor (RF_s) should be multiplied by the nominal pullout and shear capacities (P_{nom}, V_{nom}) given in Table C.4-1, to obtain the allowable pullout and shear capacities (P_{all}, V_{all}) for J-bolts.

$$P_{all} = P_{nom} \, RF_p$$

$$V_{all} = V_{nom} \, RF_s$$

Where:

P_{all} = Allowable pullout capacity of anchor

P_{nom} = Nominal pullout capacity of anchor from Table C.4-1

V_{all} = Allowable shear capacity of anchor

V_{nom} = Nominal shear capacity of anchor from Table C.4-1

$RF_p = RF_s$ = Pullout and shear capacity reduction factors for J-bolts in low strength concrete

= 1.0 for $f'_c \geq 3500$ psi

= $\sqrt{\dfrac{f'_c}{3500}}$ for $2500 \text{ psi} \leq f'_c < 3500$ psi

f'_c = Concrete compressive strength (psi)

C.4.6 Check for Concrete Cracks

The areas adjacent to J-bolt installations should be inspected for significant structural cracks which penetrate the concrete mass. Concrete with surface (craze) cracks or shrinkage cracks which only affect the surface of the concrete should be considered uncracked. Inspections for crack width should be visual (i.e., detailed measurement of crack widths is not necessary). J-bolts should be classified as outliers when either of the following two crack sizes are exceeded:

- When cracks are larger than about 0.02 inch wide and traverse through the J-bolt installation, or
- When cracks are larger than about 0.05 inches wide and exist near the J-bolt installation.

C.4.7 Shear-Tension Interaction

It is left to the user to select an appropriate shear-tension interaction formulation for use with J-bolts when both tension and shear loads are significant.

C.5 GROUTED-IN-PLACE BOLTS

The topics covered in this section of the appendix for grouted-in-place bolts are as follows. The number of each of these topics corresponds to the subsection number.

C.5.1 Nominal Allowable Capacities

C.5.2 Embedment, Spacing, and Edge Distance Checks

C.5.3 Concrete Strength Check and Cracks in Concrete

C.5.4 Shear-Tension Interaction

The specific checks described in this section should be performed in conjunction with the generic anchorage installation inspection checks described in Section 4.4.1. (See Table 4-2 for the checks which are applicable for this anchor type.)

The nominal allowable capacities and capacity reduction factors provided in this section should be used in the anchorage capacity equations given in Section 4.4.2.

C.5.1 Nominal Allowable Capacities

The nominal allowable pullout and shear capacities which can be used for grouted-in-place bolts are listed in Table C.5-1 below. Note that the values in this table are identical to those in Table C.3-1 for cast-in-place bolts and headed studs except that the pullout capacities (P_{nom}) are reduced by a factor of 10. This was done since the pullout capacity of grouted-in-place bolts is significantly affected by the method of installation. Since documentation of the method used to install grouted-in-place bolts often is n. available, the pullout capacities given in the table below are reduced significantly.

However, if the bolts were installed using effective installation procedures similar to those in Reference 28, then the pullout capacities of this grouted-in-place bolts may be taken to be the same as for cast-in-place bolts (i.e., use the capacities given in Table C.3-1). Some of the installation techniques used in Reference 28 include such things as thorough cleansing of the concrete hole, acid etching of the concrete hole to roughen the surfaces, and use of grout which expands while it is curing.

Table C.5-1

NOMINAL ALLOWABLE CAPACITIES FOR GROUTED-IN-PLACE BOLTS ($f'_c \geq 3500$ psi)[1]

Bolt/Stud Diameter (D, in.)	Pullout Capacity[2] (P_{nom}, kip)	Shear Capacity (V_{nom}, kip)	Minimum Embedment[3] (L_{min}, in.)	Minimum Spacing[4] (S_{min}, in.)	Min. Edge Distance[4] (E_{min}, in.)
3/8	0.37	1.87	3-3/4	4-3/4	3-3/8
1/2	0.67	3.33	5	6-1/4	4-3/8
5/8	1.04	5.22	6-1/4	7-7/8	5-1/2
3/4	1.50	7.51	7-1/2	9-1/2	6-5/8
7/8	2.04	10.22	8-3/4	11	7-3/4
1	2.67	13.35	10	12-5/8	8-3/4
1-1/8	3.38	16.90	11-1/4	14-1/4	9-7/8
1-1/4	4.17	20.86	12-1/2	15-3/4	11
1-3/8	5.04	25.25	13-3/4	17-3/8	12-1/8

1 The pullout and shear capacities shown here are for ASTM A-307 or equivalent strength bolts installed in sound, uncracked concrete (i.e., no cracks passing through the anchor bolt installation) with a compressive strength of 3500 psi or greater. For bolt capacities in lower strength concrete see Section C.3.5. For bolt capacities in cracked concrete see Section C.3.6.

2 The pullout capacities (P_{nom}) are based on not having used special installation practices (or not knowing whether such practices were used). However, if installation procedures similar to those in Reference 28 were used, then the pullout capacities for cast-in-place bolts (Table C.3-1) can be used in place of the values in this table.

3 See Figure C.3-1 for definition of embedment length (L). Smaller embedments than the minimum given here can be used with the reduction factor given in Section C.3.2.

4 Minimum spacings and edge distances are measured from bolt center to bolt center. Spacings and edge distances less than the minimums given here can be used with the reduction factors given in Sections C.[illegible] and C.3.4.

C.5.2 Embedment, Spacing, and Edge Distance Checks

For grouted-in-place bolts having embedments, spacings, and/or edge distances which are less than the minimum values given in Table C.5-1, the capacity reduction factors given in Sections C.3.2, C.3.3, and C.3.4 for cast-in-place bolts may be used to reduce the nominal pullout and shear capacities given in Table C.5-1.

C.5.3 Checks for Concrete Strength and Cracks in Concrete

When grouted-in-place bolts are installed in concrete which has a compressive strength of $f'_c \le 3500$ psi, the capacity reduction factors given in Section C.3.5 for cast-in-place bolts may be used to reduce the nominal pullout and shear capacities given in Table C.5-1.

If there are significant structural cracks in the concrete where the grouted-in-place bolts are installed, then the pullout capacity reduction factors given in Section C.3.6 for cast-in-place bolts may be used to reduce the nominal pullout capacities given in Table C.5-1.

C.5.4 Shear-Tension Interaction

For grouted-in-place bolts subjected to simultaneous shear and tension, the guidelines given in Section C.3.7 for cast-in-place bolts may be used to compare the allowable loads to the applied loads.

C.6 WELDS TO EMBEDDED OR EXPOSED STEEL

Equipment at nuclear plants are often anchored by welds to steel plates or channels which are embedded in concrete (see Figure C.3-1b). The strength of such an anchorage depends on the weld of the equipment to the steel and the shear and pullout resistance of the headed stud that anchors the steel into the concrete. The following topics are covered in this section of the appendix. The number of each of these topics corresponds to the subsection number.

C.6.1 Allowable Loads for Typical Welds

C.6.2 Summary of Equivalent Weld Sizes

C.6.3 Weld Check

C.6.4 Shear-Tension Interaction for Welds

C.6.5 Embedded or Exposed Steel Check

The specific checks described in this section should be performed in conjunction with the generic anchorage installation inspection checks described in Section 4.4.1. (See Table 4-2 for the checks which are applicable for welds.)

C.6.1 <u>Allowable Loads for Typical Welds</u>

The allowable loads for typical welds made with E60 electrodes are listed in Table C.6-1 below. These allowable loads are based on a weld stress allowable of 30,600 psi.

Table C.6-1

ALLOWABLE CAPACITIES FOR TYPICAL WELDS
(E60 Electrodes)

Weld Sizes t (in.)	Weld Sizes L (in.)	Throat Area (A = .707tL) ($in.^2$)	Allowable F_w (kips)
1/8	1/2	0.0442	1.35
1/8	3/4	0.0663	2.03
1/8	1	0.0884	2.70
3/16	1/4	0.0331	1.01
3/16	1/2	0.0663	2.03
3/16	3/4	0.0994	3.04
3/16	1	0.1326	4.06
1/4	1/4	0.0442	1.35
1/4	1/2	0.0884	2.70
1/4	3/4	0.1326	4.06
1/4	1	0.1768	5.41

Where:

t = Thickness of the weld leg

L = Length of the weld

A = Cross-sectional area through the throat of the weld

= 0.707tL

F_w = Allowable load capacity of weld

C.6.3 Weld Check

The welds used for anchoring equipment to embedded or exposed steel should be inspected in the following areas:

- Determine the overall length (L) and thickness (t) of the welds. The weld thickness should be limited to the thinnest part of either the weld itself or the connecting part.
- Check for weld burn-through on cabinets made of thin material.
- Check for weld quality, particularly in puddle welds which carry high tension loads.

C.6.4 Shear-Tension Interaction for Welds

When welds are subjected to simultaneous shear and tension, the allowable loads can be compared to the applied loads using the following shear-tension interaction formulation:

$$\left(\frac{P}{F_w}\right)^2 + \left(\frac{V}{F_w}\right)^2 \leq 1$$

Where: P = Pullout (tensile) load applied to weld

V = Shear load applied to weld

F_w = Allowable load for weld (from Table C 6-1)

C.6.2 Summary of Equivalent Weld Sizes

A summary of equiv lent weld sizes which have the same capacity as other types of fasteners is shown in Table C.6-2 below.

Table C.6-2

SUMMARY OF EQUIVALENT WELD SIZES

Welds		Equivalent Bolt Diameter (D, in.)	
Typical Size (L x t, in.)	Throat Area (in.^{2})	Expansion Anchor Bolts	Cast-in-Place Anchor Bolts
1/2 x 1/8	0.0442	3/8	--
1 x 1/8	0.0884	1/2	--
1 x 3/16	0.1326	3/4	3/8
1 x 1/4	0.1768	3/4	3/8
2 x 3/16	0.2651	[illegible]	1/2
2 x 1/4	0.3535	1	5/8
2 x 3/8	0.5305	--	3/4

C.6.3 Weld Check

The welds used for anchoring equipment to embedded or exposed steel should be inspected in the following areas:

- Determine the overall length (L) and thickness (t) of the welds. The weld thickness should be limited to the thinnest part of either the weld itself or the connecting part.
- Check for weld burn-through on cabinets made of thin material.
- Check for weld quality, particularly in puddle welds which carry high tension loads.

C.6.4 Shear-Tension Interaction for Welds

When welds are subjected to simultaneous shear and tension, the allowable loads can be compared to the applied loads using the following shear-tension interaction formulation:

$$\left(\frac{P}{F_w}\right)^2 + \left(\frac{V}{F_w}\right)^2 \leq 1$$

Where: P = Pullout (tensile) load applied to weld

V = Shear load applied to weld

F_w = Allowable load for weld (from Table C.6-1)

C.6.5 Embedded or Exposed Steel Check

The embedded steel or the exposed steel to which the equipment is anchored by the weld should be evaluated to determine whether it has the capacity to carry the loads applied to it.

The AISC, Part 2, allowable stresses may be used for evaluating the adequacy of exposed steel and the structural members of an embedded steel assembly. The guidelines given in Section C.3 of this appendix can be used for evaluating the cast-in-place bolts and headed studs which are a part of the embedded steel assembly.

C.6.4 Shear-Tension Interaction for Welds

When welds are subjected to simultaneous shear and tension, the allowable loads can be compared to the applied loads using the following shear-tension interaction formulation:

$$\left(\frac{P}{F_w}\right)^2 + \left(\frac{V}{F_w}\right)^2 \leq 1$$

Where: P = Pullout (tensile) load applied to weld

V = Shear load applied to weld

F_w = Allowable load for weld (from Table C.6-1)

C.6.5 Embedded or Exposed Steel Check

The embedded steel or the exposed steel to which the equipment is anchored by the weld should be evaluated to determine whether it has the capacity to carry the loads applied to it.

The AISC, Part 2, allowable stresses may be used for evaluating the adequacy of exposed steel and the structural members of an embedded steel assembly. The guidelines given in Section C.3 of this appendix can be used for evaluating the cast-in-place bolts and headed studs which are a part of the embedded steel assembly.

Appendix D

SEISMIC INTERACTION

CONTENTS

Appendix D

SEISMIC INTERACTION

D.1 INTRODUCTION

The purpose of this appendix is to describe seismic interaction and how it can be evaluated for safe shutdown equipment.

Seismic interaction is the physical interaction of any structures, piping, or equipment with a nearby item of safe shutdown equipment caused by relative motions from an earthquake. An inspection should be performed in the area adjacent to and surrounding all safe shutdown equipment to identify any seismic interaction condition which could adversely affect the capability of the safe shutdown equipment to perform its intended safe shutdown function.

The three seismic interaction effects which are included within the scope of this procedure are:

- Proximity
- Structural failure and falling
- Flexibility of attached lines and cables

These areas are described below.

There are other areas of seismic interaction which can occur in a nuclear plant but are not included within the scope of this procedure. These areas are:

- Effects of fire
- Flooding or exposure to fluids from ruptured vessels and piping systems

- Failure of distribution lines (pipes, cables, etc.) due to large relative motion between different building structures. (Note: Flexibility between the safe shutdown equipment and building structures is covered by this procedure.)

The remainder of this appendix describes the three seismic interaction effects covered by this procedure and how they can be evaluated for safe shutdown equipment. Note that the SQUG training course includes many examples covering this seismic interaction issue.

D.2 PROXIMITY

Seismic proximity interaction is the impact of adjacent equipment or structures on safe shutdown equipment due to their relative motion during seismic excitation. This relative motion can be the result of the vibration and movement of the safe shutdown equipment itself or any adjacent equipment or structures. When sufficient anchorage, bracing, or other means are provided to preclude large deflections, seismic proximity effects are not typically a concern.

Even if there is impact between adjacent equipment or structures, there may not be any significant damage to the safe shutdown equipment. In such cases, this seismic interaction would not be considered a reason for concern, provided the equipment can still accomplish its intended safe shutdown function. One exception to this is electrical cabinets containing relays which are required for a safe shutdown function. Since relays are susceptible to chatter, any impact on an electrical cabinet which has such a relay in it should be considered an unacceptable seismic interaction and cause for identifying that electrical cabinet as an outlier.

D.2.1 Piping, Raceways, and Ductwork Deflections

The motion of piping, conduit, cable raceways, and other distribution lines may result in impact interactions with safe shutdown equipment. Non-safety-related piping is commonly supported with rod hangers or other forms of flexible dead load support, with little or no lateral restraint. Where adequate clearance with safe shutdown equipment is not provided, potential impact interaction may result. The integrity of the piping is typically not a concern. (Threaded fittings, cast iron pipes and fittings, and victaulic couplings may be exceptions where large anchor movement is possible.) In general, impacts between distribution systems (piping, conduit, ducts, raceways) and safe shutdown equipment of comparable size are not a cause for concern; the potential for large relative motions between dissimilar size systems should be carefully evaluated to assure that a large system cannot carry away a smaller one.

Judgment should be exercised by the Seismic Capability Engineers in estimating potential motions of distribution systems in proximity to the safe shutdown equipment under evaluation. For screening purposes, a clearance of 2 inches for relatively rigid cable tray and conduit raceway systems and 6 inches for relatively flexible systems would normally be adequate to prevent impacts, subject to the judgment of the Seismic Capability Engineers.

Where potential interaction may involve systems with significant thermal movements during plant normal operating conditions, the thermal displacements should be evaluated along with those resulting from seismic deflections. Inter-equipment displacement limits may be developed from the applicable floor response spectra to assist in this effort.

D.2.2 Mechanical and Electrical Equipment Deflections

Inadequately anchored or inadequately braced mechanical and electrical equipment such as pumps, valves, vessels, cabinets, and switchgear may deflect or overturn during seismic loadings resulting in impact with nearby safe shutdown equipment. Certain items, such as tanks with high height-to-diameter aspect ratios, can deflect and impact nearby equipment. Electrical cabinets in proximity to each other may pound against each other.

The Seismic Capability Engineers should use judgment in such cases to evaluate the potential displacements and their potential effect on nearby safe shutdown equipment. Cabinets with essential relays warrant special concern as described above.

D.3 STRUCTURAL FAILURE AND FALLING

Safe shutdown equipment can be damaged and unable to accomplish its safe shutdown function due to impact caused by failure of overhead or adjacent equipment, systems, or structures. (This interaction hazard is commonly referred to as a Category II over Category I concern.) This seismic interaction effect can occur from nearby or overhead: (1) mechanical and electrical equipment; (2) piping, raceway, and HVAC systems; (3) architectural features; and (4) operations, maintenance, and safety equipment. The seismic interaction effects which are of concern for these types of equipment, systems, and structures are described below. It is the intent of this evaluation that realistic hazards be identified and corrected; failure of non-seismic equipment and systems located over safe shutdown equipment should not be arbitrarily assumed. The judgment of the Seismic Capability Engineers should be used to differentiate between likely and unlikely interaction hazards.

D.3.1 Mechanical and Electrical Equipment

Equipment such as tanks, heat exchangers, and electrical cabinets that are inadequately anchored or inadequately braced have historically overturned and/or slid due to earthquake excitation. In some cases this has resulted in damage to nearby equipment or systems.

D.3.2 Piping, Raceways, and HVAC Systems

Falling of non-seismically designed piping, raceways, and HVAC systems have been observed in very limited numbers during earthquakes due to unique circumstances. Most commonly reported are falling of inadequately secured louvers and diffusers on lightweight HVAC ducting. Damage to piping systems is less common and usually is limited to component failures which have rarely compromised system structural integrity. Typical damage is attributed to differential motions of systems resulting from movement of unanchored equipment, attachment of systems between buildings, or extremely flexible long runs of unrestrained piping. Very long runs of raceway systems pose a potential falling hazard when the runs are resting on, but not attached to, cantilever supports.

D.3.3 Architectural Features

Architectural features include such items as ceilings, light fixtures, platform grating, unreinforced masonry walls, and non-Seismic Category I structures. The seismic interaction effects for these are described below:

- Ceilings. T-bar suspended tiles, recessed fixtures, and sheet rock are used in some plant areas (such as the control room). Seismic capabilities of these ceilings may be low. The Seismic Capability Engineers should check for details that are known to lead to failure such as open hooks, no lateral wire bracing, etc.

- Light Fixtures. Normal and emergency light fixtures are used throughout the plant. Fixture designs and anchorage details vary widely. Light fixtures may possess a wide range of seismic capabilities. Pendant-hung fluorescent fixtures and tubes pose the highest risk of failure and damage to sensitive equipment. The Seismic Capability Engineers should check for positive anchorage, such as closed hooks and properly twisted wires. Typically this problem is not caused by lack of strength; it is usually due to poor connections. Emergency lighting units and batteries can fall and damage safe shutdown equipment due to impact or spillage of acid.

- Platform Gratings. Unrestrained platform gratings and similar personnel access provisions may pose hazards to impact-sensitive safe shutdown equipment or components mounted on them. Some reasonable positive attachment is necessary, if the item can fall.

- Unreinforced Masonry Walls. Unreinforced, masonry block walls should be evaluated for possible failure and potential seismic interaction with safe shutdown equipment unless the wall has been seismically qualified as part of the IE Bulletin 80-11 program. The Seismic Capability Engineers should review the documentation for IE Bulletin 80-11 masonry walls to determine which walls have and which walls have not been seismically qualified during that program.

- Non-Seismic Category I Structures. If any safe shutdown equipment is located in non-Seismic Class I structures, then potential structural vulnerabilities of the building should be identified; however, nuclear plant structures (including non-seismic structures) are typically seismically adequate.

D.3.4 Operations, Maintenance, and Safety Equipment

Nuclear plant operations and maintenance require specialized equipment, some of which may be permanently located or stored in locations near safety systems.

Some operations, maintenance, and safety equipment is designed so that it may be easily relocated by plant personnel. Where equipment design or plant operating procedures do not consider anchorage for permanently located equipment, this equipment may slide, fall, overturn, or impact with safe shutdown equipment. Typically such equipment include:

- <u>Cabinets and Lockers</u>. Inadequately restrained floor and wall-mounted filing cabinets and equipment storage lockers may result in overturning or falling and impact.
- <u>Gas Storage Bottles</u>. Unrestrained or inadequately restrained gas bottles may result in overturning and rolling and cause impact.
- <u>Refueling Equipment</u>. Refueling equipment such as lifting equipment and servicing and refueling tools may be stored in proximity to safe shutdown equipment. Inadequately restrained equipment may pose hazards.
- <u>Monorails, Hoists, and Cranes</u>. Monorails and service cranes are permanently located over heavy equipment requiring movement for service. Falling of service crane appurtenances such as tool and equipment boxes may result from inadequate component anchorage. They should be restrained from falling. Judgment by the Seismic Capability Engineers should be used to assess the potential for and consequences of such equipment falling.
- <u>Radiation Shields, Fire Protection and Miscellaneous Equipment</u>. Temporary and permanent radiation shielding may pose hazards. Miscellaneous maintenance tools, such as chains and dollies, test equipment, and fire protection equipment such as fire extinguishers and hose reels may fall if inadequately restrained. Equipment carts may roll into safe shutdown equipment.

D.4 FLEXIBILITY OF ATTACHED LINES

Distribution lines, such as small bore piping, tubing, conduit, or cable, which are connected to safe shutdown equipment can potentially fail if there is insufficient flexibility to accommodate relative motion between the safe shutdown equipment and the adjacent equipment or structures. Straight, in-line connections in particular are prone to failure. The scope of review of such lines extends from the item of equipment being evaluated to the first support of the attached lines.

D.5 EVALUATION OF INTERACTION EFFECTS

The Seismic Capability Engineers should identify and evaluate all credible and significant interactions in the immediate vicinity of the safe shutdown equipment. Evaluation of interaction effects should consider detrimental effects on the capability of equipment and systems to function, taking into account equipment attributes such as mass, size, support configuration, and material hardness in conjunction with the physical relationships of interacting equipment, systems, and structures. In the evaluation of proximity effects and overhead or adjacent equipment failure and interactions, the effects of intervening structures and equipment which would preclude impact should be considered.

Damage from interaction in earthquakes is from unusual circumstances or from generic, simple details such as open hooks on suspended lights. The Seismic Capability Engineers should spend most of their time looking for: 1) unusual impact situations, and 2) lack of proper anchorage or bracing, and not be concerned much with piping and other system or structural component failures.

The effects of fire, flooding or exposure to fluids from ruptured vessels and piping and the seismic interaction effects on instrument air lines and electrical and instrumentation cabling beyond the first anchor point are out of the scope of USI A-46. Individual utilities may add these to the scope of their review as an option if they desire.

D.6 SUMMARY OF INTERACTION EXAMPLES

This section briefly summarizes examples of possible seismic interaction effects. Some of the following effects may not have occurred in earthquakes, but they are included for completeness.

- Unreinforced masonry walls adjacent to equipment may spall or fall and impact equipment or cause loss of support of equipment. The wall does not have to be evaluated if it has already been addressed as part of an IE Bulletin 80-11 program.

- Emergency lighting units and batteries used for emergency lighting can fall or overturn and damage equipment by impact or spilling of acid.

- Fire extinguishers may fall and impact or roll into equipment.

- Intercom speakers can fall and impact equipment.

- Equipment carts, dollies, chains, air bottles, welding equipment, etc., may roll into, slide, overturn, or otherwise impact equipment.

- Piping, cable trays, conduit, and HVAC may deflect and impact equipment.

- Cable trays, conduit systems, and HVAC systems, including HVAC louvers and diffusers, may fall and impact equipment.

- Structures or structural elements may deform or fall and impact equipment.

- Anchor movement may cause breaks in piping, cable trays, conduit HVAC, etc. which may fall or deflect and impact adjacent equipment.

- Mechanical piping couplings can fail and lead to pipe deflection or falling and impact on equipment.

- Electrical cabinets that deflect and impact walls, structural members, another cabinet, etc., may damage devices in the cabinet or cause devices to trip or chatter.

- Storage cabinets, office cabinets, files, bookcases, wall lockers, and medicine cabinets may fall or tip into equipment.

- The doors on electrical cabinets may swing and impact devices or cause relays to chatter.

- Inadequately anchored or braced equipment such as pumps, vessels, tanks, heat exchangers, cabinets, and switchgear may deflect or overturn and impact equipment.

- Architectural features such as suspended ceilings, ceiling components such as T-bars and acoustical panels, light fixtures, fluorescent tubes, partition walls, and plate glass may deflect, overturn or break and fall and impact equipment.

- Grating may slide or fall and impact equipment.

- Sheetrock may fall and impact equipment if it was previously water-damaged or if there is severe distortion of the building.

- Unanchored room heaters, air conditioning units, sinks, and water fountains may fall or slide into equipment.

Appendix E

PREPARATORY WORK PRIOR TO WALKDOWN

CONTENTS

Appendix E

PREPARATORY WORK PRIOR TO WALKDOWN

E.1 INTRODUCTION

Experience from the SQUG trial plant reviews has demonstrated that preparatory work performed prior to conducting the plant screening evaluations will maximize the effectiveness of the walkdown. This appendix describes these preparations.

E.2 SYSTEMS ENGINEERING AND PLANT OPERATIONS

Prior to the walkdown, the systems engineer(s) and plant operations representative should review the plant design documents to familiarize themselves with plant design features and, in particular, those associated with the safe shutdown systems. Much of the required initial information is contained in the FSAR. In addition, piping and instrumentation diagrams (P&IDs), electrical one-line drawings, instrument block diagrams, operating procedures, system descriptions, plant arrangement drawings, and selected topical reports and specifications should be used to identify the safe shutdown equipment (Section 3).

Discussions with plant operations personnel are very helpful in identifying equipment within various safe shutdown trains. Systems engineers may wish to consider the inclusion of equipment which does not have seismic qualification documentation, thereby upgrading its seismic qualification status. Industrial-grade equipment which has not been reviewed for seismic adequacy is typically as seismically rugged as equipment for which seismic qualification data has been obtained.

Plant arrangement drawings should be marked with the location of each item of equipment selected for review and provided to the Seismic Capability Engineers who will be doing the seismic evaluation. In addition, the Safe Shutdown Equipment Lists (SSELs), described in Section 3 and Appendix A which identify the candidate equipment to be seismically verified, should be completed. It is recommended they be entered into a personal computer data base management program for use in preparing columns 1 - 6 of the SVDS shown in Section 4.

E.3 PRE-WALKDOWN PLANNING

The purpose of pre-walkdown planning is to organize the who, how, where, and when associated with the plant walkdown. Judicious planning will minimize the time spent in the field by the Seismic Review Team (SRT).

The planning process should be performed with active participation from the principal walkdown participants and the utility personnel with experience in the configuration and operation of the plant under review. The following organizations or individuals will typically be involved in the walkdown and hence should be part of the planning effort:

- Utility manager in charge of the USI A-46 project effort
- Utility systems engineer(s)
- Plant operations and/or radiation protection personnel
- Seismic Capability Engineers

Advance planning on when to perform the walkdown is advisable. Walkdowns should not interfere with the normal operation of the plant. Security, radiation level, operations, and maintenance considerations are necessary in deciding when each area of the plant can be visited. Some areas of the plant are inaccessible during normal operation and can only be inspected during outage periods. The Screening Verification and Data Sheets (SVDSs), discussed in Section 4, can be organized by plant location and thereby used as a checklist and itinerary for the walkdown. The itinerary, however, should be flexible to allow the walkdown teams time to revisit certain areas or alter their plans because of difficulties in determining seismic adequacy of particular types of equipment. It is also advisable to provide the walkdown teams with the itineraries in advance so that they can review the items of equipment assigned prior to the walkdown.

Advance planning and preparation are needed to gain access to operating plants, particularly if contractors are used to conduct the walkdown. The SRT may be required to obtain security clearances, access badges, and radiation training. The walkdown participants may need to be accompanied by plant security and radiation protection personnel; however, such accompaniment is costly (ties up personnel) and tends to interfere with normal plant operations and maintenance. It also increases the number of individuals involved with the walkdown which tends to slow down the pace of the effort. Advance notification and scheduling can streamline the process of gaining plant access. All people concerned with the plant walkdown including walkdown team members, plant operations personnel, health physics personnel, security personnel and utility staff should be advised of the dates and duration of the plant walkdown well in advance of the scheduled walkdowns (e.g., two months ahead of time).

The seismic review teams or individual team members may want to have discussions with other plant operations personnel prior to and during the walkdown to clarify the way a system or an item of equipment operates. If possible, these meetings should be planned well in advance so that people knowledgeable in the specific areas of concern will be available with a minimum of disruption in the normal operation of the plant.

A summary of all the available seismic design and qualification data should be prepared and provided to the SRT several weeks before their scheduled walkdown. The summary does not have to be formal, but it should be comprehensive. The Seismic Capability Engineers performing the walkdown should become thoroughly familiar with the plant seismic design basis. The greater the understanding of the plant seismic design basis and the design basis approaches taken for equipment qualification and anchorage, the easier it will be to exercise judgment and experience to eliminate outliers. The ground response spectra resulting from the Safe Shutdown Earthquake (SSE), the floor response spectra and how they were generated, and data pertaining to effective grade of each building should be provided to the SRT.

Construction details of the anchorages for the safe shutdown equipment are essential for evaluating the seismic adequacy of the equipment. Inspection and evaluation of anchorages is difficult if not impossible without the use of construction drawings, specifications, and bills of materials.

The documents which should be available to the SRT include:

1. List of the safe shutdown equipment prepared using Appendix A.
2. List of equipment for which prior seismic qualification documentation exists.
3. Summary of the plant seismic design basis, specifically: ground response spectra for the SSE, background data for effective grade definition, seismic design criteria, amplified (floor) response spectra, etc.
4. Standard details for equipment anchorages.
5. Plant arrangement drawings.
6. Health physics and plant security requirements.

Appendix F

SCREENING WALKDOWN PLAN

CONTENTS

Appendix F

SCREENING WALKDOWN PLAN

F.1 INTRODUCTION

This appendix describes an approach which can be used to perform the screening evaluation of the safe shutdown equipment during the plant walkdown. This approach is based on the experience gained in performing the SQUG trial plant reviews. This appendix covers: (1) the organization and approach which can be used by the Seismic Review Team (SRT), (2) the degree of inspection to be performed, (3) walkdown logistics, and (4) screening walkdown completion.

F.2 ORGANIZATION AND APPROACH OF SRT

The number of individuals in each Seismic Review Team (SRT) should be minimized to permit ready access to inspect equipment and facilitate movement. In addition to the two Seismic Capability Engineers, a systems or operations engineer may also be involved in the walkdown as needed by the SRT to provide information on how a system or an item of equipment operates to accomplish its safe shutdown function. Health physics and security personnel may also accompany the SRT as the need arises.

Each group of individuals walking down the plant should collectively have:

1. An understanding of the plant layout and location of the various system and equipment scheduled to be evaluated during that walkdown period;
2. An understanding of the scope and objectives of the walkdown including the methodology and procedures;
3. An understanding of the seismic verification guidelines including inspection techniques and evaluation criteria;
4. An understanding of the operational aspects of the plant and the importance of the various plant systems and equipment.

SRT decisions concerning equipment seismic adequacy should be made on the spot, if possible, and the walkdown should proceed at a pace consistent with this objective. Decisions to verify the seismic adequacy of equipment should be unanimous among the Seismic Capability Engineers. Concerns which do not permit seismic verification during the screening walkdown should be documented and left for further review to either eliminate the equipment as a required part of the safe shutdown system (i.e., select a different train or set of equipment) or identify it as an outlier for further evaluation (as described in Section 5). During the walkdown, many items of equipment may have verification results that are unknown. The SRT should decide what information or additional action is required to resolve the issue and inform the appropriate support staff personnel so that, if possible, the issue may be resolved during the later part of the walkdown.

If several Seismic Review Teams are used to conduct the screening verification and walkdown, then a means for coordinating the activities of the various teams should be used to ensure that all the equipment and activities of the evaluation are covered. This coordinating function could be performed by a single individual or by a committee of individuals from the various SRTs.

F.3 DEGREE OF INSPECTION

All of the equipment on the safe shutdown equipment list (SSEL) should be reviewed. Exceptions to this may occur (e.g., equipment in very high radiation areas or otherwise inaccessible locations), and each exception should be justified by the SRT. The level or scope of evaluation may vary depending upon the experience and judgment of the SRT.

The number of equipment items that are classified as outliers, and require further evaluation, usually depends on the original design and construction of the plant, existing available documentation, current maintenance practice, and the degree of expertise of the SRTs.

F.4 WALKDOWN LOGISTICS

The SQUG trial plant walkdowns were conducted over a two-week period using several SRTs. The following procedure was used to facilitate these walkdowns.

A three-to-four hour kick-off meeting was scheduled for the beginning of the plant walkdown. This meeting provided a briefing on the objectives of the walkdown, the organization of the walkdown groups, the planning for the walkdown, and the breakdown of the total list of equipment for which each group was responsible. Radiation training (including whole body counts and issuance of personnel dosimetry) and plant access requirements (obtaining security badges) for the SRT members were done prior to this kick-off meeting. After this kick-off meeting, the SRTs commenced with the plant walkdown.

A daily morning meeting was held in which the SRT reviewed the equipment included in that day's walkdown. Anchorage drawings were also made available and reviewed by the SRT. The walkdown was conducted in morning and afternoon sessions. A meeting was also held during the lunch break to discuss problem areas and the approaches used by other SRTs.

The afternoon session began after lunch and lasted until dinner time. At the option of the utility and the SRTs, it may be desirable to conduct the walkdown outside of normal working hours. In any case, it is not recommended that the walkdown "day" exceed a total of about 10 hours.

A short meeting was also held at the end of each day to discuss the day's walkdown, request information as required from the appropriate support staff personnel, certify the completed SVDS, review information retrieved by the support staff so that previously started evaluations could be completed, and organize the next day's activities. Any unknowns were reconciled as soon as possible after the item of equipment had been inspected. The memory of the SRT for the particular equipment verification was clearer, and the number of unknown equipment items did not mount up during the course of the walkdown.

When performing the walkdown, the SRT had the appropriate tools to collect and record data. These tools included a clip board (e.g., for SVDS and SEWS), a ten foot long tape measure capable of measuring to 1/16 inch, pencils or pens, and a flashlight. The SRT may wish to use some form of carrying pack to allow hands to be free for climbing ladders, going through crawl spaces, etc.

Other tools may be included depending on the preference of the SRT. For example, a compact camera (subject to plant policy) can be useful to record visual findings (each picture frame should have a designation and be fully described.) A small audio cassette recorder can be used to record the subject of each picture frame and general notes about the walkdown. More elaborate visual records can be obtained by using a video recorder. However, video equipment is usually cumbersome and expensive, and has not been used extensively in past plant walkdowns. It should also be understood that the use of personal equipment is typically at the individual's own risk. If equipment is contaminated or broken, there is often no compensation by the plant.

The SRT should be aware that there is usually a need for hard hats, safety glasses, hearing protection, and sometimes safety shoes. SRT members should consider wearing light cotton clothing since temperatures inside operating nuclear stations, regardless of the time of year, are usually 75° to 90°F with high humidity. These conditions can lead to extreme personnel discomfort, especially when protective clothing is required for walkdowns in contaminated and high radiation areas.

F.5 SCREENING WALKDOWN COMPLETION

At the completion of the Screening Verification and Walkdown, all identified safe shutdown equipment included in the walkdown should be classified as being either verified or an outlier. The SVDS should be completed, checked for accuracy, and certified for each item of equipment. The outlier sheets (OSVS) should be completed for each item of equipment identified as an outlier. Work sheets (SEWS), if used, should also be checked so that the information noted (judgments, description, and calculations) can be reasonably followed by a reviewer. At the completion of the Screening Verification and Walkdown, the SRT should inform the utility management about the walkdown results in detail.

Appendix G

SCREENING EVALUATION WORK SHEETS (SEWS)

CONTENTS

CONTENTS (Continued)

Appendix G

SCREENING EVALUATION WORK SHEETS

INTRODUCTION

The purpose of the Screening Evaluation Work Sheets (SEWS) is to provide a convenient summary and checklist of the seismic evaluation criteria described in Section 4, Screening Verification and Walkdown, and in Section 7, Tanks and Heat Exchangers Review. These SEWS can be used during the plant walkdown. The use of the SEWS is optional. The only required document is the Screening Verification Data Sheets (SVDS) described in Section 4. The SEWS in this appendix are compatible with the SVDS form shown in Exhibit 4-1.

There are SEWS in this appendix for Equipment Classes #0 through #21. See Table 3-1 in Section 3 for a summary of the sub-categories within each of these classes. The checklist statements are very abbreviated; see Sections 4 and 7 and Appendices B and C for a complete description of each checklist item.

Note: The work sheets cannot be used unless the user has a thorough understanding of this procedure and the reference documents.

Most of the information at the top of each SEWS (Equipment ID Number, Equipment Description, Equipment Location, etc.) can be entered on the SEWS prior to the plant walkdown. If a data base program is used to develop the Safe Shutdown Equipment List (SSEL) as described in Section 3, then the information at the top of each page of the SEWS can be printed directly from the data base file containing the SSEL information. Appendix B of the report "Results of PWR Trial Plant Review" (Reference 15) contains examples of SEWS used during a SQUG trial plant review with this information entered at the top of each page of the SEWS.

The body of the SEWS is used as a checklist by circling the appropriate symbol in response to each statement. The meaning of the symbols is given below:

Y - Yes. This criterion is met. ("Y" is always the favorable response.)

N - No. This criterion is not met.

U - Unknown. It cannot be determined whether this criterion is met.

N/A - Not Applicable. Some of the criteria may not apply for a particular item of equipment.

Some of the statements on the SEWS ask which of several alternatives is being used in the Screening Verification and Walkdown. Circle the symbol for the selected alternative. The meaning of these symbols is self-explanatory. After circling all the appropriate responses in each section of the SEWS, the final statement in each section can then be answered as either Y, N, or U. Likewise, when all the sections have a final response, the last question on the SEWS can then be answered ("Is Equipment Seismically Adequate?"). The responses to the questions in the sections and the final question can all be entered directly into the appropriate column in the SVDS (described in Section 4).

The SEWS also provide space to record information about the item of equipment, to document any comments the Seismic Capability Engineers may wish to make, to sketch the equipment, and to sign off.

Revision 2
Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS)

Sheet 1 of 2

Equip. ID No. ________________ Equip. Class 0 - Other

Equipment Description ________________________________

Location: Bldg. ________ Floor El. ______ Room, Row/Col ________________

Manufacturer, Model, Etc. ________________________________

SEISMIC CAPACITY VS DEMAND

Does capacity exceed demand? Y N U N/A

ANCHORAGE

Is the anchorage adequate? Y N U N/A

INTERACTION EFFECTS

Is equipment free of interaction effects? Y N U N/A

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ________________ Equip. Class 0 - Other ____________

Equipment Description ____

COMMENTS

Evaluated by: ______________________________________ Date: __________

______________________________________ __________

Revision 2
Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 3

Equip. ID No. ______________ Equip. Class 1 - Motor Control Centers

Equipment Description ____________________

Location: Bldg. ______ Floor El. _____ Room, Row/Col ____________

Manufacturer, Model, Etc. ______ ____________________

SEISMIC CAPACITY VS DEMAND

1.	Elevation where equipment receives seismic input		________
2.	Elevation of seismic input below about 40' from grade		Y N U
3.	Equipment has fundamental frequency above about 8 Hz		Y N U N/A
4.	Capacity based on:	Existing Documentation	DOC
		Bounding Spectrum	BS
		GERS	GERS
5.	Demand based on:	Ground Spectra	GRS
		Amplified (Floor) Spectra	AFS

Does capacity exceed demand? Y N U

CAVEATS - BOUNDING SPECTRUM

1.	Equipment is included in earthquake experience data base	Y N U N/A
2.	600 V rating or less	Y N U N/A
3.	Adjacent cabinets which are close enough to impact, or sections of multi-bay cabinets, are bolted together if they contain essential relays	Y N U N/A
4.	Attached weight (except conduit) less than about 100 lbs per cabinet bay	Y N U N/A
5.	Externally attached items rigidly anchored	Y N U N/A
6.	General configuration similar to NEMA Standards	Y N U N/A
7.	Cutouts in lower half less than 6 in. wide and 12 in. high	Y N U N/A
8.	All doors secured by latch or fastener	Y N U N/A
9.	Natural frequency relative to 8 Hz limit considered	Y N U N/A
10.	Anchorage adequate	Y N U N/A
11.	Relays mounted on equipment evaluated	Y N U N/A
12.	No other concerns	Y N U N/A

Are the caveats met for Bounding Spectrum? Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ________________ Equip. Class 1 - Motor Control Centers

Equip. Description ________________

CAVEATS - GERS

1.	Equipment is included in generic seismic test data base	Y N U N/A
2.	Meets all Bounding Spectrum caveats	Y N U N/A
3.	Floor mounted cabinet	Y N U N/A
4.	Average weight per section less than 800 pounds	Y N U N/A
5.	Base anchorage utilizing MCC base channels	Y N U N/A
6.	Adequate load transfer path from anchorage to base frame	Y N U N/A
7.	Essential relays have GERS > 4.5g (only for "function during" GERS)	Y N U N/A
8.	Able to reset starters (only for "function after" GERS)	Y N U N/A
9.	Base structural members integrally welded (only for 3.5g "function after" GERS)	Y N U N/A

Are the caveats met for GERS? Y N U N/A

ANCHORAGE

1.	Appropriate equipment characteristics determined (mass, CG, natural freq., damping, center of rotation)	Y N U N/A
2.	Type of anchorage covered by GIP	Y N U N/A
3.	Sizes and locations of anchors determined	Y N U N/A
4.	Adequacy of anchorage installation evaluated (weld quality, nuts and washers, expansion anchor tightness)	Y N U N/A
5.	Factors affecting anchorage capacity or margin of safety considered: embedment length, anchor spacing, free-edge distance, concrete strength/condition, and concrete cracking	Y N U N/A
6.	For bolted anchorages, gap under base less than 1/4-inch	Y N U N/A
7.	Factors affecting essential relays considered: gap under base, capacity reduction for expansion anchors	Y N U N/A
8	Base has adequate stiffness and effect of prying action on anchors considered	Y N U N/A
9.	Strength of equipment base and load path to CG adequate	Y N U N/A
10.	Embedded steel, grout pad or large concrete pad adequacy evaluated	Y N U N/A

Are anchorage requirements met? Y N U

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ________________ Equip. Class 1 - Motor Control Centers

Equipment Description ________________________________

INTERACTION EFFECTS

1. Soft targets free from impact by nearby equipment or structures	Y N U N/A
2. If equipment contains sensitive relays, equipment free from all impact by nearby equipment or structures	Y N U N/A
3. Attached lines have adequate flexibility	Y N U N/A
4. No collapse of overhead equipment or distribution systems	Y N U N/A
5. No other concerns	Y N U N/A
Is equipment free of interaction effects?	Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

COMMENTS

Evaluated by: ________________________________ Date: ____________

________________________________ ____________

Revision 2
Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 3

Equip. ID No. ______________ Equip. Class 2 - Low Voltage Switchgear

Equipment Description ______________________________

Location: Bldg. _______ Floor El. _____ Room, Row/Col ______________

Manufacturer, Model, Etc. ______________________________

SEISMIC CAPACITY VS DEMAND

1.	Elevation where equipment receives seismic input	________
2.	Elevation of seismic input below about 40' from grade	Y N U
3.	Equipment has fundamental frequency above about 8 Hz	Y N U N/A
4.	Capacity based on: Existing Documentation	DOC
	Bounding Spectrum	BS
	GERS	GERS
5.	Demand based on: Ground Spectra	GRS
	Amplified (Floor) Spectra	AFS

Does capacity exceed demand? Y N U

CAVEATS - BOUNDING SPECTRUM

1.	Equipment is included in earthquake experience data base	Y N U N/A
2.	600 V rating or less	Y N U N/A
3.	Adjacent cabinets which are close enough to impact, or sections of multi-bay cabinets, are bolted together if they contain essential relays	Y N U N/A
4.	Attached weight (except conduit) less than about 100 lbs per cabinet bay	Y N U N/A
5.	Externally attached items rigidly anchored	Y N U N/A
6.	General configuration similar to ANSI C37.20 Standards	Y N U N/A
7.	Cutouts in lower half of cabinet side sheathing less than 30% of width of side panel wide and less than 60% of width of side panel high excluding bus transfer compartment	Y N U N/A
8.	All doors secured by latch or fastener	Y N U N/A
9.	Anchorage adequate	Y N U N/A
10.	Relays mounted on equipment evaluated	Y N U N/A
11.	No other concerns	Y N U N/A

Are the caveats met for Bounding Spectrum? Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ________________ Equip. Class 2 - Low Voltage Switchgear

Equipment Description ____

CAVEATS - GERS

1.	Equipment is included in generic seismic test data base	Y N U N/A
2.	Meets all Bounding Spectrum caveats	Y N U N/A
3.	Floor-mounted enclosure	Y N U N/A
4.	Manufactured by major vendor (ITE/Brown Boveri, Westinghouse, GE, or Powell)	Y N U N/A
5.	Average weight per section less than 1600 lbs	Y N U N/A
6.	Separate evaluation of breaker racking mechanism completed; seismic positioner or sufficient side-to-side constraints used	Y N U N/A
7.	Anchored through base	Y N U N/A
8.	Not considered special purpose switchgear (e.g., reactor trip)	Y N U N/A
9.	All relays that could affect the function of the breaker are adequately rugged--i.e., not on Low Ruggedness Relays list	Y N U N/A
10.	Relay evaluation completed for all relays that are essential to other equipment	Y N U N/A

Are the caveats met for GERS? Y N U N/A

ANCHORAGE

1	Appropriate equipment characteristics determined (mass, CG, natural freq., damping, center of rotation)	Y N U N/A
2.	Type of anchorage covered by GIP	Y N U N/A
3.	Sizes and locations of anchors determined	Y N U N/A
4.	Adequacy of anchorage installation evaluated (weld quality, nuts and washers, expansion anchor tightness)	Y N U N/A
5.	Factors affecting anchorage capacity or margin of safety considered: embedment length, anchor spacing, free-edge distance, concrete strength/condition, and concrete cracking	Y N U N/A
6.	For bolted anchorages, gap under base less than 1/4-inch	Y N U N/A
7.	Factors affecting essential relays considered: gap under base, capacity reduction for expansion anchors	Y N U N/A
8.	Base has adequate stiffness and effect of prying action on anchors considered	Y N U N/A
9.	Strength of equipment base and load path to CG adequate	Y N U N/A
10.	Embedded steel, grout pad or large concrete pad adequacy evaluated	Y N U N/A

Are anchorage requirements met? Y N U

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ________________ Equip. Class 2 - Low Voltage Switchgear

Equipment Description ______________________________

INTERACTION EFFECTS

1. Soft targets free from impact by nearby equipment or structures — Y N U N/A
2. If equipment contains sensitive relays, equipment free from all impact by nearby equipment or structures — Y N U N/A
3. Attached lines have adequate flexibility — Y N U N/A
4. No collapse of overhead equipment or distribution systems — Y N U N/A
5. No other concerns — Y N U N/A

Is equipment free of interaction effects? Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

COMMENTS

Evaluated by: ______________________ Date: __________

______________________ __________

Revision 2
Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 3

Equip. ID No. ______________ Equip. Class 3 - Medium Voltage Switchgear

Equipment Description ______________________________

Location: Bldg. ________ Floor El. ______ Room, Row/Col ________ __________

Manufacturer, Model, Etc. ______________________________

SEISMIC CAPACITY VS DEMAND

1. Elevation where equipment receives seismic input ________
2. Elevation of seismic input below about 40' from grade Y N U
3. Equipment has fundamental frequency above about 8 Hz Y N U N/A
4. Capacity based on: Existing Documentation DOC
   Bounding Spectrum BS
   GERS GERS
5. Demand based on: Ground Spectra GRS
   Amplified (Floor) Spectra AFS

Does capacity exceed demand? Y N U

CAVEATS - BOUNDING SPECTRUM

1. Equipment is included in earthquake experience data base Y N U N/A
2. 2.4 KV to 4.16 KV rating Y N U N/A
3. Adjacent cabinets which are close enough to impact, or sections of multi-bay cabinets, are bolted together if they contain essential relays Y N U N/A
4. Attached weight (excluding conduit) less than about 100 lbs per cabinet bay Y N U N/A
5. Externally attached items rigidly anchored Y N U N/A
6. General configuration similar to ANSI C37.20 Standards Y N U N/A
7. Cutouts in lower half of cabinet sheathing less than 30% of width of side panel wide and less than 60% of width of side panel high excluding bus transfer compartment Y N U N/A
8. All doors secured by latch or fastener Y N U N/A
9. Anchorage adequate Y N U N/A
10. Relays mounted on equipment evaluated Y N U N/A
11. No other concerns Y N U N/A

Are the caveats met for Bounding Spectrum? Y N U N/A

CAVEATS - GERS

1. Equipment is included in generic seismic test data base Y N U N/A
2. Meets all Bounding Spectrum caveats Y N U N/A
3. Floor-mounted enclosure Y N U N/A
4. Circuit breakers are truck-mounted type, not jack-up or vertical-lift Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ________________ Equip. Class 3 - Medium Voltage Switchgear

Equipment Description ____

CAVEATS - GERS (Cont'd)

5. Average weight per vertical section less than 5000 lbs — Y N U N/A
6. Separate evaluation of breaker racking mechanism completed; seismic positioner or sufficient side-to-side constraints used — Y N U N/A
7. Inspection of internal component (e.g. current and potential transformers) mounting completed if capacity based on 3.0g GERS — Y N U N/A
8. Anchored through base — Y N U N/A
9. Not considered special-purpose switchgear (e.g. reactor trip) — Y N U N/A
10. All relays that could affect the function of the breaker are adequately rugged--i.e. not on Low Ruggedness Relays list — Y N U N/A
11. Relay evaluations completed for all relays that are essential to other equipment — Y N U N/A

Are the caveats met for GERS? — Y N U N/A

ANCHORAGE

1. Appropriate equipment characteristics determined (mass, CG, natural freq., damping, center of rotation) — Y N U N/A
2. Type of anchorage covered by GIP — Y N U N/A
3. Sizes and locations of anchors determined — Y N U N/A
4. Adequacy of anchorage installation evaluated (weld quality, nuts and washers, expansion anchor tightness) — Y N U N/A
5. Factors affecting anchorage capacity or margin of safety considered: embedment length, anchor spacing, free-edge distance, concrete strength/condition, and concrete cracking — Y N U N/A
6. For bolted anchorages, gap under base less than 1/4-inch — Y N U N/A
7. Factors affecting essential relays considered: gap under base, capacity reduction for expansion anchors — Y N U N/A
8. Base has adequate stiffness and effect of prying action on anchors considered — Y N U N/A
9. Strength of equipment base and load path to CG adequate — Y N U N/A
10. Embedded steel, grout pad or large concrete pad adequacy evaluated — Y N U N/A

Are anchorage requirements met? — Y N U

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ________________ Equip. Class 3 - Medium Voltage Switchgear

Equipment Description ____

INTERACTION EFFECTS

1. Soft targets free from impact by nearby equipment or structures — Y N U N/A
2. If equipment contains sensitive relays, equipment free from all impact by nearby equipment or structures — Y N U N/A
3. Attached lines have adequate flexibility — Y N U N/A
4. No collapse of overhead equipment or distribution systems — Y N U N/A
5. No other concerns — Y N U N/A

Is equipment free of interaction effects? Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

COMMENTS

Evaluated by: ______________________________ Date: ____________

______________________________ ____________

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 3

Equip. ID No. ________________ Equip. Class 3 - Medium Voltage Switchgear

Equipment Description ______________________ ______________________

Location: Bldg. _________ Floor El. ______ Room, Row/Col ____________________

Manufacturer, Model, Etc. ______________________________ __________

SEISMIC CAPACITY VS DEMAND

1. Elevation where equipment receives seismic input __________
2. Elevation of seismic input below about 40' from grade Y N U
3. Equipment has fundamental frequency above about 8 Hz Y N U N/A
4. Capacity based on: Existing Documentation DOC
   Bounding Spectrum BS
   GERS GERS
5. Demand based on: Ground Spectra GRS
   Amplified (Floor) Spectra AFS

Does capacity exceed demand? Y N U

CAVEATS - BOUNDING SPECTRUM

1. Equipment is included in earthquake experience data base Y N U N/A
2. 2.4 KV to 4.16 KV rating Y N U N/A
3. Adjacent cabinets which are close enough to impact, or sections of multi-bay cabinets, are bolted together if they contain essential relays Y N U N/A
4. Attached weight (excluding conduit) less than about 100 lbs per cabinet bay Y N U N/A
5. Externally attached items rigidly anchored Y N U N/A
6. General configuration similar to ANSI C37.20 Standards Y N U N/A
7. Cutouts in lower half of cabinet sheathing less than 30% of width of side panel wide and less than 60% of width of side panel high excluding bus transfer compartment Y N U N/A
8. All doors secured by latch or fastener Y N U N/A
9. Anchorage adequate Y N U N/A
10. Relays mounted on equipment evaluated Y N U N/A
11. No other concerns Y N U N/A

Are the caveats met for Bounding Spectrum? Y N U N/A

CAVEATS - GERS

1. Equipment is included in generic seismic test data base Y N U N/A
2. Meets all Bounding Spectrum caveats Y N U N/A
3. Floor-mounted enclosure Y N U N/A
4. Circuit breakers are truck-mounted type, not jack-up or vertical-lift Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ________________ Equip. Class 3 - Medium Voltage Switchgear

Equipment Description ____

CAVEATS - GERS (Cont'd)

5.	Average weight per vertical section less than 5000 lbs	Y	N	U	N/A
6.	Separate evaluation of breaker racking mechanism completed; seismic positioner or sufficient side-to-side constraints used	Y	N	U	N/A
7.	Inspection of internal component (e.g. current and potential transformers) mounting completed if capacity based on 3.0g GERS	Y	N	U	N/A
8.	Anchored through base	Y	N	U	N/A
9.	Not considered special-purpose switchgear (e.g. reactor trip)	Y	N	U	N/A
10.	All relays that could affect the function of the breaker are adequately rugged--i.e. not on Low Ruggedness Relays list	Y	N	U	N/A
11.	Relay evaluations completed for all relays that are essential to other equipment	Y	N	U	N/A

Are the caveats met for GERS? Y N U N/A

ANCHORAGE

1.	Appropriate equipment characteristics determined (mass, CG, natural freq., damping, center of rotation)	Y	N	U	N/A
2.	Type of anchorage covered by GIP	Y	N	U	N/A
3.	Sizes and locations of anchors determined	Y	N	U	N/A
4.	Adequacy of anchorage installation evaluated (weld quality, nuts and washers, expansion anchor tightness)	Y	N	U	N/A
5.	Factors affecting anchorage capacity or margin of safety considered: embedment length, anchor spacing, free-edge distance, concrete strength/condition, and concrete cracking	Y	N	U	N/A
6.	For bolted anchorages, gap under base less than 1/4-inch	Y	N	U	N/A
7.	Factors affecting essential relays considered: gap under base, capacity reduction for expansion anchors	Y	N	U	N/A
8.	Base has adequate stiffness and effect of prying action on anchors considered	Y	N	U	N/A
9.	Strength of equipment base and load path to CG adequate	Y	N	U	N/A
10.	Embedded steel, grout pad or large concrete pad adequacy evaluated	Y	N	U	N/A

Are anchorage requirements met? Y N U

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ________________ Equip. Class 3 - Medium Voltage Switchgear

Equipment Description ________________

INTERACTION EFFECTS

1.	Soft targets free from impact by nearby equipment or structures	Y N U N/A
2.	If equipment contains sensitive relays, equipment free from all impact by nearby equipment or structures	Y N U N/A
3.	Attached lines have adequate flexibility	Y N U N/A
4.	No collapse of overhead equipment or distribution systems	Y N U N/A
5.	No other concerns	Y N U N/A

Is equipment free of interaction effects? Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

COMMENTS

Evaluated by: ________________ ________________ Date: ________________

________________ ________________

Revision 2
Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 3

Equip. ID No. ________________ Equip. Class 4 - Transformers

Equipment Description ______________________________

Location: Bldg. ________ Floor El. ______ Room, Row/Col ______________

Manufacturer, Model, Etc. ______________________________

SEISMIC CAPACITY VS DEMAND

1. Elevation where equipment receives seismic input ________
2. Elevation of seismic input below about 40' from grade Y N U
3. Equipment has fundamental frequency above about 8 Hz Y N U N/A
4. Capacity based on: Existing Documentation DOC
   Bounding Spectrum BS
   GERS GERS
5. Demand based on: Ground Spectra GRS
   Amplified (Floor) Spectra AFS

Does capacity exceed demand? Y N U

CAVEATS - BOUNDING SPECTRUM

1. Equipment is included in earthquake experience data base Y N U N/A
2. 4.16 KV rating or less Y N U N/A
3. For floor-mounted dry- and oil-type unit, transformer coils restrained within cabinet Y N U N/A
4. For wall-mounted units, transformer coils anchored to enclosure near enclosure support surface Y N U N/A
5. For floor-mounted units, anchorage does not rely on weak-way bending of cabinet structures under lateral forces Y N U N/A
6. Adjacent cabinets which are close enough to impact are bolted together if they contain essential relays Y N U N/A
7. All doors secured by latch or fastener Y N U N/A
8. Anchorage adequate Y N U N/A
9. Relays mounted on equipment evaluated Y N U N/A
10. No other concerns Y N U N/A

Are the caveats met for Bounding Spectrum? Y N U N/A

CAVEATS - GERS

1. Equipment is included in generic seismic test data base Y N U N/A
2. Meets all Bounding Spectrum caveats Y N U N/A
3. Dry-type unit (not oil-filled) Y N U N/A
4. Wall or floor-mounted NEMA-type enclosure Y N U N/A
5. 120 to 480 VAC rating Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ________________ Equip. Class 4 - Transformers

Equipment Description ________________________________

CAVEATS - GERS (Cont'd)

6.	7.5 to 225 KVA rating	Y	N	U	N/A	
7.	180 to 2000 pound weight		N	U	N/A	
8.	Internal supports provide positive attachment of transformer components	Y	N	U	N/A	
	Are the caveats met for GERS?					Y N U N/A

ANCHORAGE

1.	Appropriate equipment characteristics determined (mass, CG, natural freq., damping, center of rotation)	Y	N	U	N/A	
2.	Type of anchorage covered by GIP	Y	N	U	N/A	
3.	Sizes and locations of anchors determined	Y	N	U	N/A	
4.	Adequacy of anchorage installation evaluated (weld quality, nuts and washers, expansion anchor tightness)	Y	N	U	N/A	
5.	Factors affecting anchorage capacity or margin of safety considered: embedment length, anchor spacing, free-edge distance, concrete strength/condition, and concrete cracking	Y	N	U	N/A	
6.	For bolted anchorages, gap under base less than 1/4-inch	Y	N	U	N/A	
7.	Factors affecting essential relays considered: gap under base, capacity reduction for expansion anchors	Y	N	U	N/A	
8.	Base has adequate stiffness and effect of prying action on anchors considered	Y	N	U	N/A	
9.	Strength of equipment base and load path to CG adequate	Y	N	U	N/A	
10.	Embedded steel, grout pad or large concrete pad adequacy evaluated	Y	N	U	N/A	
	Are anchorage requirements met?					Y N U

INTERACTION EFFECTS

1.	Soft targets free from impact by nearby equipment or structures	Y	N	U	N/A	
2.	If equipment contains sensitive relays, equipment free from all impact by nearby equipment or structures	Y	N	U	N/A	
3.	Attached lines have adequate flexibility	Y	N	U	N/A	
4.	No collapse of overhead equipment or distribution systems	Y	N	U	N/A	
5.	No other concerns	Y	N	U	N/A	
	Is equipment free of interaction effects?					Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ________________ Equip. Class 4 - Transformers

Equipment Description ____

COMMENTS

Evaluated by: ____ Date: ____________

____ ____________

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________ Equip. Class 5 - Horizontal Pumps

Equipment Description ____________

Location: Bldg. ______ Floor El. ______ Room, Row/Col ____________

Manufacturer, Model, Etc. ____________

Horsepower/Motor Rating ______ RPM ______ Head ______ Flow Rate ______

SEISMIC CAPACITY VS DEMAND

1. Elevation where equipment receives seismic input ____________
2. Elevation of seismic input below about 40' from grade Y N U
3. Equipment has fundamental frequency above about 8 Hz Y N U N/A
4. Capacity based on: Existing Documentation DOC
   Bounding Spectrum BS
5. Demand based on: Ground Spectra GRS
   Amplified (Floor) Spectra AFS

Does capacity exceed demand? Y N U

CAVEATS - BOUNDING SPECTRUM

1. Equipment is included in earthquake experience data base Y N U N/A
2. Driver and pump connected by rigid base or skid Y N U N/A
3. No indication that shaft does not have thrust restraint in both axial directions Y N U N/A
4. No risk of excessive nozzle loads such as gross pipe motion or differential displacement Y N U N/A
5. Base vibration isolators adequate for seismic loads Y N U N/A
6. Attached lines (cooling, air, electrical) have adequate flexibility Y N U N/A
7. Anchorage adequate Y N U N/A
8. Relays mounted on equipment evaluated Y N U N/A
9. No other concerns Y N U N/A

Are the caveats met for Bounding Spectrum? Y N U N/A

ANCHORAGE

1. Appropriate equipment characteristics determined (mass, CG, natural freq., damping, center of rotation) Y N U N/A
2. Type of anchorage covered by GIP Y N U N/A
3. Sizes and locations of anchors determined Y N U N/A
4. Adequacy of anchorage installation evaluated (weld quality, nuts and washers, expansion anchor tightness) Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ________________ Equip. Class 5 - Horizontal Pumps

Equipment Description ______________________________

ANCHORAGE (Cont'd)

5. Factors affecting anchorage capacity or margin of safety considered: embedment length, anchor spacing, free-edge distance, concrete strength/condition, and concrete cracking — Y N U N/A
6. For bolted anchorages, gap under base less than 1/4-inch — Y N U N/A
7. Factors affecting essential relays considered: gap under base, capacity reduction for expansion anchors — Y N U N/A
8. Base has adequate stiffness and effect of prying action on anchors considered — Y N U N/A
9. Strength of equipment base and load path to CG adequate — Y N U N/A
10. Embedded steel, grout pad or large concrete pad adequacy evaluated — Y N U N/A

Are anchorage requirements met? — Y N U

INTERACTION EFFECTS

1. Soft targets free from impact by nearby equipment or structures — Y N U N/A
2. If equipment contains sensitive relays, equipment free from all impact by nearby equipment or structures — Y N U N/A
3. Attached lines have adequate flexibility — Y N U N/A
4. No collapse of overhead equipment or distribution systems — Y N U N/A
5. No other concerns — Y N U N/A

Is equipment free of interaction effects? — Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? — Y N U

COMMENTS

Evaluated by: ______________________________ Date: ______________

______________________________ ______________

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No. ________________ Equip. Class 6 - Vertical Pumps

Equipment Description ________________

Location: Bldg. ________ Floor El. ______ Room, Row/Col ________________

Manufacturer, Model, Etc. ________________

Horsepower/Motor Rating __________ RPM __________ Head __________ Flow Rate ______

SEISMIC CAPACITY VS DEMAND

1. Elevation where equipment receives seismic input __________
2. Elevation of seismic input below about 40' from grade Y N U
3. Equipment has fundamental frequency above about 8 Hz Y N U N/A
4. Capacity based on: Existing Documentation DOC
   Bounding Spectrum BS
5. Demand based on: Ground Spectra GRS
   Amplified (Floor) Spectra AFS

Does capacity exceed demand? Y N U

CAVEATS - BOUNDING SPECTRUM

1. Equipment is included in earthquake experience data base Y N U N/A
2. Casing and impeller shaft not cantilevered more than 20 feet, with radial bearing at bottom to support shaft Y N U N/A
3. No risk of excessive nozzle loads such as gross pipe motion or differential displacement Y N U N/A
4. Attached lines (cooling, air, electrical) have adequate flexibility Y N U N/A
5. Anchorage adequate Y N U N/A
6. Relays mounted on equipment evaluated Y N U N/A
7. No other concerns Y N U N/A

Are the caveats met for Bounding Spectrum? Y N U N/A

ANCHORAGE

1. Appropriate equipment characteristics determined (mass, CG, natural freq., damping, center of rotation) Y N U N/A
2. Type of anchorage covered by GIP Y N U N/A
3. Sizes and locations of anchors determined Y N U N/A
4. Adequacy of anchorage installation evaluated (weld quality, nuts and washers, expansion anchor tightness) Y N U N/A
5. Factors affecting anchorage capacity or margin of safety considered: embedment length, anchor spacing, free-edge distance, concrete strength/condition, and concrete cracking Y N U N/A
6. For bolted anchorages, gap under base less than 1/4-inch Y N U N/A

Revision 2
Sheet 2 of 2

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No ________________ Equip. Class 6 - Vertical Pumps

Equipment Description ______________________________

ANCHORAGE (Cont'd)

7. Factors affecting essential relays considered: gap under base, capacity reduction for expansion anchors Y N U N/A
8. Base has adequate stiffness and effect of prying action on anchors considered Y N U N/A
9. Strength of equipment base and load path to CG adequate Y N U N/A
10. Embedded steel, grout pad or large concrete pad adequacy evaluated Y N U N/A

Are anchorage requirements met? Y N U

INTERACTION EFFECTS

1. Soft targets free from impact by nearby equipment or structures Y N U N/A
2. If equipment contains sensitive relays, equipment free from all impact by nearby equipment or structures Y N U N/A
3. Attached lines have adequate flexibility Y N U N/A
4. No collapse of overhead equipment or distribution systems Y N U N/A
5. No other concerns Y N U N/A

Is equipment free of interaction effects? Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

COMMENTS

Evaluated by: ______________________________ Date: ______________

______________________________ ______________

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 7 - Fluid-Operated Valves

Equipment Description ____

Location: Bldg. ________ Floor El. ______ Room, Row/Col ____________________

Pipe Size and Design Classification ________________________________

Manufacturer, Model, Etc. ____

SEISMIC CAPACITY VS DEMAND

1.	Elevation where equipment receives seismic input	________	
2.	Elevation of seismic input below about 40' from grade	Y N U	
3.	Capacity based on: Existing Documentation	DOC	
	Bounding Spectrum	BS	
	GERS	GERS	
4.	Demand based on: Ground Spectra	GRS	
	Amplified (Floor) Spectra	AFS	
Does capacity exceed demand?			Y N U

CAVEATS - BOUNDING SPECTRUM

1.	Equipment is included in earthquake experience data base	Y N U N/A	
2.	No cast iron body	Y N U N/A	
3.	No cast iron yoke (for spring-operated pressure relief or piston-operated valves)	Y N U N/A	
4.	Mounted on 1 inch diameter pipe or larger	Y N U N/A	
5.	Centerline of pipe to top of operator within restrictions of Figure B.7-1 of Appendix B, or yoke can take static 3g load (for air-operated diaphragm, lightweight piston-operated, and spring-operated pressure relief valves)	Y N U N/A	
6.	Centerline of pipe to top of operator within restrictions of Figure B.7-2 of Appendix B, or yoke can take static 3g load (for piston-operated valve of substantial weight)	Y N U N/A	
7.	Actuator and yoke not braced independently from pipe	Y N U N/A	
8.	Attached lines (air, electrical) have adequate flexibility	Y N U N/A	
9.	No other concerns	Y N U N/A	
Are the caveats met for Bounding Spectrum?			Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 7 - Fluid-Operated Valves

Equipment Description ____

CAVEATS - GERS

(Note that GERS for this class apply up to attachment point of valve to piping system; valve/pipe interface is not covered.)

1. Equipment is included in the generic seismic test data base Y N U N/A
2. Meets all Bounding Spectrum caveats Y N U N/A
3. Air-operated gate or globe valve with spring-opposed diaphragm-type pneumatic actuator Y N U N/A
4. Use amplified response spectrum of piping system at piping/valve interface Y N U N/A
5. Valve and operator will not impact surrounding structures and components Y N U N/A
6. Mounted on 1 to 3 inch nominal pipe line Y N U N/A
7. Carbon steel (not cast iron) yoke or bonnet Y N U N/A

Are the caveats met for GERS? Y N U N/A

INTERACTION EFFECTS

1. Soft targets free from impact by nearby equipment or structures Y N U N/A
2. Attached lines have adequate flexibility Y N U N/A
3. No collapse of overhead equipment or distribution systems Y N U N/A
4. No other concerns Y N U N/A

Is equipment free of interaction effects? Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

COMMENTS

Evaluated by: ______________________________ Date: ____________

______________________________ ____________

Revision 2
Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No. ____________________ Equip. Class 8A - Motor-Operated Valves

Equipment Description ____________________

Location: Bldg. ________ Floor El. _______ Room, Row/Col ____________________

Pipe Size and Design Classification: ____________________

Manufacturer, Model, Etc. ____________________

SEISMIC CAPACITY VS DEMAND

1. Elevation where equipment receives seismic input ________
2. Elevation of seismic input below about 40' from grade Y N U
3. Capacity based on: Existing Documentation DOC
   Bounding Spectrum BS
   GERS GERS
4. Demand based on: Ground Spectra GRS
   Amplified (Floor) Spectra AFS

Does capacity exceed demand? Y N U

CAVEATS - BOUNDING SPECTRUM

1. Equipment is included in earthquake experience data base Y N U N/A
2. No cast iron body Y N U N/A
3. No cast iron yoke Y N U N/A
4. Mounted on 1 inch diameter pipe or larger Y N U N/A
5. Centerline of pipe to operator within restrictions of Figure B.8-1 of Appendix B, or yoke can take static 3g load Y N U N/A
6. Actuator and yoke not braced independently from pipe Y N U N/A
7. Attached lines (electrical) have adequate flexibility Y N U N/A
8. No other concerns Y N U N/A

Are caveats met for Bounding Spectrum? Y N U N/A

CAVEATS - GERS

(Note that GERS for this class apply to only motor operator and its connection to valve; valve itself and valve/pipe interface are not covered.)

1. Equipment is included in generic seismic test data base Y N U N/A
2. Meets all Bounding Spectrum caveats Y N U N/A
3. Use amplified response spectrum of piping system and valve at valve/operator interface Y N U N/A
4. Motor axis is horizontal Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 8A - Motor-Operated Valves

Equipment Description ____

CAVEATS - GERS (Cont'd)

5. Valve and operator will not impact surrounding structures and components — Y N U N/A
6. Motor controls remotely located — Y N U N/A
7. If valve has side mounted actuator attached to secondary reducer, seismic brackets are used — Y N U N/A

Are the caveats met for GERS? — Y N U N/A

INTERACTION EFFECTS

1. Soft targets free from impact by nearby equipment or structures — Y N U N/A
2. Attached lines have adequate flexibility — Y N U N/A
3. No collapse of overhead equipment or distribution systems — Y N U N/A
4. No other concerns — Y N U N/A

Is equipment free of interaction effects? — Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? — Y N U

COMMENTS

Evaluated by: ______________________ Date: ____________

______________________ ____________

Revision 2
Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No. ____________ Equip. Class 8B - Solenoid-Ope. ed Valves

Equipment Description ______________________________

Location: Bldg. ________ Floor El. ________ Room, Row/Col ______________

Pipe Size and Design Classification: ______________________________

Manufacturer, Model, Etc. ______________________________

SEISMIC CAPACITY VS DEMAND

1. Elevation where equipment receives seismic input ____________
2. Elevation of seismic input below about 40' from gr Y N U
3. Capacity based on: Existing Documentation DOC
   Bounding Spectrum BS
   GERS GERS
4. Demand based on: Ground Spectra GRS
   Amplified (Floor) Spectra AFS

Does capacity exceed demand? Y N U

CAVEATS - BOUNDING SPECTRUM

1. Equipment is included in earthquake experience data base Y N U N/A
2. No cast iron body Y N U N/A
3. No cast iron yoke Y N U N/A
4. [Caveat does not apply to SOVs]
5. Centerline of pipe to operator within restrictions of Figure B.8-1 of Appendix B, or yoke can take static 3g load Y N U N/A
6. Actuator and yoke not braced independently from pipe Y N U N/A
7. Attached lines (electrical) have adequate flexibility Y N U N/A
8. No other concerns Y N U N/A

Are caveats met for Bounding Spectrum? Y N U N/A

CAVEATS - GERS

(Note that GERS for this class apply up to attachment point of valve to piping system or parent valve (if SOV is a pilot valve); valve/pipe interface or parer valve is not covered.)

1. Equipment is included in generic seismic test data base Y N U N/A
2. Meets all Bounding Spectrum caveats Y N U N/A
3. Use amplified response spectrum for piping system at piping/valve interface Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 8B - Solenoid-Operated Valves

Equipment Description ____________________

CAVEATS - GERS (Cont'd)

4.	Valve and operator will not impact surrounding structures and components	Y N U N/A
5.	Nominal pipe size is 1 inch or less	Y N U N/A
6.	Valve body is forged brass or steel	Y N U N/A
7.	Housing oriented in accordance with manufacturer's recommendations	Y N U N/A
8.	Height of valve (pipe centerline to top of housing) does not exceed 12 in.	Y N U N/A
9.	If SOV is a pilot on a larger valve, use amplified response spectrum at attachment point of SOV to larger valve	Y N U N/A

Are the caveats met for GERS? Y N U N/A

INTERACTION EFFECTS

1.	Soft targets free from impact by nearby equipment or structures	Y N U N/A
2.	Attached lines have adequate flexibility	Y N U N/A
3.	No collapse of overhead equipment or distribution systems	Y N U N/A
4.	No other concerns	Y N U N/A

Is equipment free of interaction effects? Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

COMMENTS

Evaluated by: ____________________ Date: ____________

____________________ ____________

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________ Equip. Class 9 - Fans

Equipment Description ____________

Location: Bldg. ______ Floor El. ______ Room, Row/Col ____________

Manufacturer, Model, Etc. ____________

SEISMIC CAPACITY VS DEMAND

1. Elevation where equipment receives seismic input ________
2. Elevation of seismic input below about 40' from grade Y N U
3. Equipment has fundamental frequency above about 8 Hz Y N U N/A
4. Capacity based on: Existing Documentation DOC
   Bounding Spectrum BS
5. Demand based on: Ground Spectra GRS
   Amplified (Floor) Spectra AFS

Does capacity exceed demand? Y N U

CAVEATS - BOUNDING SPECTRUM

1. Equipment is included in earthquake experience data base Y N U N/A
2. Drive motor and fan mounted on common base Y N U N/A
3. For axial fan with long shaft between fan and motor, shaft supported at fan as well as motor Y N U N/A
4. No possibility of excessive duct distortion causing binding or misalignment of fan Y N U N/A
5. Base vibration isolators adequate for seismic loads Y N U N/A
6. Attached lines (electrical) have adequate flexibility Y N U N/A
7. Anchorage adequate Y N U N/A
8. No other concerns Y N U N/A

Are the caveats met for Bounding Spectrum? Y N U N/A

ANCHORAGE

1. Appropriate equipment characteristics determined (mass, CG, natural freq., damping, center of rotation) Y N U N/A
2. Type of anchorage covered by GIP Y N U N/A
3. Sizes and locations of anchors determined Y N U N/A
4. Adequacy of anchorage installation evaluated (weld quality, nuts and washers, expansion anchor tightness) Y N U N/A
5. Factors affecting anchorage capacity or margin of safety considered: embedment length, anchor spacing, free-edge distance, concrete strength/condition, and concrete cracking Y N U N/A
6. For bolted anchorages, gap under base less than 1/4-inch Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 9 - Fans

Equipment Description ____________________

ANCHORAGE (Cont'd)

7.	Base has adequate stiffness and effect of prying action on anchors considered	Y N U N/A
8.	Strength of equipment base and load path to CG adequate	Y N U N/A
9.	Embedded steel, grout pad or large concrete pad adequacy evaluated	Y N U N/A

Are anchorage requirements met? Y N U

INTERACTION EFFECTS

1.	Soft targets free from impact by nearby equipment or structures	Y N U N/A
2.	Distribution lines have adequate flexibility	Y N U N/A
3.	No collapse of overhead equipment or distribution systems	Y N U N/A
4.	No other concerns	Y N U N/A

Is equipment free of interaction effects? Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

COMMENTS

Evaluated by: ____________________ Date: __________

____________________ __________

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________ Equip. Class 10 - Air Handlers

Equipment Description ____________

Location: Bldg. ________ Floor El. ______ Room, Row/Col ________ ______

Manufacturer, Model, Etc. ____________

SEISMIC CAPACITY VS DEMAND

1. Elevation where equipment receives seismic input ________
2. Elevation of seismic input below about 40' from grade Y N U
3. Equipment has fundamental frequency above about 8 Hz Y N U N/A
4. Capacity based on: Existing Documentation DOC
   Bounding Spectrum BS
5. Demand based on: Ground Spectra GRS
   Amplified (Floor) Spectra AFS

Does capacity exceed demand? Y N U

CAVEATS - BOUNDING SPECTRUM

1. Equipment is included in earthquake experience data base Y N U N/A
2. Anchorage of heavy internal components is adequate; internal vibration isolators have seismic stops to limit uplift and lateral movement Y N U N/A
3. All doors secured by latch or fastener Y N U N/A
4. Base vibration isolators adequate for seismic loads Y N U N/A
5. Attached lines (water, air, electrical) have adequate flexibility Y N U N/A
6. Anchorage adequate Y N U N/A
7. Relays mounted on equipment evaluated Y N U N/A
8. No other concerns Y N U N/A

Are the caveats met for Bounding Spectrum? Y N U N/A

ANCHORAGE

1. Appropriate equipment characteristics determined (mass, CG, natural freq., damping, center of rotation) Y N U N/A
2. Type of anchorage covered by GIP Y N U N/A
3. Sizes and locations of anchors determined Y N U N/A
4. Adequacy of anchorage installation evaluated (weld quality, nuts and washers, expansion anchor tightness) Y N U N/A
5. Factors affecting anchorage capacity or margin of safety considered: embedment length, anchor spacing, free-edge distance, concrete strength/condition, and concrete cracking Y N U N/A
6. For bolted anchorages, gap under base less than 1/4-inch Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 10 - Air Handlers

Equipment Description ____________________

ANCHORAGE (Cont'd)

7.	Factors affecting essential relays considered: gap under base, capacity reduction for expansion anchors	Y N U N/A
8.	Base has adequate stiffness and effect of prying action on anchors considered	Y N U N/A
9.	Strength of equipment base and load path to CG adequate	Y N U N/A
10.	Embedded steel, grout pad or large concrete pad adequacy evaluated	Y N U N/A

Are anchorage requirements met? Y N U

INTERACTION EFFECTS

1.	Soft targets free from impact by nearby equipment or structures	Y N U N/A
2.	If equipment contains sensitive relays, equipment free from all impact by nearby equipment or structures	Y N U N/A
3.	Attached lines have adequate flexibility	Y N U N/A
4.	No collapse of overhead equipment or distribution systems	Y N U N/A
5.	No other concerns	Y N U N/A

Is equipment free of interaction effects? Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

COMMENTS

Evaluated by: ____________________ Date: __________

____________________ __________

Revision 2
Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 11 - Chillers ____________

Equipment Description ____

Location: Bldg. ________ Floor El. _______ Room, Row/Col ________________________

Manufacturer, Model, Etc. ____

SEISMIC CAPACITY VS DEMAND

1. Elevation where equipment receives seismic input	__________	
2. Elevation of seismic input below about 40' from grade	Y N U	
3. Equipment has fundamental frequency above about 8 Hz	Y N U N/A	
4. Capacity based on: Existing Documentation	DOC	
Bounding Spectrum	BS	
5. Demand based on: Ground Spectra	GRS	
Amplified (Floor) Spectra	AFS	
Does capacity exceed demand?		Y N U

CAVEATS - BOUNDING SPECTRUM

1. Equipment is included in earthquake experience data base	Y N U N/A	
2. Evaporator and condenser tanks reasonably braced between themselves for lateral forces without relying on weak-way bending of steel plates or structural steel shapes	Y N U N/A	
3. Base and/or compressor/motor vibration isolators adequate for seismic loads	Y N U N/A	
4. Anchorage adequate	Y N U N/A	
5. Relays mounted on equipment evaluated	Y N U N/A	
6. No other concerns	Y N U N/A	
Are the caveats met for Bounding Spectrum?		Y N U N/A

ANCHORAGE

1. Appropriate equipment characteristics determined (mass, CG, natural freq., damping, center of rotation)	Y N U N/A
2. Type of anchorage covered by GIP	Y N U N/A
3. Sizes and locations of anchors determined	Y N U N/A
4. Adequacy of anchorage installation evaluated (weld quality, nuts and washers, expansion anchor tightness)	Y N U N/A
5. Factors affecting anchorage capacity or margin of safety considered: embedment length, anchor spacing, free-edge distance, concrete strength/condition, and concrete cracking	Y N U N/A
6. For bolted anchorages, gap under base less than 1/4-inch	Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 11 - Chillers

Equipment Description ______________________________

ANCHORAGE (cont'd)

7. Factors affecting essential relays considered: gap under base, capacity reduction for expansion anchors — Y N U N/A
8. Base has adequate stiffness and effect of prying action on anchors considered — Y N U N/A
9. Strength of equipment base and load path to CG adequate — Y N U N/A
10. Embedded steel, grout pad or large concrete pad adequacy evaluated — Y N U N/A

Are anchorage requirements met? — Y N U

INTERACTION EFFECTS

1. Soft targets free from impact by nearby equipment or structures — Y N U N/A
2. If equipment contains sensitive relays, equipment free from all impact by nearby equipment or structures — Y N U N/A
3. Attached lines have adequate flexibility — Y N U N/A
4. No collapse of overhead equipment or distribution systems — Y N U N/A
5. No other concerns — Y N U N/A

Is equipment free of interaction effects? — Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? — Y N U

COMMENTS

Evaluated by: ______________________ Date: __________

______________________ __________

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No. ____________ Equip. Class 12 - Air Compressors

Equipment Description ____________

Location: Bldg. ______ Floor El. ______ Room, Row/Col ____________

Manufacturer, Model, Etc. ____________

SEISMIC CAPACITY VS DEMAND

1. Elevation where equipment receives seismic input ______
2. Elevation of seismic input below about 40' from grade Y N U
3. Equipment has fundamental frequency above about 8 Hz Y N U N/A
4. Capacity based on: Existing Documentation DOC
   Bounding Spectrum BS
5. Demand based on: Ground Spectra GRS
   Amplified (Floor) Spectra AFS

Does capacity exceed demand? Y N U

CAVEATS - BOUNDING SPECTRUM

1. Equipment is included in earthquake experience data base Y N U N/A
2. Base vibration isolators adequate for seismic loads Y N U N/A
3. Attached lines have adequate flexibility Y N U N/A
4. Anchorage adequate Y N U N/A
5. Relays mounted on equipment evaluated Y N U N/A
6. No other concerns Y N U N/A

Are the caveats met for Bounding Spectrum? Y N U N/A

ANCHORAGE

1. Appropriate equipment characteristics determined (mass, CG, natural freq., damping, center of rotation) Y N U N/A
2. Type of anchorage covered by GIP Y N U N/A
3. Sizes and locations of anchors determined Y N U N/A
4. Adequacy of anchorage installation evaluated (weld quality, nuts and washers, expansion anchor tightness) Y N U N/A
5. Factors affecting anchorage capacity or margin of safety considered: embedment length, anchor spacing, free-edge distance, concrete strength/condition, and concrete cracking Y N U N/A
6. For bolted anchorages, gap under base less than 1/4-inch Y N U N/A
7. Factors affecting essential relays considered: gap under base, capacity reduction for expansion anchors Y N U N/A
8. Base has adequate stiffness and effect of prying action on anchors considered Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ______________ Equip. Class 12 - Air Compressors

Equipment Description ______________

ANCHORAGE (Cont'd)

9. Strength of equipment base and load path to CG adequate Y N U N/A
10. Embedded steel, grout pad or large concrete pad adequacy evaluated Y N U N/A

Are anchorage requirements met? Y N U

INTERACTION EFFECTS

1. Soft targets free from impact by nearby equipment or structures Y N U N/A
2. If equipment contains sensitive relays, equipment free from all impact by nearby equipment or structures Y N U N/A
3. Attached lines have adequate flexibility Y N U N/A
4. No collapse of overhead equipment or distribution systems Y N U N/A
5. No other concerns Y N U N/A

Is equipment free of interaction effects? Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

COMMENTS

Evaluated by: ______________ Date: ______________

______________ ______________

Revision 2
Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No. ____________________ Equip. Class __13 - Motor-Generators________

Equipment Description ____

Location: Bldg. ________ Floor El. _______ Room, Row/Col _______________

Manufacturer, Model, Etc. ____

SEISMIC CAPACITY VS DEMAND

1.	Elevation where equipment receives seismic input	__________	
2.	Elevation of seismic input below about 40' from grade	Y N U	
3.	Equipment has fundamental frequency above about 8 Hz	Y N U N/A	
4.	Capacity based on: Existing Documentation	DOC	
	Bounding Spectrum	BS	
5.	Demand based on: Ground Spectra	GRS	
	Amplified (Floor) Spectra	AFS	
	Does capacity exceed demand?		Y N U

CAVEATS - BOUNDING SPECTRUM

1.	Equipment is included in earthquake experience data base	Y N U N/A	
2.	Main driver and driven equipment connected by a rigid support or skid	Y N U N/A	
3.	Base vibration isolators adequate for seismic loads	Y N U N/A	
4.	Attached lines have adequate flexibility	Y N U N/A	
5.	Anchorage adequate	Y N U N/A	
6.	Relays mounted on equipment evaluated	Y N U N/A	
7.	No other concerns	Y N U N/A	
	Are the caveats met for Bounding Spectrum?		Y N U N/A

ANCHORAGE

1.	Appropriate equipment characteristics determined (mass, CG, natural freq., damping, center of rotation)	Y N U N/A
2.	Type of anchorage covered by GIP	Y N U N/A
3.	Sizes and locations of anchors determined	Y N U N/A
4.	Adequacy of anchorage installation evaluated (weld quality, nuts and washers, expansion anchor tightness)	Y N U N/A
5.	Factors affecting anchorage capacity or margin of safety considered: embedment length, anchor spacing, free-edge distance, concrete strength/condition, and concrete cracking	Y N U N/A
6.	For bolted anchorages, gap under base less than 1/4-inch	Y N U N/A
7.	Factors affecting essential relays considered: gap under base, capacity reduction for expansion anchors	Y N U N/A
8.	Base has adequate stiffness and effect of prying action on anchors considered	Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 13 - Motor-Generators

Equipment Description ____

ANCHORAGE (Cont'd)

9. Strength of equipment base and load path to CG adequate — Y N U N/A
10. Embedded steel, grout pad or large concrete pad adequacy evaluated — Y N U N/A

Are anchorage requirements met? — Y N U

INTERACTION EFFECTS

1. Soft targets free from impact by nearby equipment or structures — Y N U N/A
2. If equipment contains sensitive relays, equipment free from all impact by nearby equipment or structures — Y N U N/A
3. Attached lines have adequate flexibility — Y N U N/A
4. No collapse of overhead equipment or distribution systems — Y N U N/A
5. No other concerns — Y N U N/A

Is equipment free of interaction effects? — Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? — Y N U

COMMENTS

Evaluated by: ______________________________ Date: ____________

______________________________ ____________

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________ Equip. Class 13 - Motor-Generators

Equipment Description ____________

Location: Bldg. ______ Floor El. ______ Room, Row/Col ____________

Manufacturer, Model, Etc. ____________

SEISMIC CAPACITY VS DEMAND

1. Elevation where equipment receives seismic input ______
2. Elevation of seismic input below about 40' from grade Y N U
3. Equipment has fundamental frequency above about 8 Hz Y N U N/A
4. Capacity based on: Existing Documentation DOC
   Bounding Spectrum BS
5. Demand based on: Ground Spectra GRS
   Amplified (Floor) Spectra AFS

Does capacity exceed demand? Y N U

CAVEATS - BOUNDING SPECTRUM

1. Equipment is included in earthquake experience data base Y N U N/A
2. Main driver and driven equipment connected by a rigid support or skid Y N U N/A
3. Base vibration isolators adequate for seismic loads Y N U N/A
4. Attached lines have adequate flexibility Y N U N/A
5. Anchorage adequate Y N U N/A
6. Relays mounted on equipment evaluated Y N U N/A
7. No other concerns Y N U N/A

Are the caveats met for Bounding Spectrum? Y N U N/A

ANCHORAGE

1. Appropriate equipment characteristics determined (mass, CG, natural freq., damping, center of rotation) Y N U N/A
2. Type of anchorage covered by GIP Y N U N/A
3. Sizes and locations of anchors determined Y N U N/A
4. Adequacy of anchorage installation evaluated (weld quality, nuts and washers, expansion anchor tightness) Y N U N/A
5. Factors affecting anchorage capacity or margin of safety considered: embedment length, anchor spacing, free-edge distance, concrete strength/condition, and concrete cracking Y N U N/A
6. For bolted anchorages, gap under base less than 1/4-inch Y N U N/A
7. Factors affecting essential relays considered: gap under base, capacity reduction for expansion anchors Y N U N/A
8. Base has adequate stiffness and effect of prying action on anchors considered Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 13 - Motor-Generators

Equipment Description ______________________________

ANCHORAGE (Cont'd)

9.	Strength of equipment base and load path to CG adequate	Y N U N/A
10.	Embedded steel, grout pad or large concrete pad adequacy evaluated	Y N U N/A

Are anchorage requirements met? Y N U

INTERACTION EFFECTS

1.	Soft targets free from impact by nearby equipment or structures	Y N U N/A
2.	If equipment contains sensitive relays, equipment free from all impact by nearby equipment or structures	Y N U N/A
3.	Attached lines have adequate flexibility	Y N U N/A
4.	No collapse of overhead equipment or distribution systems	Y N U N/A
5.	No other concerns	Y N U N/A

Is equipment free of interaction effects? Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

COMMENTS

Evaluated by: ______________________________ Date: ____________

______________________________ ____________

Revision 2
Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS)

Sheet 1 of 3

Equip. ID No. ____________ Equip. Class 14 - Distribution Panels

Equipment Description ____________

Location: Bldg. ______ Floor El. ______ Room, Row/Col ______

Manufacturer, Model, Etc. ____________

SEISMIC CAPACITY VS DEMAND

1. Elevation where equipment receives seismic input ______
2. Elevation of seismic input below about 40' from grade Y N U
3. Equipment has fundamental frequency above about 8 Hz Y N U N/A
4. Capacity based on: Existing Documentation DOC
   Bounding Spectrum BS
   GERS GERS
5. Demand based on: Ground Spectra GRS
   Amplified (Floor) Spectra AFS

Does capacity exceed demand? Y N U

CAVEATS - BOUNDING SPECTRUM

1. Equipment is included in earthquake experience data base Y N U N/A
2. Contains only circuit breakers and switches Y N U N/A
3. All latches and fasteners in door secured Y N U N/A
4. Adjacent cabinets which are close enough to impact, or sections of multi-bay cabinets, are bolted together if they contain essential relays Y N U N/A
5. Wall- or floor-mounted NEMA-type enclosure Y N U N/A
6. Anchorage adequate Y N U N/A
7. Relays mounted on equipment evaluated Y N U N/A
8. No other concerns Y N U N/A

Are the caveats met for Bounding Spectrum? Y N U N/A

CAVEATS - GERS

1. Equipment is included in the generic seismic test data base Y N U N/A
2. Meets all Bounding Spectrum caveats Y N U N/A
3. Use panelboard GERS unless unit is free-standing and designated as a switchboard by manufacturer Y N U N/A

Are the caveats met for GERS? Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 14 - Distribution Panels

Equipment Description ______________________________

ANCHORAGE

1.	Appropriate equipment characteristics determined (mass, CG, natural freq., damping, center of rotation)	Y N U N/A
2.	Type of anchorage covered by GIP	Y N U N/A
3.	Sizes and locations of anchors determined	Y N U N/A
4.	Adequacy of anchorage installation evaluated (weld quality, nuts and washers, expansion anchor tightness)	Y N U N/A
5.	Factors affecting anchorage capacity or margin of safety considered: embedment length, anchor spacing, free-edge distance, concrete strength/condition, and concrete cracking	Y N U N/A
6.	For bolted anchorages, gap under base less than 1/4-inch	Y N U N/A
7.	Factors affecting essential relays considered: gap under base, capacity reduction for expansion anchors	Y N U N/A
8.	Base has adequate stiffness and effect of prying action on anchors considered	Y N U N/A
9.	Strength of equipment base and load path to CG adequate	Y N U N/A
10.	Embedded steel, grout pad or large concrete pad adequacy evaluated	Y N U N/A

Are anchorage requirements met? Y N U

INTERACTION EFFECTS

1.	Soft targets free from impact by nearby equipment or structures	Y N U N/A
2.	If equipment contains sensitive relays, equipment free from all impact by nearby equipment or structures	Y N U N/A
3.	Attached lines have adequate flexibility	Y N U N/A
4.	No collapse of overhead equipment or distribution systems	Y N U N/A
5.	No other concerns	Y N U N/A

Is equipment free of interaction effects? Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 14 - Distribution Panels

Equipment Description ____________________

COMMENTS

Evaluated by: ____________________ Date: ____________

____________________ ____________

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 15 - Batteries on Racks

Equipment Description ____________________

Location: Bldg. ________ Floor El. _______ Room, Row/Col ____________________

Manufacturer, Model, Etc. ____________________

SEISMIC CAPACITY VS DEMAND

1. Elevation where equipment receives seismic input __________
2. Elevation of seismic input below about 40′ from grade Y N U
3. Equipment has fundamental frequency above about 8 Hz Y N U N/A
4. Capacity based on: Existing Documentation DOC
   Bounding Spectrum BS
   GERS GERS
5. Demand based on: Ground Spectra GRS
   Amplified (Floor) Spectra AFS

Does capacity exceed demand? Y N U

CAVEATS - BOUNDING SPECTRUM

1. Equipment is included in earthquake experience data base Y N U N/A
2. Plates of the cells are of lead-calcium flat-plate, Planté or of Manchex design Y N U N/A
3. Each individual battery weighs less than 450 lbs Y N U N/A
4. Close-fitting, crush resistant spacers fill two-thirds of vertical space between cells Y N U N/A
5. Cells restrained by end and side rails Y N U N/A
6. Racks have longitudinal cross bracing Y N U N/A
7. Wood racks evaluated to industry accepted standards Y N U N/A
8. Batteries greater than 10 years old specifically evaluated for aging effects Y N U N/A
9. Anchorage adequate Y N U N/A
10. No other concerns Y N U N/A

Are the caveats met for Bounding Spectrum? Y N U N/A

CAVEATS - GERS

1. Equipment is included in generic seismic test data base Y N U N/A
2. Meets all Bounding Spectrum caveats Y N U N/A
3. Plates of the cells are of lead-calcium flat-plate design (i.e., not Manchex design) Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 15 - Batteries on Racks

Equipment Description ____

CAVEATS - GERS (Cont'd)

4. Batteries supported on two-step racks or single-tier racks; restrained by double side and end rails which are symmetrically located with respect to the cell center-of-gravity — Y N U N/A

Are the caveats met for GERS? — Y N U N/A

ANCHORAGE

1. Appropriate equipment characteristics determined (mass, CG, natural freq., damping, center of rotation) — Y N U N/A
2. Type of anchorage covered by GIP — Y N U N/A
3. Sizes and locations of anchors determined — Y N U N/A
4. Adequacy of anchorage installation evaluated (weld quality, nuts and washers, expansion anchor tightness) — Y N U N/A
5. Factors affecting anchorage capacity or margin of safety considered: embedment length, anchor spacing, free-edge distance, concrete strength/condition, and concrete cracking — Y N U N/A
6. For bolted anchorages, gap under base less than 1/4-inch — Y N U N/A
7. Base has adequate stiffness and effect of prying action on anchors considered — Y N U N/A
8. Strength of equipment base and load path to CG adequate — Y N U N/A
9. Embedded steel, grout pad or large concrete pad adequacy evaluated — Y N U N/A

Are anchorage requirements met? — Y N U

INTERACTION EFFECTS

1. Soft targets free from impact by nearby equipment or structures — Y N U N/A
2. Attached lines have adequate flexibility — Y N U N/A
3. No collapse of overhead equipment or distribution systems — Y N U N/A
4. No other concerns — Y N U N/A

Is equipment free of interaction effects? — Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? — Y N U

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 15 - Batteries on Racks

Equipment Description ____

COMMENTS

Evaluated by: ________________________________ Date: __________

________________________________ __________

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 3

Equip. ID No. ________________ Equip. Class 16 - Battery Chargers & Inverters

Equipment Description ____

Location: Bldg. ________ Floor El. _______ Room, Row/Col ________________

Manufacturer, Model, Etc. ____

SEISMIC CAPACITY VS DEMAND

1.	Elevation where equipment receives seismic input	________
2.	Elevation of seismic input below about 40' from grade	Y N U
3.	Equipment has fundamental frequency above about 8 Hz	Y N U N/A
4.	Capacity based on: Existing Documentation	DOC
	Bounding Spectrum	BS
	GERS	GERS
5.	Demand based on: Ground Spectra	GRS
	Amplified (Floor) Spectra	AFS

Does capacity exceed demand? Y N U

CAVEATS - BOUNDING SPECTRUM

1.	Equipment is included in earthquake experience data base	Y N U N/A
2.	Solid state type	Y N U N/A
3.	For floor-mounted, transformer positively anchored and mounted near base, or load path is evaluated	Y N U N/A
4.	Base assembly of floor-mounted unit properly braced or stiffened for lateral forces	Y N U N/A
5.	For wall-mounted, transformer supports and bracing provide adequate load path to the rear cabinet wall	Y N U N/A
6.	All latches and fasteners in doors secured	Y N U N/A
7.	Anchorage adequate	Y N U N/A
8.	Relays mounted on equipment evaluated	Y N U N/A
9.	No other concerns	Y N U N/A

Are the caveats met for Bounding Spectrum? Y N U N/A

CAVEATS - GERS

1.	Equipment is included in generic seismic test data base	Y N U N/A
2.	Meets all Bounding Spectrum caveats	Y N U N/A
3.	Silicon-Controlled Rectifier (SCR) power controls; wall- or floor-mounted NEMA-type enclosure	Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ________________ Equip. Class 16 - Battery Chargers & Inverters

Equipment Description ____

CAVEATS - GERS (Cont'd)

4. Battery charger ratings:
   - 24-250 VDC — Y N U N/A
   - 120-480 VAC — Y N U N/A
   - 25-600 amps — Y N U N/A
   - 150-2850 pounds — Y N U N/A
5. Inverter ratings:
   - 120 VDC only — Y N U N/A
   - 120-480 VAC — Y N U N/A
   - 0.5-15 KVA — Y N U N/A
   - 300-2000 pounds — Y N U N/A
6. Heavy components are located in lower half of cabinet and are supported from base or rear panel with no panel cutouts adjacent to attachment — Y N U N/A

Are the caveats met for GERS? — Y N U N/A

ANCHORAGE

1. Appropriate equipment characteristics determined (mass, CG, natural freq., damping, center of rotation) — Y N U N/A
2. Type of anchorage covered by GIP — Y N U N/A
3. Sizes and locations of anchors determined — Y N U N/A
4. Adequacy of anchorage installation evaluated (weld quality, nuts and washers, expansion anchor tightness) — Y N U N/A
5. Factors affecting anchorage capacity or margin of safety considered: embedment length, anchor spacing, free-edge distance, concrete strength/condition, and concrete cracking — Y N U N/A
6. For bolted anchorages, gap under base less than 1/4-inch — Y N U N/A
7. Factors affecting essential relays considered: gap under base, capacity reduction for expansion anchors — Y N U N/A
8. Base has adequate stiffness and effect of prying action on anchors considered — Y N U N/A
9. Strength of equipment base and load path to CG adequate — Y N U N/A
10. Embedded steel, grout pad or large concrete pad adequacy evaluated — Y N U N/A

Are anchorage requirements met? — Y N U

INTERACTION EFFECTS

1. Soft targets free from impact by nearby equipment or structures — Y N U N/A
2. If equipment contains sensitive relays, equipment free from all impact by nearby equipment or structures — Y N U N/A
3. Attached lines have adequate flexibility — Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ______________ Equip. Class 16 - Battery Chargers & Inverters

Equipment Description ____

INTERACTION EFFECTS (Cont'd)

4. No collapse of overhead equipment or distribution systems — Y N U N/A
5. No other concerns — Y N U N/A

Is equipment free of interaction effects? — Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? — Y N U

COMMENTS

Evaluated by: ______________________________ Date: ____________

______________________________ ____________

Revision 2
Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No ____________ Equip. Class 17 - Engine-Generators

Equipment Description ____________

Location: Bldg. ______ Floor El. ______ Room, Row/Col ____________

Manufacturer, Model, Etc. ____________

SEISMIC CAPACITY VS DEMAND

1. Elevation where equipment receives seismic input ______
2. Elevation of seismic input below about 40' from grade Y N U
3. Equipment has fundamental frequency above about 8 hz Y N U N/A
4. Capacity based on: Existing Documentation DOC
   Bounding Spectrum BS
5. Demand based on: Ground Spectra GRS
   Amplified (Floor) Spectra AFS

Does capacity exceed demand? Y N U

CAVEATS - BOUNDING SPECTRUM

1. Equipment is included in earthquake experience data base Y N U N/A
2. Driver and driven equipment connected by a rigid support or common skid Y N U N/A
3. Base vibration isolators adequate for seismic loads Y N U N/A
4. Attached lines (cooling, air, electrical) have adequate flexibility Y N U N/A
5. Anchorage adequate Y N U N/A
6. Relays mounted on equipment evaluated Y N U N/A
7. No other concerns Y N U N/A

Are the caveats met for Bounding Spectrum? Y N U N/A

ANCHORAGE

1. Appropriate equipment characteristics determined (mass, CG, natural freq., damping, center of rotation) Y N U N/A
2. Type of anchorage covered by GIP Y N U N/A
3. Sizes and locations of anchors determined Y N U N/A
4. Adequacy of anchorage installation evaluated (weld quality, nuts and washers, expansion anchor tightness) Y N U N/A
5. Factors affecting anchorage capacity or margin of safety considered: embedment length, anchor spacing, free-edge distance, concrete strength/condition, and concrete cracking Y N U N/A
6. For bolted anchorages, gap under base less than 1/4-inch Y N U N/A
7. Factors affecting essential relays considered: gap under base, capacity reduction for expansion anchors Y N U N/A
8. Base has adequate stiffness and effect of prying action on anchors considered Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 17 - Engine-Generators

Equipment Description ____________________

ANCHORAGE (Cont'd)

9. Strength of equipment base and load path to CG adequate — Y N U N/A
10. Embedded steel, grout pad or large concrete pad adequacy evaluated — Y N U N/A

Are anchorage requirements met? — Y N U

INTERACTION EFFECTS

1. Soft targets free from impact by nearby equipment or structures — Y N U N/A
2. If equipment contains sensitive relays, equipment free from all impact by nearby equipment or structures — Y N U N/A
3. Attached lines have adequate flexibility — Y N U N/A
4. No collapse of overhead equipment or distribution systems — Y N U N/A
5. No other concerns — Y N U N/A

Is equipment free of interaction effects? — Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? — Y N U

COMMENTS

Evaluated by: ____________________ Date: ____________

____________________ ____________

Revision 2
Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS)

Sheet 1 of 3

Equip. ID No. ____________ Equip. Class 18 - Instruments on Racks

Equipment Description ______________________

Location: Bldg. ______ Floor El. ______ Room, Row/Col ______

Manufacturer, Model, Etc. ______________________

SEISMIC CAPACITY VS DEMAND

1. Elevation where equipment receives seismic input	______	
2. Elevation of seismic input below about 40' from grade	Y N U	
3. Equipment has fundamental frequency above about 8 Hz	Y N U N/A	
4. Capacity based on: Existing Documentation	DOC	
Bounding Spectrum	BS	
GERS	GERS	
5. Demand based on: Ground Spectra	GRS	
Amplified (Floor) Spectra	AFS	
Does capacity exceed demand?		Y N U

CAVEATS - BOUNDING SPECTRUM

1. Equipment is included in earthquake experience data base	Y N U N/A	
2. No computers or programmable controllers	Y N U N/A	
3. Steel frame and sheet metal structurally adequate	Y N U N/A	
4. Adjacent racks which are close enough to impact or sections of multi-bay racks are bolted together if they contain essential relays	Y N U N/A	
5. Natural frequency relative to 8 Hz limit considered	Y N U N/A	
6. Attached lines have adequate flexibility	Y N U N/A	
7. Anchorage adequate	Y N U N/A	
8. Relays mounted on equipment evaluated	Y N U N/A	
9. No other concerns	Y N U N/A	
Are the caveats met for Bounding Spectrum?		Y N U N/A

CAVEATS - GERS

1. Equipment is included in the generic seismic test data base	Y N U N/A
2. Meets all Bounding Spectrum caveats	Y N U N/A
3. Component is a pressure, temperature, level or flow transmitter	Y N U N/A
4. Component is one of the specific makes and models tested, as listed in Appendix B	Y N U N/A
5. Necessary function of component not sensitive to seismically induced system perturbations (e.g., sloshing)	Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 18 - Instruments on Racks

Equipment Description ____________________

CAVEATS - GERS (Cont'd)

6.	No vacuum tubes	Y N U N/A
7.	All external mounting bolts in place	Y N U N/A
8.	Demand based on amplified portion of 3% damped floor response spectrum if estimated natural frequency of rack less than 33 Hz	Y N U N/A
9.	Rack capable of structurally transferring GERS level seismic loads to anchorage	Y N U N/A

Are the caveats met for GERS? Y N U N/A

ANCHORAGE

1.	Appropriate equipment characteristics determined (mass, CG, natural freq., damping, center of rotation)	Y N U N/A
2.	Type of anchorage covered by GIP	Y N U N/A
3.	Sizes and locations of anchors determined	Y N U N/A
4.	Adequacy of anchorage installation evaluated (weld quality, nuts and washers, expansion anchor tightness)	Y N U N/A
5.	Factors affecting anchorage capacity or margin of safety considered: embedment length, anchor spacing, free-edge distance, concrete strength/condition, and concrete cracking	Y N U N/A
6.	For bolted anchorages, gap under base less than 1/4-inch	Y N U N/A
7.	Factors affecting essential relays considered: gap under base, capacity reduction for expansion anchors	Y N U N/A
8.	Base has adequate stiffness and effect of prying action on anchors considered	Y N U N/A
9.	Strength of equipment base and load path to CG adequate	Y N U N/A
10.	Embedded steel, grout pad or large concrete pad adequacy evaluated	Y N U N/A

Are anchorage requirements met? Y N U

INTERACTION EFFECTS

1.	Soft targets free from impact by nearby equipment or structures	Y N U N/A
2.	If equipment contains sensitive relays, equipment free from all impact by nearby equipment or structures	Y N U N/A
3.	Attached lines have adequate flexibility	Y N U N/A
4.	No collapse of overhead equipment or distribution systems	Y N U N/A
5.	No other concerns	Y N U N/A

Is equipment free of interaction effects? Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 18 - Instruments on Racks

Equipment Description ____

COMMENTS

Evaluated by: ______________________________________ Date: ____________

______________________________________ ____________

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 19 - Temperature Sensors

Equipment Description ____

Location: Bldg. ________ Floor El. _______ Room, Row/Col ________________________

Manufacturer, Model, Etc. ____

SEISMIC CAPACITY VS DEMAND

1. Elevation where equipment receives seismic input ___________
2. Elevation of seismic input below about 40' from grade Y N U
3. Equipment has fundamental frequency above about 8 Hz Y N U N/A
4. Capacity based on: Existing Documentation DOC
   Bounding Spectrum BS
5. Demand based on: Ground Spectra GRS
   Amplified (Floor) Spectra AFS

Does capacity exceed demand? Y N U

CAVEATS - BOUNDING SPECTRUM

1. Equipment is included in earthquake experience data base Y N U N/A
2. No possibility of detrimental differential displacement between mounting of connection head and mounting of temperature sensor Y N U N/A
3. Associated electronics are all solid state (no vacuum tubes) Y N U N/A
4. Attached lines have adequate flexibility Y N U N/A
5. No other concerns Y N U N/A

Are the caveats met for Bounding Spectrum? Y N U N/A

INTERACTION EFFECTS

1. Soft targets free from impact by nearby equipment or structures Y N U N/A
2. Attached lines have adequate flexibility Y N U N/A
3. No collapse of overhead equipment or distribution systems Y N U N/A
4. No other concerns Y N U N/A

Is equipment free of interaction effects? Y N U

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 19 - Temperature Sensors ____

Equipment Description ____

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

COMMENTS

Evaluated by: ____ Date: ______________

____ ______________

Revision 2
Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No. ______________ Equip. Class 20 - Instr. & Control Panels & Cabinets

Equipment Description ____

Location: Bldg. ________ Floor El. _____ __ Room, Row/Col ________________

Manufacturer, Model, Etc. ____

SEISMIC CAPACITY VS DEMAND

1. Elevation where equipment receives seismic input ___________
2. Elevation of seismic input below about 40' from grade Y N U
3. Equipment has fundamental frequency above about 8 Hz Y N U N/A
4. Capacity based on: Existing Documentation DOC
   Bounding Spectrum BS
5. Demand based on: Ground Spectra GRS
   Amplified (Floor) Spectra AFS

Does capacity exceed demand? Y N U

CAVEATS - BOUNDING SPECTRUM

1. Equipment is included in earthquake experience data base Y N U N/A
2. No computers or programmable controllers Y N U N/A
3. No strip chart recorders Y N U N/A
4. Steel frame and sheet metal structurally adequate Y N U N/A
5. Adjacent cabinets or panels which are close enough to impact, or sections of multi-bay cabinets or panels, are bolted together if they contain essential relays Y N U N/A
6. Drawers and equipment on slides restrained from falling out Y N U N/A
7. All doors secured by latch or fastener Y N U N/A
8. Attached lines have adequate flexibility Y N U N/A
9. Anchorage adequate Y N U N/A
10. Relays mounted on equipment evaluated Y N U N/A
11. No other concerns Y N U N/A

Are the caveats met for Bounding Spectrum? Y N U N/A

ANCHORAGE

1. Appropriate equipment characteristics determined (mass, CG, natural freq., damping, center of rotation) Y N U N/A
2. Type of anchorage covered by GIP Y N U N/A
3. Sizes and locations of anchors determined Y N U N/A
4. Adequacy of anchorage installation evaluated (weld quality, nuts and washers, expansion anchor tightness) Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ______________ Equip. Class 20 - Instr. & Control Panels & Cabinets

Equipment Description ____

ANCHORAGE (Cont'd)

5. Factors affecting anchorage capacity or margin of safety considered: embedment length, anchor spacing, free-edge distance, concrete strength/condition, and concrete cracking — Y N U N/A
6. For bolted anchorages, gap under base less than 1/4-inch — Y N U N/A
7. Factors affecting essential relays considered: gap under base, capacity reduction for expansion anchors — Y N U N/A
8. Base has adequate stiffness and effect of prying action on anchors considered — Y N U N/A
9. Strength of equipment base and load path to CG adequate — Y N U N/A
10. Embedded steel, grout pad or large concrete pad adequacy evaluated — Y N U N/A

Are anchorage requirements met? — Y N U

INTERACTION EFFECTS

1. Soft targets free from impact by nearby equipment or structures — Y N U N/A
2. If equipment contains sensitive relays, equipment free from all impact by nearby equipment or structures — Y N U N/A
3. Attached lines have adequate flexibility — Y N U N/A
4. No collapse of overhead equipment or distribution systems — Y N U N/A
5. No other concerns — Y N U N/A

Is equipment free of interaction effects? — Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? — Y N U

COMMENTS

Evaluated by: ______________________________ Date: ____________

______________________________ ____________

Revision 2
Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No. ____________ Equip. Class 21 - Tanks and Heat Exchangers

Equipment Description ____________

Location: Bldg. ________ Floor El. ________ Room, Row/Col ____________

Manufacturer, Model, Etc. ____________

SHELL CAPACITY VS DEMAND

Buckling capacity of shell of large, flat-bottom, vertical tank is equal to or greater than demand: Y N U N/A

ANCHOR BOLTS AND EMBEDMENT

Capacity of anchor bolts and their embedments is equal to or greater than demand: Y N U N/A

CONNECTION BETWEEN ANCHOR BOLTS AND SHELL

Capacity of connections between the anchor bolts and the tank shell is equal to or greater than the demand: Y N U N/A

FLEXIBILITY OF ATTACHED PIPING

Attached piping has adequate flexibility to accommodate motion of large, flat-bottom, vertical tank: Y N U N/A

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 21 - Tanks and Heat Exchangers

Equipment Description ____

COMMENTS

Evaluated by: ______________________________________ Date: ______________

______________________________________ ______________