Crystal River Unit 3
Docket No. 50-302

August 27, 1993
3F0893-12

Attachment 3

FLORIDA POWER CORPORATION

PLANT SPECIFIC PROCEDURE

(PSP)

FOR SEISMIC VERIFICATION OF

NUCLEAR PLANT EQUIPMENT

Revision 0

PREPARED: [signature] DATE: 8/6/93

LICENSING
CONCURRENCE: [signature] DATE: 8/6/93

APPROVED: [signature] DATE: 8/17/93

Supervisor, Nuclear Operations Engineering - Mechanical/Structural

PURPOSE:

This Plant Specific Procedure for resolution of Unresolved Safety Issue A-46 is to provide guidance to engineers, technicians, supervisors, and others involved with this effort. The following paragraphs explain how this document is to be approved, revised, and distributed. Section 1 of the procedure gives a further explanation into the purpose, background, and the approach to be used in resolving the A-46 issue. This procedure will be controlled through NEP-115 as a "Procedural Manual".

APPROVALS:

This Plant Specific Procedure shall be prepared by a Florida Power responsible engineer or designee. This document also requires licensing concurrence, and shall be approved by the Supervisor, Nuclear Operations Engineering - Mechanical/Structural.

REVISIONS:

All revisions to this document shall receive the same level of review and approval as described above under "APPROVALS". A revision history page shall be used to describe any future revisions. The entire document may be issued as a revision, or replacement pages only may be issued. Areas revised must be identified by a vertical revision bar in the right margin. Revisions are effective as of the Supervisor's approval date. Revisions which are editorial in nature do not require a review and comment cycle.

DISTRIBUTION:

This document and its revisions shall be distributed through Energy Supply Engineering Services Document Control using a Data Transmittal Sheet (DTS) per NEP-131 in accordance with the standard document distribution list. A copy shall be set to CR3 Records Management.

INTERPRETATION CONTACT:

Supervisor, Nuclear Operations Engineering
(Mechanical/Structural)

Revision Log Page

Revision	Description	Pages Revised
0	Initial Issue of Document	n/a

GLOSSARY OF TERMS

AC	-	Alternating Current
ADS	-	Automatic Depressurization System
AF	-	Amplification Factor
AFW	-	Auxiliary Feedwater
ARS	-	Amplified Response Spectra
ASME	-	American Society of Mechanical Engineers
B&PV	-	Boiler and Pressure Vessel
CCW	-	Component Cooling Water
CRD	-	Control Rod Drive
CST	-	Condensate Storage Tank
DC	-	Direct Current
DG	-	Diesel Generator
DH	-	Decay Heat
EE	-	Earthquake Experience
EPRI	-	Electric Power Research Institute
ESW	-	Emergency Service Water
FPC	-	Florida Power Corporation
FRS	-	Floor Response Spectrum
FS	-	Factor of Safety
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
IRS	-	In-structure Response Spectrum
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
NEP	-	Non-Exceedance Probability
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
PGA	-	Peak Ground Acceleration
PORV	-	Power-Operated Relief Valve
PSP	-	Plant Specific Procedure

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
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

CONTENTS

Section 1

INTRODUCTION

1.1 PURPOSE

The purpose of this procedure is to summarize the technical approach and provide procedures and documentation requirements which can be used by FPC to verify the seismic adequacy of the mechanical and electrical equipment needed to bring Crystal River Unit 3 (CR3) 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. In addition, this procedure includes guidelines for evaluating the seismic adequacy of tanks and heat exchangers.

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 adequacy 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 adequacy 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. Reference 36 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. Reference 36 is evaluated considering the low seismicity of the Crystal River site and detailed in Reference 37. This procedure is a simplification of Reference 36 when the various considerations mentioned in Reference 37 are accounted for.

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) described in Reference 12. 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:

- Tanks and Heat Exchangers Review (Section 7)

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

Each of the sections of the PSP (Sections 2 through 9) is divided into commitments and implementation guidance. The commitments, which follow the introduction in each of these sections, describe the key features of this procedure. The remainder of each section provides guidance for implementing the commitments.

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.

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 participation on the Seismic Review Teams (SRTs) is an important element in this 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 alternative 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.

The scope of equipment which should be reviewed for resolution of USI A-46 includes active mechanical and electrical equipment, tanks, and heat exchangers which are needed for safe shutdown. Excluded from the scope of review because of their demonstrated ruggedness (as summarized in Reference 17) are major pieces of equipment in the Nuclear Steam Supply System (NSSS) which are located inside containment (e.g., reactor vessel, steam generators, etc.). Section 3.3 discusses the scope of equipment to be reviewed in more detail.

Cable conduit raceway systems are excluded from the scope due to their seismic design at CR3 and to CR3's low seismicity (see Reference 37, Appendix B).

Relays are also excluded from the scope due to the low number of actuations anticipated at a low seismic site such as CR3, and the ability of the operators to quickly diagnose and react to any relay actuations that may occur.

Screening guidelines are provided in the PSP for evaluating the seismic adequacy of most types of equipment which are used in CR3 for safe shutdown. However, as discussed below, if an item of equipment which is within the scope of USI A-46 is not covered by the screening guidelines, then it should be identified as an outlier and evaluated separately.

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 tanks and heat exchangers is described in Section 7 and is 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 certain generic, 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. Seismic demand has been pre-screened and is discussed in detail in Reference 37.
- 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 PSP are considered outliers (i.e., they lay outside the scope of coverage for the screening criteria) and should be evaluated further as described in Section 5.

Methods of outlier resolution are typically more time consuming and expensive than the screening evaluations provided in the PSP. 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

Not applicable (see Reference 37, Appendix C).

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

Not applicable (see Reference 37, Appendix B).

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
- Seismic Evaluation Report
- Completion Letter

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 procedure. The seismic evaluation personnel include individuals who identify safe shutdown equipment, who perform the plant walkdown and verify the seismic adequacy of equipment. This may involve a number of plant and engineering disciplines including structural, mechanical, electrical, systems, earthquake, and plant operations.

Florida Power prefers to implement this procedure using a designated team of individuals; i.e., a Seismic Review Team (SRT). 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. FPC will be 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 FPC commits 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 purpose and content of the SQUG training courses are summarized in Section 2.6.

2.1 FPC COMMITMENTS

Florida Power commits to the following in regard to the qualifications of individuals responsible for implementing the procedure.

2.1.1 Systems Engineers

Florida Power 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

Florida Power will provide qualified Seismic Capability Engineers to perform the following tasks described in Sections 4 and 7.

1. Conduct a walkdown of plant equipment on the safe shutdown equipment list.
2. Assess the seismic adequacy of this equipment using this procedure, the GIP, along with the Seismic Review Team's 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

Not used.

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 the Seismic Capability Engineers who evaluate the seismic adequacy of the equipment.

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) to confirm that the SSEL is compatible with approved normal and emergency operating procedures (EOPs) for shutting down the plant. 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.

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 this procedure, the GIP (Ref. 36) and other reference documents.
- Become familiar with the seismic design basis of CR3 especially the equipment on the safe shutdown equipment list and the postulated Safe Shutdown Earthquake (SSE).

- Read and fully understand the basis and requirements of the Technical Basis for the Crystal River Unit 3 Plant Specific Procedure to resolve NRC Generic Letter 87-02 (Reference 37).

- Conduct the seismic evaluations and walkdowns of equipment and systems as described in the following sections:

  - Screening Verification and Walkdown (Section 4)

  - Tanks and Heat Exchangers Review (Section 7)

- Use this procedure, along with 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 enhance 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 this procedure.

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

Not applicable (see Reference 37, Appendix C).

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. Guidance is also provided on estimating in-cabinet amplification factors for electrical cabinets containing relays 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 this procedure and the GIP and applicable references to select safe shutdown equipment and to verify their seismic adequacy.

- These courses are required for implementation of this procedure.

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 FPC 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.

For resolution of USI A-46, it is not necessary to verify the seis. 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 there is redundancy and diversity in the design of 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 train) 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). 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.

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 FPC COMMITMENTS

Florida Power commits 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, FPC will identify equipment needed to achieve and maintain a safe shutdown condition following a safe shutdown earthquake (SSE). To identify this equipment, FPC will use a two-stage approach:

1. FPC 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, FPC 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 FPC 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, FPC 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.

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; and electrical penetration assemblies.
- 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.
- Cable and conduit raceways
- Relays

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. Note that in SSER #2 the NRC has expressed their intent that pressurized water reactors (PWRs) lower their temperature and pressure within 72 hours to the point at which decay heat removal equipment could be used, but not necessarily required decay heat removal equipment to be included on the SSEL.

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 decay heat removal 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 or preferable to add decay heat removal 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 or technical specification limits under a loss of offsite power condition. If a plant takes longer to achieve hot shutdown conditions than the 72 hours, then FPC should

discuss with, and obtain prior written consent from, the NRC staff on a case-by-case basis before implementing the USI A-46 program. It should also 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.

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.

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. 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.

Appropriate changes to operator training should be made if FPC finds that changes to the plant operating procedures are necessary to achieve compatibility with the SSEL. Training will be modified only to the extent needed to familiarize operators with these procedure changes.

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 earthquake experience data or generic seismic testing data are available. Appendix B provides a summary description of the equipment included in the earthquake experience equipment classes. References 4, 5, and 6 provide additional details on the type of equipment included in these equipment classes.

Table 3-1

EQUIPMENT CLASSES

O OTHER

1 MOTOR CONTROL CENTERS

Motor control center
Wall- or rack-mounted motor controllers

2 LOW VOLTAGE SWITCHGEAR

Low voltage draw-out switchgear (typically 600 Volt)
Low voltage disconnect switches (typically 600 Volt)
Unit substations

3 MEDIUM VOLTAGE SWITCHGEAR

Medium voltage draw-out switchgear (typically 4160 Volt)
Medium voltage disconnect switches (typically 4160 Volt)
Unit substations

4 TRANSFORMERS

Liquid-filled medium/low voltage transformers (typically 4160/480 Volt)
Dry-type medium/low voltage transformers (typically 4160/480 Volt)
Distribution transformers (typically 480/120 Volt)

5 HORIZONTAL PUMPS

Motor-driven horizontal centrifugal pumps
Engine-driven horizontal centrifugal pumps
Turbine-driven horizontal centrifugal pumps
Motor-driven reciprocating pumps

Table 3-1 (continued)

EQUIPMENT CLASSES

6 VERTICAL PUMPS

Vertical single-stage centrifugal pumps
Vertical multi-stage deep-well pumps

7 FLUID-OPERATED VALVES

Diaphragm-operated pneumatic valves
Piston-operated pneumatic valves
Spring-operated pressure relief valves

8A MOTOR-OPERATED VALVES

Motor-operated valves
Motor-operators

8B SOLENOID-OPERATED VALVES

Solenoid-operated valves

9 FANS

Blowers
Axial fans
Centrifugal fans

10 AIR HANDLERS

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

EQUIPMENT CLASSES

11 CHILLERS

Water chillers
Refrigerant chillers

12 AIR COMPRESSORS

Reciprocating-piston compressors
Centrifugal compressors

13 MOTOR-GENERATORS

Motor-generators

14 DISTRIBUTION PANELS

Distribution panelboards (120-480 Volt, AC & DC)
Distribution switchboards (120-480 Volt, AC & DC)

15 BATTERIES ON RACKS

Lead-cadmium flat plate batteries
Lead-calcium flat plate batteries
Planté (Manchex) batteries
Battery racks (2 tiers or less)

16 BATTERY CHARGERS & INVERTERS

Solid state battery chargers
Solid state static inverters

Table 3-1 (continued)

EQUIPMENT CLASSES

17 ENGINE-GENERATORS

Piston engine-generators

18 INSTRUMENTS ON RACKS

Transmitters (Pressure, temperature, level, flow)
Wall-mounted sensors/transmitters
Rack-mounted sensors/transmitters
Supporting racks

19 TEMPERATURE SENSORS

Thermocouples
RTDs

20 INSTRUMENTATION AND CONTROL PANELS AND CABINETS

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

21 TANKS AND HEAT EXCHANGERS

22 CABLE AND CONDUIT RACEWAYS

Equipment Class #21 is for tanks and heat exchangers. Selection of this equipment is discussed later in Sections 3.3.10.

Equipment Class #O (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 earthquake experience data or generic seismic testing 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.

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 included in the earthquake experience or generic seismic testing equipment classes, i.e., not one of the types of equipment listed as a sub-category in 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 earthquake experience equipment class. 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 earthquake experience or generic seismic testing equipment classes.

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 and need not be included on the Safe Shutdown Equipment List. Also excluded are the supports for this equipment along with all the components mounted in or on this equipment. The technical basis for excluding such equipment from the scope of USI A-46 is included in Reference 17. 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], and in-core instrumentation
- Reactor coolant and reactor recirculation pumps and their supports and drive motors
- Steam generators and their supports and tubes
- Pressurizer and its supports and heaters
- Reactor coolant system piping and recirculation lines

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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.

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 class 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.

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 USI A-46 to verify the seismic adequacy of passive equipment such as piping, filters, and electrical penetration assemblies, nor building structures. One exception to this rule is tanks and heat exchangers (covered in Section 7). Likewise, it is not in the scope of USI A-46 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.

3.3.5 Inherently Rugged Equipment

Certain types of potentially 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.

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 working copy of the SSEL for reference purposes to show what item of equipment is used to accomplish this active function. However, this manual valve need not be evaluated for seismic adequacy and need not be included on the Seismic Review SSEL.

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 Seismic Review SSEL and it should <u>also</u> be evaluated for seismic adequacy.

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

Not used.

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. Table 3-2 provides examples of the primary process variables which can be measured to monitor these safe shutdown functions for pressurized water reactors (PWRs).

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.

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.

Table 3-2

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

1. Reactor Reactivity Control

   - Core Neutron Flux

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

2. Reactor Coolant Pressure Control

   - Reactor Coolant Pressure

   - Subcooling Margin or Reactor Coolant Cold Leg Temperature

   - Pressurizer Level[3]

3. Reactor Coolant Inventory Control

   - Pressurizer Level

   - Reactor Vessel Water Level[4]

4. Decay Heat Removal

   - 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.

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, Borated Water Storage Tanks (BWSTs) 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 BWSTs and any other large, flat-bottom, metal storage tanks needed for safe shutdown, is considered an acceptable method for resolving Unresolved Safety Issue (USI) A-40, Seismic Design Criteria, as it applies to operating plants.

3.3.11 Cable and Conduit Raceways

Not Used.

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 these 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 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 Decay Heat Removal (DH) System can be operated.
- When the reactor coolant system is connected to the low pressure DH system, the system pressure should not exceed a maximum pressure for the low pressure DH 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 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 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.

3.5.1 <u>Reactor Reactivity Control</u>

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 High Pressure Injection (HPI) and Low Pressure Injection (LPI) which originate from either the Makeup and Purification (MU) System or Decay Heat Removal (DH) System, respectively.

3.5.2 <u>Reactor Coolant Pressure Control</u>

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 Decay Heat Removal (DH) System pumps 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 Decay 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 Primary System steam from the pressurizer power-operated relief valve (PORV).
- Discharge of Secondary System steam via the atmospheric dump valves.
- Discharge of Primary System 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 reactor coolant letdown through the Makeup and Purification System.
- Discharge via the decay heat removal safety relief valve while at low pressure.

Typical methods for increasing reactor coolant system pressure include:

- Feed via the high pressure injection (HPI) via the Makeup and Purification System.
- Increase the saturation temperature of the reactor coolant in the pressurizer via the pressurizer heaters.
- Feed via the low pressure injection (LPI) via the Decay Heat Removal System while at low pressure.

3.5.3 Reactor Coolant Inventory Control

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 B&W PWRs include:

- Feed via the high pressure injection (HPI) via the MU System.
- Feed via the low pressure injection (LPI) via the DH 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[1] leakoff.
- Discharge via the letdown paths.
- Discharge via the power-operated relief valve (PORV).
- Discharge via the pressurizer safety relief valves (SRVs) at their set point.
- Discharge via other vents and drains.

3.5.4 Decay Heat Removal

While the reactor coolant system is at high temperature and pressure, 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 valves. The main steam safety valves (MSSVs) can also be used to discharge steam if the secondary side pressure is allowed to go up to the MSSV set point. Makeup water can be fed into the secondary side of the steam generator via the Emergency Feedwater System.

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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 temperature. If these services are not included in the selected safe shutdown approach, the consequences of seal failure leakage should also be addressed.

If it is preferred (or required due to certain plant limitations) to bring the plant to a cold shutdown condition, the Decay Heat Removal 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 200 psia and 280°F). The heat from the DH System is transferred to the Ultimate Heat Sink via the Decay Heat Closed Cycle Cooling Water System and the Nuclear Services and Decay Heat Seawater (RW) System.

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 in Section 3.5 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.

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.

The four SSELs generated for the fluid system equipment may be combined into one Composite SSEL. This Composite SSEL should contain (1) equipment which should be evaluated for seismic adequacy, and (2) other equipment which may be needed for safe shutdown but does not need to be reviewed for seismic adequacy.

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&ID's or commonly referred to as Flow Diagrams) 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 isolation valves in the main and branch lines which form the boundary of the system. The plant configuration during normal power operation should be used. It is optional whether passive items of equipment are listed on the SSEL.

As one traces the fluid flow path and any branch lines, the equipment in the flow should be entered onto an 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, etc.).
- 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 evaluation to be performed on the item of equipment, i.e., a seismic review ("S").
- 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 being supported 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 (as described in Section 3.6.1 above). These SSELs may also be combined into the Composite SSEL generated for the fluid system equipment.

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 Seismic Review SSEL should be generated from the Composite SSEL 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 would be a subset of the Composite SSEL and should contain only one line entry for each unique item of equipment; duplicate items of equipment should be deleted.

This Seismic Review SSEL can be generated from the Composite SSEL by selecting the records containing an "S" in the "Eval. Type" field of Exhibit A-1 in Appendix A. A blank Seismic Review 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 Review 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 Safety Shutdown Equipment List (SSEL) for Relay Evaluation

Not used.

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 Composite SSEL. This SSEL was then sorted to develop a single Seismic 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 compatibility with the plant normal and emergency operating procedures. 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 use a simulator. 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 limited 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 where the 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 a PWR.

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. The guidelines contained in this section can be used as the first level of screening of this equipment for seismic adequacy. If the equipment does not pass this screen, other more refined or sophisticated methods for verifying the seismic adequacy of the equipment may be used as described in Section 5, Outlier Identification and Resolution.

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, based on earthquake experience data, generic seismic testing data, or equipment-specific seismic qualification data, should be greater than the seismic demand imposed on the equipment by the safe shutdown earthquake (SSE). This item has been pre-screened by Reference 37. All CR3 SSEL equipment is considered to have a seismic capacity in excess of the seismic demand as long as all applicable equipment Caveats are met; however, equipment anchorage must be reviewed separately in accordance with Section 4.4.

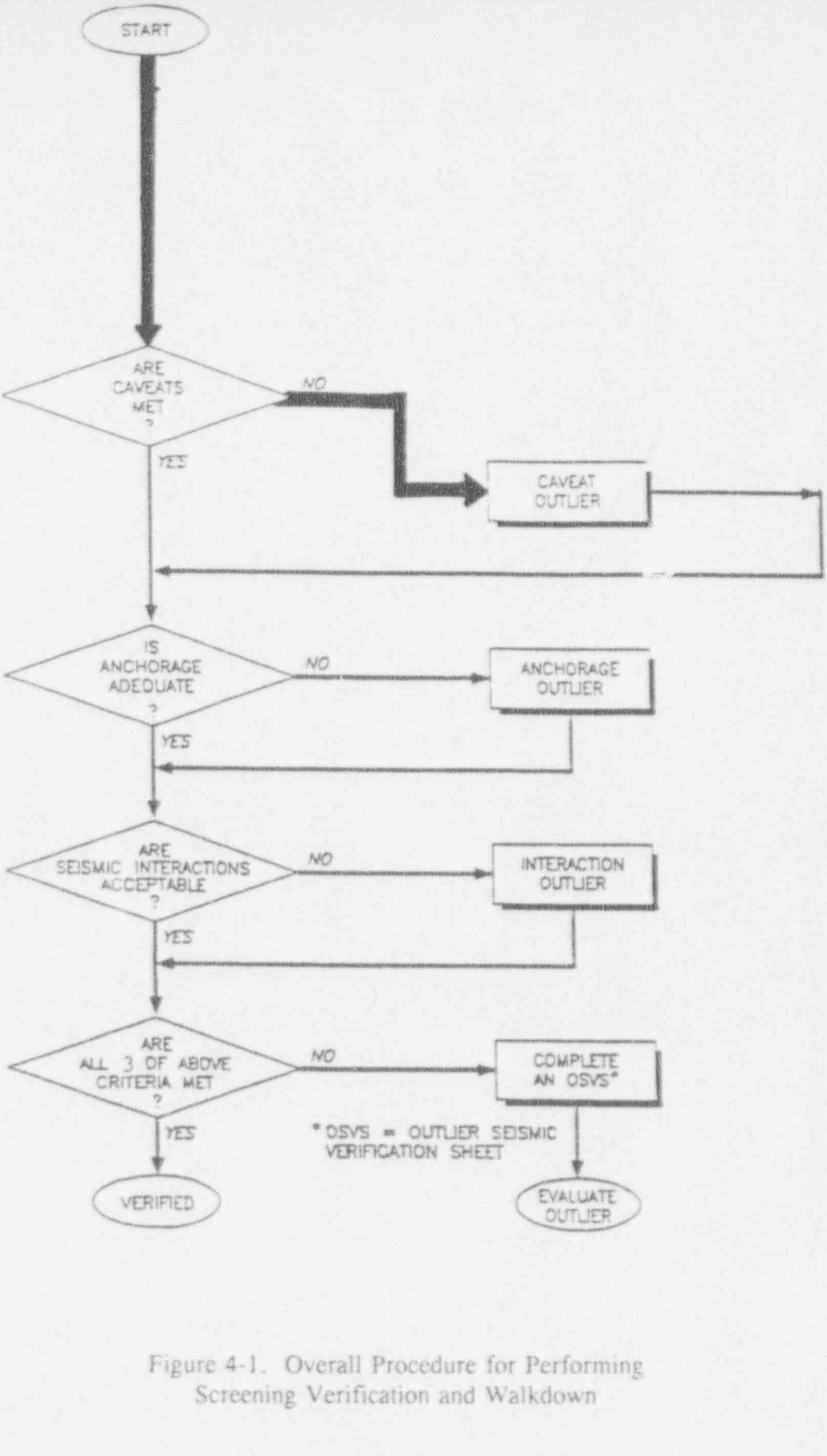


Figure 4-1. Overall Procedure for Performing Screening Verification and Walkdown

- Caveats - In order to use the seismic capacity defined by the earthquake experience Bounding Spectrum or the generic seismic testing GERS, the equipment should be similar to the equipment in the earthquake experience equipment class or the generic seismic testing equipment class and also meet the intent of the specific caveats for that class of equipment. If equipment-specific seismic qualification data is used, then any specific restrictions or caveats for that qualification data apply instead.

- 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 spatial 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, or other supporting data, subject to the judgement of the SCE's.

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 Tanks and Heat Exchangers are covered in Section 7.

To enhance relay performance during and following an earthquake, FPC will take the following measures for any SSEL cabinets containing relays (Note: no effort is being made to identify essential relays).

- Seismic interaction, including mild bumping, is not allowed on these cabinets.

- Anchorage of these cabinets will be reviewed to assure that local uplift and impact of cabinet base does not occur.

Organization of Section

The remainder of this section is organized as follows:

- Section 4.1 lists the requirements to which FPC will commit to 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 screening 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 FPC COMMITMENTS

FPC commits 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

FPC will use the following three 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). As previously stated, seismic demand has been pre-screened by Reference 37. No other action is required.
- 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 tanks and heat exchangers is discussed in Section 7 of this procedure.

4.1.2 Determination of Seismic Capacity

FPC will determine the seismic capacity of safe shutdown equipment using:

- Earthquake experience data with capacity defined by the Bounding Spectrum.
- Equipment-specific seismic qualification data, or data on similar equipment.

4.1.3 Use of Caveats

FPC 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.

4.1.4 Anchorage Verification

FPC will verify anchorage adequacy with an approach incorporating these elements:

- Evaluation of the anchorage to verify that it is free of gross installation defects.
- 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 Seismic Capability Engineers, based on other anchorage evaluation results, radiation dose concerns, or other factors.

4.1.5 Seismic Interaction

FPC will evaluate seismic spatial 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

FPC 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. Reference 37 contains a detailed discussion of the CR3 seismic demand versus seismic capacity of equipment at CR3. The conclusion of this document is that no case-by-case evaluation is required.

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 (1) the equipment characteristics are generally similar to the earthquake experience equipment class or the generic seismic testing equipment class and (2) the equipment meets the intent of the specific caveats for the equipment class. This review is only necessary when the Bounding Spectrum 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 instead, 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 either the earthquake or testing equipment class (i.e., the equipment class sub-categories shown 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 in the earthquake experience equipment class or the generic seismic testing equipment class. 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 based on the earthquake experience data and the generic seismic testing data.

"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 caveats for the earthquake experience equipment class and for the generic seismic testing equipment class.

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. Each item of equipment should be evaluated to determine whether it meets the specific wording of the applicable caveats and their intent. However, if an item of equipment meets the intent of the caveats but the specific wording of the caveat rule is not met, then that item is considered to have met the caveat; these cases should be reported to the NRC and the reason for this conclusion should be documented in the plant records per Section 9.4.

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" as defined in Section 3.3.3 which could be seismically vulnerable such as added attachments, missing or obviously inadequate anchorage of components, heavy objects mounted high up in the equipment, components which are known to be seismically sensitive, 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 preferred method to determine the adequacy of anchorage, support, and anchorage load path

is through the inspection and judgment of Seismic Capability Engineers (SCEs). SCEs should consider the anchorage attributes in Section 4.4.1 of the GIP (Reference 36), as they judge appropriate, in their evaluation of the specific anchorage, support, or load path. If SCEs cannot determine the adequacy of anchorage, support, or load path by inspection, then an engineering review of the anchorage, support, or load path should be conducted (which does not have to be performed by SCEs). The engineering review should include a review of existing design calculations or the performance of new calculations.

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 there are relays in the electrical cabinets, 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.

4.6 DOCUMENTATION

The results of the Screening Verification and Walkdown should be documented on walkdown checklists, such as the SEWS contained in Appendix G, and on Screening Verification Data Sheets (SVDSs), shown in Exhibit 4-1 at the end of this section. Preparation of the SEWS and SVDSs includes a review of generic and plant-specific seismic documentation and a plant walkdown of the safe shutdown equipment. The completed SEWS and 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. These may include calculations, sketches, photographs, etc. Use of informal documentation is optional.

Instructions for completing the SEWS are included in Appendix G. Instructions for completing the SVDS are provided below.

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. Prior to arriving at this final judgment, there may have been several walkdowns, 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 (References 16 and 25), 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.

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 Exhibit A-1 in Appendix A.

<u>Column 1</u> contains the equipment class number from Table 3-1 of Section 3.

Column 2 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.

Column 3 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.

Column 4 identifies the building in which the equipment is located.

Column 5 contains the floor elevation from which the item of equipment can be viewed by the Seismic Capability Engineers.

Column 6 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).

Column 7 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 floor elevation given in Column 5.

Columns 8 through 12 are used to document the results of the evaluation of the equipment against the three seismic screening guidelines: caveat compliance, anchorage adequacy, and seismic interaction.

Column 8 indicates whether the equipment is within the scope of the earthquake/testing equipment class and meets the intent of all the caveats for the equipment class. The following codes may be used:

Y Yes, the equipment is in the equipment class, and the intent of all applicable caveats is satisfied.

N No, the equipment is not in the equipment class, or the intent of all applicable caveats is not satisfied.

U Unknown whether the equipment is in the equipment class or whether the intent of all applicable caveats is satisfied.

N/A The earthquake/test equipment class and the caveats are not applicable to this item of equipment.

Column 9 indicates whether the equipment anchorage meets the anchorage screening guidelines. The following codes may be used:

Y Yes, anchorage strength is adequate, free of gross installation defects, and has adequate stiffness.

N No, anchorage capacity is not adequate, or anchorage is not free of gross installation defects, or anchorage does not have adequate stiffness.

U Unknown whether anchorage capacities are adequate, or whether anchorage is free of gross installation defects or has adequate stiffness.

N/A Anchorage guidelines are not applicable to this equipment; e.g., valves are not evaluated for anchorage.

Column 10 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 11 and 12 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.

Column 11 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, 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) the equipment is in the earthquake/test equipment class and the intent of all the caveats is met.
(2) equipment anchorage is adequate, and
(3) 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 11 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 12 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. This column should also be used to identify when the intent of any caveat is met, but the specific wording of the caveat rule is not.

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)	Caveats OK? (8)	Anchorage OK? (9)	Interact. OK? (10)	Equipment OK? (11)	Notes (12)

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 Procedure. The screening guidelines are intended 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),
- Tanks and heat exchangers (Section 7)

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 and 7).

The remainder of the section is organized as follows:

- The requirements to which FPC commits 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 FPC COMMITMENTS

FPC will 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 and 7 FPC will classify an item of identified safe shutdown equipment as an outlier if the screening guidelines defined in these sections cannot be met.

5.1.2 Resolution of Outliers

FPC 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 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 sections of this procedure. The topics included in

these screening guidelines are listed below for the various types of equipment covered by this procedure:

Section 4 - Active Mechanical and Electrical Equipment
(Equipment Class #0 through #20)

- Caveats
- Anchorage
- Seismic Interaction

Section 7 - Tanks and Heat Exchangers
(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

If an item of equipment is identified as an outlier during a screening evaluation in one of these other sections of this procedure, 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 seven 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.

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. 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.

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. 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 and 7). The details for resolving outliers, however, are beyond the scope of this procedure. It is the responsibility of the Seismic Capability Engineers 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 this procedure 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 this procedure 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.

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 earthquake experience and generic testing data used to develop the GIP (Reference 36). FPC may use the Screening Verification and Walkdown procedure described in Section 4 in applying earthquake experience 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, FPC may choose to not perform corrective modifications or replacement of outliers. FPC must then explain to the NRC the safety implications of not modifying or replacing the outliers as described in Part I, Section 2.3.1. The NRC must then 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 equipment class may be expanded to include the equipment or specific equipment features of interest. The scope of the earthquake experience data which is documented in References 4 and 5 represents only a portion of the total data available. (Note that although the NRC Staff has fully reviewed the data in Reference 5, they have not reviewed the latest version of Reference 4.) An expansion of the earthquake experience equipment classes beyond the scope included in Appendix B 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. Extension of the generic experience equipment classes beyond the descriptions in this procedure is 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 this procedure or in compliance with some other seismic qualification method.

3. The subject equipment may be replaced with equipment which is covered by screening guidelines in this procedure or the GIP 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. For example, when 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. An alternate method of shutting the plant down may be selected if certain items of equipment can not be readily verified to be seismically adequate.

8. Information not available during the Screening Verification and Walkdown may be obtained and used to meet this procedure screening guidelines.

9. Screening criteria for the GIP GERS may be used.

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 earthquake experience or generic testing data 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 tc 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		Tank and Heat Exchangers	
Caveats	____	Shell Buckling[1]	____
Anchorage	____	Anchor Bolts and Embedment	____
Seismic Interaction	____	Anchorage Connections	____
Other	____	Flexibility of Attached Piping[1]	____
		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.

__________________ __________________ __________Print or Type Name
Signature Date

__________________ __________________ __________Print or Type Name
Signature Date

__________________ __________________ __________Print or Type Name
Signature Date

Section 6

RELAY FUNCTIONALITY REVIEW

No specific relay functionality review is required under the Florida Power Plant Specific Procedure.

For further explanation see Reference 37.

Users of this procedure are urged to review Section 6 of the GIP (Reference 36).

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 those tanks and heat exchangers which are needed for safe shutdown during and following a Safe Shutdown Earthquake (SSE) as identified in Section 3. These guidelines are intended only for use on existing tanks and heat exchangers, and are not to be used for new installations.

The guidelines contained in this section are based on Reference 26. Note, however, that to provide consistency with the remainder of the PSP some of the nomenclature and symbols used in this section are slightly different than those used in Reference 26.

This section contains the FPC 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, is

considered an acceptable method for 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 FPC COMMITMENTS

FPC commits to the following in regard to the verification of seismic adequacy of tanks and heat exchangers.

7.1.1 Scope of Equipment

FPC will evaluate for seismic adequacy tanks and heat exchangers identified pursuant to Section 3 of this procedure.

7.1.2 Evaluation Methodology

For identified tanks and heat exchangers, FPC 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

FPC 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.

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, FPC

may use existing analyses or alternative analysis methods which verify the seismic adequacy of its tanks and heat exchangers in lieu of this procedure, provided the Seismic Capability Engineers verify that these other analyses address the same type of loading as this procedure (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 for overturning moment and shear loadings on the tanks. The slosh height of the fluid surface for vertical tanks is based on using 1/2% damped ground or floor response spectra. If 4% and 1/2% damped response spectra are not directly available, then they may be estimated by scaling from spectra at other damping values using standard techniques.

7.3 VERTICAL TANKS

This section covers the following topics for vertical tanks:

- Scope of vertical tanks
- Seismic demand applied to vertical tanks
- Overturning moment capacity calculation
- Shear load capacity vs. demand
- Freeboard clearance vs. slosh height
- 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 Section 7.3.7.) 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. Where practical, as-built drawings should be used or a walkdown should be performed to gather data on the tank.

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_l (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.]

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 for overturning moment and shear loadings on tanks and at 1/2% damping for fluid slosh height.

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 $\sum_{i=1}^{n} h_i = H'$

$$t_{ef} = \frac{t_{av} + t_{min}}{2}$$

(Effective thickness of tank shell [in.]

t_{ef}/R

$$A_b = \frac{\pi d^2}{4}$$

(Cross-sectional area of embedded anchor bolt) [in^2]

$$t' = \left[\frac{N\ A_b}{2\pi R}\right] \left[\frac{E_b}{E_s}\right]$$

(Equivalent shell thickness having the same cross-sectional area as the anchor bolts) [in.]

$$c' = \left[\frac{t'}{t_s}\right] \left[\frac{h_c}{h_b}\right]$$

(Coefficient of tank wall thicknesses and lengths 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:

$$F_f = F'_f \left[\frac{1200}{R}\right]$$

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 4% damped horizontal ground or floor response spectrum (the maximum horizontal component) for the surface on which the tank is mounted, with the fluid-structure modal frequency:

F_f [Hz] (from Step 3)

and determine the maximum spectral acceleration:

Sa_f [g] (from horizontal 4% damped 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 26, 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:

$$Q = Q' \; W \; Sa_f \quad [lbf]$$

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 determir the base overturning moment coefficient:

M' (from Figure 7-4)

Compute the overturning moment at the base of the tank:

$$M = M' \; W \; H \; Sa_f \quad [in\text{-}lbf]$$

This completes the determination of the seismic demand applied to a vertical tank.

7.3.3 Overturning Moment Capacity Calculation

The seismic capacity of the tank shell and its anchorage to resist the overturning moment (M) calculated above is determined as explained 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 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.

The overturning moment capacity calculation is broken down into four parts. First, the anchor bolt capacity is determined by the procedure given in Section 4 and Appendix C of the GIP for cast-in-place bolts or J-bolts and is taken as the bolt yield capacity. 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 to carry the anchor bolt yield capacity.

Therefore, the second part of the overturning moment capacity calculation is to determine the anchorage connection capacity. If it is determined that the anchorage connection assembly has lower capacity than that determined for the anchor bolt itself, then this lower capacity should be used. The failure mode governing the connection capacity should also be determined, i.e., is it ductile or brittle. For a brittle failure mode, the moment capacity is determined without allowing inelastic stretching (yielding) of the bolt.

The third part is to calculate the compressive axial buckling stress capacity of the tank shell. The fourth and final part is to determine the controlling overturning moment capacity using the calculated bolt tension capacity and tank shell buckling capacity and compare this to the overturning moment seismic demand determined in Step 6.

7.3.3.1 Bolt Tensile Capacity

Step 7 - Determine bolt tensile load capacity, P_u (lbf), per guidelines for cast-in-place bolts in Section 4 and Appendix C of the GIP. 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 of the GIP. The bolt capacities from Section 4 and Appendix C of the GIP are based on the weak link being the anchor bolt rather than the concrete such that the postulated failure mode is ductile. 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 of the GIP)

A_b = cross-sectional area of embedded anchor bolt [in^2]
(from Step 2)

If the Section 4 and Appendix C of the GIP 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 brittle. Determine an appropriate reduced allowable anchor bolt stress (F_t) 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.

7.3.3.2 Anchorage Connection Capacity

In the previous step for determining bolt tensile capacity, 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 are taken from Reference 26 which primarily uses the design guidelines developed by the American Iron and Steel Institute (Reference 27). Figure 7-5 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 7-6 depicts two other less commonly-used anchor chair details. The detail shown in Figure 7-6(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 7-5. A similar approach can be used for other types of anchor bolt chairs, however appropriate equations should be used. In particular the tank shell stress equation given below in Step 9 is only applicable for the type of chair assembly shown in Figure 7-5.

If each of the anchorage connection components meets the acceptance criteria defined below, then the bolt tensile capacity determined in the previous Step 7 is limiting. If, however, any of

the components does not meet these guidelines, the reduced anchor bolt tension capacity represented by the equivalent value of anchor bolt allowable stress (F_r), as calculated here, should be used. Note that, if the failure mode of the weak link is nonductile, the procedure for computing M_{cap} (in Section 7.3.3.4) 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. For the purposes of these guidelines, nonductile failure modes are classified as "brittle".

The procedure given below, Steps 8 through 11, 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. The symbols used in the equations given in these steps are defined in Figure 7-5.

Step 8 - Top Plate. 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 7-5). 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:

$$\sigma = \frac{(0.375g - 0.22d)\ P_u}{f\ c^2} \qquad \text{[psi]}$$

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 compute the overturning moment capacity in Section 7.3.3.4.

Step 9 - Tank Shell Stress. 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 eccentricity 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. Note that the stress equation given below is only applicable for the type of chair assembly shown in Figure 7-5.

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:

$$Z = \frac{1.0}{\dfrac{(0.177\text{in}^{-1})a\ t_b}{\sqrt{Rt_s}} \left[\dfrac{t_b}{t_s}\right]^2 + 1.0}$$

Note: The terms a, t_b, t_s, and R in the above equation should all be in units of inches to be consistent with the proportionality factor of 0.177 which, as used in this equation, has units of [in $^{-1}$].

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).

$$F_r = F_b \left[\frac{f_y}{\sigma}\right] \quad \text{[psi]}$$

This reduced allowable anchor bolt stress should then be used to compute the overturning moment capacity in Section 7.3.3.4.

Step 10 - Vertical Stiffener Plates. The vertical stiffener plates are considered adequate for shear stress, buckling, and compressive stress if the following three guidelines are satisfied:

- $$\frac{k}{j} < \frac{95}{\sqrt{\frac{f_y}{1000}}}$$

- $j > 0.04(h - c)$ 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 connection will fail in a nonductile manner before the anchor bolts will yield. For the purposes of these guidelines, nonductile failure modes are classified as "brittle". Determine an appropriate reduced allowable anchor bolt stress (F_r) per applicable code requirements, and compute the overturning moment capacity in Section 7.3.3.4. 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.

Step 11 - Chair-to-Tank Wall Weld. 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:

$$W_w = P_u \sqrt{\left[\frac{1}{a + 2h}\right]^2 + \left[\frac{e}{a h + 0.667 h^2}\right]^2}$$

The weld is adequate if the following guideline is satisfied:

$$W_w \leq \frac{30{,}600\ t_w}{\sqrt{2}}$$

where 30,600 psi in the above equation is the allowable weld strength.

If the chair-to-tank wall weld does not meet this guideline, then the anchorage will fail in a nonductile manner before the anchor bolts will yield. For the purposes of these guidelines, nonductile failure modes are classified as "brittle." Determine an appropriate reduced allowable anchor bolt stress (F_t) per applicable code requirements, and compute the overturning moment capacity in Section 7.3.3.4. 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.

7.3.3.3 Tank Shell Buckling Capacity

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:

Step 12 - Determine the fluid pressure for elephant-foot buckling (P_e) by entering Figure 7-7 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 7-7)

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 13 - Determine the elephant-foot buckling stress capacity factor

σ_{pe} [ksi] (from Figure 7-8)

by entering Figure 7-8 with:

P_e [psi] (from Step 12)

t_s/R (from Step 2)

Convert σ_{pe} into units of psi by multiplying by 1000.

This value of σ_{pe} is for carbon steel. For other material, use the following formula:

$$\sigma_{pe} = \frac{0.6E_s}{(R/t_s)} \left[1 - \left(\frac{P_e R}{\sigma_y t_s} \right)^2 \right] \left[1 - \frac{1}{1.12 + S_1^{1.5}} \right] \left[\frac{S_1 + \sigma_y/36{,}000 \text{ psi}}{S_1 + 1} \right] [psi]$$

where:

$$S_1 = \frac{R}{400\, t_s}$$

σ_y = yield strength of tank shell material [psi] (from Step 1)

E_s = elasticity modulus of tank shell material [psi] (from Step 1)

t_s = minimum thickness of tank shell in the lowest 10% of the shell height (H') [in.] (from Step 1)

R = nominal radius of tank [in.] (from Step 1)

P_e = fluid pressure at the base of tank for elephant-foot buckling of tank shell [psi] (from Step 12)

Step 14 - Determine the fluid pressure for diamond-shape buckling (P_d) by entering Figure 7-9 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 7-9)

Compute the fluid pressure at the base of the vertical tank for diamond-shape buckling:

$$P_d = P_d' \gamma_f R \quad \text{[psi]}$$

Step 15 - Determine the diamond-shape buckling stress capacity factor:

σ_{pd} [ksi] (from Figure 7-10)

by entering Figure 7-10 with:

P_d [psi] (from Step 14)

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:

$$\gamma = 1 - 0.73(1-e^{-\phi})$$

$$\phi = \frac{1}{16}\sqrt{\frac{R}{t_s}}$$

E_s = elastic modulus of tank shell material [psi] (from Step 1)

R = nominal radius of tank [in.] (from Step 1)

t_s = minimum thickness of tank shell in the lowest 10% of the shell height (H') [in.] (from Step 1)

$\Delta\gamma$ = increase factor for internal pressure (from Figure 7-11)

Step 16 - Select the allowable buckling stress, σ_c, as 72% of the lower value of σ_{pe} or σ_{pd}:

$$\sigma_c = 0.72\ [\min.(\sigma_{pe}, \sigma_{pd})] \quad [\text{psi}]$$

7.3.3.4 Overturning Moment Capacity

Step 17 - The overturning moment capacity of the tank, M_{cap}, is dependent upon whether the postulated weak link failure mode is ductile or brittle.
A ductile failure mode is defined as one in which the weak link is one of the following:

- Anchor bolt stretching (Step 7)
- Chair top plate bending (Step 8)
- Tank shell bending (Step 9)

A brittle mode of failure is defined as one in which the weak link is one of the following:

- Concrete cone failure (Step 7)
- Chair stiffener plate shear or buckling failure (Step 10)

- Chair-to-tank wall weld shear failure (Step 11)

(a) Determine the base overturning moment coefficient for ductile failure:

M'_{cap} [dimensionless] (from Figure 7-12)

by entering Figure 7-12 with:

c' [dimensionless] (from Step 2)

σ_c [psi] (from Step 16)

F_b = smaller of F_b (from Step 7)
or F_r (from Steps 8 or 9) [psi]

h_c [in] (from Step 1)

h_b [in] (from Step 1)

If the postulated weak link failure mode is ductile, go to Step (c) below. If the postulated weak link failure mode is brittle, continue on to Step (b) below.

(b) If the postulated weak link failure mode is brittle, 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)

Compare the M'_{cap} value determined above with the M'_{cap} value determined in Step (a) above and select the lower of the two values for use in 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 17(a) for ductile failure mode or 17(b) for brittle failure mode)

F_b = smaller of F_b or F_r (from Steps 7, 8, 9, 10, or 11) [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 18 - Compare the overturning moment capacity of the tank (M_{cap}, from Step 17) with the overturning moment (M, from Step 6). If

$$M_{cap} \geq M$$

then the tank is adequate for this loading; 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.

7.3.4 Shear Load Capacity vs. Demand

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 19 - Compute the base shear load capacity of the tank:

$$Q_{cap} = 0.55\,(1 - 0.21\,Sa_f)\,W$$

using:

Sa_f [g] (from Step 4)

W [lbf] (from Step 2)

Step 20 - Compare the base shear load capacity of the tank (Q_{cap}, from Step 19) with the shear load (Q, from Step 5). If

$$Q_{cap} \geq Q$$

then the tank is adequate for this loading; proceed to Step 21. 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 vs. Slosh Height

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 21 - The slosh height is given by the following equation:

$$h_s = 0.837 \, R \, Sa_s$$

where:

R = nominal radius of tank [in.] (from Step 1)

Sa_s = spectral acceleration (1/2% damping) of the ground or floor on which the tank is mounted at the frequency of the sloshing mode (F_s, determined below).

In calculating the slosh height from this equation, the Sa_s value must be obtained from the input demand spectrum at the sloshing mode frequency, F_s, and damping value of 1/2%. Care should be exercised in assuring that the spectrum values are accurately defined in the sloshing mode frequency range, typically for 0.5 Hz to O.2 Hz. The sloshing mode frequency can be calculated from the following equation:

$$F_s = \frac{1}{2\pi} \sqrt{\frac{1.84G}{R} \tanh\left(\frac{1.84H}{R}\right)} \qquad [\text{Hz}]$$

where:

G = acceleration of gravity

= 386.4 [in/sec^2]

R [in.] (from Step 1)

H [in.] (from Step 1)

Alternately, 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)

In calculating the slosh height given in Table 7-5, it has been assumed that for an input spectrum normalized to a ZPA of 1 g, the Sa_s (1/2% damping) values vary linearly from 0.75 g at 0.5 Hz to 0.4 g at 0.2 Hz.

Compute the slosh height of the fluid in the tank for the ZPA of the ground or floor on which the tank is mounted:

$$h_s = h'_s \, ZPA$$

using:

h'_s [in.] (from above)

ZPA [g] (from horizontal response spectrum)

Step 22 - 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 21). If

$$h_f \geq h_s$$

then the tank is adequate for this condition; proceed to Step 23. 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 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.

7.3.7 Tank Foundation

The screening guidelines contained herein are for use with all types of tank foundations typically found in the nuclear industry except ring-type foundations. Ring foundations should be identified as outliers and evaluated separately.

An acceptable outlier evaluation method for ring-type foundations is to check the tank overturning resistance and the adequacy of the rebar in the foundation. The overturning resistance may be checked by using the energy method to compute how much the tank and attached ring foundation lift up and whether there is adequate flexibility in the tank floor, shell, and associated welds, as well as any attached piping.

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 7-5) [in.]
b	-	Depth of chair top plate perpendicular to shell (see Figure 7-5) [in.]
c	-	Thickness of chair top plate (see Figure 7-5) [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 7-5) [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_s	-	Sloshing mode frequency [Hz]
f	-	Distance from outside edge of chair top plate to edge of hole (see Figure 7-5) [in.]
f_y	-	Minimum specified yield strength of shell, chair, saddle, or base plate material [psi]
G	-	Acceleration of gravity [386.4 in/sec^2]
g	-	Distance between vertical plates of chair (see Figure 7-5) [in.]

Table 7-2 (Continued)

NOMENCLATURE USED FOR VERTICAL TANKS

Symbol		Description [Units]
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.]
h	-	Height of chair (see Figure 7-5) [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 7-5) [in.]
k	-	Width of chair vertical plate (see Figure 7-5). Use average width for tapered plates [in.].
M	-	Overturning moment at base of tank [in-lbf]
M'	-	Base overturning moment coefficient [dimensionless]
$M_{ca}p$	-	Overturning moment capacity of tank [in-lbf]
M'_{cap}	-	Base overturning moment capacity coefficient [dimensionless]
N	-	Number of anchor bolts [dimensionless]
P_c	-	Fluid pressure at base of tank for elephant-foot buckling of tank shell [psi]
P_c'	-	Pressure coefficient for elephant-foot buckling [dimensionless]

Table 7-2 (Continued)

NOMENCLATURE USED FOR VERTICAL TANKS

Symbol		Description [Units]
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]
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 (4% damping) of the ground or floor on which the tank is mounted at the frequency of the fluid-structure interaction mode (F_f) [g]
Sa_s	-	Spectral acceleration (1/2% damping) of the ground or floor on which the tank is mounted at the frequency of the sloshing mode (F_s) [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 7-5) [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.]

Table 7-2 (Continued)

NOMENCLATURE USED FOR VERTICAL TANKS

Symbol		Description [Units]
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.]
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]
ß	-	Percentage damping [%]
γ	-	Buckling 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 7-10
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]
ϕ	-	Buckling coefficient $[(1/16)(R/t_s)^{1/2}]$ [dimensionless]

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_{cr}/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	2' 1	15.8	12.7	10.5	9.0
1.5	0.005	70.6	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	3.6
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

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_{rf}/R	60	120	180	240	300	360	420
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
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'_s, 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

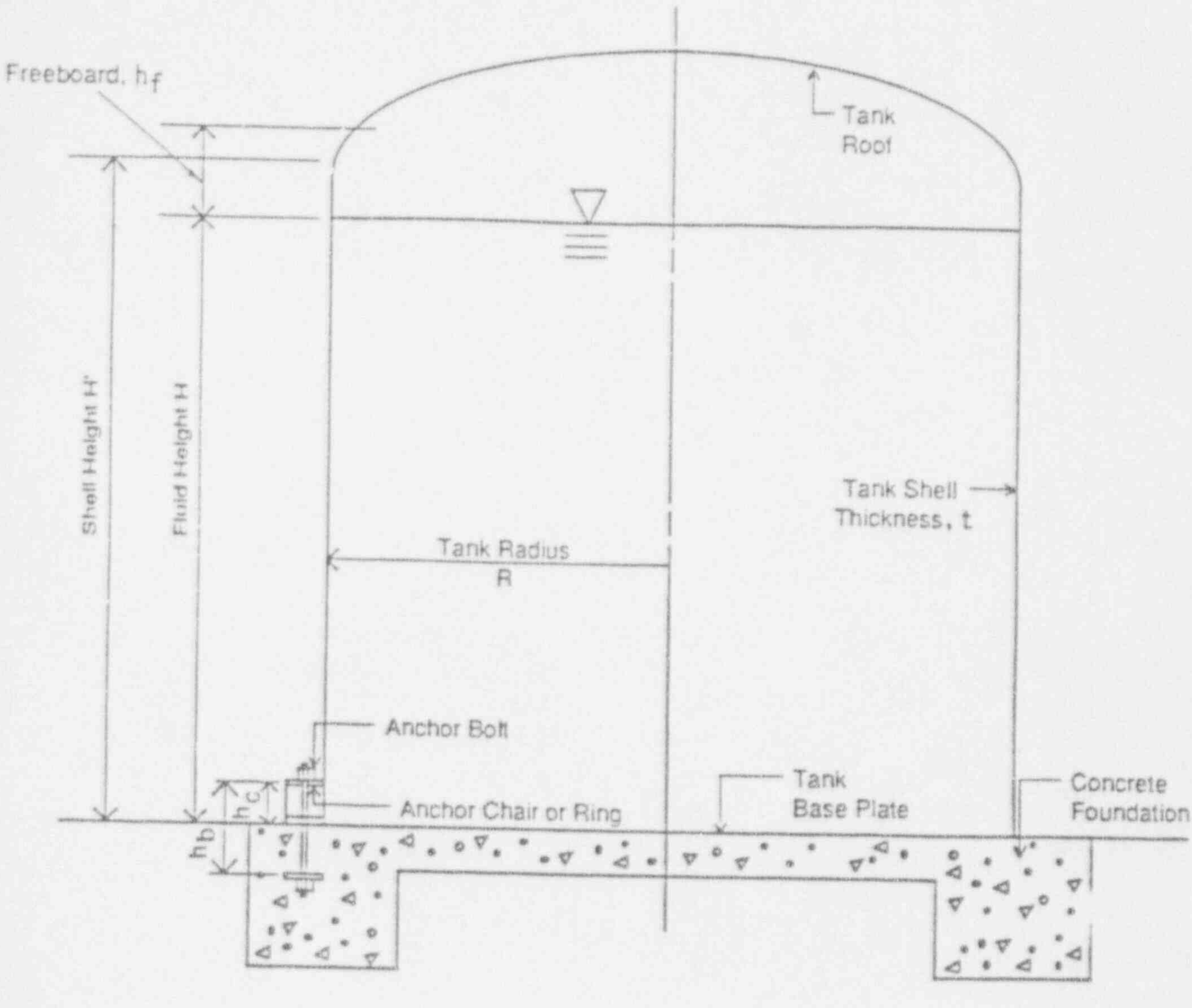


Figure 7-1. Large Vertical Tank
(Source: Reference 26, Figure 2.1)

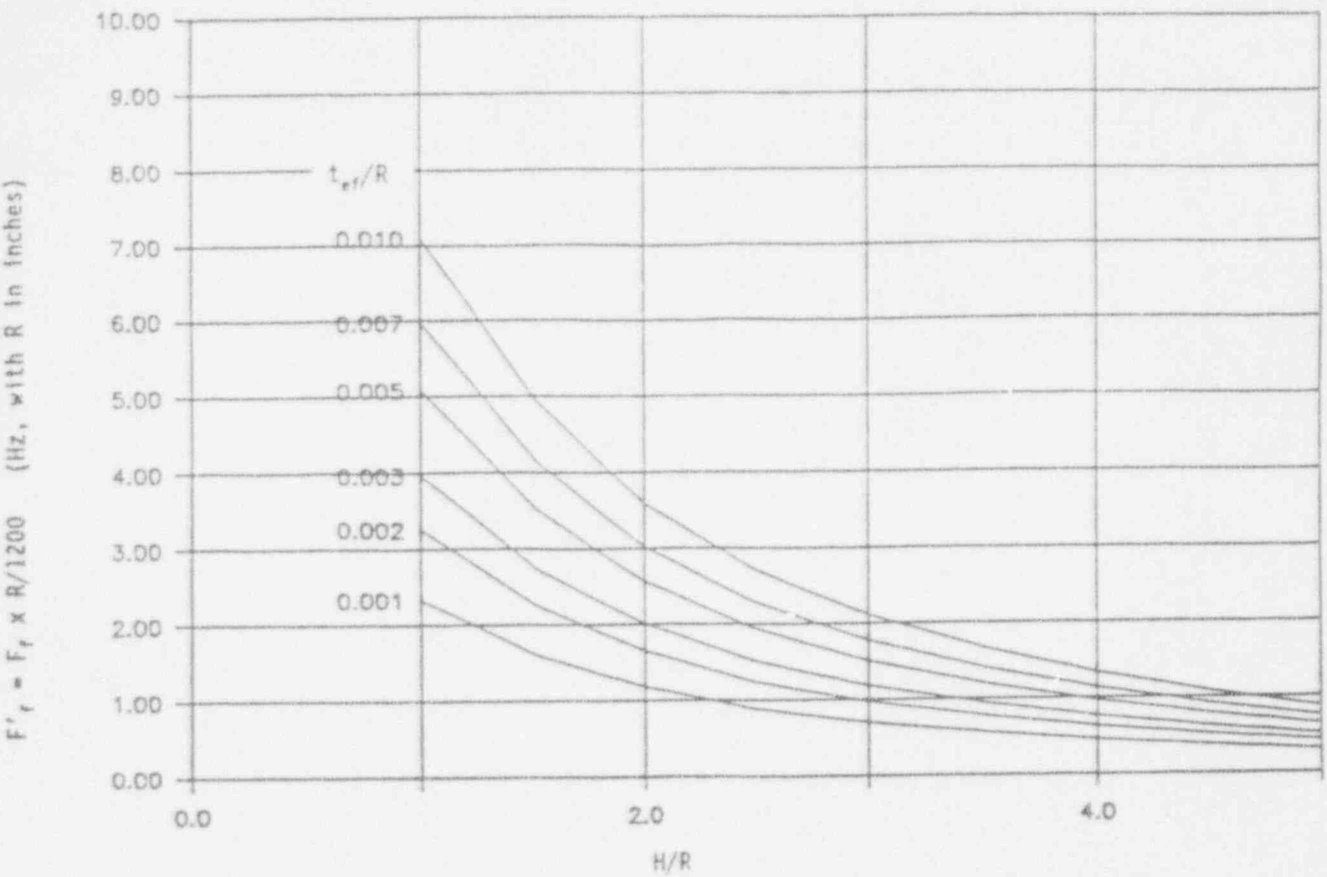


Figure 7-2. Fluid-Structure Impulsive Mode Frequency Coefficient for Vertical Carbon Steel Tanks Containing Water. (Source: Reference 26, Figure 2.3)

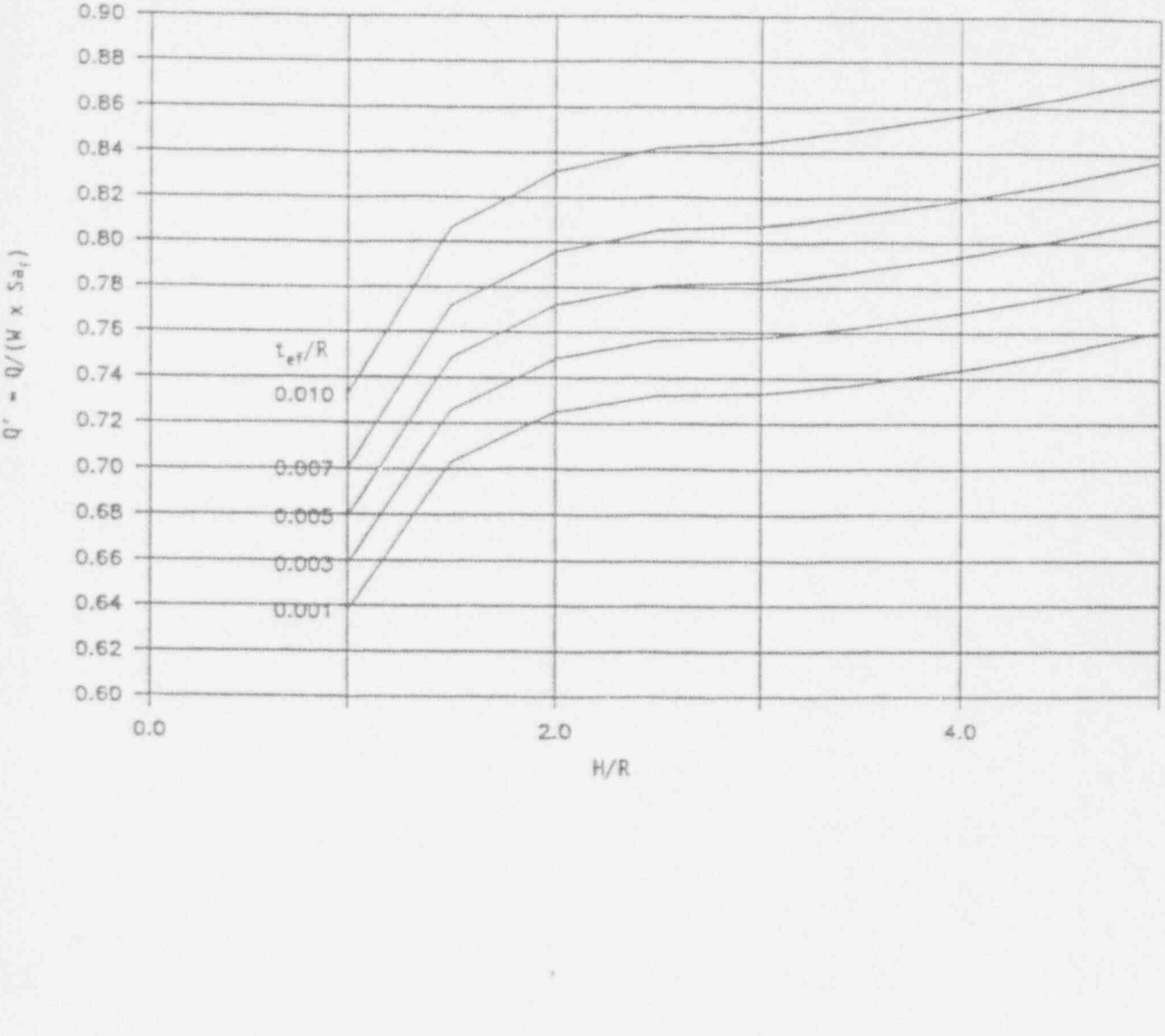


Figure 7-3. Base Shear Load Coefficient For Vertical Tanks
(Source: Reference 26, Figure 2.4)

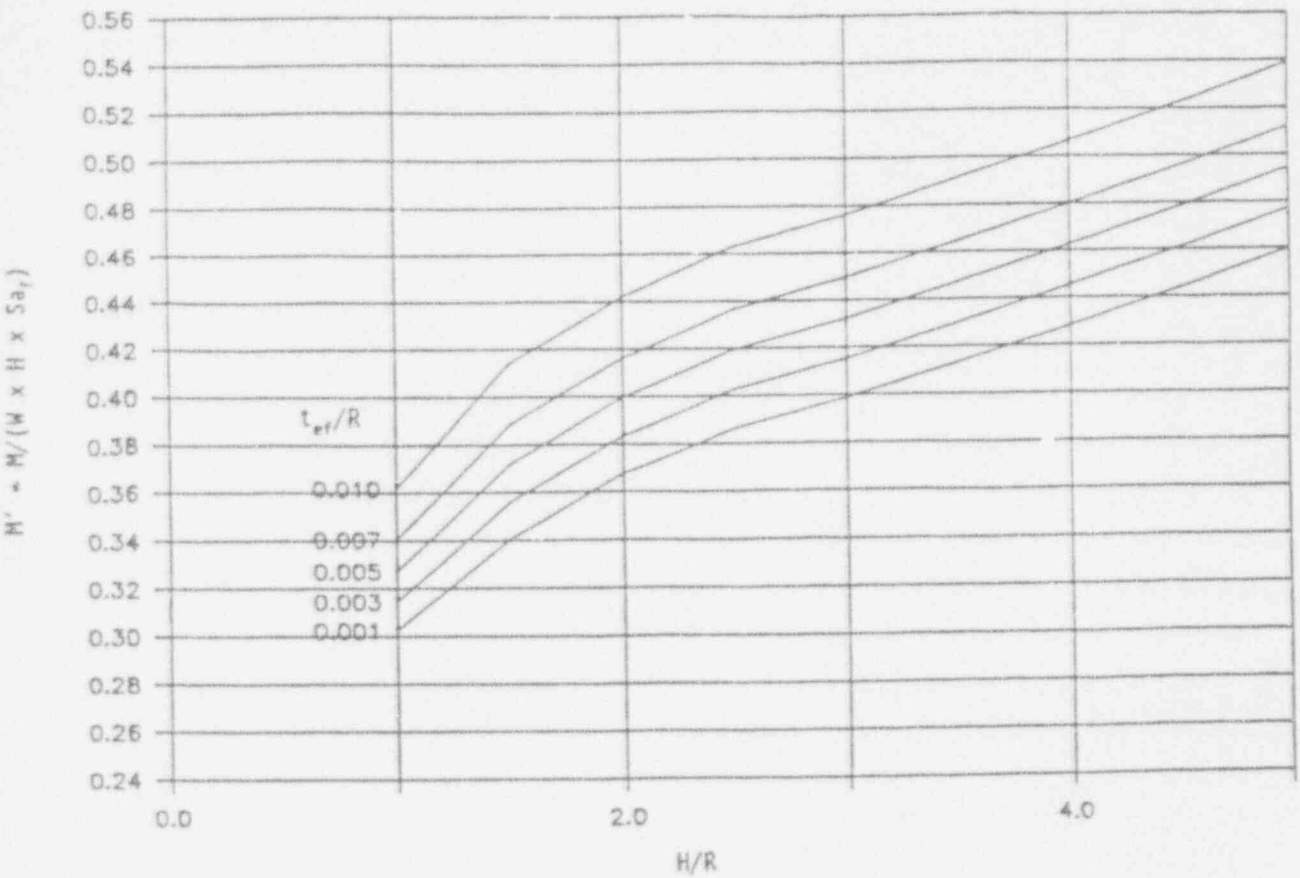
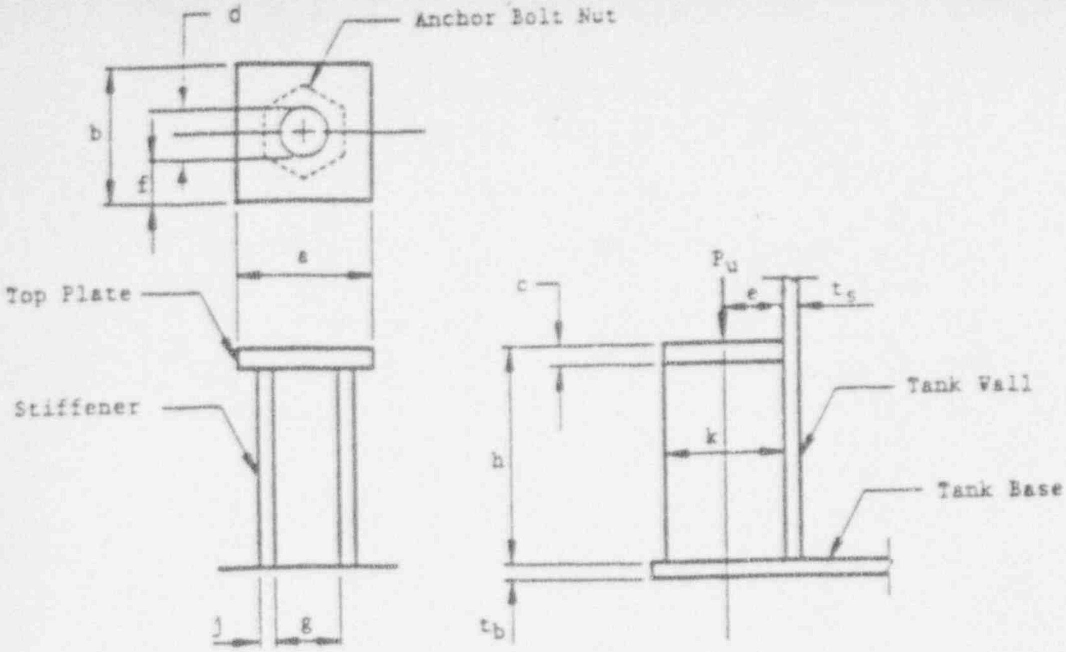


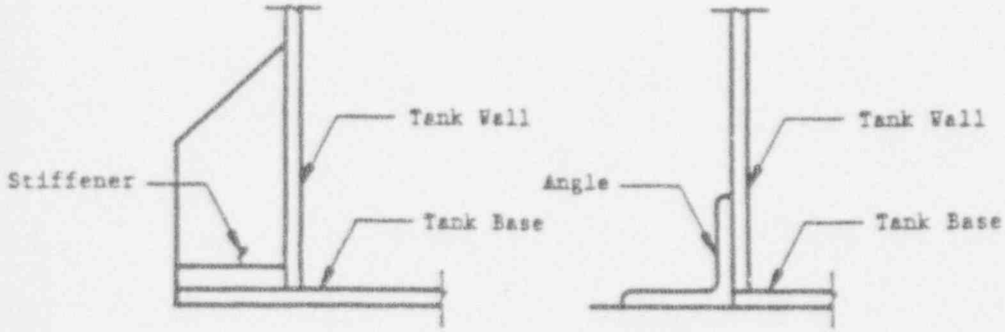
Figure 7-4. Base Overturning Moment Coefficient For Vertical Tanks (Source:Reference 26, Figure 2.5)



(a) Typical Plan and Outside Views

(b) Side View

Figure 7-5. Typical Anchor Bolt Chair
(Source: Reference 26, Figure 2.13)



(a) Side View

(b) Angle Chair Side View

Figure 7-6. Alternate Anchor Bolt Chairs
(Source: Reference 26, Figure 2.14)

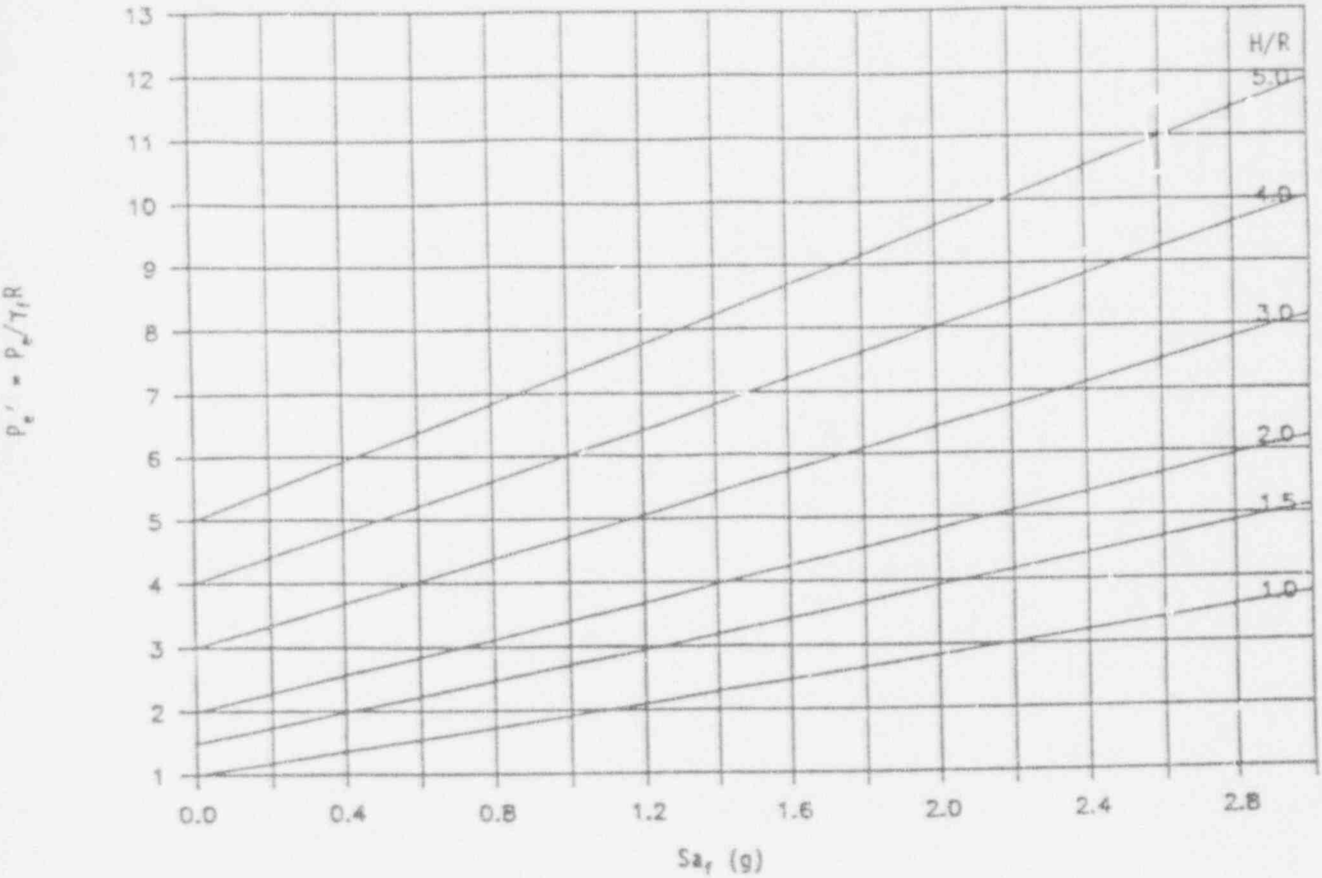


Figure 7-7. Pressure Coefficient For Elephant-Foot Buckling of Vertical Tanks
(Source: Reference 26, Figure 2.6)

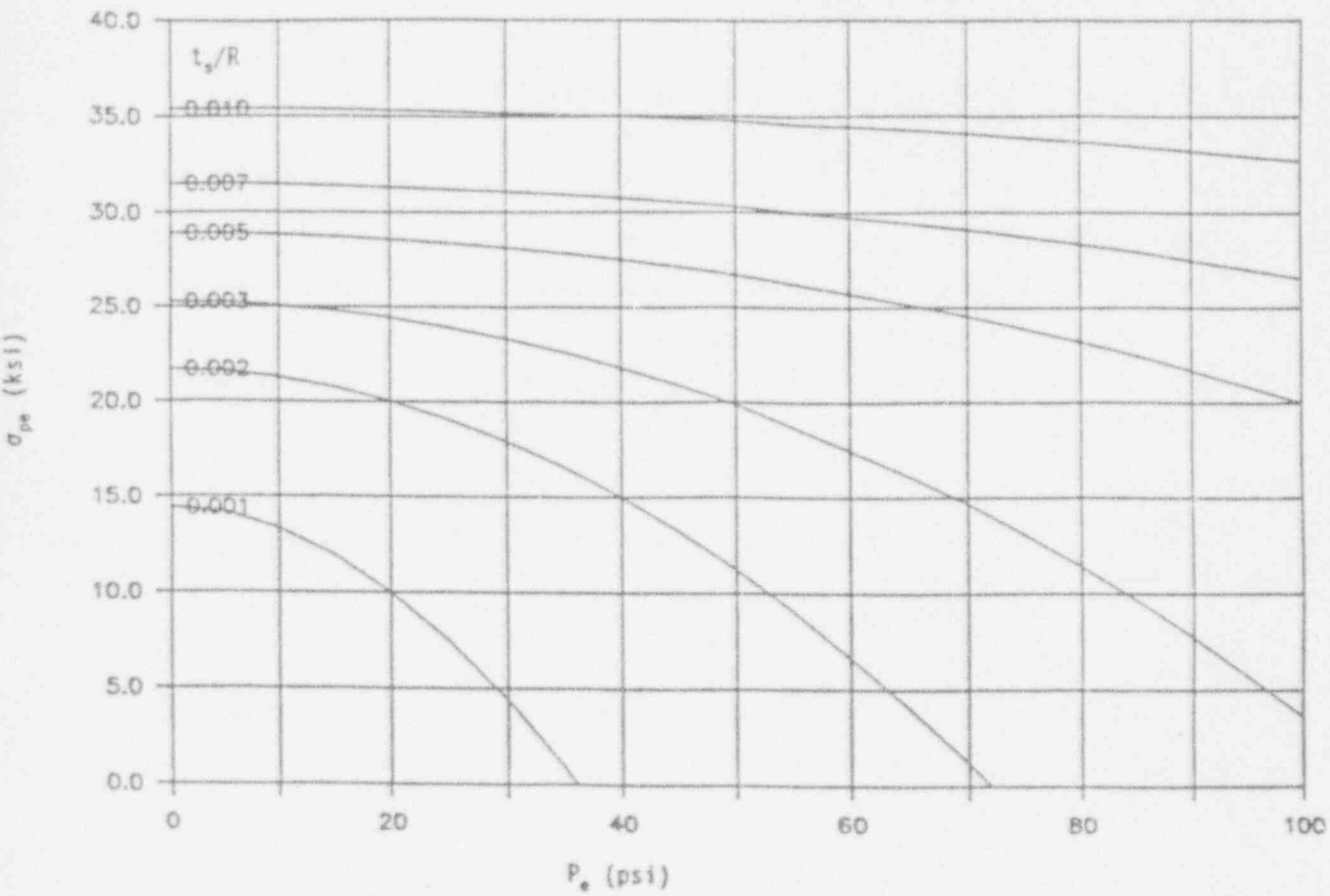


Figure 7-8 Compressive Axial Stress Capacity For Vertical Tanks, Elephant-Foot Buckling (Steel, E = 30,000 psi, σ_y = 36,000 psi) (Source: Reference 26, Figure 2.8)

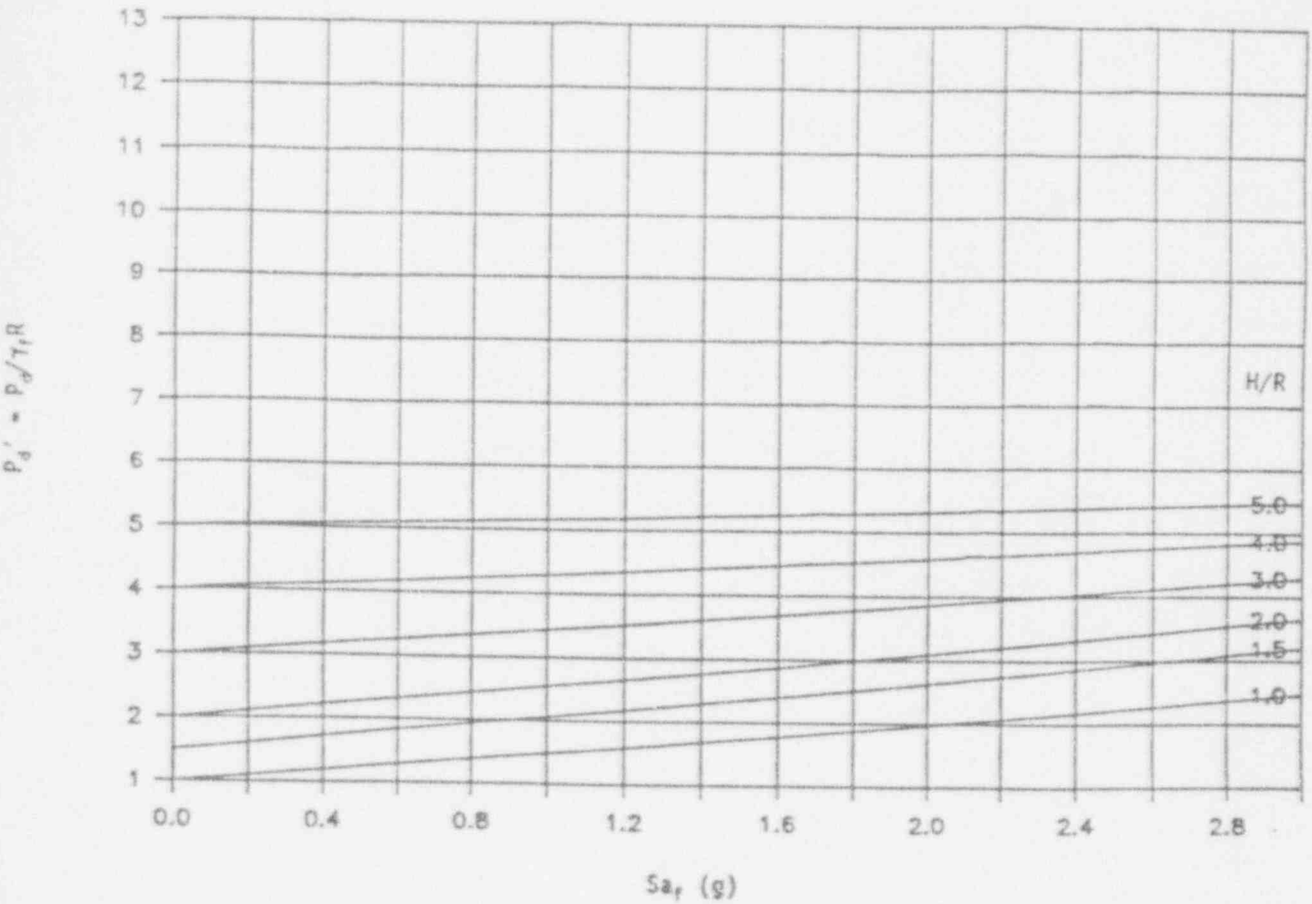


Figure 7-9. Pressure Coefficient For Diamond-Shape Buckling of Vertical Tanks (Source: Reference 26, Figure 2.7)

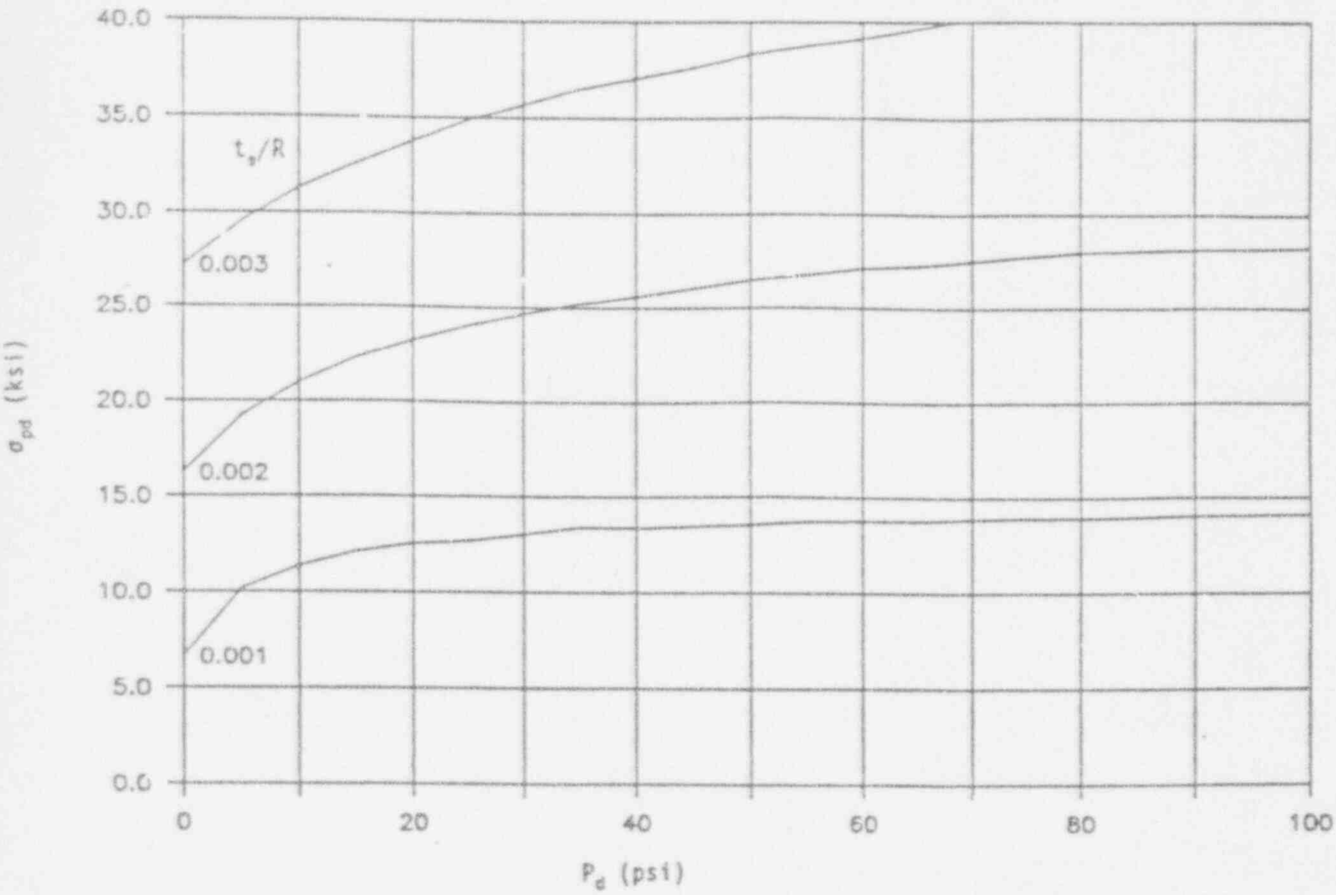


Figure 7-10. Compressive Axial Stress Capacity For Vertical Tanks, Diamond-Shape Buckling (Steel, E = 30,000 psi) (Source: Reference 26, Figure 2.10)

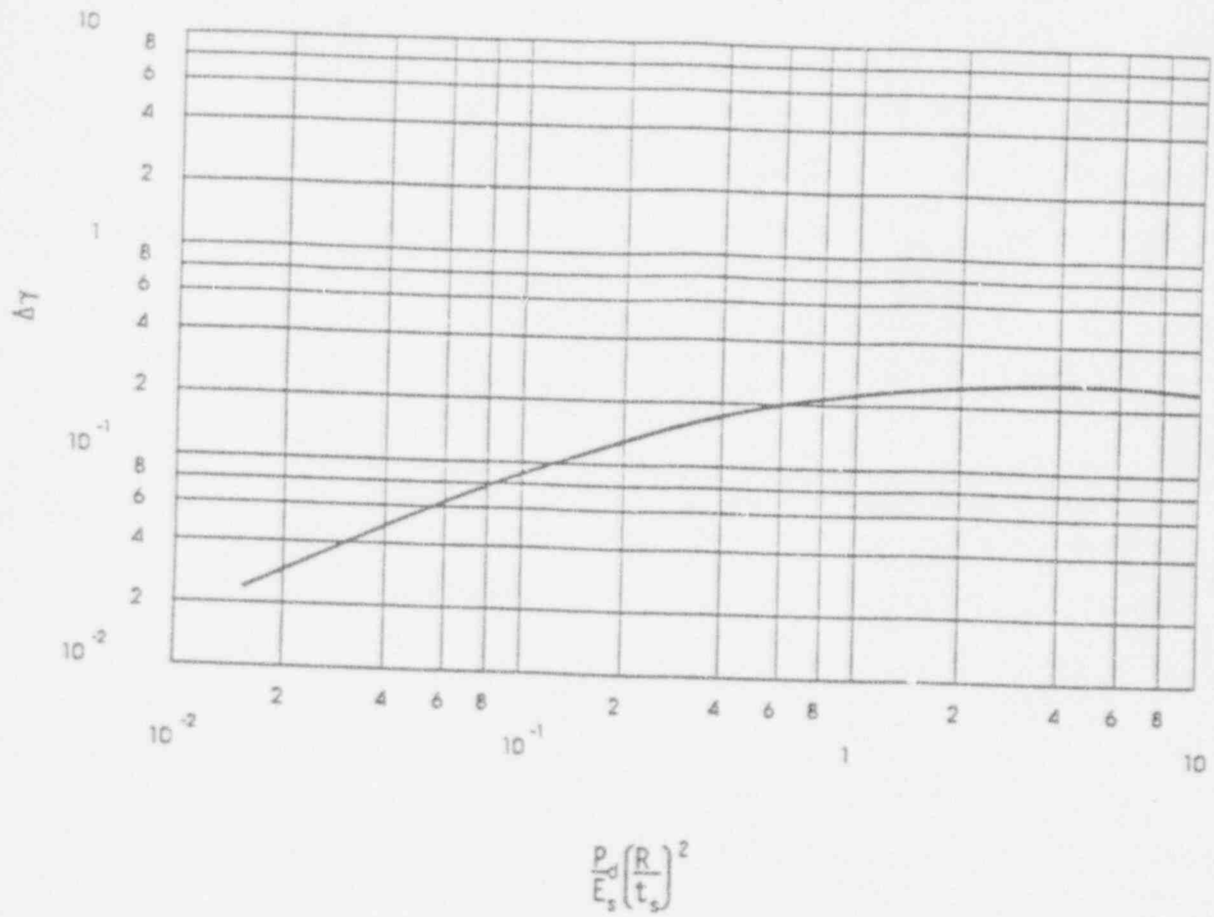


Figure 7-11. Increase Factor $\Delta\gamma$ for Diamond-Shape Buckling
(Source: Reference 26, Figure 2.9)

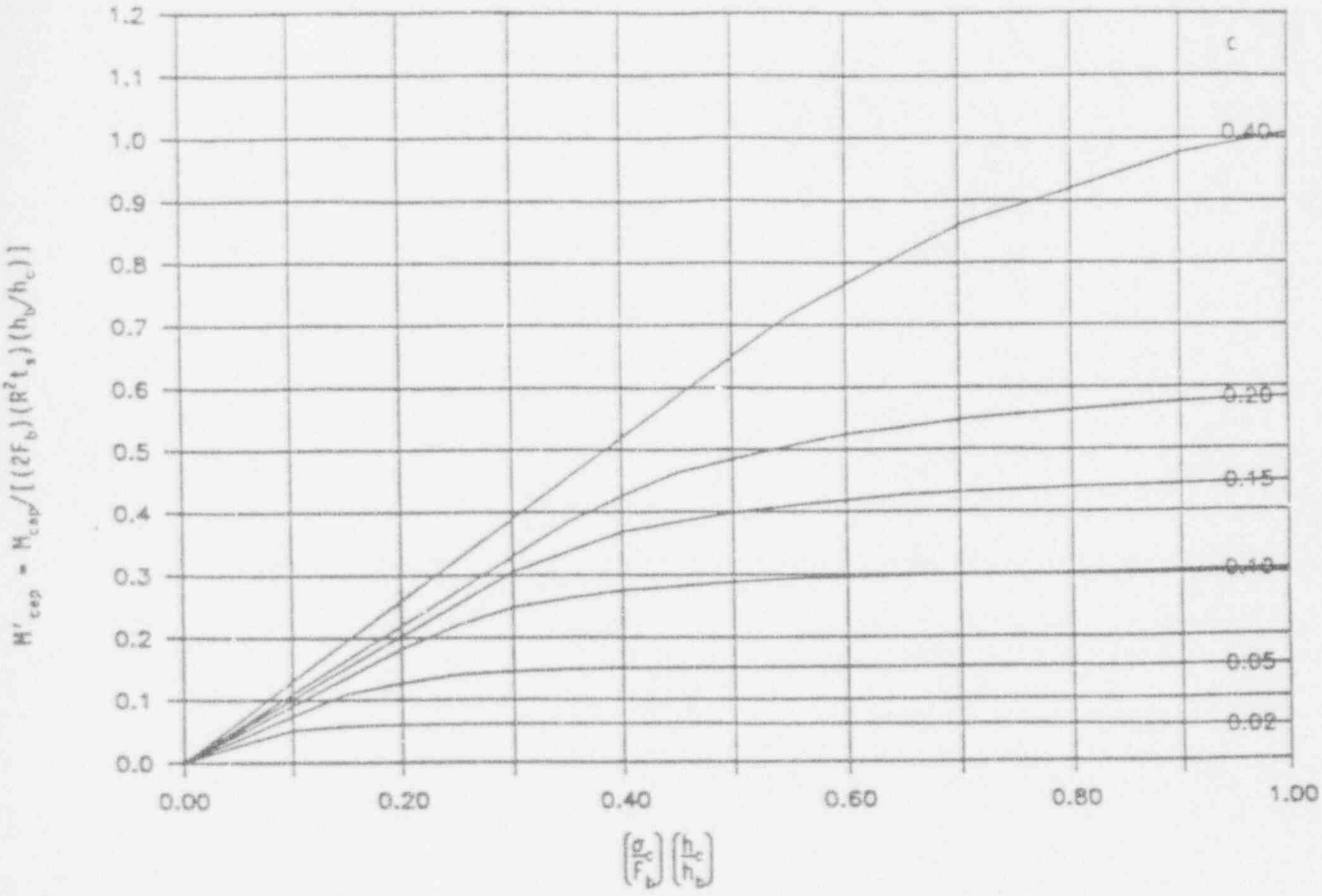


Figure 7-12. Base Overturning Moment Capacity
Coefficient For Vertical Tanks
(Source: Reference 26, Figure 2.12)

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 of the GIP 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.

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 capacity, 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 direction.

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

<u>Step-By-Step Procedure for Horizontal Tanks</u>

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 (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 of the GIP.

P_u' [lbf] (from Section 4.4 and Appendix C of the GIP)

V_u' [lbf] (from Section 4.4 and Appendix C of the GIP)

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):

$$RB = \frac{f_y}{\sigma} = \frac{f_y\, t_b^2}{3P_u'}$$

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 twice the distance from the bolt centerline to the vertical saddle plate; i.e., $2\,e_s$. 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:

$P_u = P_u'$ x (Smaller of: RB or RW) [lbf]

The shear allowable anchorage load is:

$V_u = V_u'$ [lbf]

Step 6 - Calculate the following ratios and values:

$$\alpha = P_u/V_u$$

$$W_b = \frac{W_u}{NS \cdot NL \cdot NB}$$

V_u/W_b

H_{cg}/D'

H_{cg}/S

$$F_1 = \sqrt{(NS)^2 + 1}$$

$$F_2 = \sqrt{NL^2\left(\frac{H_{cg}}{D'}\right)^2 + \left(\frac{2}{3}\right)^2 + \left(\frac{H_{cg}}{S}\right)^2\left(\frac{(NS)^2}{(NS-1)^2}\right)}$$

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:

$$\lambda_l = \left[\frac{V_u}{W_b}\right]\left[\frac{1}{F_1}\right] \quad [g]$$

$$\lambda_u = \frac{\frac{V_u}{W_b} + \frac{0.7}{\alpha}}{\left[\frac{0.7}{\alpha}\right] F_2 + F_1} \quad [g]$$

λ = (Smaller of λ_l or λ_u) [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., $F_{trans} \geq 33$ 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:

$$F_{long.} = \frac{1}{2\pi}\sqrt{\frac{k_s\, g}{W_{t^c}}} \quad [Hz]$$

Where the saddle stiffness (k_s) is:

$$k_s = \frac{1}{\dfrac{h^3}{3\ E\ I_{yy}} + \dfrac{h}{A_s\ G}} \qquad [lbf/in]$$

If the longitudinal resonant frequency (F_{long}) is greater than or equal to about 30 Hz:

$$F_{long} \geq 33\ Hz$$

then the tank is rigid in the longitudinal direction, otherwise it is flexible.

Step 10 - 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

$F_{long} \geq 33\ Hz$

then determine the ZPA from the 4% damped floor response spectrum (maximum horizontal component). See Section 4.4.3, Step 1 for a discussion of input spectral acceleration.

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

$F_{long} < 33$ 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.

- Longitudinal seismic loads

** 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.

- 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.

This completes the seismic evaluation for horizontal tanks.

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 180 lbf/ft^3

Assumptions:

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 piate 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 bolt [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 ($F_{trans} \geq 30$ 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 bolt [lbf]
W_b	-	Weight of tank per anchor bolt,

$$W_b = \frac{W_{tf}}{NS \cdot NL \cdot NB} \quad [\text{lbf}]$$

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, $\alpha = \frac{P_u}{V_u}$ [dimensionless]
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]

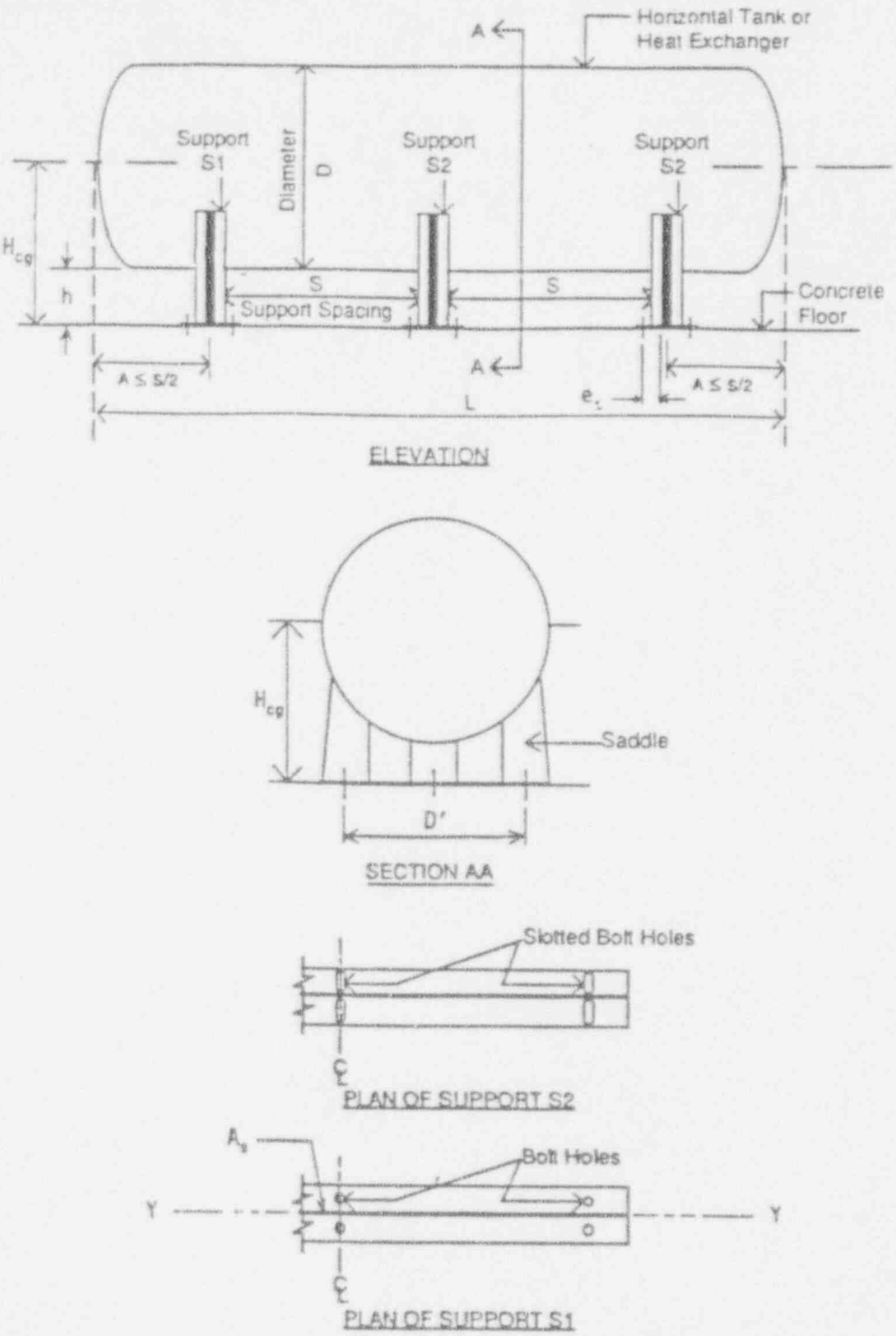


Figure 7-13. Horizontal Tank or Heat Exchanger
(Source: Reference 26, Figure 3.1)

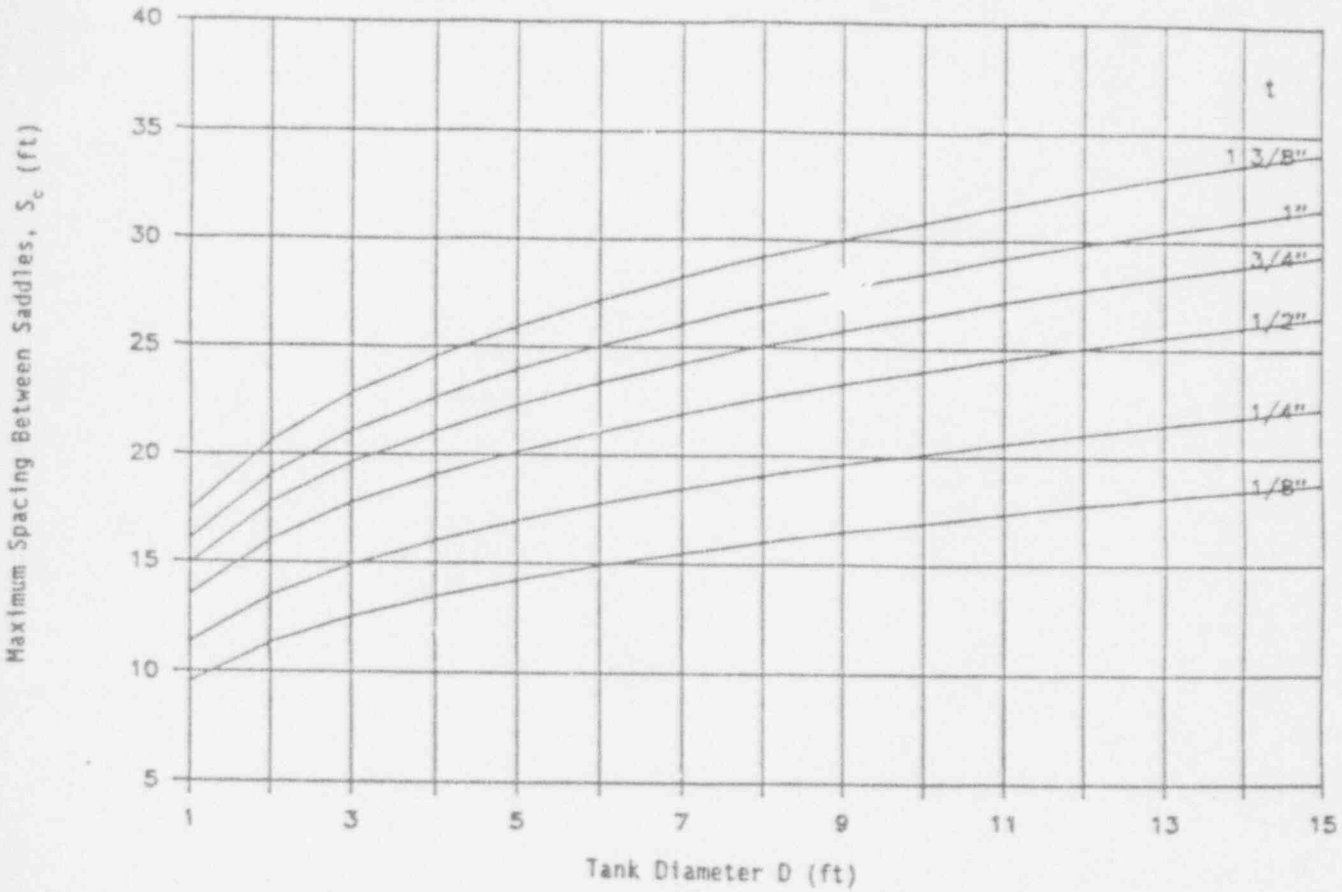


Figure 7-14. Maximum Saddle Spacing For Rigid ($F_{trans} \geq 30$ Hz) Horizontal Tanks ($\gamma_t \leq 75$ lbf/ft^3) (Source: Reference 26, Figure 3.7)

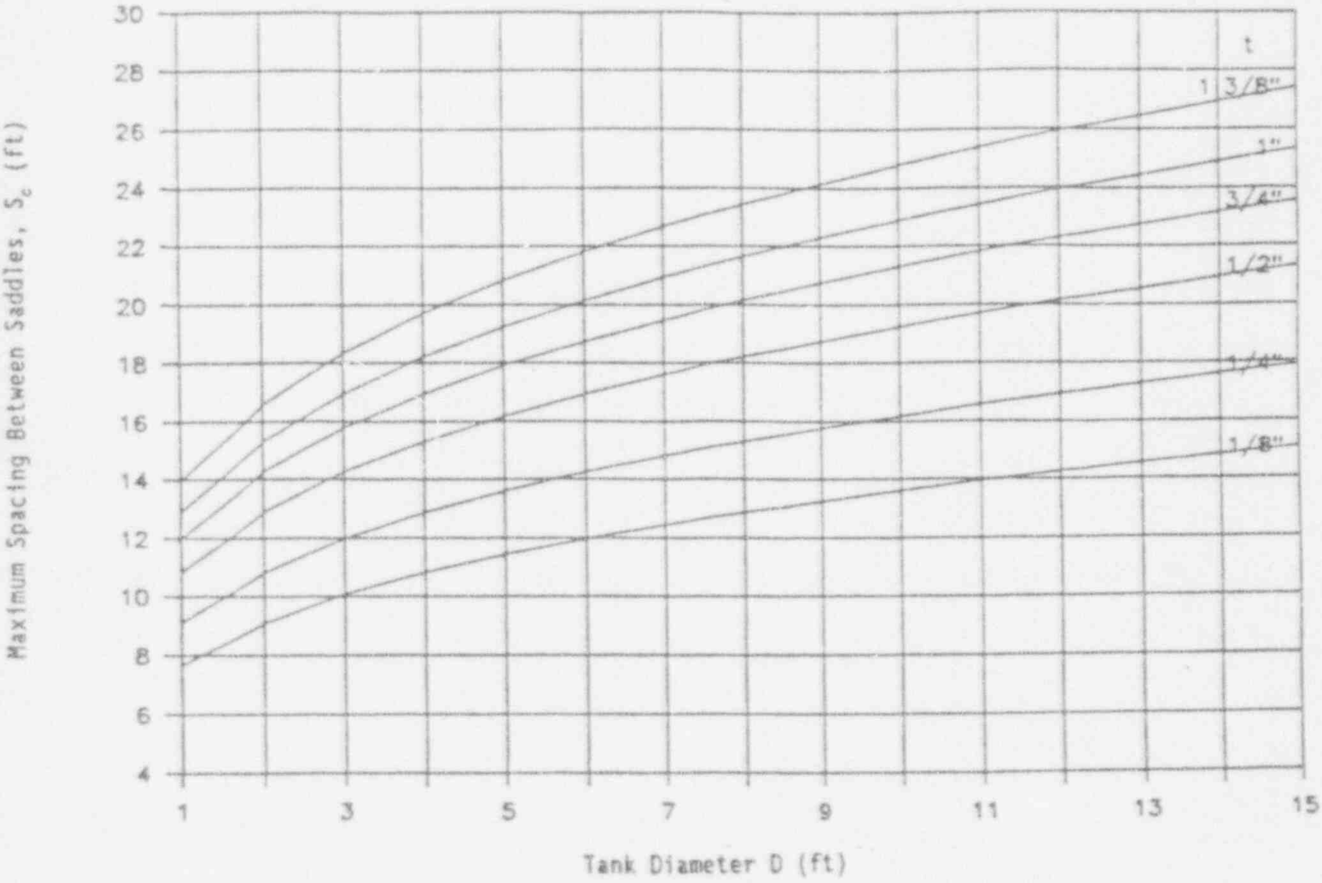


Figure 7-15. Maximum Saddle Spacing for Rigid ($F_{trans} \geq 30$ Hz) Horizontal Heat Exchangers ($\gamma_h \leq 180$ lbf/ft^3) (Source: Reference 26, Figure 3.8)

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 all possible causes for a tank or heat exchanger being classified as an outlier are identified before proceeding to Section 5 to resolve it.

The 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, generic 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 FPC 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

No specific cable and conduit raceway review is required under the Florida Power Plant Specific Procedure.

For further explanation see Appendix B of Reference 37.

Users of this procedure are urged to review Section 8.0 of the GIP (Reference 36).

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 three major types of documents are described in this section.

- Safe Shutdown Equipment List (SSEL) 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 three major documents. The important features of these documents as shown in this figure are summarized below.

The first type of document to be generated is a Safe Shutdown Equipment List (SSEL) Report. There are two types of SSELs that can be developed for this report, as described in Section 3 and Appendix A:

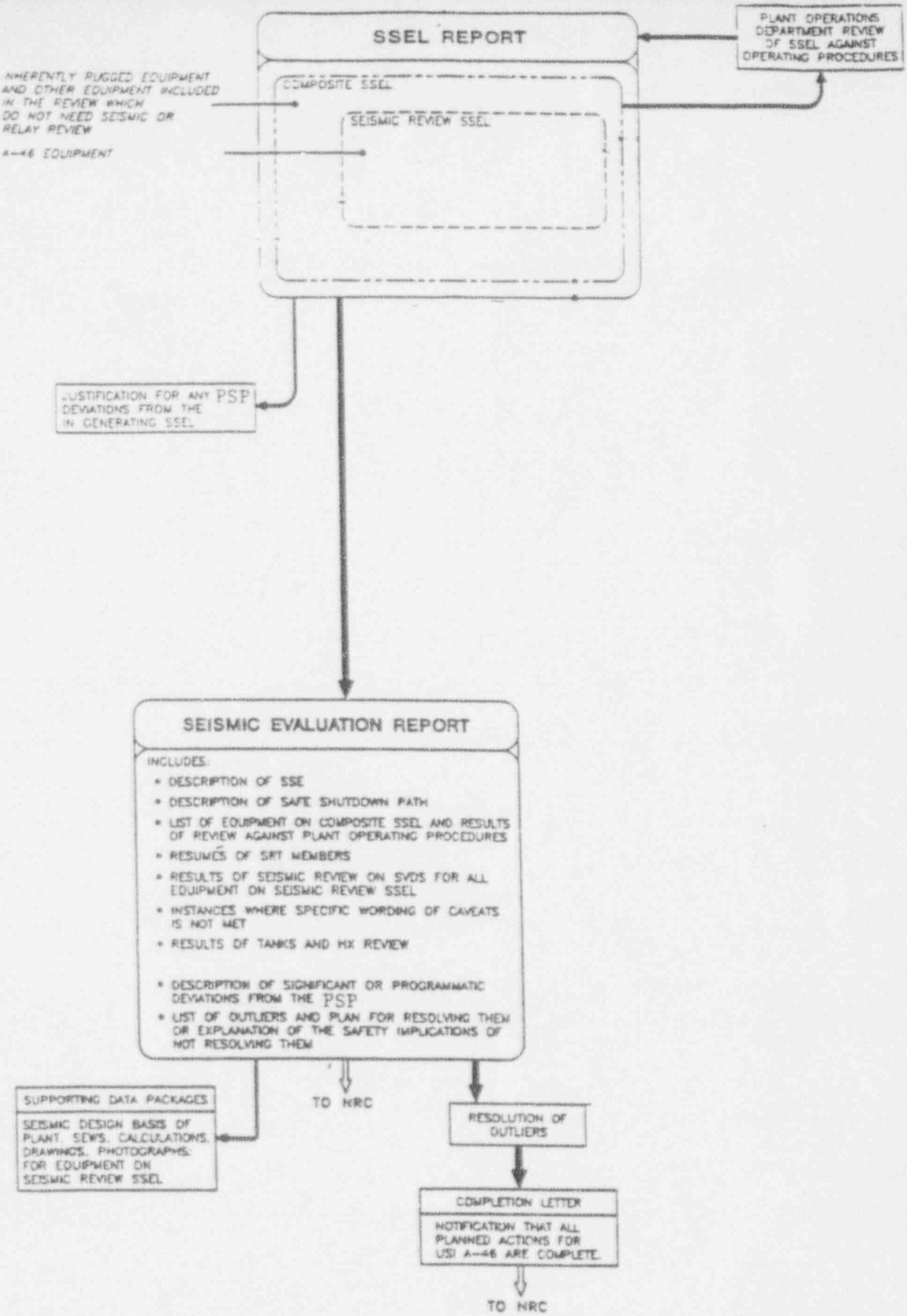


Figure 9-1. Documentation for USI A-46

- The Composite SSEL includes all of the equipment identified as being needed for safe shutdown of the plant including (1) equipment which should be reviewed for seismic adequacy, (2) other types of equipment needed for safe shutdown but which need not be reviewed for seismic adequacy, e.g., inherently rugged equipment like check valves and manual valves or passive equipment like filters.

- The Seismic Review SSEL is a subset of the Composite SSEL and includes only those items of active mechanical and electrical equipment and tanks and heat exchangers for which a seismic review should be performed.

The Seismic Review SSELs are input for the Seismic Evaluation Report. Note also that the plant Operations Department should review the SSEL against the plant operating procedures.

The Seismic Evaluation Report is the second type of document to be generated for the USI A-46 review. This report describes the results of the seismic reviews of active mechanical and electrical equipment (Section 4) and tanks and heat exchangers (Section 7).

The Seismic Evaluation Report should be submitted to the NRC. Also, if there are any items of equipment identified as outliers during these seismic reviews, they would be subject to resolution.

After resolving all the outliers which FPC plans to address, a Completion Letter will be sent to the NRC notifying them that all planned actions for resolution of USI A-46 are complete.

This section describes both the type of documentation to be developed and retained by the utility to support the resolution of USI A-46 and the documentation to be sent to the NRC at the completion of the program.

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 this procedure and 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 certify that the results

of the Screening Verification and Walkdown are correct and accurate. One of these signatories should also be a licensed professional engineer.

9.1 FPC COMMITMENTS

FPC commits 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 tanks and heat exchangers review, and the outlier identification and resolution.

FPC 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 resolution of USI A-46, i.e., systems selected for achieving and maintaining safe shutdown. If the scope of review is expanded beyond the systems required for safe shutdown and this expanded scope of equipment is submitted as part of the USI A-46 summary report, then these additional systems should be identified.

2. 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.

3. List of the equipment on the Composite SSEL.

4. List of equipment on the Seismic Review SSEL and the location of equipment in the plant (building and floor evaluation).

5. Description of the SSE used in the USI A-46 program including a description of how the seismic demand input motion to each item of equipment was determined.
6. Qualifications of the Seismic Capability Engineers.

7. Results of the Screening Verification and Walkdown for mechanical and electrical equipment.

8. Identification of instances in which the intent of the caveat is met without meeting the specific wording of the caveat rule.

9. Results of the tanks and heat exchangers review.

10. Description of the outliers and any deficiencies.

11. List of the unresolved outliers (i.e., those not meeting this procedure's screening guidelines) and an explanation of the safety implications of not resolving these outliers.

12. Proposed schedule for complete resolution, future modifications and replacements of those outliers which will be resolved.

After all planned actions to resolve outliers are complete, FPC 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 two types of SSELs which are described below.

- The Composite SSEL should contain all of the equipment described in Section 3 which should be evaluated for seismic adequacy. Other equipment in the safe shutdown systems (e.g., inherently rugged and passive equipment) may also be added to this SSEL at the option of FPC.
- 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 SSEL Report should also describe the method used by the Operations Department for verifying the compatibility of the SSEL with the plant operation 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 Seismic Evaluation Report described below.

- Description of the safe shutdown path(s) chosen for resolution of USI A-46, i.e, systems selected for achieving and maintaining safe shutdown. If the scope of the review is expanded beyond the systems required for safe shutdown and this expanded scope of equipment is submitted as part of the USI A-46 summary report, then these additional

systems should be identified.

- List of equipment included on the Composite SSEL.

- List of equipment included on the Seismic Review SSEL and location of equipment in the plant (building and floor evaluation).

- 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

Not used.

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 found (e.g., rock or soil; effective grade of plant, etc.), and basis for establishing the degree of uncertainty in the natural frequency of the building structure if unbroadened response spectra are used with frequency shifting of response peaks.

- List of equipment on the Composite SSEL.

- List of the equipment on the Seismic Review SSEL.

- Resumes of Seismic Capability Engineers.

- Checklists (e.g., SEWS, and Exhibits 8-1, 8-2, and 8-3).

- Notes, photographs, drawings, calculations, assumptions, judgements, 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, including descriptions of any cases which specific caveats are met by intent without meeting the specific wording of the caveat rule.

- Results of the tanks and heat exchangers evaluation.

- 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 including a description of how the seismic demand input motion to each item of equipment was determined.
- Resumes of the Seismic Capability Engineers.
- Results of the Screening Verification and Walkdown for mechanical and electrical equipment.
- Identification of instances in which the intent of caveat is met without meeting the specific wording of the caveat rule.
- Results of the tanks and heat exchangers review.
- Description of the equipment outliers.
- List of the unresolved outliers (i.e., those not meeting the GIP screening guidelines) and an explanation of the safety implications of not resolving these outliers.
- Proposed schedule for complete resolution, future modifications and replacements of those outliers which will be resolved.

After submitting this information to the NRC, FPC will 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 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

REFERENCES

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9. EPRI Report NP-7151, "Cable Tray and Conduit System Seismic Evaluation Guidelines," Electric Powe. Research Institute, Palo Alto, CA, prepared by EQE Engineering Consultants, March 1991.

10. EPRI Report NP-7150, "The Performance of Raceway Systems in Strong Motion Earthquakes," Electric Power Research Institute, Palo Alto, CA, prepared by EQE Engineering Consultants, March 1991.

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13. (This reference number not used.)

14. S&A Report, "ANCHOR Users' Guide, 3.0, Rev. 0," Stevenson & Associates, Boston, Massachusetts, August 16, 1990.

15. (This reference number not used.)

16. MPR Report, "Results of PWR Trial Plant Review (Trail Plant 1)," MPR Associates, Inc., Washington, D.C., June 1987.

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18. NFPA 70-1984, "Natural Electrical Code," National Fire Protection Association, Boston, MA, 1984.

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20. EPRI Report NP-7152, "Seismic Evaluation of Rod Hanger Supports for Electrical Raceway Systems," Electric Power Research Institute, Palo Alto, CA, prepared by EQE Engineering Consultants, March 1991.

21. NUREG/CR-1489, UCRL-52746, "Best Estimate Method vs. Evaluation Method: A Comparison of Two Techniques in Evaluating Seismic Analysis and Design," Lawrence Livermore National Laboratory, Livermore, California, May 1980.

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Washington, D.C., May 22, 1992.

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36. Generic Implementation Procedure (GIP) "For Seismic Verification of Nuclear Plant Equipment", Revision 2A, Dated March 1993.

37. "Technical Basis for the Crystal River Unit 3 Plant Specific Procedure to Resolve NRC Generic Letter 87-02", Prepared by Paul Smith and Harry Johnson, Revision 0, Dated June 23, 1993.

APPENDIX A

PROCEDURE FOR IDENTIFICATION OF SAFE SHUTDOWN EQUIPMENT

CONTENTS - APPENDIX A

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 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

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

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.

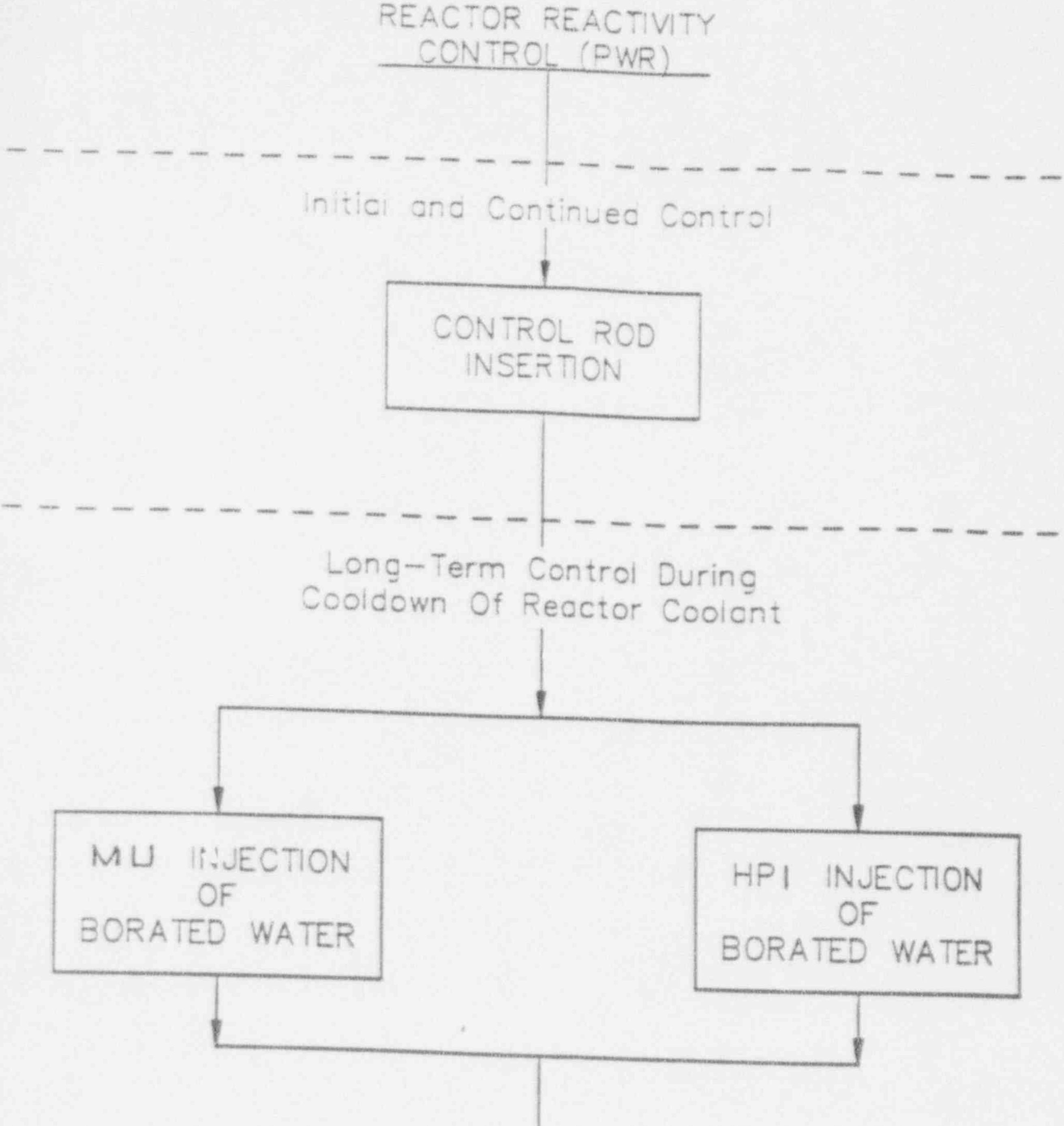

Figure A-1. Safe Shutdown Alternatives for Reactor Reactivity Control of PWRs.

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 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:

- Make-up and Purification System, or
- High Pressure Injection (HPI) system.

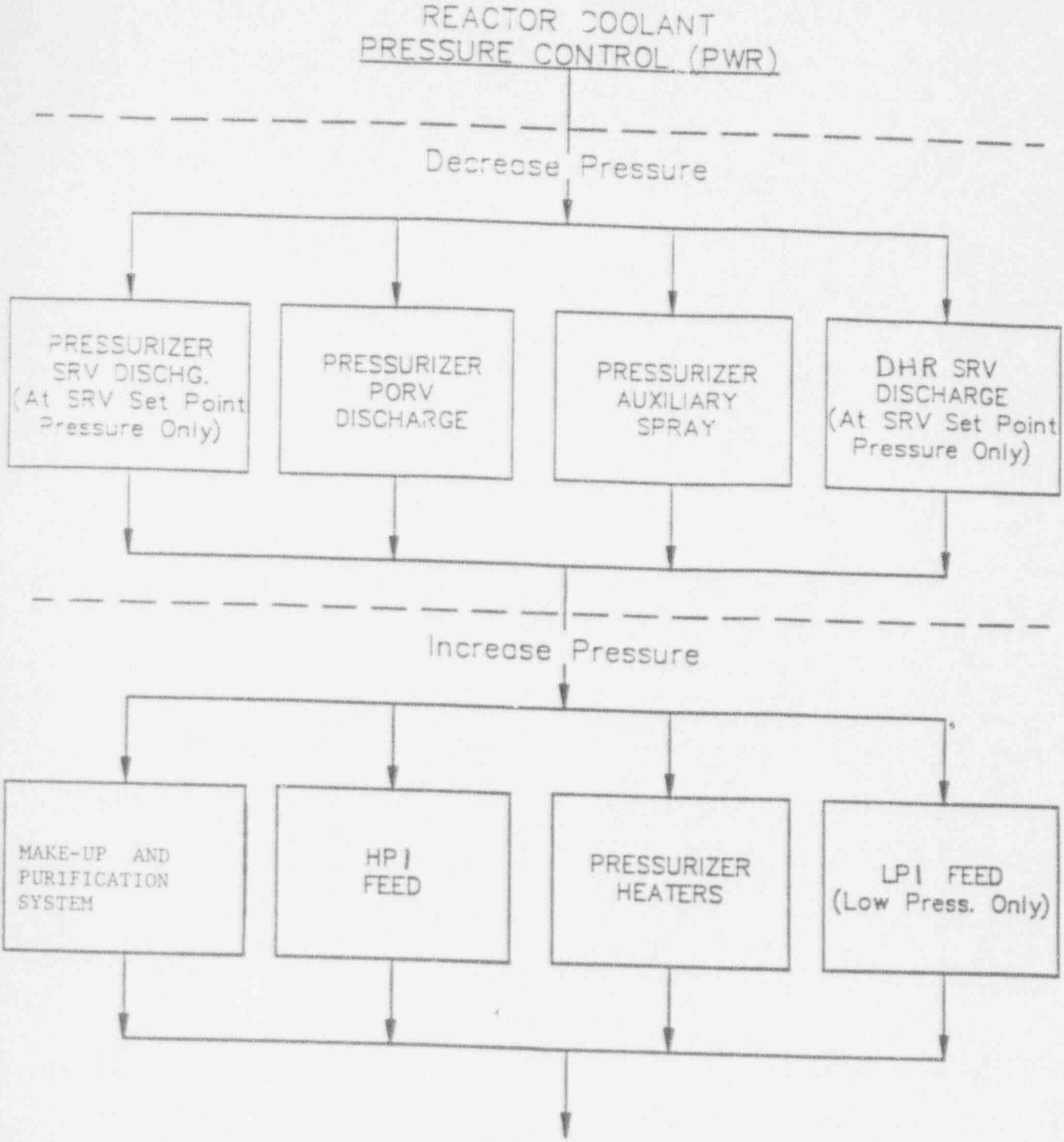

Figure A-2. Safe Shutdown Alternatives for Reactor Coolant Pressure Control of PWRs.

A.2.2 Reactor Coolant Pressure Control

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 psig) 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 valve (PORV) 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 auxiliary spray system. (Normal spray is not available since the reactor coolant pumps are not running due to the assumed loss of offsite power.)

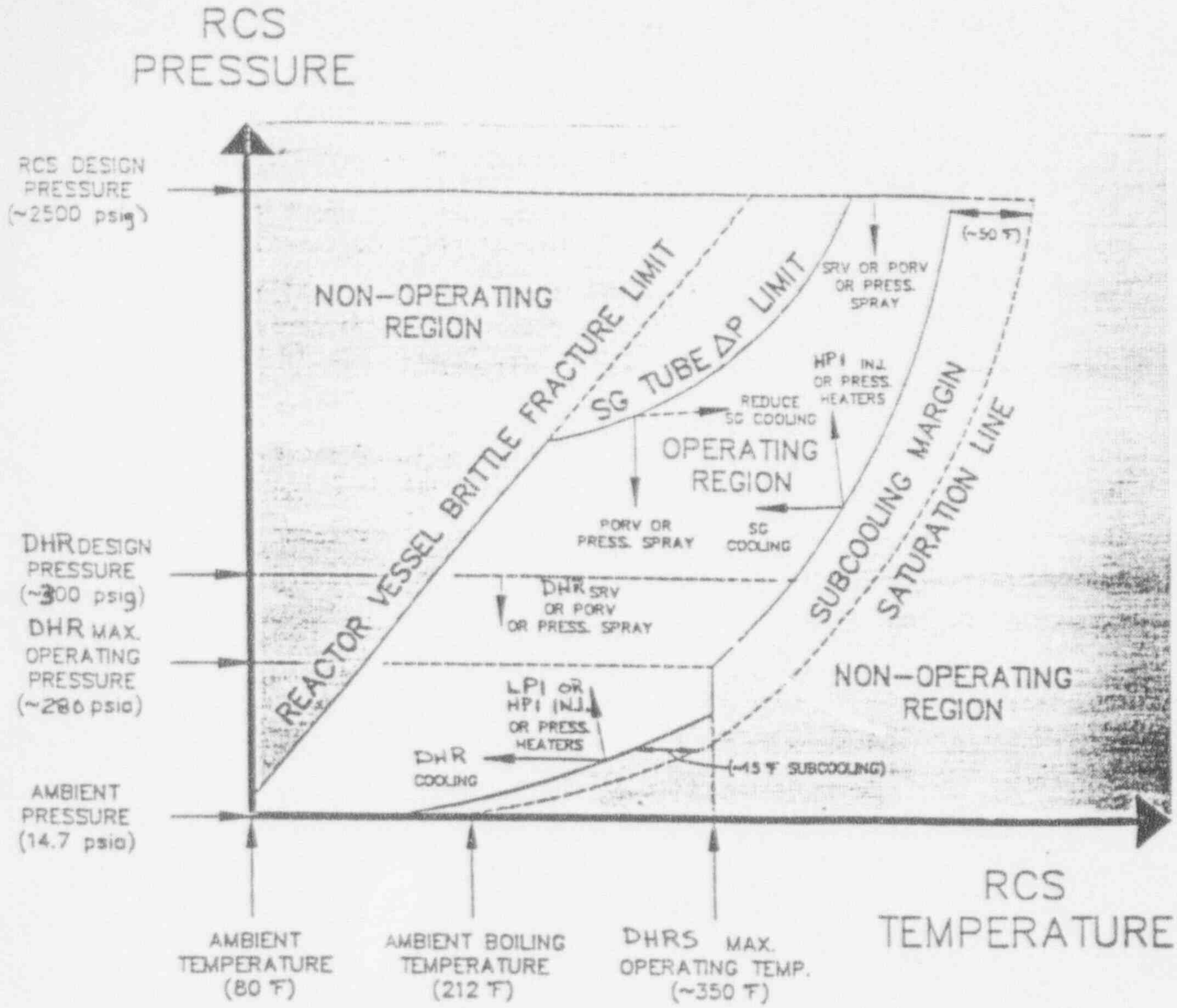

Figure A-3. Pressure-Temperature Limits For Typical PWR Reactor Coolant System Without Reactor Coolant Pumps Operating.

The subcooling margin 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 suction side of the decay heat removal (DH) system (about 280 psig), the make-up and purification system (MU) or the high pressure injection (HPI) 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 injection (LPI) 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 280 psig, natural circulation decay heat removal via the steam generators (SGs) can be used. For pressures lower than this, the decay heat removal (DH) system 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 decay heat removal (DH) system design pressure (about 300 psig) should not be exceeded after the decay 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 DH system also can be used when the DH system is connected to the reactor coolant system. Note that it is not necessary to use the DH system unless the plant elects to go to cold shutdown.

A.2.3 Reactor Coolant Inventory Control

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. Typically, there are three safe shutdown alternatives available for feeding the reactor coolant system:

- Make-up and Purification System (MU),
- High Pressure Injection (HPI) system, or
- Low Pressure Injection (LPI) system (at low pressure only).

The MU and HPI systems can be used to control the reactor coolant inventory at both high and low system pressure. The LPI system can only inject reactor coolant into the system at pressures below about 280 psig.

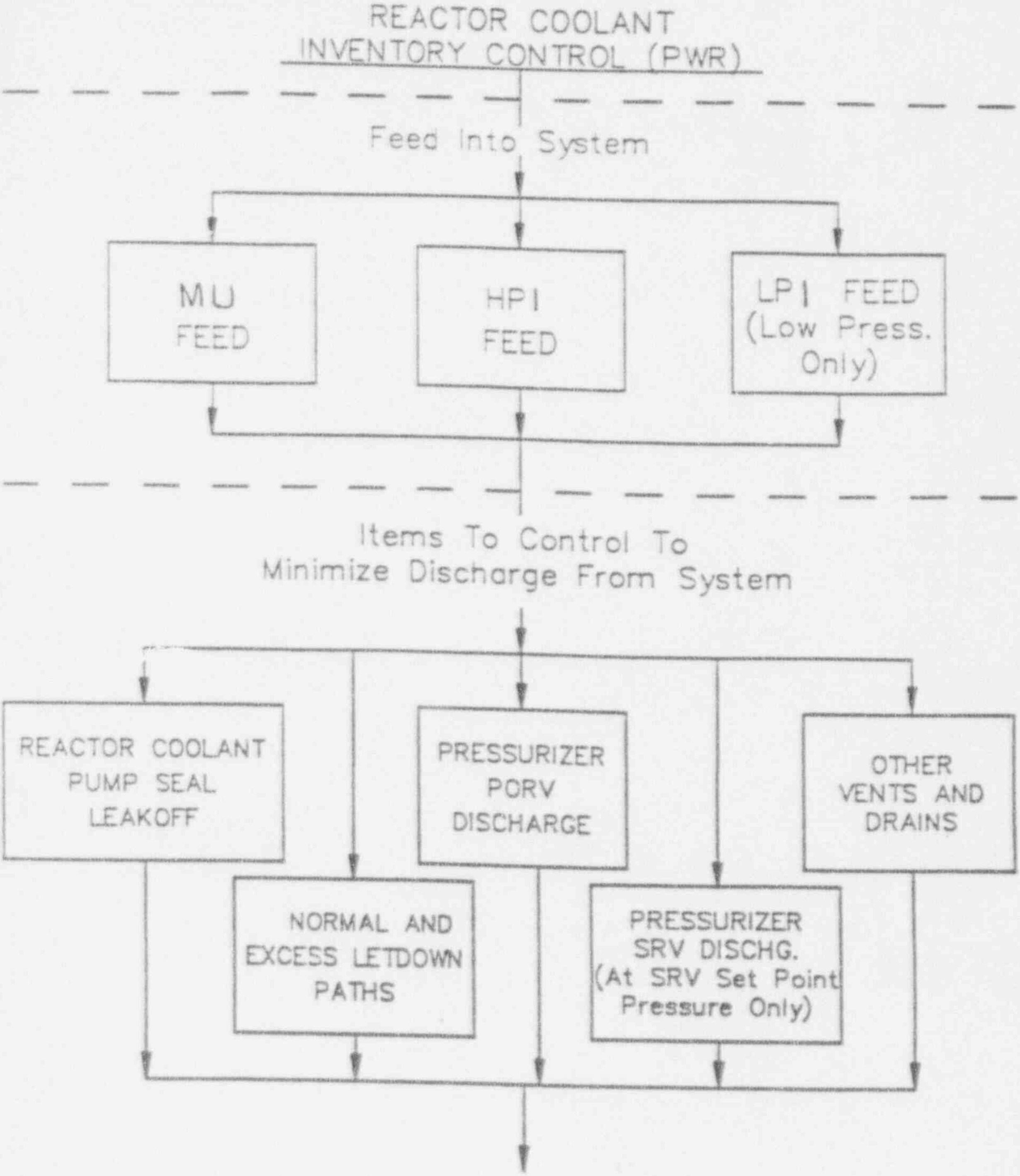

Figure A-4. Safe Shutdown Alternatives for Reactor Coolant Inventory Control of PWRs.

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

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 decay heat removal system can also be used.

---

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.

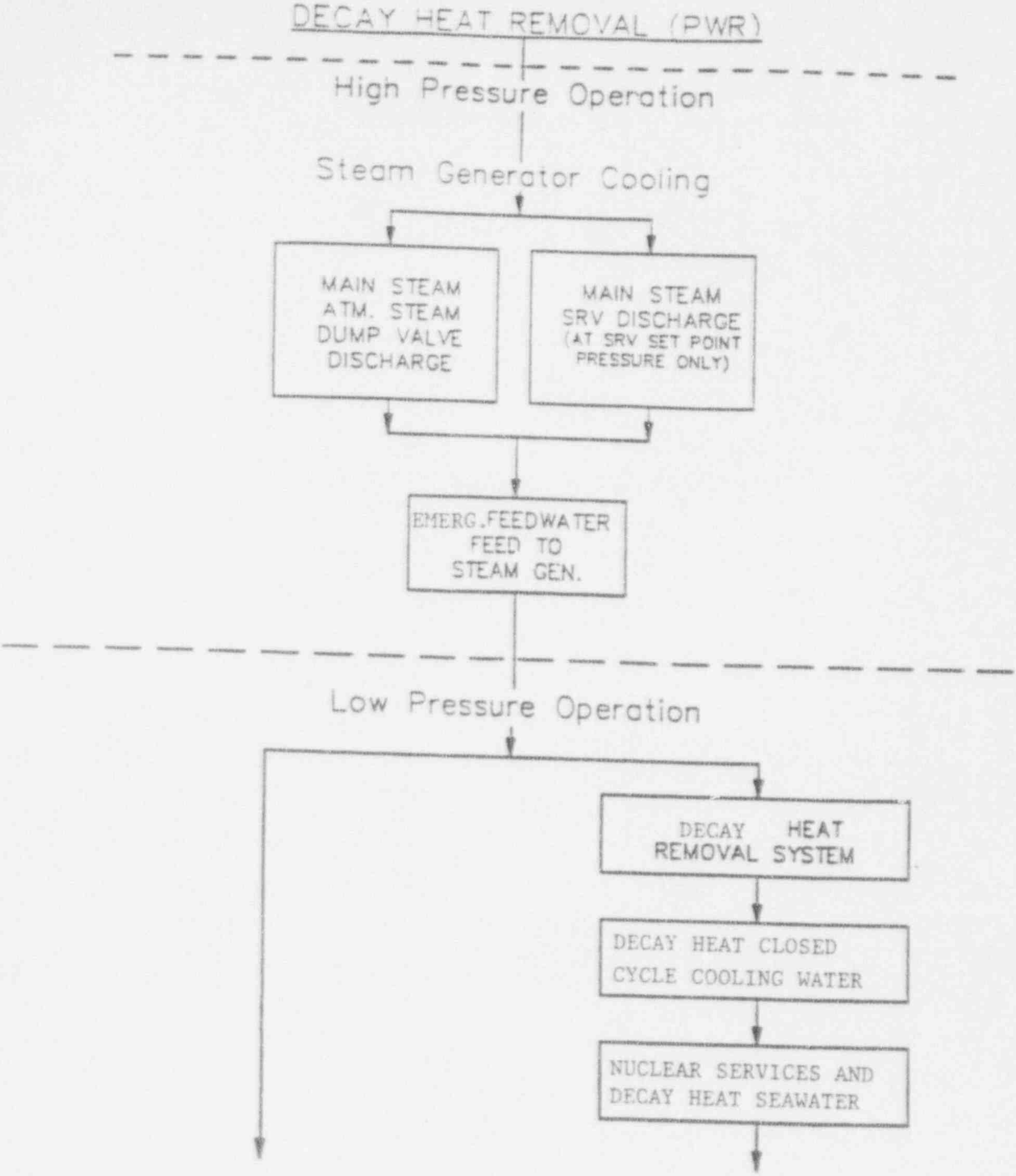

Figure A-5. Safe Shutdown Alternatives for Decay Heat Removal of PWRs.

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 (MSSVs) 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 feedwater (EF) system. The dedicated emergency feedwater tank is the preferred source of emergency feedwater, with the condensate storage tank 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.

If it is preferred (or required due to certain plant limitations) to bring the plant to a cold shutdown condition, the decay heat removal (DH) system can be used to remove decay heat from the core after the reactor coolant system pressure and temperature are typically below about 280 psig and 280°F. This system 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 DH heat exchangers to the decay heat closed cycle cooling water
system which has its own set of pumps for circulating water. Heat is transferred from the DC system to the nuclear services and decay heat seawater (RW) system in another heat exchanger and from there to the ultimate heat sink (Gulf of Mexico).

A.3 Not Applicable

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 from the SSELs generated above. This major task is shown in Step 17 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 (flow diagrams, electrical one-line diagrams, etc.), (3) safe shutdown equipment lists (SSELs) for each safe shutdown function and any other SSELs for support systems, and (4) an SSEL for seismic 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 on 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 poweroperated 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 c'.. llenge 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 alternatives 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: <u>Decay Heat Removal</u>

  -- Description of alternative for accomplishing the safe shutdown function, for example:

ALTERNATIVE: SG Cooling/EFW 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 (Flow diagrams, electrical system one-line 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.

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 include the isolation valves in the main and branch lines which form the boundary of the system. The configuration of the system used during normal operation of the plant should be used when marking the diagram and identifying the boundary. It is optional whether passive items of equipment are listed on the SSEL.

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 diagram (e.g., flow diagram, electrical system one-line 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
6	Schematic Drawing Number and Zone. The schematic drawing number and zone is optional. It can be used to help retrace the steps used in identifying the safe shutdown equipment.
10	Type of Evaluation Needed
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 (flow diagrams); 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)
ON	(Equipment is on and normally operating)
OFF	(Equipment is off and normally not operating)
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 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. 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. 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. 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. 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 the table at each location where there is an asterisk (*) or a pound symbiol (#) to determine what answer should be placed in Column (14) of the SSEL:

(*) = (the desired operating state to achieve safe shutdown function.)

(#) = (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)

**Or does power need to be interrupted? If the answer is "YES", then include the supporting equipment on the SSEL.

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)

<u>Step 11 - Identify Instruments for Function</u>

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) should be identified as an essential instrument. Note that other process variables and instruments, needed to <u>control</u> 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
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
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

pporting systems since they support several safe shutdown functions. For example, the mergency diesel generators could be needed for both the decay heat removal function and the nventory 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.

tep 16 - Are All Four Functions Evaluated?

is step asks whether all four of the safe shutdown functions have been evaluated for safe tdown equipment. If they have not all been evaluated, then go back to Step 1 and select ther safe shutdown function to evaluate. A new SSEL should be generated for this new tion.

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 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)
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.

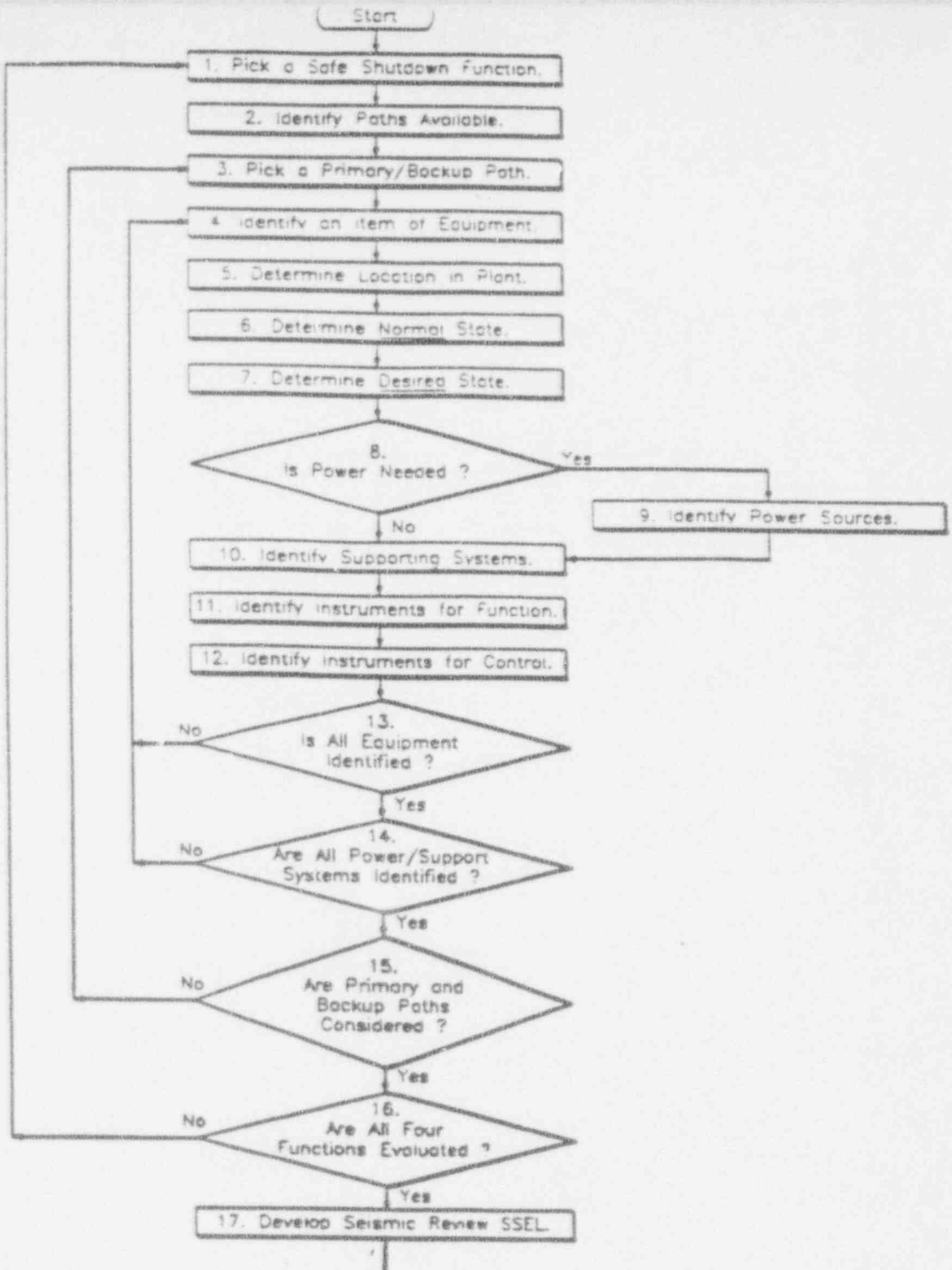

Figure A-10. Steps for Identifying Safe Shutdown Equipment.

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)

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

Not Used

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 / 09:24:46
Index File Name/Date/Time: WD_UNID4.NDX / 05-23-90 / 09:27:50
Index File Contents: COMPID
Program File Name & Version: Nmp1prt v1.0

APPENDIX B

SUMMARY OF EQUIPMENT CLASS DESCRIPTIONS AND CAVEATS

CONTENTS - APPENDIX B

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 determined to be seismically rugged based on earthquake experience data and generic seismic testing data. The "equipment class descriptions" summarize the general parameters of this equipment. The "caveats" identify the important characteristics and features which an item of equipment should have in order to verify its seismic adequacy.

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 data or generic seismic testing data summarized in this appendix, 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.

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.

B.1 MOTOR CONTROL CENTERS

The seismic capacity for the equipment class of motor control centers (MCCs) may be based on earthquake experience data (as described in Section 4.2), provided the intent of each of the caveats listed below is met. This equipment class 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 typically 20 to 24 inches wide, and 90 inches tall. The depth of each section typically varies from about 18 to 24 inches. Typical weight of each section is less than about 650 pounds.

MCC cabinets can weigh up to about 800 pounds per section for assemblies consisting of at leat two adjacent cabinet sections which are bolted together. Narrower depth MCC cabinets should be top braced or attached to the wall.

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 equipment class 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, and include attachments such as junction boxes, conduit and cables. 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. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

MCC/BS Caveat 1 - Earthquake Experience Equipment Class. The MCC should be similar to and bounded by the MCC class of equipment described above. The equipment class descriptions are general and the Seismic Capability Engineers should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

MCC/BS Caveat 2 - Rating of 600 V or Less. The MCC should have a 600 V rating or less. This is the upper limit voltage rating of MCCs in the earthquake experience equipment class.

MCC/BS Caveat 3 - Adjacent Cabinets Bolted Together. 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 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 impact-sensitive relays to chatter.

MCC/BS Caveat 4 - 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 5 - 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 equipment class (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 6 - Adequate Anchorage. The unit should be properly anchored in accordance with the guidelines of Section 4.4.

MCC/BS Caveat 7 - Any Other Concerns? The Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the MCC as described in Section 4.3.

regard to the gage of the steel, internal structure and support. This caveat is intended to preclude unusual designs not covered by the equipment class (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 6 - Adequate Anchorage. The unit should be properly anchored in accordance with the guidelines of Section 4.4.

MCC/BS Caveat 7 - Any Other Concerns? The Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the MCC as described in Section 4.3.

B.2 LOW VOLTAGE SWITCHGEAR

The seismic capacity for the equipment class of low voltage switchgear (LVS) assemblies may be based on earthquake experience data (as described in Section 4.2), provided the intent of each of the caveats listed below is met. This equipment class 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 and 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. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

LVS/BS Caveat 1 - Earthquake Experience Equipment Class. The low voltage switchgear should be similar to and bounded by the LVS class of equipment described above. The equipment class descriptions are general and the Seismic Capability Engineers should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

LVS/BS Caveat 2 - Rating of 600 V or Less. 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 equipment class.

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 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 relays to chatter.

LVS/BS Caveat 4 - 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 5 - 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 equipment class (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 6 - Adequate Anchorage. The unit should be properly anchored in accordance with the guidelines of Section 4.4.

LVS/BS Caveat 7 - Any Other Concerns? Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the switchgear as described in Section 4.3.

B.3 MEDIUM VOLTAGE SWITCHGEAR

The seismic capacity for the equipment class of medium voltage switchgear (MVS) assemblies may be based on earthquake experience data (as described in Section 4.2), provided the intent of each of the caveats listed below is met. this equipment class 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.

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. Lateral restraint of the circuit breaker should be provided by the cabinet framing and not solely by the jack lifts.

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. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

MVS/BS Caveat 1 - Earthquake Experience Equipment Class. The switchgear should be similar to and bounded by the MVS class of equipment described above. The equipment class descriptions are general and the Seismic Capability Engineers should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

MVS/BS Caveat 2 - Rating between 2.4 KV and 4.16 KV. The switchgear should have a rating between 2.4 KV and 4.16 KV. This is the typical voltage range of MVS of this earthquake experience equipment class.

MVS/BS Caveat 3 - Transformers Restrained from Relative Motion. Potential transformers and/or control power transformers mounted on the switchgear should have restraints that limit relative motion of the transformers to prevent damage or disconnection of contacts. In particular, trunnion mounted transformers should have positive vertical restraint to keep the trunnion pin in its cradle. Positive vertical restraint of the trunnion pin is not required if the seismic demand at the base of the switchgear cabinet is less than or equal to about 1/2 of 1.5 x Bounding Spectrum, i.e., less than 0.75 x Bounding Spectrum.

MVS/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 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 relays to chatter.

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 equipment class (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 - Adequate Anchorage. The unit should be properly anchored in accordance with the guidelines of Section 4.4.

MVS/BS Caveat 8 - Any Other Concerns? Seismic Capability Engine [illegible] seek out suspicious details or uncommon situations not specifically covered by the [illegible] which could adversely affect the seismic capacity of the switchgear as described in Section 4.3.

B.4 TRANSFORMERS

The seismic capacity for the equipment class of transformers (TRN) may be based on earthquake experience data (as described in Sction 4.2), provided the intent of each of the caveats listed below is met. This equipment class 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 equipment class. Small transformers that are components of electrical equipment, such as motor control centers or control panels, are also not included in this equipment 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. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

<u>TRN/BS Caveat 1 - Earthquake Experience Equipment Class.</u> The transformer should be similar to and bounded by the TRN class of equipment described above. The equipment class descriptions are general and the Seismic Capability Engineers should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

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 earthquake experience equipment class.

TRN/BS Caveat 3 - Transformer Coils Positively Restrained Within Cabinet. For floor-mounted dry and oil-type units, the transformer coils should be positively 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 - Coils Top Braced or Analyzed for Large Transformers. Large transformers of 750 kVA or larger should also have the top of the coils braced by a structural frame or should be analyzed for adequate restraint. If the unit is factory-sealed or constructed so that removing shipping anchors is precluded, no internal inspection is necessary.

TRN/BS Caveat 5 - Clearance Between Energized Component and Cabinet. For 750 kVA transformers and larger, there should be at least a 2-inch gap between the energized component and the upper portion of the transformer cabinet. If the gap is less than 2 inches, it should be verified by analysis that there is sufficient gap and/or there should be provisions for relative lateral displacement to preclude contact between the energized component and the cabinet. The concern is that without adequate clearance, transformers could be shorted out during the earthquake and thereby rendered inoperable.

TRN/BS Caveat 6 - Adequate Slack in High Voltage Leads. For 750 kVA transformers and larger, the connection between the high voltage leads and the first anchor point should accomodate at least a 3-inch relative displacement, or should be analyzed for adequate slack for relative displacement.

TRN/BS Caveat 7 - 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 8 - 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 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 relays to chatter.

TRN/BS Caveat 9 - Adequate Anchorage. The unit should be properly anchored in accordance with the guidelines of Section 4.4.

TRN/BS Caveat 10 - Any Other Concerns? Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the transformer as described in Section 4.3.

B.5 HORIZONTAL PUMPS

The seismic capacity for the equipment class of Horizontal Pumps (HP) may be based on earthquake experience data (as described in Section 4.2), provided the intent of each of the caveats listed below is met. This equipment class 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 support on the building or nearby structure 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. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

HP/BS Caveat 1 - Earthquake Experience Equipment Class. The horizontal pump should be similar to and bounded by the HP class of equipment described above. The equipment class descriptions are general and the Seismic Capability Engineers should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

HP/BS Caveat 2 - Driver and Pump on Rigid Skid. 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.

HP/BS Caveat 3 - Thrust Bearings in Both Axial Directions. 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.

HP/BS Caveat 4 - 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.

HP/BS Caveat 5 - 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).

HP/BS Caveat 6 - Adequate Anchorage. The unit should be properly anchored in accordance with the guidelines of Section 4.4.

HP/BS Caveat 7 - Any Other Concerns? Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the pump as described in Section 4.3.

B.6 VERTICAL PUMPS

The seismic capacity for the equipment class of Vertical Pumps (VP) may be based on earthquake experience data (as described in Section 4.2), provided the intent of each of the caveats listed below is met. This equipment class 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 in the earthquake experience equipment class are 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 up to their first support on the building or nearby structure 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. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

VP/BS Caveat 1 - Earthquake Experience Equipment Class. The vertical pump should be similar to and bounded by the VP class of equipment described above. The equipment class descriptions are general and the Seismic Capability Engineers should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

VP/BS Caveat 2 - Cantilever Impeller Shaft Less Than 20 Feet Long. 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 equipment class. 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 - 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 4 - Adequate Anchorage. The unit should be properly anchored in accordance with the requirements of Section 4.4.

VP/BS Caveat 5 - Any Other Concerns? Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the pump as described in Section 4.3.

B.7 FLUID-OPERATED VALVES

The seismic capacity for the equipment class of Fluid-Operated Valves (FOV) may be based on earthquake experience data (as described in Section 4.2), provided the intent of each of the caveats listed below is met. This equipment class 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 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, the inlet and outlet lines up to their first support on the building or nearby structure, 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. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

FOV/BS Caveat 1 - Earthquake Experience Equipment Class. The valve should be similar to and bounded by the FOV class of equipment described above. The equipment class descriptions are general and the Seismic Capability Engineers should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

FOV/BS Caveat 2 - 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 3 - Any Other Concerns? Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the valve as described in Section 4.3.

B.8A MOTOR-OPERATED VALVES

The seismic capacity for the equipment class of Motor-Operated Valves (MOV) may be based on earthquake experience data (as described in Section 4.2), provided the intent of each of the caveats listed below is met. This equipment class includes a wide diversity of sizes, types, and applications.

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. Valve operators may have a local motor controller built into the operator housing. The valve 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.

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 valves includes all valves actuated by an electric motor. The valve, the operator, and the inlet and outlet lines and attached conduit up to their first support on the building or nearby structure are included in the Motor-Operated Valve equipment class.

The Bounding Spectrum (BS) represents the seismic capacity of a Motor-Operated Valve (MOV) if the valve meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not net, then a reason for concluding that the intent has been met should be provided on the SEWS.

MOV/BS Caveat 1 - Earthquake Experience Equipment Class. The valve should be similar to and bounded by the MOV class of equipment described above. The equipment class descriptions are general and the Seismic Capability Engineers should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

MOV/BS Caveat 2 - 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).

MOV/BS Caveat 3 - Any Other Concerns? Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the valve as described in Section 4.3.

B.8B SOLENOID-OPERATED VALVES

The seismic capacity for the equipment class of Solenoid-Operated Valves (SOV) may be based on earthquake experience data (as described in Section 4.2), provided the intent of each of the caveats listed below is met. This equipment class includes a wide diversity of sizes, types, and applications.

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 valves. 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 solenoid-operated valves includes all valves actuated by a solenoid. The valve, the operator, and the inlet and outlet lines and attached conduit up to their first support on the building or nearby structure are included in the Solenoid-Operated Valve equipment class.

The Bounding Spectrum (BS) represents the seismic capacity of a Solenoid-Operated Valve (SOV) if the valve meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rules is not met then a reason for concluding that the intent has been met should be provided on the SEWS.

SOV/BS Caveat 1 - Earthquake Experience Equipment Class. The valve should be similar to and bounded by the SOV class of equipment described above. The equipment class descriptions are general and the Seismic Capability Engineers should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

SOV/BS Caveat 2 - 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).

SOV/BS Caveat 3 - Any Other Concerns? Seismic Capacity Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the valve as described in Section 4.3.

B.9 FANS

The seismic capacity for the equipment call of Fans (FAN) may be based on earthquake experience data (as described in Section 4.2), provided the intent of each of the caveats listed below is met. This equipment class 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. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

FAN/BS Caveat 1 - Earthquake Experience Equipment Class. The fan should be similar to and bounded by the FAN class of equipment described above. The equipment class descriptions are general and the Seismic Capability Engineers should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

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 - Base Vibration Isolation System Checked. If unit is mounted on vibration isolators, the adequacy of the vibration isolators for seismic loads should be evaluated in accordance with Section 4.4.

FAN/BS Caveat 5 - 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).

FAN/BS Caveat 6 - Adequate Anchorage. The unit should be properly anchored in accordance with the guidelines of Section 4.4.

FAN/BS Caveat 7 - Any Other Concerns? Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the fan as described in Section 4.3.

B.10 AIR HANDLERS

The seismic capacity for the equipment class of Air Handlers (AH) may be based on earthquake experience data (as described in Section 4.2), provided the intent of each of the caveats listed below is met. This equipment class 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 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. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

<u>AH/BS Caveat 1 - Earthquake Experience Equipment Class.</u> The air handler should be similar to and bounded by the AH class of equipment described above. The equipment class descriptions are general and the Seismic Capability Engineers should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

<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 4.4.

<u>AH/BS Caveat 3 - 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 4 - 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 5 - Adequate Anchorage.</u> The unit should be properly anchored in accordance with the guidelines of Section 4.4.

<u>AH/BS Caveat 6 - Any Other Concerns?</u> Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the air handler as described in Section 4.3

B.11 CHILLERS

The seismic capacity for the equipment class of chillers (CHL) may be baded on earthquak experience data (as described in Section 4.2), provided the intent of each of the caveats listed below is met. This equipment class 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 which are attached to the same skid 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. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

<u>CHL/BS Caveat 1 - Earthquake Experience Equipment Class.</u> The chiller should be similar to and bounded by the CHL class of equipment described above. The equipment class descriptions are general and the Seismic Capability Engineers should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

<u>CHL/BS Caveat 2 - 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 3 - Adequate Anchorage.</u> The unit should be properly anchored in accordance with the guidelines of Section 4.4.

<u>CHL/BS Caveat 4 - Any Other Concerns?</u> Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the chiller as described in Section 4.3.

B.12 AIR COMPRESSORS

The seismic capacity for the equipment class of Air compressor (AC) may be based on earthquake experience data (as described in Section 4.2), provided the intent of each of the caveats listed below is met. This equipment class 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. Drive motor sizes typically range from fractional horsepower to over 100 horsepower. 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. Smaller reciprocating piston compressors are commonly mounted atop an air receiver tank.

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. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

AC/BS Caveat 1 - Earthquake Experience Equipment Class. The air compressor should be similar to and bounded by the AC class of equipment described above. The equipment class descriptions are general and the Seismic Capability Engineers should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

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 6 - Any Other Concerns? Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the compressor as described in Section 4.3.

B.13 MOTOR-GENERATORS

The seismic capacity for the equipment class of Motor-Generators (MG) may be based on earthquake experience data (as described in Section 4.2), provided the intent of each of the caveats listed below is met. This equipment class 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. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

MG/BS Caveat 1 - Earthquake Experience Equipment Class. The motor-generator should be similar to and bounded by the MG class of equipment described above. The equipment class descriptions are general and the Seismic Capability Engineers should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

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 - Any Other Concerns? Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the motor-generator as described in Section 4.3.

B.14 DISTRIBUTION PANELS

The seismic capacity for the equipment class of Distribution Panels (DP) may be based on earthquake experience data (as described in Section 4.2), provided the intent of each of the caveats listed below is met. This equipment class consists of circuit breakers or fusible disconnect 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 typical 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. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

<u>DP/BS Caveat 1 - Earthquake Experience Equipment Class.</u> The distribution panel should be similar to and bounded by the DP class of equipment described above. The equipment class descriptions are general and the Seismic Capability Engineers should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class.

These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

<u>DP/BS Caveat 2 - 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 relays. The concern addressed in this caveat is that unbolted cabinets could respond out of phase to one antoher 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 componets.

<u>DP/BS Caveat 3 - General Configuration Similar to NEMA Standards.</u> 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 equipment class (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.

<u>DP/BS Caveat 4 - Adequate Anchorage.</u> The unit should be properly anchored in accordance with the guidelines of Section 4.4.

<u>DP/BS Caveat 5 - Any Other Concerns?</u> Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the panel as described in Section 4.3.

B.15 BATTERIES ON RACKS

The seismic capacity for the equipment class of Batteries on Racks (BAT) may be based on earthquake experience data (as described in Section 4.2), provided the intent of each of the caveats listed below is met. This equipment class 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 no examples of antimony flat plate and tubular batteries in experience data, 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. 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. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

<u>BAT/BS Caveat 1 - Earthquake Experience Equipment Class.</u> The batteries and racks should be similar to and bounded by the BAT class of equipment described above. The equipment class descriptions are general and the Seismic Capability Engineers should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class.

These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

BAT/BS Caveat 2 - Plates of the Battery Cells Are Lead-Calcium Flat-Plate or They Are of Planté or Manchex Design. 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 equipment class.

BAT/BS Caveat 3 - Each Individual Battery Weighs Less Than 450 Pounds. 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 equipment class.

BAT/BS Caveat 4 - Close-Fitting, Crush-Resistant Spacers Between Cells. 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.

BAT/BS Caveat 5 - Batteries Restrained by Side and End Rails. 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.

BAT/BS Caveat 6 - Battery Racks Have Longitudinal Cross Bracing. 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 are recommended 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.

BAT/BS Caveat 7 - Racks Constructed of Wood To Be Evaluated. 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.

BAT/BS Caveat 8 - Batteries Greater Than 10 Years Old To Be Evaluated. Batteries that are more than 10 years old should be identified as outliers. 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.

BAT/BS Caveat 9 - Adequate Anchorage. The unit should be properly anchored in accordance with the guidelines of Section 4.4.

BAT/BS Caveat 10 - Any Other Concerns? Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the batteries on racks as described in Section 4.3.

B.16 BATTERY CHARGERS AND INVERTERS

The seismic capacity for the equipment class of Battery Chargers and Inverters (BCI) may be based on earthquake experience data (as described in Section 4.2), provided the intent of each of the caveats listed below is met. Chargers and Inverters are grouped into a single equipment class since 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 battery chargers are based on solid-state rectifiers consisting of semiconductors. This equipment class is limited to solid-state battery chargers and inverters.

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 and Underwriters Laboratories. 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. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

<u>BCI/BS Caveat 1 - Earthquake Experience Equipment Class.</u> The battery charger or inverter should be similar to and bounded by the BCI class of equipment described above. The

equipment class descriptions are general and the Seismic Capability Engineers should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

<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 equipment class. 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 - 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 5 - Adequate Anchorage.</u> The unit should be properly anchored in accordance with the guidelines of Section 4.4.

<u>BCI/BS Caveat 6 - Any Other Concerns?</u> Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the battery charger or inverter as described in Section 4.3.

B.17 ENGINE-GENERATORS

The seismic capacity for the equipment class of Engine-Generators (EG) may be based on earthquake experience data (as described in Section 4.2), provided the intent of each of the caveats listed below is met. This equipment class includes a wide range of sizes and types of generators driven by piston engines. Turbine driven generators are not incuded in this equipment class. 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. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

EG/BS Caveat 1 - Earthquake Experience Equipment Class. The engine-generator should be similar to and bounded by the EG class of equipment described above. The equipment class descriptions are general and the Seismic Capability Engineers should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

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 - Any Other Concerns? Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the generator as described in Section 4.3.

B.18 INSTRUMENTS ON RACKS

The seismic capacity for the equipment class of Instruments on Racks (IR) may be based on earthquake experience data (as described in Section 4.2), provided the intent of each of the caveats listed below is met. This equipment class 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. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

<u>IR/BS Caveat 1 - Earthquake Experience Equipment Class.</u> The instruments and racks should be similar to and bounded by the IR class of equipment described above. The equipment class

descriptions are general and the Seismic Capability Engineers should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

IR/BS Caveat 2 - Structure Adequate. 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.

IR/BS Caveat 3 - Adjacent Racks Bolted Together. 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 as defined in Section 6. 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 relays to chatter.

IR/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).

IR/BS Caveat 5- Adequate Anchorage. The unit should be properly anchored in accordance with the guidelines of Section 4.4.

IR/BS Caveat 6 - Any Other Concerns? Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the instrument rack as described in Section 4.3.

B.19 TEMPERATURE SENSORS

The seismic capacity for the equipment class of Temperature Sensors (TS) may be based on earthquake experience data (as described in Section 4.2), provided the intent of each of the caveats listed below is met. This equipment class 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. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

TS/BS Caveat 1 - Earthquake Experience Equipment Class. The temperature sensor should be similar to and bounded by the TS class of equipment described above. The equipment class descriptions are general and the Seismic Capability Engineers should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

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 equipment class only includes 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 - Any Other Concerns? Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the temperature sensor as described in Section 4.3.

B.20 INSTRUMENTATION AND CONTROL PANELS AND CABINETS

The seismic capacity for the equipment class of Instrumentation and Control Panels and Cabinets (I&C) may be based on earthquake experience data (as described in Section 4.2), provided the intent of each of the caveats listed below is met. This equipment class 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. These enclosures are generally categorized as either switchboards or benchboards as described below.

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 benchboard consists of a control desk with an attached vertical panel. A control desk has components mounted on the desk top, and interior access through swinging doors in the rear. 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, relays (provided they meet relay requirements), controllers, solid-state circuit 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. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

<u>I&C/BS Caveat 1 - Earthquake Experience Equipment Class.</u> The panel or cabinet should be similar to and bounded by the I&C class of equipment described above. The equipment class descriptions are general and the Seismic Capability Engineers should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

<u>I&C/BS Caveat 2 - Structural Adequacy.</u> 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.

<u>I&C/BS Caveat 3 - Adjacent Cabinets or Panels Bolted Together.</u> 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 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 relays to chatter.

<u>I&C/BS Caveat 4 - 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 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>I&C/BS Caveat 6 - Adequate Anchorage.</u> The unit should be properly anchored in accordance with the guidelines of Section 4.4.

<u>I&C/BS Caveat 7 - Any Other Concerns?</u> Seismic Capability Engineers should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the cabinet or panel as described in Section 4.3.

APPENDIX C

ANCHORAGE DATA

Appendix C

ANCHORAGE DATA

The Seismic Engineers are to use judgement to verify the adequacy of equipment anchorage.

For guidance and anchorage data refer to Section 4.4 and Appendix C of the GIP (Reference 36).

APPENDIX D

SEISMIC INTERACTION

CONTENTS - APPENDIX D

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. Impact on an electrical cabinet which has a relay(s) 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 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-seismically supported 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:

- Cabinets and Lockers. Inadequately restrained floor and wall-mounted filing cabinets and equipment storage lockers may result in overturning or falling and impact.

- Gas Storage Bottles. Unrestrained or inadequately restrained gas bottles may result in overturning and rolling and cause impact.

- Refueling Equipment. 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.

- Monorails, Hoists, and Cranes. 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.

- Radiation Shields, Fire Protection and Miscellaneous Equipment. 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 for flexibility of these lines extends from the item of equipment being evaluated to their first support on the building or nearby structure.

D.5 EVALUATION OF INTERACTION EFFECTS

The Seismic Capability Engineers should ide, y and evaluate all credible and significant interactions in the immediate vicinity of the safe shutdown equipment. This includes consideration of seismic interactions on the equipment itself and on any connected distribution lines (e.g., instrument air lines, electrical cable, and instrumentation cabling) which are in the vicinity of the item of 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 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.

- 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 wa- 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

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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, flow diagrams, electrical one-line drawings, 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. Most of the industrial-grade equipment in the earthquake experience equipment class has been shown to be seismically rugged with seismic capacity at least as great as the earthquake experience Bounding Spectrum even though it has not been qualified for seismic loadings.

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, Exhibit 4-1.

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 FPC 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:

- FPC manager in charge of the USI A-46 project effort
- FPC 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 CR3 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 in-structure 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 in-structure 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

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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 permi 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 seismic review 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.

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

1.0 1.1 1.25 1.4 1.6 1.8 2.0 2.2 2.5 2.8 3.2 3.6 4.0

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

F.4 WALKDOWN LOGISTICS

A kick-off meeting may be scheduled at the beginning of the plant walkdown. This meeting will provide 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 may be done prior to this kick-off meeting. After this kick-off meeting, the SRTs commence with the plant walkdown.

A daily morning meeting may be held in which the SRT will review the equipment included in that day's walkdown. Anchorage drawings will also be made available and reviewed by the SRT. The walkdown will be conducted in morning and afternoon sessions.

At the option of FPC 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 may be 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 may be reconciled as soon as possible after the item of equipment had been inspected. The memory of the SRT for the particular equipment verification may be clearer, and the number of unknown equipment items did not mount up during the course of the walkdown.

When performing the walkdown, the SRT will have 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

CONTENTS - APPENDIX G

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. The equipment class caveats contained in Appendix B are also summarized on the SEWs. These SEWS, or a similar checklist, should be used during the plant walkdown to document the results of the evaluation. The SEWS in this appendix are designed to be compatible with the Screening Verification Data Sheets (SVDS) shown in Exhibit 4-1 of Section 4 so that the summary information from the SEWS can be transferred directly to the SVDS.

This appendix contains SEWS for Equipment Classes #0 through #21. See Section 3.3 for a summary of the equipment included within the scope of USI A-46. 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, the GIP, 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 16) 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 SEWS can be 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, i.e., all the "Y" symbols should be circled if an item of equipment is seismically adequate.)

N - No. This criterion is not met.

U - Unknown. It cannot be determined whether this criterion is met at this time. (This response can be used while the screening verification is in progress to identify criteria which must be evaluated later.)

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 final

question in each section and the last overall question can all be entered directly into the appropriate column in the SVDS (shown in Exhibit 4-1 of Section 4).

The SEWS also provide space to record information about the item of equipment (e.g., manufacturer, model), to document any comments the Seismic Capability Engineers may wish to make, to document the reason why the intent of any caveats are met without meeting the specific wording of the caveat rule, to sketch the equipment, and to sign off.

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. (optional but not recommended) ________________

ANCHORAGE

Is the anchorage adequate? Y N U N/A

INTERACTION EFFECTS

Is equipment free of adverse seismic interaction effects? Y N U N/A

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 2 of 2

Equip. ID No. ________________ Equip. Class 0 - Other

Equipment Description ____

COMMENTS

Evaluated by: ______________________________ Date: __________

______________________________ __________

Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No. ________________ Equip. Class 1 - Motor Control Centers

Equipment Description ____________________

Location: Bldg. ________ Floor El. ______ Room, Row/Col ____________________

Manufacturer, Model, Etc. (optional) ____________________

CAVEATS - BOUNDING SPECTRUM (Identify with an asterisk (*) those caveats which are met by intent without meeting the specific wording of the caveat rule and explain the reason for this conclusion in the COMMENTS section below)

1.	Equipment is included in earthquake experience equipment class	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 relays	Y N U N/A
4.	Externally attached items rigidly anchored	Y N U N/A
5.	General configuration similar to NEMA Standards	Y N U N/A
6.	Anchorage adequate (See checklist below for details)	Y N U N/A
7.	Have you looked for and found no other adverse concerns?	Y N U N/A

Is the intent of all the caveats met for Bounding Spectrum? Y N U N/A

ANCHORAGE

1. Based on Walkdown Inspection and Judgement, is the installation and factors affecting anchorage capacity adequate? Y N U N/A

2. Have you looked for an found no other adverse concerns? Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 2 of 2

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 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.	Overhead equipment or distribution systems are not likely to collapse	Y N U N/A
5.	Have you looked for and found no other adverse 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: ____________

________________________________ ____________

Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No. ________________ Equip. Class 2 - Low Voltage Switchgear

Equipment Description ____

Location: Bldg. ________ Floor El. ______ Room, Row/Col ____________________

Manufacturer, Model, Etc. (optional) ______________________________

CAVEATS - BOUNDING SPECTRUM (Identify with an asterisk (*) those caveats which are met by intent without meeting the specific wording of the caveat rule and explain the reason for this conclusion in the COMMENTS section below)

1.	Equipment is included in earthquake experience equipment class	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 relays	Y N U N/A
4.	Externally attached items rigidly anchored	Y N U N/A
5.	General configuration similar to ANSI C37.20 Standards	Y N U N/A
6.	Anchorage adequate (See checklist below for details)	Y N U N/A
7.	Have you looked for and found no other adverse concerns?	Y N U N/A

Is the intent of all the caveats met for Bounding Spectrum? Y N U N/A

<u>SCREENING EVALUATION WORK SHEET</u> (SEWS) Sheet 2 of 2

Equip. ID No. ________________ Equip. Class <u>2 - Low Voltage Switchgear</u>

Equipment Description ____

<u>ANCHORAGE</u>

1.	Based on walkdown inspection and judgement is the installation and factors affecting anchorage capacity adequate.	Y N U N/A
2.	Have you looked for and found no other adverse concerns.	Y N U N/A
	Are anchorage requirements met?	Y N U

<u>INTERACTION EFFECTS</u>

1.	Soft targets free from impact by nearby equipment or structures	Y N U N/A
2.	If equipment contains 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.	Overhead equipment or distribution systems are not likely to collapse	Y N U N/A
5.	Have you looked for and found no other adverse concerns?	Y N U N/A
	Is equipment free of interaction effects?	Y N U

<u>IS EQUIPMENT SEISMICALLY ADEQUATE</u>? Y N U

<u>COMMENTS</u>

Evaluated by: ________________________________ Date: ____________

________________________________ ____________

Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No. ________________ Equip. Class 3 - Medium Voltage Switchgear

Equipment Description ____________________________________

Location: Bldg. _________ Floor El. ______ Room, Row/Col ____________________

Manufacturer, Model, Etc. (optional) ____________________________

CAVEATS - BOUNDING SPECTRUM (Identify with an asterisk (*) those caveats which are met by intent without meeting the specific wording of the caveat rule and explain the reason for this conclusion in the COMMENTS section below)

1.	Equipment is included in earthquake experience equipment class	Y N U N/A
2.	2.4 KV to 4.16 KV rating	Y N U N/A
3.	Internally mounted potential and/or control power transformers are restrained to prevent damage to or disconnection of contacts	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 relays	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.	Anchorage adequate (see checklist below for details)	Y N U N/A
8.	Have you looked for and found no other adverse concerns?	Y N U N/A
	Is the intent of all the caveats met for Bounding Spectrum?	Y N U N/A

ANCHORAGE

1.	Based on walkdown inspection and judgement, is the installation and factors affecting anchorage capacity adequate?	Y N U N/A
3.	Have you looked for and found no other adverse concerns?	Y N U N/A
	Are anchorage requirements met?	Y N U

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 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. Overhead equipment or distribution systems are not likely to collapse	Y N U N/A
5. Have you looked for and found no other adverse 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: ____________

______________________________ ____________

Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No. ________________ Equip. Class 4 - Transformers

Equipment Description ________________

Location: Bldg. ________ Floor El. ______ Room, Row/Col ________________

Manufacturer, Model, Etc. (optional) ________________

CAVEATS - BOUNDING SPECTRUM (Identify with an asterisk (*) those caveats which are met by intent without meeting the specific wording of the caveat rule and explain the reason for this conclusion in the COMMENTS section below)

1.	Equipment is included in earthquake experience equipment class	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 are positively restrained within cabinet	Y N U N/A
4.	For 750 kVA or larger units, coils are top braced or adequacy shown by evaluation	Y N U N/A
5.	For 750 kVA or larger units, 2-inch clearance is provided between energized component and cabinet	Y N U N/A
6.	For 750 kVA or larger units, the slack in the connection between the high-voltage leads and the first anchor accomodates 3-inch relative displacement	Y N U N/A
7.	For wall-mounted units, transformer coils anchored to enclosure near enclosure support surface	Y N U N/A
8.	Adjacent cabinets which are close enough to impact are bolted together if they contain relays	Y N U N/A
9.	Anchorage adequate (See checklist below for details)	Y N U N/A
10.	Have you looked for and found no other adverse concerns?	Y N U N/A
	Is the intent of all the caveats met for Bounding Spectrum?	Y N U N/A

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 2 of 2

Equip. ID No. ______________ Equip. Class 4 - Transformers

Equipment Description ______________

ANCHORAGE

1. Based on walkdown inspection and judgement, is the installation and factors affecting anchorage capacity adequate?	Y	N	U	N/A
2. Have you looked for and found no other adverse concerns?	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 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. Overhead equipment or distribution systems are not likely to collapse	Y	N	U	N/A
5. Have you looked for and found no other adverse 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: ______________

______________ ______________

Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No. ______________ Equip. Class 5 - Horizontal Pumps

Equipment Description ______________

Location: Bldg. _______ Floor El. _______ Room, Row/Col ______________

Manufacturer, Model, Etc. (optional) ______________

Horsepower/Motor Rating (opt.)____ RPM (opt.)____ Head (opt.)____ Flow Rate (opt.)_____

CAVEATS - BOUNDING SPECTRUM (Identify with an asterisk (*) those caveats which are met by intent without meeting the specific wording of the caveat rule and explain the reason for this conclusion in the COMMENTS section below)

1. Equipment is included in earthquake experience equipment class	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. Base vibration isolators adequate for seismic loads	Y N U N/A
5. Attached lines (cooling, air, electrical) have adequate flexibility	Y N U N/A
6. Anchorage adequate (See checklist below for details)	Y N U N/A
7. Have you looked for and found no other adverse concerns?	Y N U N/A
Is the intent of all the caveats met for Bounding Spectrum?	Y N U N/A

ANCHORAGE

1. Based on walkdown inspection and judgement, is the installation and factors affecting anchorage capacity adequate?	Y N U N/A
2. Have you looked for and found no other adverse concerns?	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 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. Overhead equipment or distribution systems are not likely to collapse	Y N U N/A
5. Have you looked for and found no other adverse concerns?	Y N U N/A
Is equipment free of interaction effects?	Y N U

Equip. ID No. ______________ Equip. Class 5 - Horizontal Pumps

Equipment Description ______________________________

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

COMMENTS

Evaluated by: ______________________________ Date: ______________

______________________________ ______________

Status Y N U

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. (optional) ____________________________

Horsepower/Motor Rating (opt.)____ RPM (opt.)____ Head (opt.)____ Flow Rate (opt.)____

CAVEATS - BOUNDING SPECTRUM (Identify with an asterisk (*) those caveats which are met by intent without meeting the specific wording of the caveat rule and explain the reason for this conclusion in the COMMENTS section below)

1.	Equipment is included in earthquake experience equipment class	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.	Attached lines (cooling, air, electrical) have adequate flexibility	Y	N	J	N/A
4.	Anchorage adequate (See checklist below for details)	Y	N	U	N/A
5.	Have you looked for and found no other adverse concerns?	Y	N	U	N/A
	Is the intent of all the caveats met for Bounding Spectrum?	Y	N	U	N/A

ANCHORAGE

1.	Based on walkdown inspection and judgement, is the installation and factors affecting anchorage capacity adequate?	Y	N	U	N/A
2.	Have you looked for and found no other adverse concerns?	Y	N	U	N/A

SCREENING EVALUATION WORK SHEET (SEWS)   Sheet 2 of 2

Equip. ID No. ________________   Equip. Class 6 - Vertical Pumps

Equipment Description ____

INTERACTION EFFECTS

1. Soft targets free from impact by nearby equipment or structures	Y N U N/A
2. If equipment contains 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. Overhead equipment or distribution systems are not likely to collapse	Y N U N/A
5. Have you looked for and found no other adverse 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: ______________

________________________________   ______________

Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No. ____________ Equip. Class 7 - Fluid-Operated Valves

Equipment Description ____________

Location: Bldg. ______ Floor El. ______ Room, Row/Col ____________

Pipe Size and Design Classification (optional) ____________

Manufacturer, Model, Etc. (optional) ____________

CAVEATS - BOUNDING SPECTRUM (Identify with an asterisk (*) those caveats which are met by intent without meeting the specific wording of the caveat rule and explain the reason for this conclusion in the COMMENTS section below)

1. Equipment is included in earthquake experience equipment class — Y N U N/A
2. Attached lines (air, electrical) have adequate flexibility — Y N U N/A
3. Have you looked for and found no other adverse concerns? — Y N U N/A

Is the intent of all 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. Overhead equipment or distribution systems are not likely to collapse — Y N U N/A
4. Have you looked for and found no other adverse 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)   Sheet 2 of 2

Equip. ID No. ____________________   Equip. Class 7 - Fluid-Operated Valves

Equipment Description ____

COMMENTS

Evaluated by: ____ Date: _______________

____ _______________

Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 1

Equip. ID No. ____________________ Equip. Class 8A - Motor-Operated Valves

Equipment Description ______________________________

Location: Bldg. ________ Floor El. _______ Room, Row/Col ______________

Pipe Size and Design Classification: (optional) ______________________

Manufacturer, Model, Etc. (optional) ______________________________

CAVEATS - BOUNDING SPECTRUM (Identify with an asterisk (*) those caveats which are met by intent without meeting the specific wording of the caveat rule and explain the reason for this conclusion in the COMMENTS section below)

1. Equipment is included in earthquake experience equipment class Y N U N/A
2. Attached lines (electrical) have adequate flexibility Y N U N/A
3. Have you looked for and found no other adverse concerns? Y N U N/A

Is the intent of all 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. Overhead equipment or distribution systems are not likely to collapse Y N U N/A
4. Have you looked for and found no other adverse 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: ____________

______________________________ ____________

Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 1

Equip. ID No. ____________________ Equip. Class 8B - Solenoid-Operated Valves

Equipment Description ______________________________

Location: Bldg. ________ Floor El. _______ Room, Row/Col ______________

Pipe Size and Design Classification: (optional) ______________________

Manufacturer, Model, Etc. (optional) ______________________

CAVEATS - BOUNDING SPECTRUM

1. Equipment is included in earthquake experience equipment class — Y N U N/A
2. Attached lines (electrical) have adequate flexibility — Y N U N/A
3. Have you looked for and found no other adverse concerns? — Y N U N/A

Is the intent of all 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. Overhead equipment or distribution systems are not likely to collapse — Y N U N/A
4. Have you looked for and found no other adverse 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: ____________

______________________ ____________

Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 1

Equip. ID No. ____________ Equip. Class 9 - Fans

Equipment Description ____________

Location: Bldg. ________ Floor El. _______ Room, Row/Col __________ __________

Manufacturer, Model, Etc. (optional) ____________

CAVEATS - BOUNDING SPECTRUM (Identify with an asterisk (*) those caveats which are met by intent without meeting the specific wording of the caveat rule and explain the reason for this conclusion in the COMMENTS section below)

1. Equipment is included in earthquake experience equipment class — 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. Attached lines (electrical) have adequate flexibility — Y N U N/A
5. Anchorage adequate (See checklist below for details) — Y N U N/A
6. Have you looked for and found no other adverse concerns? — Y N U N/A

Is the intent of all the caveats met for Bounding Spectrum? — Y N U N/A

ANCHORAGE

1. Based on walkdown inspection and judgement, is the installation and factors affecting anchorage capacity adequate? — Y N U N/A
2. Have you looked for and found no other adverse concerns? — Y N U N/A

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. Overhead equipment or distribution systems are not likely to collapse — Y N U N/A
4. Have you looked for and found no other adverse 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: ____________

____________ ____________

Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No. ____________________ Equip. Class 10 - Air Handlers

Equipment Description ____________________

Location: Bldg. __________ Floor El. ________ Room, Row/Col ____________________

Manufacturer, Model, Etc. (optional) ____________________

CAVEATS - BOUNDING SPECTRUM (Identify with an asterisk (*) those caveats which are met by intent without meeting the specific wording of the caveat rule and explain the reason for this conclusion in the COMMENTS section below)

1. Equipment is included in earthquake experience equipment class — 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. Base vibration isolators adequate for seismic loads — Y N U N/A
4. Attached lines (water, air, electrical) have adequate flexibility — Y N U N/A
5. Anchorage adequate (See checklist below for details) — Y N U N/A
6. Have you looked for and found no other adverse concerns? — Y N U N/A

Is the intent of all the caveats met for Bounding Spectrum? — Y N U N/A

ANCHORAGE

1. Based on walkdown inspection and judgement, is the installation and factors affecting anchorage capacity adequate? — Y N U N/A
2. Have you looked for and found no other adverse concerns? — 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 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. Overhead equipment or distribution systems are not likely to collapse — Y N U N/A
5. Have you looked for and found no other adverse concerns? — Y N U N/A

Is equipment free of interaction effects? — Y N U

Equip. ID No. ____________ Equip. Class 10 - Air Handlers

Equipment Description ____________

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

COMMENTS

Evaluated by: ____________ Date: ____________

____________ ____________

Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No. ____________________ Equip. Class 11 - Chillers

Equipment Description ____________________

Location: Bldg. ________ Floor El. _______ Room, Row/Col ____________________

Manufacturer, Model, Etc. (optional) ____________________

CAVEATS - BOUNDING SPECTRUM (Identify with an asterisk (*) those caveats which are met by intent without meeting the specific wording of the caveat rule and explain the reason for this conclusion in the COMMENTS section below)

1.	Equipment is included in earthquake experience equipment class	Y N U N/A
2.	Base and/or compressor/motor vibration isolators adequate for seismic loads	Y N U N/A
3.	Anchorage adequate (See checklist below for details)	Y N U N/A
6.	Have you looked for and found no other adverse concerns?	Y N U N/A
	Is the intent of all the caveats met for Bounding Spectrum?	Y N U N/A

ANCHORAGE

1.	Based on walkdown inspection and judgement, is the installation and factors affecting anchorage capacity adequate?	Y N U N/A
2.	Have you looked for and found no other adverse concerns?	Y N U N/A
	Are anchorage requirements met?	Y N U

Equip. ID No. ____________________ Equip. Class 11 - Chillers

Equipment Description ______________________________

INTERACTION EFFECTS

1.	Soft targets free from impact by nearby equipment or structures	Y N U N/A
2.	If equipment contains 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.	Overhead equipment or distribution systems are not likely to collapse	Y N U N/A
5.	Have you looked for and found no other adverse 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: ____________

______________________________ ____________

Status Y N U

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. (optional) ____

CAVEATS - BOUNDING SPECTRUM (Identify with an asterisk (*) those caveats which are met by intent without meeting the specific wording of the caveat rule and explain the reason for this conclusion in the COMMENTS section below)

1. Equipment is included in earthquake experience equipment class	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 (See checklist below for details)	Y	N	U	N/A
5. Have you looked for and found no other adverse concerns?	Y	N	U	N/A
Is the intent of all the caveats met for Bounding Spectrum?	Y	N	U	N/A

ANCHORAGE

1. Based on walkdown inspection and judgement, is the installation and factors affecting anchorage capacity adequate?	Y	N	U	N/A
2. Have you looked for and found no other adverse concerns?	Y	N	U	N/A
Are anchorage requirements met?	Y	N	U	

SCREENING EVALUATION WORK SHEET (SEWS)   Sheet 2 of 2

Equip. ID No. ____________________   Equip. Class 12 - Air Compressors

Equipment Description ____________________

INTERACTION EFFECTS

1.	Soft targets free from impact by nearby equipment or structures	Y N U N/A
2.	If equipment contains 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.	Overhead equipment or distribution systems are not likely to collapse	Y N U N/A
5.	Have you looked for and found no other adverse 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: ____________

____________________   ____________

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. (optional) ____________

CAVEATS - BOUNDING SPECTRUM (Identify with an asterisk (*) those caveats which are met by intent without meeting the specific wording of the caveat rule and explain the reason for this conclusion in the COMMENTS section below)

1.	Equipment is included in earthquake experience equipment class	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 (See checklist below for details)	Y N U N/A
6.	Have you looked for and found no other adverse concerns?	Y N U N/A
	Is the intent of all the caveats met for Bounding Spectrum?	Y N U N/A

ANCHORAGE

1.	Based on walkdown inspection and judgement, is the installation and factors affecting anchorage capacity adequate?	Y N U N/A
2.	Have you looked for and found no other adverse concerns?	Y N U N/A
	Are anchorage requirements met?	Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 2 of 2

Equip. ID No. ____________________ Equip. Class 13 - Motor-Generators

Equipment Description ______________________________

INTERACTION EFFECTS

1.	Soft targets free from impact by nearby equipment or structures	Y N U N/A
2.	If equipment contains 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.	Overhead equipment or distribution systems are not likely to collapse	Y N U N/A
5.	Have you looked for and found no other adverse 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: ______________

______________________________ ______________

Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No. ____________________ Equip. Class 14 - Distribution Panels

Equipment Description ____

Location: Bldg. ________ Floor El. _______ Room, Row/Col ____________________

Manufacturer, Model, Etc. (optional) ________________________________

CAVEATS - BOUNDING SPECTRUM (Identify with an asterisk (*) those caveats which are met by intent without meeting the specific wording of the caveat rule and explain the reason for this conclusion in the COMMENTS section below)

1. Equipment is included in earthquake experience equipment class — Y N U N/A
2. Adjacent cabinets which are close enough to impact, or sections of multi-bay cabinets, are bolted together if they contain relays — Y N U N/A
3. Wall- or floor-mounted NEMA-type enclosure — Y N U N/A
4. Anchorage adequate (See checklist below for details) — Y N U N/A
5. Have you looked for and found no other adverse concerns? — Y N U N/A

Is the intent of all the caveats met for Bounding Spectrum? — Y N U N/A

Equip. ID No. ____________ Equip. Class 14 - Distribution Panels

Equipment Description ____________

ANCHORAGE

1. Based on walkdown inspection and judgement is the installation and factors affecting anchorage capacity adequate? Y N U N/A
2. Have you looked for and found no other adverse concerns? 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 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. Overhead equipment or distribution systems are not likely to collapse Y N U N/A
5. Have you looked for and found no other adverse concerns? Y N U N/A

Is equipment free of interaction effects? Y N U

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

Evaluated by: ____________ Date: ____________

____________ ____________

Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No. ____________________ Equip. Class 15 - Batteries on Racks

Equipment Description ____

Location: Bldg. ________ Floor El. _______ Room, Row/Col ____________________

Manufacturer, Model, Etc. (optional) ____

CAVEATS - BOUNDING SPECTRUM (Identify with an asterisk (*) those caveats which are met by intent without meeting the specific wording of the caveat rule and explain the reason for this conclusion in the COMMENTS section below)

1.	Equipment is included in earthquake experience equipment class	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 (See checklist below for details)	Y N U N/A
10.	Have you looked for and found no other adverse concerns?	Y N U N/A

Is the intent of all the caveats met for Bounding Spectrum? Y N U N/A

Equip. ID No. ____________________ Equip. Class 15 - Batteries on Racks ________

Equipment Description ____

ANCHORAGE

1. Based on walkdown inspection and judgement, is the installation and factors affecting anchorage capacity adequate? Y N U N/A
2. Have you looked for and found no other adverse concerns? 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. Overhead equipment or distribution systems are not likely to collapse Y N U N/A
4. Have you looked for and found no other adverse 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: ______________

________________________________ ______________

Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No. ______________ Equip. Class 16 - Battery Chargers & Inverters

Equipment Description ______________________________

Location: Bldg. ________ Floor El. _______ Room, Row/Col ______________

Manufacturer, Model, Etc. (optional) ______________________________

CAVEATS - BOUNDING SPECTRUM (Identify with an asterisk (*) those caveats which are met by intent without meeting the specific wording of the caveat rule and explain the reason for this conclusion in the COMMENTS section below)

1. Equipment is included in earthquake experience equipment class — 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. For wall-mounted units, transformer supports and bracing provide adequate load path to the rear cabinet wall — Y N U N/A
5. Anchorage adequate (See checklist below for details) — Y N U N/A
6. Have you looked for and found no other adverse concerns? — Y N U N/A

Is the intent of all the caveats met for Bounding Spectrum? — Y N U N/A

Equip. ID No. ______________ Equip. Class 16 - Battery Chargers & Inverters

Equipment Description ______________________________

ANCHORAGE

1. Based on walkdown inspection and judgement, is the installation and factors affecting anchorage capacity adequate?	Y N U N/A
2. Have you looked for and found no other adverse concerns?	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 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. Overhead equipment or distribution systems are not likely to collapse	Y N U N/A
5. Have you looked for and found no other adverse 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: __________

______________________ __________

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. (optional) ____________________

CAVEATS - BOUNDING SPECTRUM (Identify with an asterisk (*) those caveats which are met by intent without meeting the specific wording of the caveat rule and explain the reason for this conclusion in the COMMENTS section below)

1. Equipment is included in earthquake experience equipment class — 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 (See checklist below for details) — Y N U N/A
6. Have you looked for and found no other adverse concerns? — Y N U N/A

Is the intent of all the caveats met for Bounding Spectrum? — Y N U N/A

ANCHORAGE

1. Based on walkdown inspection and judgement, is the installation and factors affecting anchorage capacity adequate? — Y N U N/A
2. Have you looked for and found no other adverse concerns? — Y N U N/A

Are anchorage requirements met? — Y N U

SCREENING EVALUATION WORK SHEET (SEWS)

Equip. ID No. ____________________ Equip. Class 17 - Engine-Generators

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. Overhead equipment or distribution systems are not likely to collapse	Y N U N/A
5. Have you looked for and found no other adverse 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: ______________

______________________________ ______________

Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No. ____________________ Equip. Class 18 - Instruments on Racks

Equipment Description ____________________

Location: Bldg. ________ Floor El. ________ Room, Row/Col ____________________

Manufacturer, Model, Etc. (optional) ____________________

CAVEATS - BOUNDING SPECTRUM (Identify with an asterisk (*) those caveats which are met by intent without meeting the specific wording of the caveat rule and explain the reason for this conclusion in the COMMENTS section below)

1.	Equipment is included in earthquake experience equipment class	Y	N	U	N/A
2.	Steel frame and sheet metal structurally adequate	Y	N	U	N/A
3.	Adjacent racks which are close enough to impact or sections of multi-bay racks are bolted together if they contain relays	Y	N	U	N/A
4.	Attached lines have adequate flexibility	Y	N	U	N/A
5.	Anchorage adequate (See checklist below for details)	Y	N	U	N/A
6.	Have you looked for and found no other adverse concerns?	Y	N	U	N/A
	Is the intent of all the caveats met for Bounding Spectrum?	Y	N	U	N/A

Equip. ID No. ____________________ Equip. Class 18 - Instruments on Racks

Equipment Description ____

ANCHORAGE

1. Based on walkdown inspection and judgement, is the installation and factors affecting anchorage capacity adequate? Y N U N/A
2. Have you looked for and found no other adverse concerns? 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 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. Overhead equipment or distribution systems are not likely to collapse Y N U N/A
5. Have you looked for and found no other adverse 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: ______________

______________________________ ______________

Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 1

Equip. ID No. ____________ Equip. Class 19 - Temperature Sensors

Equipment Description ____________________

Location: Bldg. ______ Floor El. ______ Room, Row/Col ____________

Manufacturer, Model, Etc. (optional) ____________________

CAVEATS - BOUNDING SPECTRUM (Identify with an asterisk (*) those caveats which are met by intent without meeting the specific wording of the caveat rule and explain the reason for this conclusion in the COMMENTS section below)

1. Equipment is included in earthquake experience equipment class — 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. Have you looked for and found no other adverse concerns? — Y N U N/A

Is the intent of all 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. Overhead equipment or distribution systems are not likely to collapse — Y N U N/A
4. Have you looked for and found no other adverse 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: ____________

____________________ ____________

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. (optional) ________________________________

CAVEATS - BOUNDING SPECTRUM (Identify with an asterisk (*) those caveats which are met by intent without meeting the specific wording of the caveat rule and explain the reason for this conclusion in the COMMENTS section below)

1. Equipment is included in earthquake experience equipment class	Y N U N/A
2. Steel frame and sheet metal structurally adequate	Y N U N/A
3. Adjacent cabinets or panels which are close enough to impact, or sections of multi-bay cabinets or panels, are bolted together if they contain relays	Y N U N/A
4. Drawers and equipment on slides restrained from falling out	Y N U N/A
5. Attached lines have adequate flexibility	Y N U N/A
6. Anchorage adequate (See checklist below for details)	Y N U N/A
7. Have you looked for and found no other adverse concerns?	Y N U N/A
Is the intent of all the caveats met for Bounding Spectrum?	Y N U N/A

ANCHORAGE

1. Based on walkdown inspection and judgement, is the installation and factors affecting anchorage capacity adequate?	Y N U N/A
2. Have you looked for an found no other adverse concerns?	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 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. Overhead equipment or distribution systems are not likely to collapse	Y N U N/A
5. Have you looked for and found no other adverse 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 20 - Instr. & Control Panels & Cabinets

Equipment Description ____

IS EQUIPMENT SEISMICALLY ADEQUATE?   Y N U

COMMENTS

Evaluated by: ________________________________ Date: ______________

________________________________ ______________

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. (optional) ______________________________

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

TANK FOUNDATION

Ring-type foundation is not used to support large, flat-bottom, vertical tank: Y N U N/A

IS EQUIPMENT SEISMICALLY ADEQUATE? Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 2 of 2

Equip. ID No. ____________________ Equip. Class 21 - Tanks and Heat Exchangers

Equipment Description ____________________

COMMENTS

Evaluated by: ____________________ Date: ____________

____________________ ____________