UCRL-ID-115714 Rev 2

WALKTHROUGH SCREENING EVALUATION FIELD GUIDE

NATURAL PHENOMENA HAZARDS AT DEPARTMENT OF ENERGY FACILITIES

Stephen J. Eder
Mark W. Eli
Michael W. Salmon

November 1993

Lawrence Livermore National Laboratory

This is an informal report intended primarily for internal or limited external distribution. The opinions and conclusions stated are those of the author and may or may not be those of the Laboratory.
Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

Walkthrough Screening Evaluation Field Guide

Natural Phenomena Hazards at Department of Energy Facilities

Revision 2
November 1993

Prepared for:
U.S. DEPARTMENT OF ENERGY

ENVIRONMENT, SAFETY, AND HEALTH
Office of Risk Analysis and Technology
and
Office of Nuclear Safety Policy and Standards
and
DEFENSE PROGRAMS
Office of Engineering and Operations Support

Prepared by:
LAWRENCE LIVERMORE NATIONAL LABORATORY
and
EQE ENGINEERING CONSULTANTS

50058-01/WSECVR.pm4 (11/24/93)

WALKTHROUGH SCREENING EVALUATION FIELD GUIDE

NATURAL PHENOMENA HAZARDS AT DEPARTMENT OF ENERGY FACILITIES

Revision 2
November 1993

Authors and Affiliations
Stephen J. Eder - EQE Engineering Consultants
Mark W. Eli - Lawrence Livermore National Laboratory
Michael W. Salmon - EQE Engineering Consultants

Prepared for:
U.S. DEPARTMENT OF ENERGY

ENVIRONMENT, SAFETY, AND HEALTH
Office of Risk Analysis and Technology
and
Office of Nuclear Safety Policy and Standards
and
DEFENSE PROGRAMS
Office of Engineering and Operations Support

TABLE OF CONTENTS

TABLE OF REVISIONS

Revision	Date	Comments
0	October 1991	Special release for 3rd DOE Natural Phenomena Hazards Mitigation Conference in St. Louis, MO.
1	November 1992	General revision to incorporate lessons learned from facility walkthrough screening evaluations and technical safety appraisals.
2	November 1993	Issued as UCRL publication. Includes minor update revisions.

Walkthrough Screening Evaluation Field Guide
Natural Phenomena Hazards at Department of Energy Facilities

1. Introduction

The U.S. Department of Energy (DOE) has a large inventory of existing facilities. Many of these facilities were not designed and constructed to current natural phenomena hazard (NPH) criteria. The NPH events include earthquakes, extreme winds and tornadoes, and floods. DOE Order 5480.28 (Reference 1), establishes policy and requirements for NPH mitigation for DOE facilities. DOE is conducting a multiyear project to develop evaluation guidelines for assessing the condition and determining the need for upgrades at DOE facilities.

One element of the NPH evaluation guidelines' development involves the existing systems and components at DOE facilities. This effort is described in detail in Reference 2. In the interim period prior to availability of the final guidelines, DOE facilities are encouraged to implement an NPH walkthrough screening evaluation process by which systems and components that need attention can be rapidly identified. Guidelines for conducting the walkthrough screening evaluations are contained herein. The result of the NPH walkthrough screening evaluation should be a prioritized list of systems and components that need further action. Simple and inexpensive fixes for items identified in the walkthrough as marginal or inadequate should be implemented without further study. By implementing an NPH walkthrough screening evaluation, DOE facilities may realize significant reduction in risk from NPH in the short term.

2. Purpose

The purpose of this field guide is to direct walkthrough screening evaluations of DOE facilities in the technical area involving potential hazards caused by natural phenomena. The walkthroughs should focus on the existing features of a facility that present risk, the design attributes installed at the facility to mitigate risk, and features with high replacement cost or that are critical for facility mission. The major emphasis for NPH evaluations is the ability of a facility to achieve its designated performance goals.

> *A walkthrough screening evaluation is an in-plant appraisal of key physical attributes. Items that pass the screen are considered to possess no obvious deficiencies; documented verification may be deferred. Items not passing the screen may be of concern; detailed review or upgrade may be appropriate for these cases depending on potential risk.*

This field guide was developed from field experience including NPH investigations, test reports, analytical studies, and observations from plant walkdown efforts. Additional guidance for the screening and follow-up evaluations is contained in the background reference reports listed in Section 13.

3. Performance Goals

A performance goal is the mean annual probability of exceedance of acceptable behavior limits used as a target in the NPH requirements for DOE facilities. Although a performance goal is defined as a probability value (e.g., 1×10^{-5}), the term "performance goal" is also used to describe the behavior limits themselves. For example, a performance goal of 1×10^{-5} is reasonable for highly hazardous facilities, where confinement of contents and public and environmental protection are of paramount importance. The descriptive "performance goal" for this facility may be "assurance of material confinement."

DOE management has the responsibility for selecting performance goals. Selection of performance goals for facilities subjected to natural phenomena hazards is based on characteristics of the facility under consideration, including:

- Vulnerability of occupants
- Cost of replacement of facility and contents
- Mission dependence or programmatic impact of the facility on operations at the DOE site
- Characteristics of hazardous materials contained within the facility, including quantity, physical state, and toxicity
- Factors affecting off-site release of hazardous materials, such as a high energy source or transport mechanism, as well as off-site land use and population distribution

Performance goals including guidelines for establishing quantitative annual probabilities of unacceptable performance are further discussed in References 3 and 4. For the purposes of the NPH walkthrough screening evaluations, it is essential that the qualitative performance goals for the facility as well as its systems and components are understood by the evaluation team. Performance goals to be considered during the review may include some or all of the following:

- Place hazardous operations (such as handling of radioactive or chemical/toxic materials) into a safe state
- Confine radioactive or chemical/toxic materials
- Continue operation of safety systems, auxiliary utilities, or emergency services
- Control damage and recover facility operations
- Maintain life satety and facility occupancy

The established performance goals at the facility will direct the scope of the reviews. In addition, the performance goals associated with the biggest consequences should be given highest priority during the NPH walkthrough screening evaluations. For example, at a highly hazardous facility, the walkthrough screening evaluations should first address features of the facility associated with placing hazardous operations into a safe state and confining hazardous materials. Lower priority should be given to features associated with recovery of production operations and facility occupancy.

4. Screening Evaluation Scope

The scope of the walkthrough screening evaluations should be commensurate with the performance goals of the facility under review. In general, the scope of the review is controlled by the number of structures, systems, and components (SSCs) to be investigated, and the level or rigor involved in the review of each SSC. It is reasonable to expect that the evaluations for facilities posing potential hazards to public safety and the environment because of contents would be more encompassing than for lower-hazard or general-use facilities. A detailed walkthrough screening evaluation addresses all of the following:

- Anchorage
- Anchorage load path
- Structural integrity
- Seismic systems interaction
- Operability (where appropriate)
- Relay chatter evaluation
- Building structure evaluation

For performance goals such as placing hazardous operations into a safe state and hazardous materials confinement, the evaluation should consider all of these items. For lesser performance goals, such as damage control and recovery, the walkthrough evaluations do not need to address operability and relay chatter evaluation. For life-safety goals, the evaluation should address anchorage, load path, and structural integrity. Selection of the appropriate features that constitute the walkthrough evaluation will involve interaction with facility operations staff.

This field guide provides checklists (Attachments 1 and 2) to aid in the documentation of the reviews as they are conducted on a facility-by-facility or area-by-area basis. In addition, informal field notes should be taken to supplement the review documentation.

The main product of a walkthrough screening evaluation is not filled-out checklists and field notes, but a report to the facility management that summarizes the evaluation results, particularly the final recommendations for upgrades. The content of the summary report should include:

- A brief description of the objectives and the approach for the walkthrough screening evaluation
- The scope of the review (SSCs)
- Prioritization considerations for the evaluations and follow-up recommendations
- Identification of items passing screening and those with possible or obvious deficiencies
- Detailed and prioritized recommendations for upgrades or further evaluations

5. Reviewer Qualifications

Walkthrough screening evaluations are an efficient tool for examining equipment components, distribution systems, and supporting structures. As there is generally limited available time allotted for the review, it is very important that the review team is constantly alert for and actively seeks out credible hazards.

This field guide is intended for use by degreed engineers of the civil/structural or mechanical disciplines. The engineers performing the walkthrough evaluations should have at least three years of experience in design or evaluation of facility features relative to the NPH concerns addressed herein. The field guide format only serves as a reminder for potential areas of concern; considerable engineering judgment must be exercised during any facility review.

Walkthrough evaluations should be conducted by teams. The walkthrough team should include plant personnel who are capable of identifying equipment for the scope of review, who perform the screening evaluation for NPH adequacy of equipment, and who perform operability and relay evaluations. When the facility building structure warrants a review, a separate team consisting of civil/structural engineers is recommended to focus on the building evaluation. A suggested team composition for the facility systems and components is listed below:

- Systems Engineer. The responsibility of the systems engineer is to identify systems that are essential for meeting facility performance goals. Operators or safety analysis personnel may be used as the systems engineer.
- NPH Screening Engineer. The responsibility of the NPH screening engineers is to conduct the walkthrough of plant equipment and important systems identified by the systems engineer and to assess the adequacy of this equipment to perform under NPH loadings. The team should include at least two NPH screening engineers.
- Relay Reviewer. The responsibility of the relay reviewer is to assess the ability of essential relays to function under NPH loadings and to address potential effects of relay chatter during seismic motion.
- Plant Maintenance Representative. A plant staff electrical or instrumentation and controls maintenance representative is very helpful in establishing the location, mounting, types, and characteristics of equipment being reviewed, including relays.

Workshops are being given that provide additional training on the implementation of this field guide and overview of many of its supporting documents. Attendance at a workshop is highly recommended.

6. Preparation for Evaluation

Prior to the walkthrough screening evaluations, certain facility design information should be collected to help maximize the benefit of the reviews. The following provides a checklist of example data that should be collected prior to NPH review of a facility:

- ❑ Map of site with outline of structures and structure identifiers
- ❑ Performance goals for the facility SSCs
- ❑ Design-basis definitions of seismic ground motion, wind speed, floodwater elevation, etc.
- ❑ Hazard curves for earthquake, wind, and flood at the facility
- ❑ Structural drawings for buildings, including current as-built key plans where possible
- ❑ Date of construction of each facility (including dates of modifications as appropriate)
- ❑ Available soils data, etc.
- ❑ General description of processes, etc., housed in the building
- ❑ Safety analysis reports
- ❑ Preliminary listing of essential equipment components
- ❑ Emergency response procedures related to NPH

In addition, facility procedural requirements for a walkthrough should be obtained. For example, these procedures may include the security access requirements for the facility, needs for a camera pass, or arrangement for a site photographer.

7. Interaction with Facility Operators

The facility operations personnel should be interviewed both prior to and during the walkthrough screening evaluation. A constructive information exchange between the NPH review team and the facility operators and managers greatly increases the efficiency and potential benefits from the review.

First, the assumptions and applicable natural phenomena events should be described to the operators to give them a sense of what the NPH review is trying to accomplish. Example scenarios should be presented for each applicable NPH event. For example, it is useful to describe to operators that for the seismic event:

- The entire facility will be shaken simultaneously with no prior warning
- The strong shaking will last about 10 to 20 seconds
- There will be a loss of off-site power

Once presented with the NPH scenario, the operators will be able to focus on which systems and components they will first turn to following the event. At this stage, the facility component and system review scope and means of achieving performance goals will start falling into place.

The following are high-priority items to specifically question the facility operators about:

1. What are the designated high- and moderate-hazard features at the facility?
2. What are the hazards to the public or environment upon failure of facility SSCs?
3. What are the confinement systems in place to protect the public or environment from facility operations or accidents?
4. What, if any, are the operational requirements for components in the confinement systems?
5. What are the procedures in the event of a loss of off-site power?
6. Upon loss of off-site power, what is the failure state of active confinement systems (e.g., will air be needed to re-open dampers)?
7. What success paths are available for placing any hazardous operations into a safe state? (Include those requiring operator action.)
8. What are the facility emergency response and evacuation procedures for a major natural phenomena event? Be aware that natural phenomena are initiating events that may cause loss of several systems (off-site power, phone service, water supply, etc.) for long periods.
9. Are there any highly important expensive experiments, or unique components that if lost would jeopardize the mission of the plant (excessive downtime)?

If any systems are required to operate in order to provide confinement, additional questions should be asked regarding those systems. If there are no "vital" components (i.e., fail-safe operation) the walkthrough should concentrate on the structural integrity of the passive confinement systems, and interaction issues that could have adverse effects. Additional questions that might be posed to facility operators include:

10. Are there essential instrumentation and controls for those vital components?

11. Is any operator intervention required to operate the vital components?

At this point, a preliminary list of vital components and required operator actions should be generated, which may serve as the basis for the walkthrough. Additional items that should be included in the walkthrough are emergency systems. Example questions to ask include:

1. What type of fire protection system does the facility have? (Identify wet systems, dry systems, functional requirements of any pumps.)

2. What type of monitoring equipment does the facility have? (Identify continuous air monitors, high-radiation area monitors, stack monitors, and their associated operational requirements.)

3. What type of alarm systems does the facility have?

The following section provides a listing of typical systems and components for review at DOE facilities. Once the review scope is established and the performance goals are understood, it is important to remain in contact with the operations staff. They can answer specific questions about individual components. The operators may also provide input regarding other previous NPH evaluations at the facility.

8. Systems and Components

This section provides a list of systems and components that typically should be addressed during walkthrough screening evaluations of DOE facilities for NPH concerns. This list should be used to supplement the information gained via operator interviews and document collection.

8.1 Standby Power Sources

During and following a major natural phenomena event, it is very likely that facility off-site electrical power sources will be disrupted and potentially cutoff for long periods of time. If meeting the performance goals requires availability of electrical power, then standby power sources should be reviewed. Standby power source component examples include:

- Diesel generators and supporting peripheral equipment
  - Air start tanks, air lines, and control and solenoid valves
  - Day tanks, fuel pumps, and fuel lines
  - Battery start system
  - Lube oil and cooling systems
  - Control and relay panels
  - Air intake and exhaust systems
  - Fuel storage tanks and transfer pumps
  - Electrical distribution systems (essential conduit, transformers, etc.)
- Uninterruptible power supplies
  - Batteries, battery racks, and enclosure structures
  - Battery chargers and inverters
  - Electrical distribution systems (essential conduit, transformers, etc.)

8.2 Other Emergency Systems

DOE facilities may include safety and backup safety systems that are needed in the case of an NPH event. Required safety systems should be reviewed during a walkthrough screening evaluation. In addition to review of individual components, system aspects such as spurious actuation (e.g., inadvertent trip of fire alarm resulting in deluge actuation and water spray) and manual switch overrides (e.g., ability to reset tripped motor starter contacts for pumps) should be considered and addressed. Example safety systems and associated components include:

- Plant-specific supplementary safety systems
- Seismic instrumentation and trigger systems
  - Motion detectors, control panels, triggers, and alarms
  - Seismic shutoff valves for natural gas, fuel lines, etc.

- Fire protection
  - Water supply tanks, pumps, lines, and deluge systems
  - Sprinkler piping, and spray nozzles
  - Heat/smoke detection devices, alarm and control panels

- Toxic chemical release detection and alarms
  - Flow meters, pressure transmitters, sensors, etc.
  - Alarm panels and alarms

- Radiation monitoring and alarms
  - Dose rate meters, air monitors, alarm panels, and alarms

- Facility confinement system
  - Ventilation operating equipment
  - Duct system
  - Louvers, dampers, and electric or pneumatic controls
  - Filters and stacks

- Facility evacuation alarms

8.3 Plant-specific Reactor Safe Shutdown Systems

Walkthrough screening evaluations at DOE reactor facilities should address the systems and components needed to bring the reactor to a safe shutdown and maintain it for a period of about three days. Many DOE reactors are not very complex systems and can be understood and reviewed by a walkthrough screening evaluation. More complex reactors such as DOE Class A reactors should be subject to a more rigorous evaluation; walkthrough screening evaluations may augment these. Facility-specific reactor safe-shutdown systems may include:

- Reactor reactivity control systems and components
- Reactor coolant pressure control systems and components
- Reactor coolant inventory control systems and components
- Decay heat removal systems and components
- Confinement system boundary seal and ventilation
- Containment system structures and components

8.4 Electrical Equipment

Electrical equipment required to support facility safety systems or to sustain production should be reviewed. Example electrical equipment components associated with power distribution and control include:

- Low- and medium-voltage switchgear
- Motor control centers, distribution panelboards, and switchboards
- Instrumentation and control panels and relay cabinets
- Transformers
    - Liquid-filled and dry-type medium/low voltage
    - Distribution and power control transformers
- Motor-generator sets
- Electrical distribution systems
    - Cable trays
    - Conduit
    - Bus ducts

8.5 Mechanical Equipment

Mechanical systems and equipment components needed to support facility safety systems or to sustain production should be included in the review. Example mechanical systems and components, including distribution systems include:

- Cooling water, service water, fluid/steam supply
    - Large- and small-bore piping
    - Air-, motor-, solenoid-operated, and pressure relief valves
    - Manual valves and check valves
    - Horizontal and vertical pumps
    - Horizontal and vertical storage and surge tanks
    - Heat exchangers and boilers
    - Cooling towers and chillers
- Service air
    - Air compressors and tanks
    - Tubing, valves, and pressure/temperature gages
    - Filters and traps
- Heating, ventilation, air conditioning, and confinement
    - Fans and blowers
    - Ducting

- Filter compartments
- Dampers, louvers, and control equipment/instrumentation

■ Temperature sensors, transmitters, instruments, and racks

8.6 Mission-dependent Considerations

The NPH walkthrough screening evaluations should review items with a high cost impact if adversely affected. Consideration for inclusion should address replacement costs, repair costs, realignment costs, and costs associated with facility downtime. Example components include:

■ Experimental configurations

■ Data processing and storage equipment

■ Test apparatus and instrumentation

■ Plant-specific process/manufacturing equipment

- Glove boxes and handling equipment
- Storage racks and carts
- Monitoring equipment
- Heavy/light machinery

■ Storage and handling equipment

■ Service and maintenance equipment

■ Security systems features

■ Transportation and access structures

8.7 Conflicting Code Requirements

Individuals performing the walkthrough evaluation should become aware of any conflicting code requirements. These situations should be obvious during the operator interview phase of the walkthrough. Some of the codes that could have a potential conflict between requirements include: fire protection, seismic design and evaluation, nuclear criticality safety, life safety, occupational safety, and electrical codes. In cases where different codes call for incompatible requirements, the requirement that should be followed is the one that ultimately reduces the risk to the public or the environment.

A hot cell with an inert atmosphere is one example where the governing codes for fire protection (NFPA-13), seismic design and evaluation (UCRL-15910), and nuclear criticality safety (DOE 5382.series) may have different requirements regarding the amount of water allowed (or desired) in the room in the event of a fire. A specific example of conflicting code requirements is found in NFPA-13, Appendix A-3-5, which states that *"Sprinkler piping should be located so as to minimize the possibility of damage due to impact by mobile material handling equipment and other vehicles. For example, risers adjacent to structural columns...are generally safe."*

In section 4.3 of UCRL-15910, under the heading **"Survival of Emergency Systems"** it is stated that *"Fire Protection systems must remain operational after an earthquake."* Given this guidance, it would be preferable to locate sprinklers away from possible sources of impact such as columns. General guidance provided in this document, as well as other seismic walkdown guidelines, generally recommend sprinkler systems to be well supported in order to prevent sprinkler heads from impacting hard-surfaces to avoid possible loss of function. In instances such as these, considerable judgment must be exercised by the evaluator as to which code should govern.

8.8 Buildings and Structures

Buildings and other structures that house or provide structural support for facility safety systems and components should be reviewed. These buildings and structures should receive some attention during the evaluations. Example structures include:

- Buildings
- Equipment supports, enclosures, pedestals, and foundations
- Building interior and exterior architectural features
  - Partitions, confinement barriers, and shielding walls
  - Penetration doors, hatches, and seals
  - Elevated floors and suspended ceilings
  - Miscellaneous steel framing and platforms
  - Parapet walls and overhangs
  - Windows, louvers, etc.
  - Exterior cladding and roofing
- Stacks and towers
- Susceptibility of local site to soil liquefaction
- Soil stability and landslides
- Service and access roads and bridges
- Large storage tanks

9. Earthquake Screening Evaluation

The items to be addressed for walkthrough screening evaluations for earthquake effects include anchorage, load path, structural integrity, operability (including relay chatter), systems interaction, and building adequacy. This section provides many example illustrations for the items discussed for screening evaluations. Some of the figures present good seismic engineering details and others show configurations that may result in poor performance and should be screened for further evaluation. The common slashed-circle "no" symbol is drawn over the illustrations with poor seismic details.

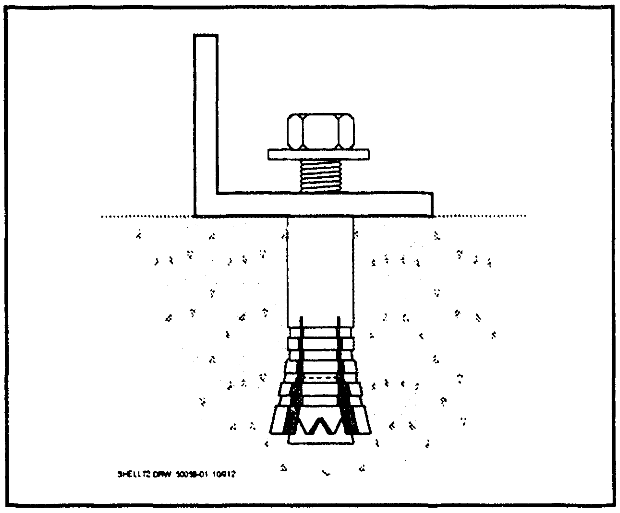

Figure 9-1: Shell-type anchor

9.1 Anchorage

Adequate anchorage is almost always essential to the survivability of any item. Anchorage should always receive special attention during walkthrough screening evaluations. Anchorage integrity requires adequate installation and capacity. Example concerns for each of the major anchorage types (i.e., expansion anchors, cast-in-place anchors, and welded anchors) follow.

- Expansion Anchors. The shell-type or displacement controlled (see Figure 9-1) and wedge-type or torque controlled (see Figure 9-2) expansion anchors have been widely tested and have reasonably consistent capacity when properly installed in sound concrete. Some effort should be spent to determine the type of anchors used (e.g., look at abandoned anchors, interview construction or maintenance personnel, or review installation specifications).

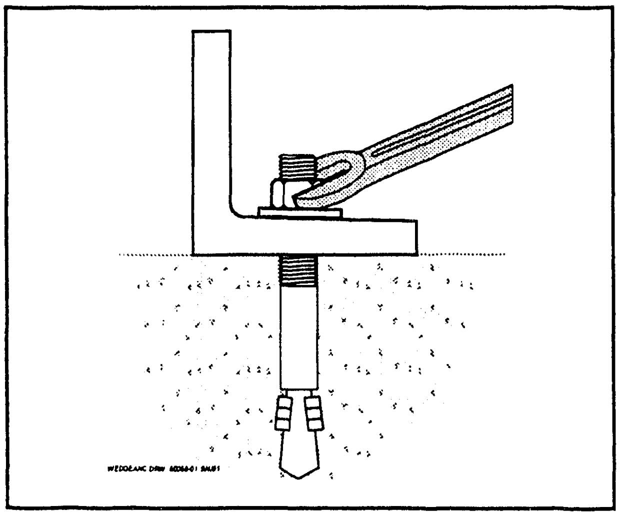

Figure 9-2: Wedge-type anchor

Other types of nonexpanding anchors such as lead cinch anchors (see Figure 9-3), plastic inserts, and lag screw shields are not as reliable and should be screened as a potential concern, especially if seismic demand loads are judged to be close to the capacity of the anchor.

Items to consider when reviewing expansion anchor bolts include:

- Bolt embedment length may not be adequate if part of the shell is exposed or if there is a long stud protruding above the concrete surface. Inadequate embedment also may result from use of shims or tall grout pads as shown in Figure 9-4.

- About 10 bolt diameters' spacing and edge distance are required to gain full capacity (see Figure 9-5).

- Cracks in the concrete may reduce the bolt capacity.

- Anchors in damp areas or harsh environments should be checked for corrosion deterioration if heavy surface rust is observed.

- Expansion anchors may have low resistance to imposed bolt bending moment (may result from gaps between base and floor).

- Loose nuts may indicate inadequate anchor set.

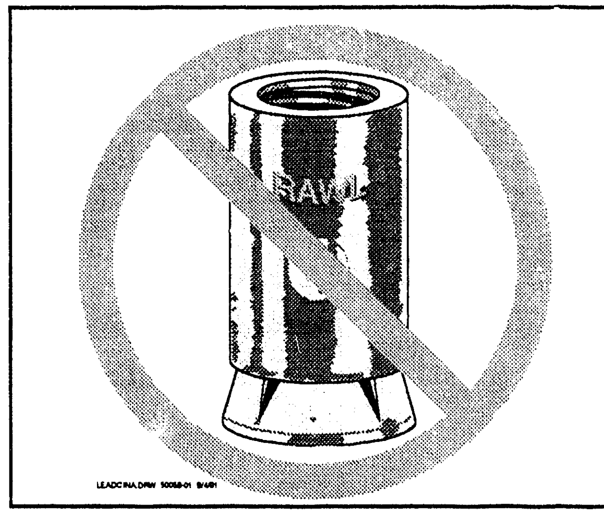

Figure 9-3: Lead cinch anchors have lower capacity

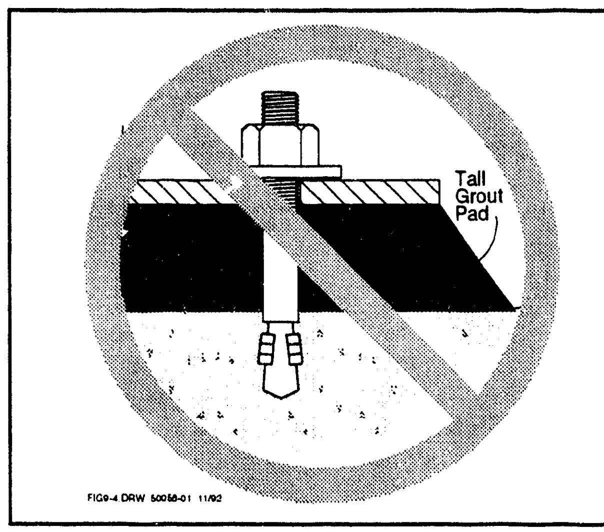

Figure 9-4: Tall grout pad results in minimal anchor embedment

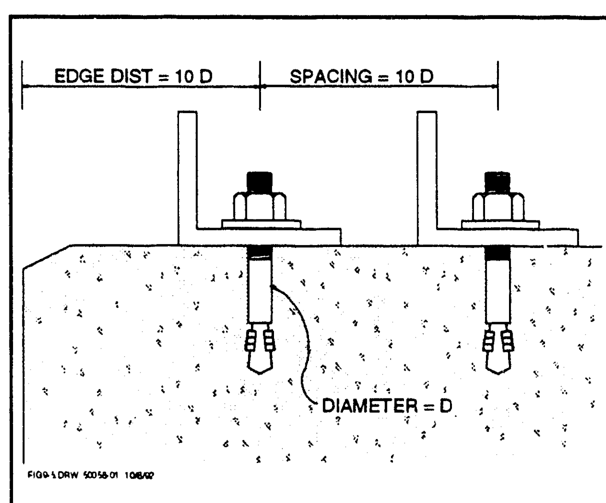

Figure 9-5: Edge distance and spacing should be 10 D minimum

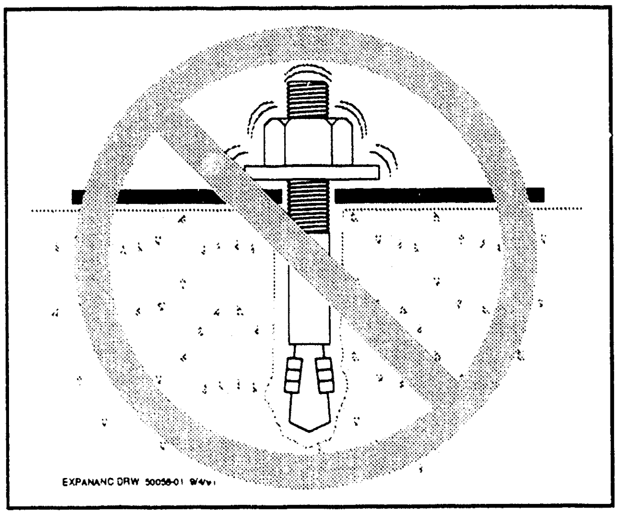

Figure 9-6: Repeated vibrating loads damage expansion anchors

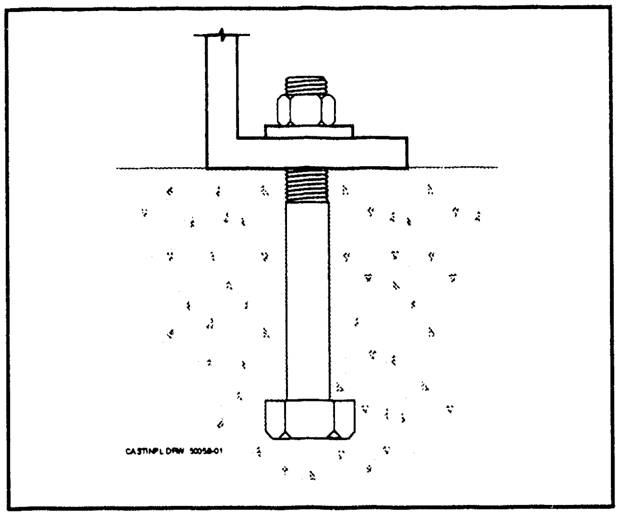

Figure 9-7: Cast-in-place bolt

- Expansion anchors used for vibrating equipment may rattle loose and have little to no tensile capacity (see Figure 9-6).

- Expansion anchors installed in masonry block walls have lower capacity than those in concrete. Block wall adequacy (anchorage and reinforcement) should also be checked.

■ <u>Cast-in-place Anchors</u>. Properly designed, deeply embedded cast-in-place (CIP) headed studs (see Figure 9-7) and J-bolts are desirable anchors since the failure mode is ductile (steel governs). Properly installed undercut anchors with long embedment lengths (see Figure 9-8) behave like CIP bolts and are desirable.

Special consideration should be given to grouted-in-place anchors (see Figure 9-9) since capacity is highly dependent on the installation practice used (e.g., if grout shrinks at all, the anchor may have no tensile capacity).

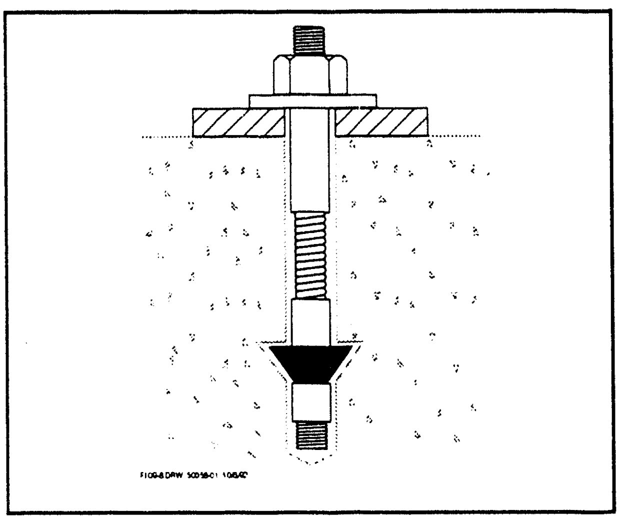

Figure 9-8: Undercut anchor

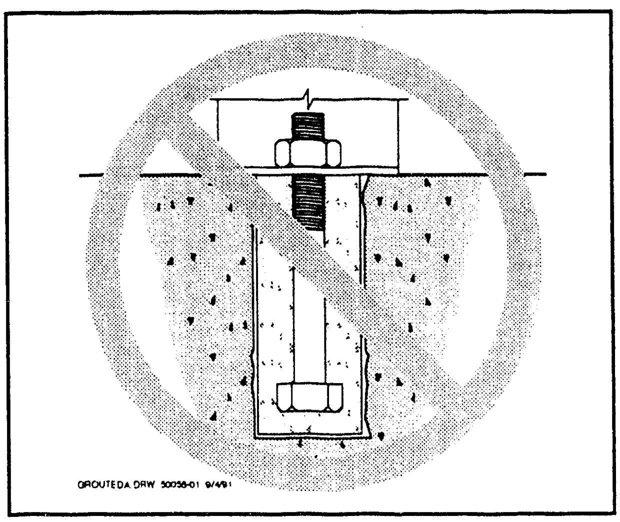

Figure 9-9: Grouted anchor with no tensile capacity

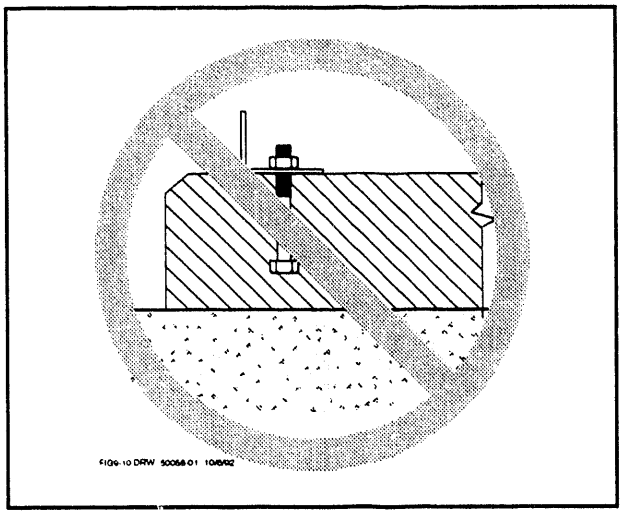

Figure 9-10: Raised pad with no connection to concrete floor

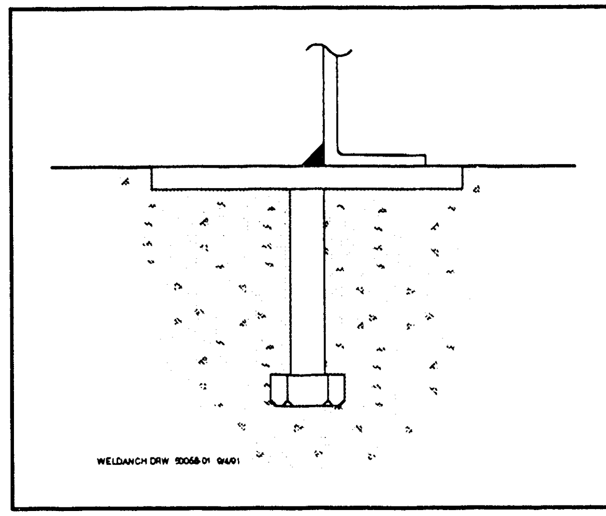

Figure 9-11: Welded anchor

Items to consider when reviewing CIP bolts include:

- Raised pads should be checked since embedment may not extend down to the floor slab as shown in Figure 9-10 (a design drawing review is usually the only way to check embedment length).
- About 10 bolt diameters' spacing and edge distance are required to gain full capacity.
- CIP anchors in badly cracked concrete may have significantly reduced capacity.
- Anchors in damp areas or harsh environments should be checked for corrosion deterioration if heavy surface rust is observed.

■ Welded Anchors. Well-designed and detailed welded connections to embedded plates (Figure 9-11) or structural steel provide high-capacity anchorage.

Items to consider when reviewing welded anchors include:

- Presence of weld burn-through at light-gage steel indicates weak connection.
- Line welds have minimal resistance to bending moments applied about the axis of the weld--this may occur when there is weld only on one side of a flange.

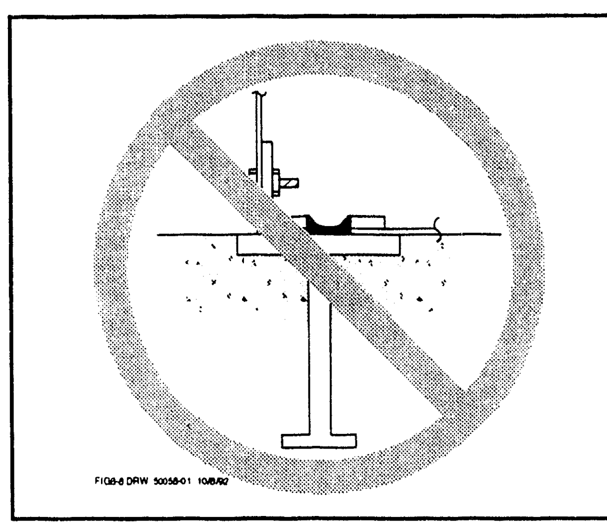

Figure 9-12: Plug welds have low capacity to resist uplift

- Puddle welds and plug welds used to fill bolt holes in equipment bases (see Figure 9-12) have relatively little capacity for applied tensile loads.

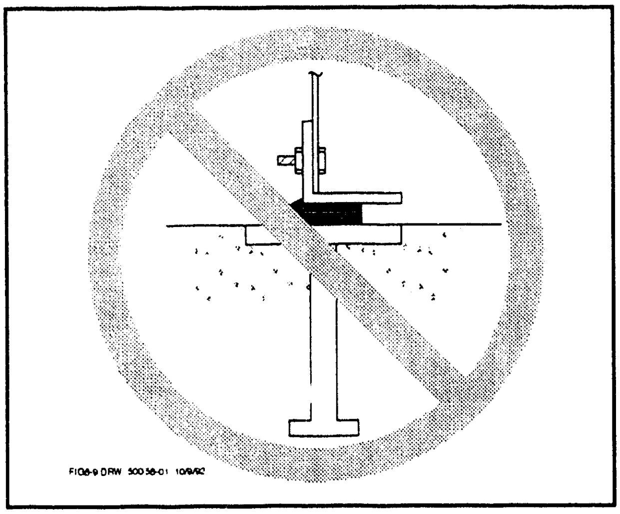

Figure 9-13: Welds across shims may have very low capacity

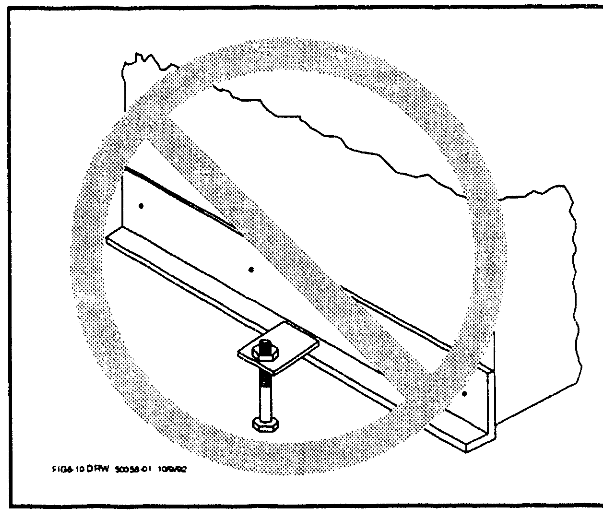

Figure 9-14: Friction clips provide no positive anchorage

- Fillet welds built up across stacked shim plates may appear to be large but have very small effective throat area and thus low capacity (see Figure 9-13).
- Welded anchors in damp areas or harsh environments should be checked for corrosion deterioration.

9.2 Load Path

In addition to anchorage, an adequate structural-load-resisting path is needed from the item to its anchorage attachment point. During screening evaluations, the anchorage inspection should also carefully review the load path through the item to its anchorage for adequate strength, stiffness, and ductility. The review must check the connections as well as the support members. Example anchorage load path features to review include:

- Friction Connectors. Friction connections such as holddown clips (see Figure 9-14) often pry off or completely slip out of place during seismic loading and become completely ineffective. Adequate anchorage requires positive connection.
- Vibration Isolators. Vibration isolators such as that shown in Figure 9-15 must be retrofitted with bumpers that provide a load path in lateral and vertical directions.

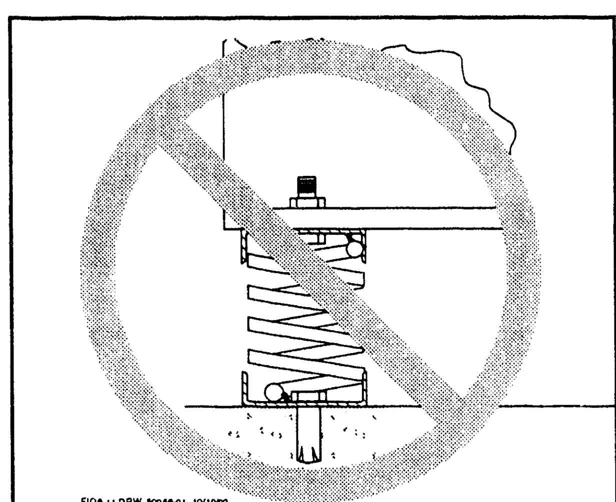

Figure 9-15: Vibration isolators perform poorly

- Thin Framing and Clip Angles. Thin framing members and clip angles may lack the strength and stiffness required to transfer loads to anchor bolts. Stiff load paths with little eccentricity are preferable for anchorage. Figure 9-16 shows an example of a good anchorage load path for an electrical cabinet.

- Sheet Metal Enclosures. Thin cabinet bases should be reinforced with steel angle framing so that seismic loads may be transferred to anchor points. In addition, oversized washers are required when anchors are bolted directly through thin sheet metal bases (see Figure 9-17).

- Weak-way Bending. Heavy components that are mounted on upright channel sections may need to rely on weak-way bending of the channel to transfer shear loads to the anchorage (see Figure 9-18). Unstiffened, light-gage channels may not have enough strength to handle this load transfer.

- Tie Downs to Supports. Distribution systems or equipment components such as tanks should be positively attached to their support bracket or saddle. Examples of concerns include:

    - Distribution systems on supports that allow for sliding should have end restraint to limit movement.

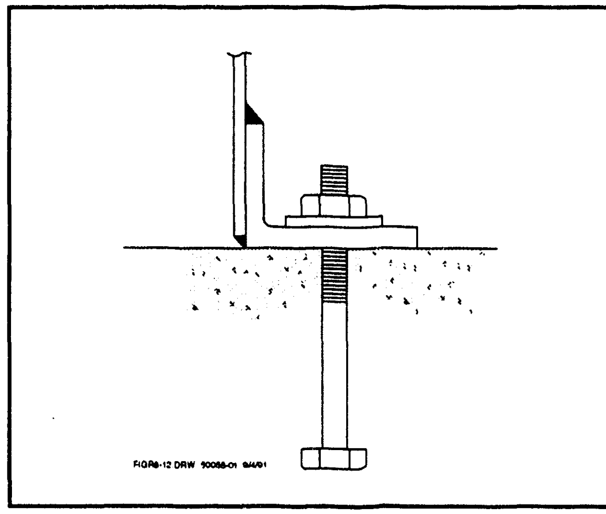

Figure 9-16: Preferred stiff anchor

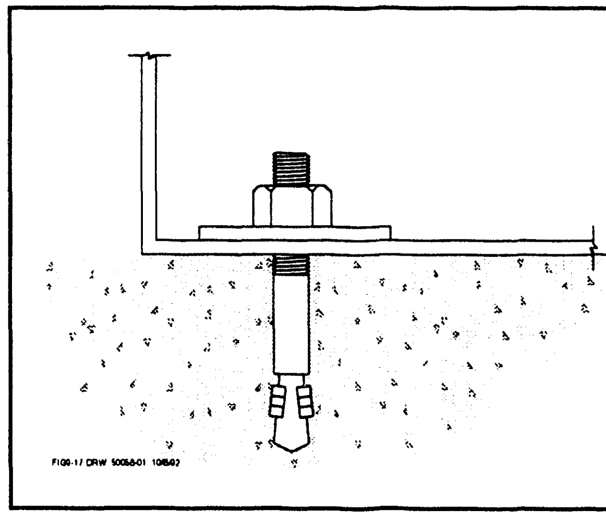

Figure 9-17: Oversized washer reinforces sheet metal load path

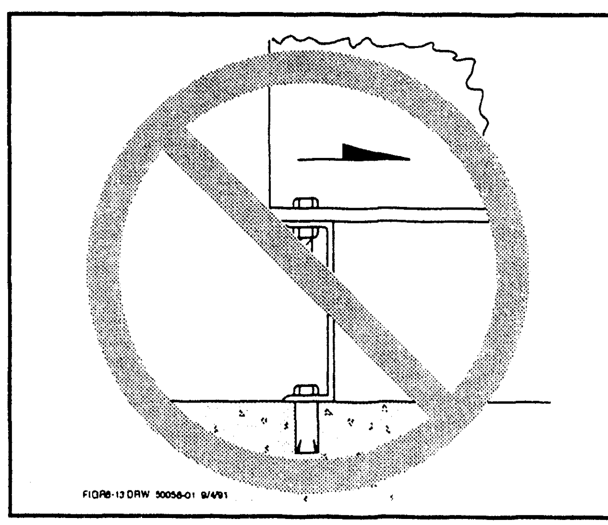

Figure 9-18: Weak-way bending provides poor load path

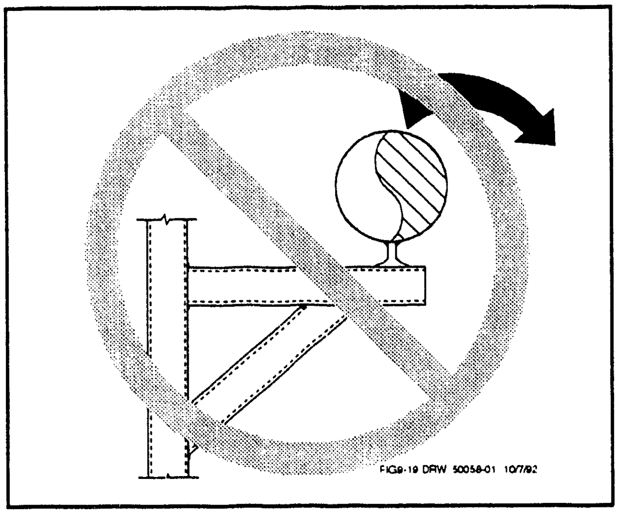

Figure 9-19: Pipe shoe without lateral restraint may fall off end of bracket

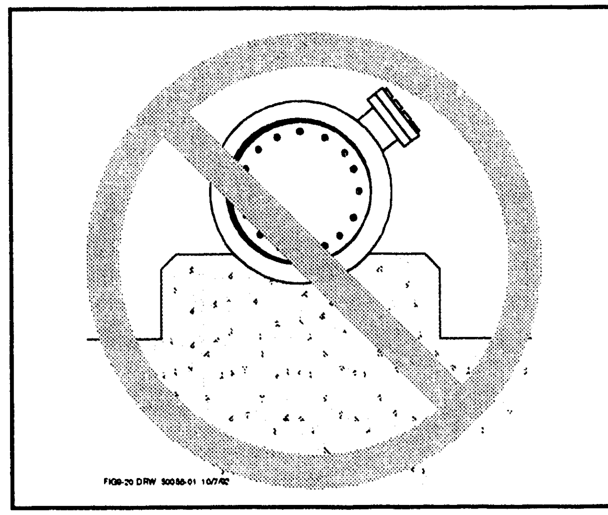

Figure 9-20: Tanks not tied to support may slide

Figure 9-19 shows an example pipe support that lacks guides.

- Unsecured tanks (lack of tie down) such as shown in Figure 9-20 are free to slide or rock, which can cause attached piping to become damaged.

- Battery racks must have wrap-around restraint to prevent sliding and toppling of batteries.

■ Beam Clamps. Beam clamps should not be oriented so that loads are resisted by frictional clamping (see Figure 9-21). Eccentricities in the load path cause prying and are also a concern.

9.3 Structural Integrity

Structural integrity is important. Components required to function after an earthquake must remain intact as well as remain in place. As with anchorage load path, this requires adequate strength, stiffness, and ductility. Examples of specific structural integrity features to be alert for include:

■ Connections. The adequacy of the connections in the structural system's load-resisting path is a key item for structural integrity. Example features to check for include:

- Missing bolts in some holes of connected parts.

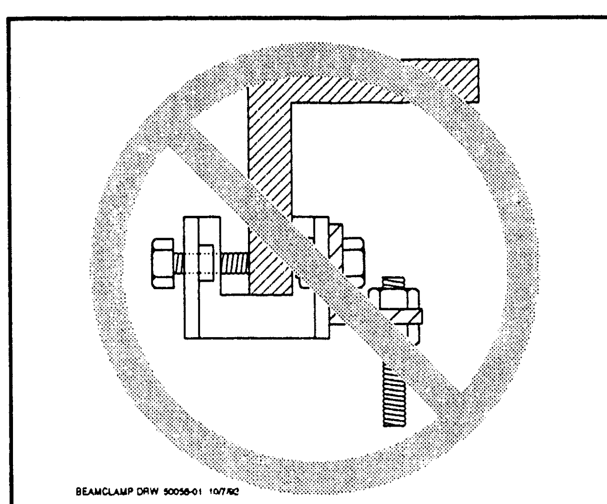

Figure 9-21: Clamps resisting loads by friction may slip off

- Structural members with oversized holes or flame-cut holes (see Figure 9-22).

- Nuts without full thread engagement.

- Weld discontinuities (such as cracks, undercut, rollover, undersized leg, and inadequate effective throat) (see Figure 9-23).

- Cotter pins not installed properly (ears not bent over).

- Fasteners missing positive locking devices for vibrating equipment.

■ Nonductile Materials. Nonductile materials in the load-resisting path should be screened out and evaluated in more detail. Example nonductile materials include ceramics (used as insulators), cast iron (used in piping joints, see Figure 9-24), and plastic (used in restrainers and clips).

■ Cut-outs and Coping. Cut-outs in side panels of electrical cabinets or HVAC ducting should be reinforced.

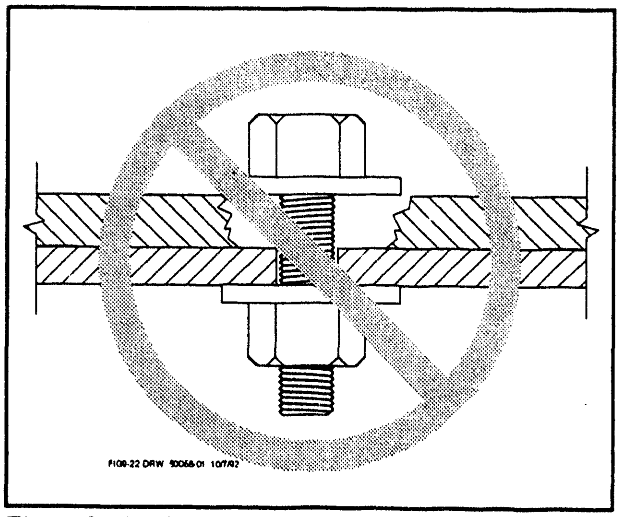

Figure 9-22: Oversized flame-cut holes result in poor connections

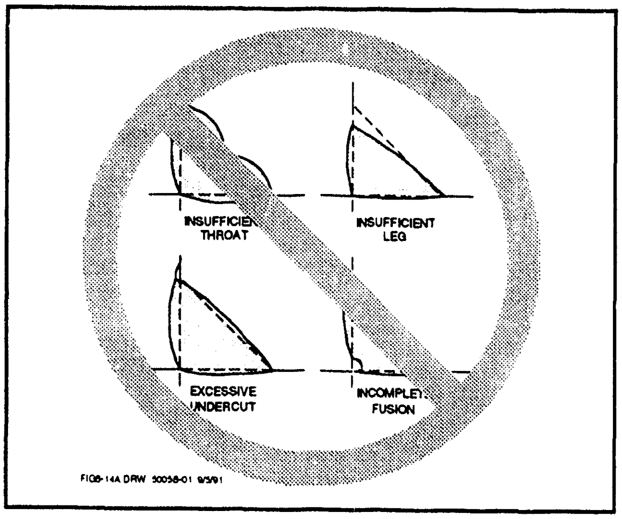

Figure 9-23: Example of poor fillet weld profiles

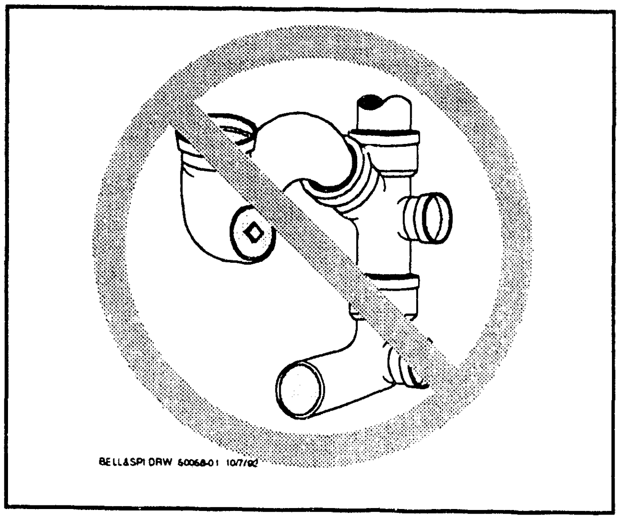

Figure 9-24: Bell-and-spigot piping joints of cast iron are brittle

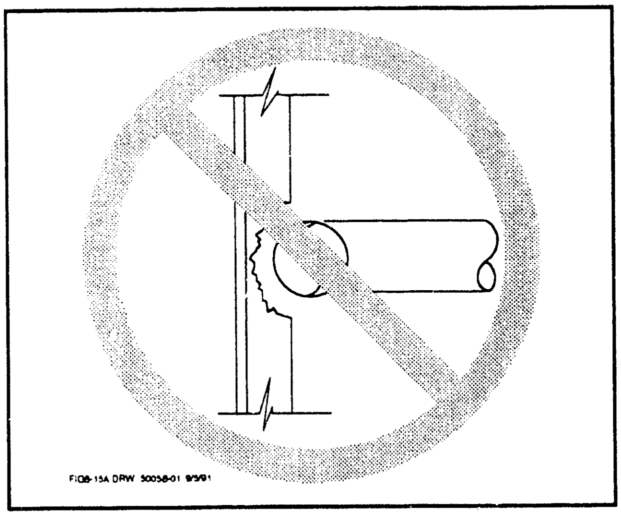

Figure 9-25: Structural members coped out (to give clearance for piping) have reduced strength

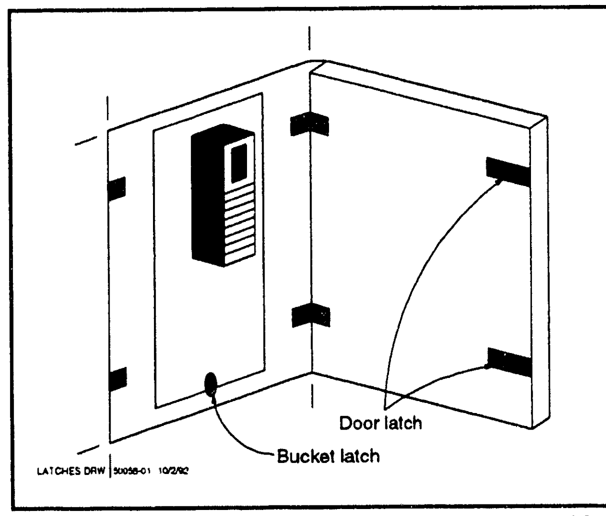

Figure 9-26: Doors and latches on cabinets should be secured

Unreinforced cut-outs reduce the shear-load-resisting strength of sheet metal. Structural members with excessive coping (see Figure 9-25, for example) of flanges and/or webs may have significantly reduced section properties (and strength).

- Door Latches. Doors of electrical cabinets should be positively latched or screwed shut to maintain continuity of the cabinet shear panel resistance. Internal assemblies such as motor controller devices (see Figure 9-26) should also be latched to prevent contactor damage.

- Subcomponents and In-line Components. Heavy internal components and in-line components should be located near anchor points and positively restrained. Lack of restraint may result in significant damage to the parent component or distribution system.

- Rod Hangers. Rod hanger supported items behave well, provided attached branch lines can accommodate seismic-induced displacements (see Figure 9-27). Short, isolated rod hangers with fixed-end connection details (see Figure 9-28) and heavy supported loads may experience a fatigue failure and loss of structural integrity.

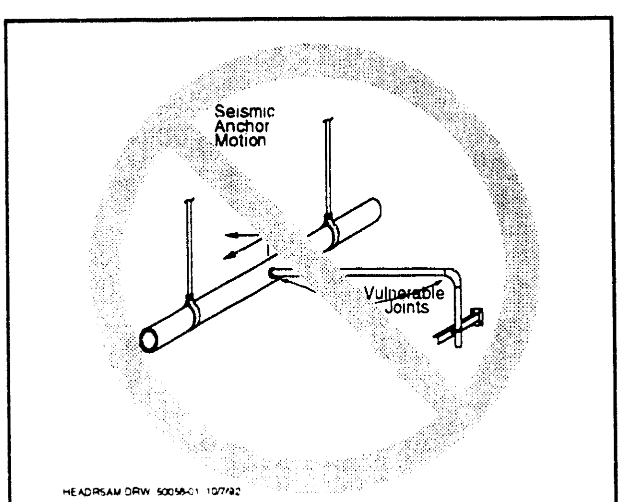

Figure 9-27: Branches are vulnerable to header seismic anchor motion

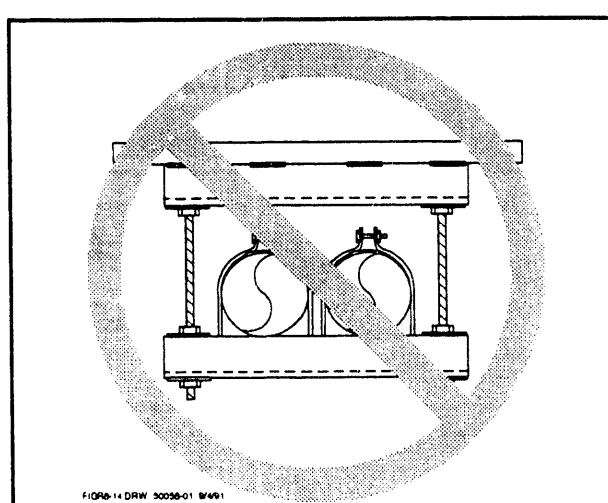

Figure 9-28: Fixed-end rods are subject to fatigue damage

- Flexible Joints. Flexible joints such as bellows or Dresser couplings (see Figure 9-29) cannot transfer loads from their attached distribution systems. If there is no independent restraint to handle these loads, structural integrity may be lost.

- Rack Framing. The framing system for racks such as battery racks and instrument racks should be capable of resisting lateral loads. Longitudinal cross bracing is preferable for racks supporting station batteries.

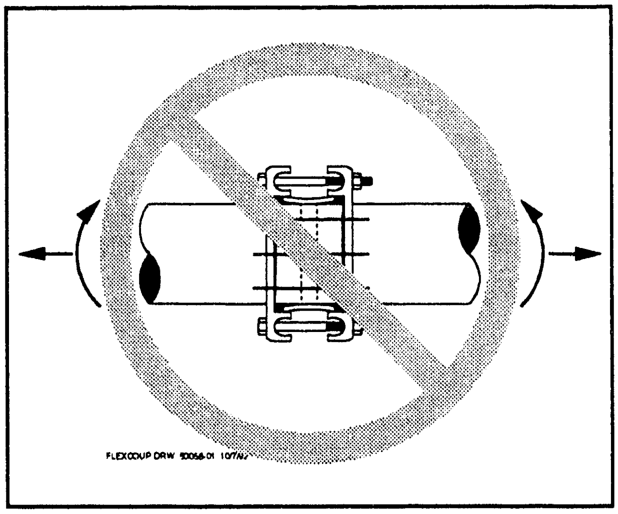

Figure 9-29: Flexible couplings without pipe restraints cannot handle imposed pipe loads

Within the context of structural integrity, many types of mechanical equipment components are inherently very rugged and need not be subject to more than a brief review of anchorage and load path. Examples include compressors, pumps, motors, engines, and generators.

9.4 Operability

Component operability needs to be maintained for systems that must function during or immediately after a seismic event. A relay chatter evaluation should be performed for electrical components whose operability must be maintained during an earthquake. In addition, this often requires a detailed review of differential displacement considerations and subcomponent response. Examples of features to be alert for during walkthrough screening evaluations for operability include:

- Failure Position. The failure state or failure position of certain components, even possibly those that are not required to operate, should be reviewed to check if the failure state may render a system inoperable. For example, ventilation dampers may not be required to operate but may restrict flow or adversely affect vital system performance if they fail closed.

- Relays. A systems review is generally needed to identify relays whose chatter or inadvertent change of state during seismic motion may result in loss of function of vital equipment. This generally requires more effort and time than is available for a walkdown screening evaluation. However, during walkthrough screening evaluations, equipment should be reviewed for the presence of trip- sensitive (or "low ruggedness") devices. Examples of these include:

    - Mercury switches (see Figure 9-30).
    - Sudden pressure switches (such as Buholtz relays on switchyard transformers).
    - General Electric relay types CFD, CFVB, CEH, CPB, IJD, HGA, PVD11 and 12, RAVII, and HFA65.
    - Westinghouse relay types HLF, HU, ITH, ARMLA, PMQ, SG, SV, SC, SSC, and COM-5.

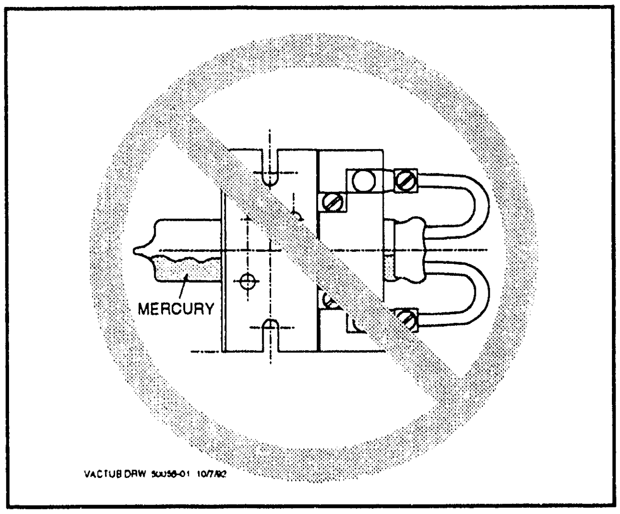

Figure 9-30: Mercury-filled vacuum tubes indicate vibration-sensitive switches

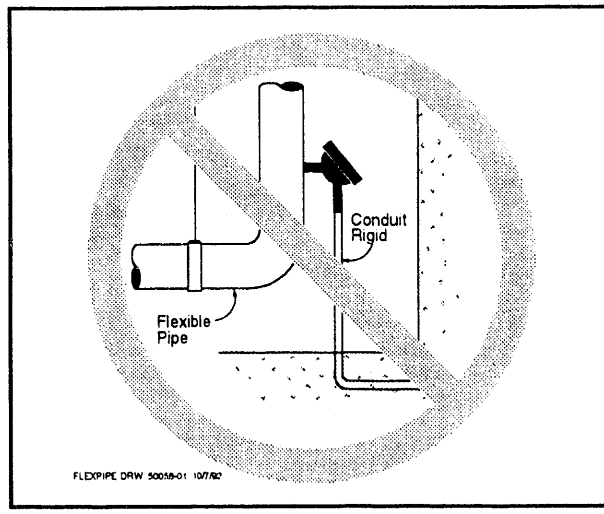

Figure 9-31: Motion of flexible pipe can damage attached conduit

Adjacent cabinets containing relays should be bolted together to prevent impact. Relays are very sensitive to impact loads.

- Tubing and Conduit Slack. Attached tubing and conduit need to have enough flexibility to accommodate seismic and thermal motion of components. Watch for conduit attached to in-line components of flexible piping systems (see Figure 9-31).

- Transformer Coils. Internal coils of dry-type transformers need to be restrained to prevent short-out by contact with their sheet metal enclosure (see Figure 9-32). This internal inspection requires partial disassembly of the transformer cabinet. Similarly, busbars must have adequate clearance where they penetrate cabinet sidewalls to avoid short-out during seismic motion.

- Electrical Equipment. Subcomponents of electrical equipment with electrical contacts (such as switchgear breakers with secondary contacts) need to have adequate support and stiffness so that motion does not cause contact damage or misalignment. Figure 9-33 shows a favorable restraining bracket on a low- voltage breaker unit.

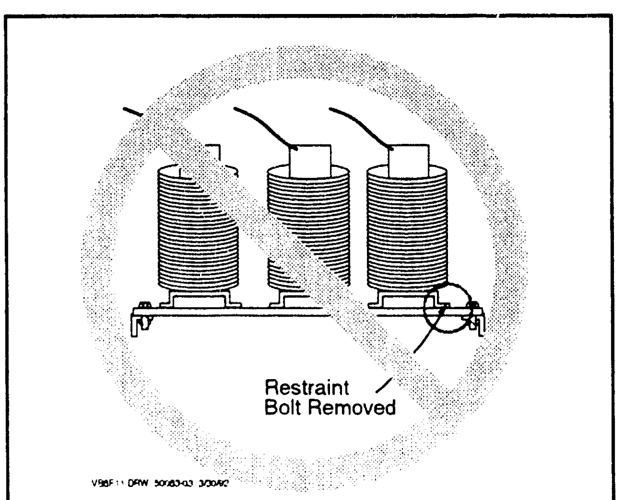

Figure 9-32: Core coil bolts should be in place

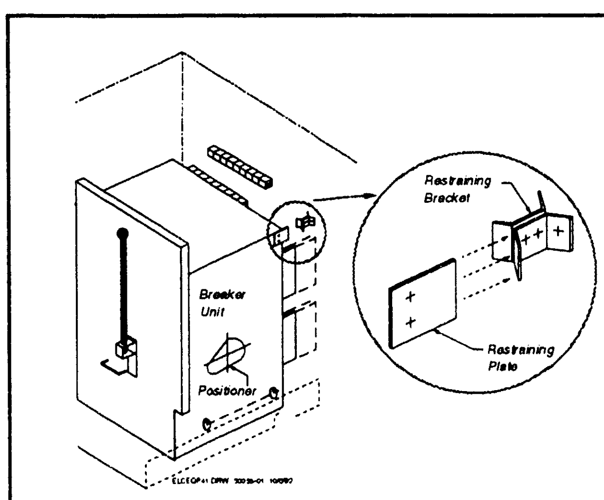

Figure 9-33: Restraining bracket prevents damage of contacts on breaker

Batteries more than about 10 years old may become brittle and be vulnerable to seismic loading. Batteries should also have spacers between adjacent cell jars to prevent jar impact and transfer of loads through busbars and terminal posts.

- Mechanical Equipment. The motor driver and equipment item (such as pump, fan, or generator) should be attached to a common rigid skid (see Figure 9-34) to prevent shaft binding, which leads to inoperability.

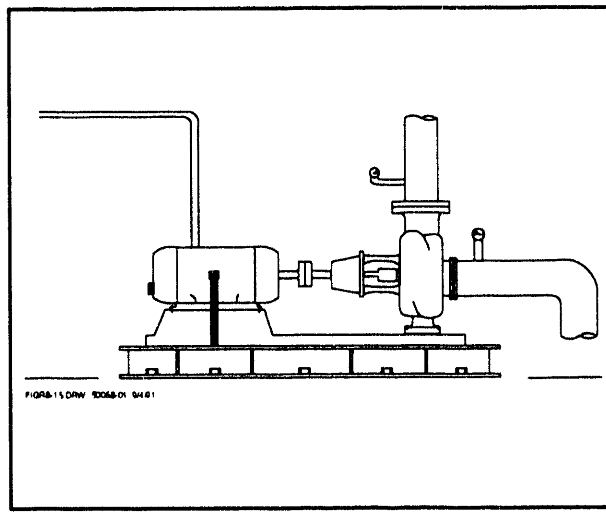

Figure 9-34: Common rigid skid is favorable mounting

9.5 Systems Interaction

Potential seismic systems interaction hazards need to be evaluated. Seismic systems interaction is the physical interaction (bumping, falling) of items close to one another. Vital components with fragile appurtenances (such as instrumentation tubing, air lines, and glass site tubes) are most prone to damage by interactions. The types of seismic systems interactions that need to be reviewed include:

- Structural Failure and Falling. Inadequately anchored and unanchored components may slide or topple and fall, causing damage to vital components (see Figure 9-35). Plant operations, safety, and maintenance equipment as well as facility architectural features are commonly overlooked in seismic design programs and present sources of seismic interaction concerns. Examples of potential seismic interaction failure and falling sources include the following:
  - Partition walls and unreinforced masonry block walls.
  - Ceiling tiles on unrestrained T-bar grid systems.
  - Overhead walkway platform grating lacking tie-downs.
  - Suspended light fixtures and fluorescent tubes.
  - Storage cabinets, files, and bookcases.
  - Tool carts on wheels and tool chests.
  - Ladders and scaffolding.

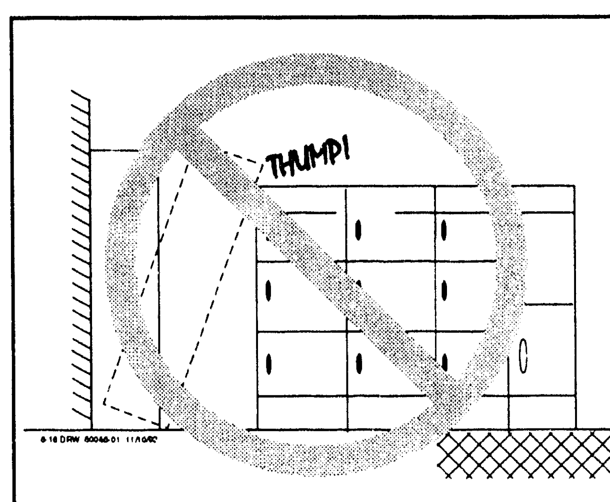

Figure 9-35: Failure and falling interaction hazards

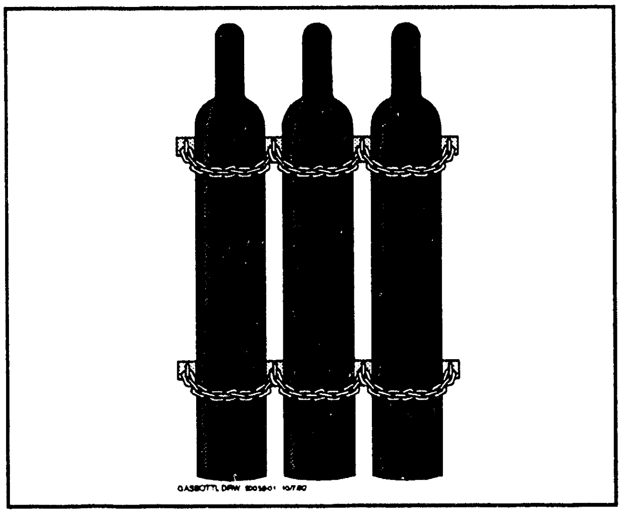

Figure 9-36: Upper and lower restraints are required for gas bottles

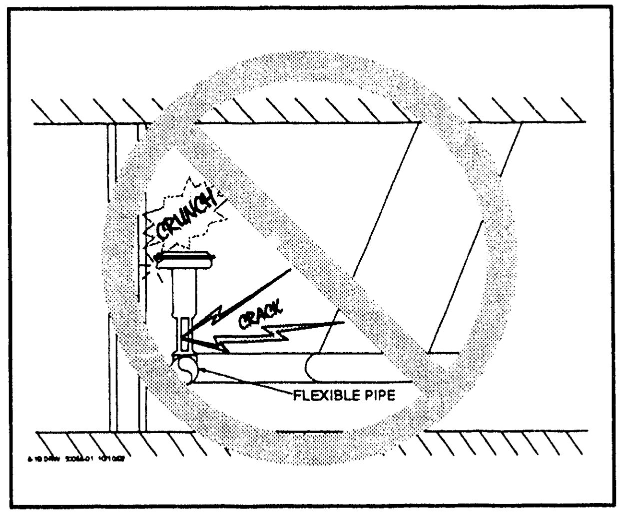

Figure 9-37: Proximity and impact interaction hazard

- Portable testing equipment.
- Unrestrained gas bottles (see Figure 9-36) and fire extinguishers.
- Unrestrained equipment on wall-mounted supports.

■ Proximity and Impact. Adjacent components may impact each other and become damaged if there is not adequate clearance between them to accommodate seismic-induced deflections (see Figure 9-37). This is especially a concern if one of the items is fragile or if one of the items has sufficient mass, hardness, and response (energy) to damage the other. Examples of impact interaction sources to investigate for include:

- Flexibly supported piping, ducting, and raceways (consider also thermal motion of piping) in proximity to vital equipment.
- Flexible electrical panels in proximity to walls and columns.
- Suspended equipment components such as room heaters and air conditioning units.

■ Differential Displacement. Distribution systems that span between different structural systems need to have sufficient flexibility to accommodate the differential motion of the supporting structures (see Figure 9-38). Piping may be vulnerable where it interfaces with a building structure foundation.

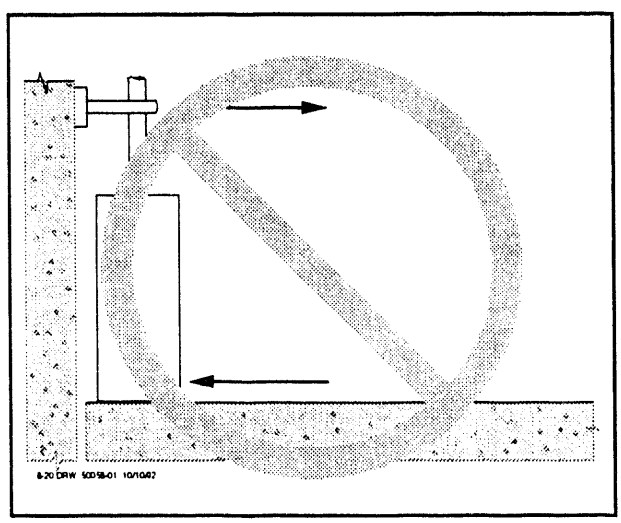

Figure 9-38: Differential displacement interaction hazard

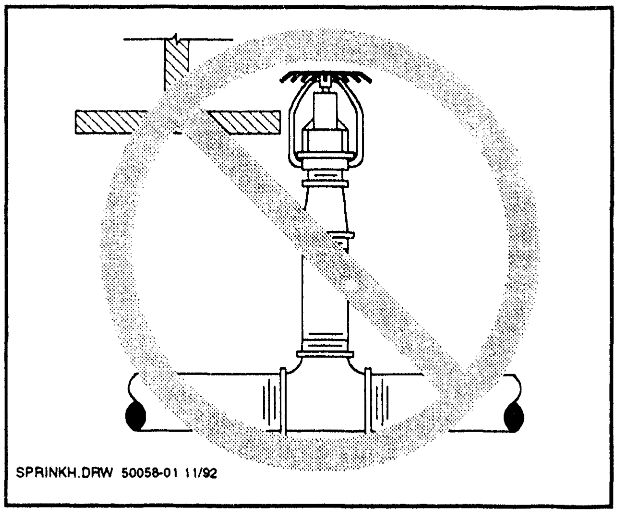

Figure 9-39: Fusible link sprinkler heads are sensitive to impact

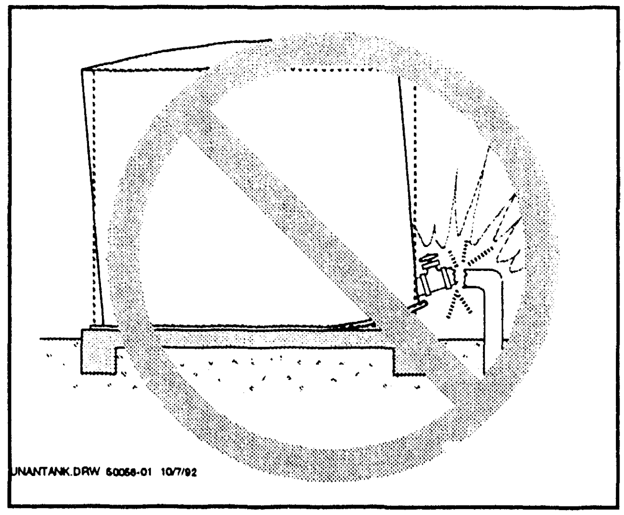

Figure 9-40: Pipe break potential for unanchored tanks

- Spray/Flood/Fire. Potential seismic-induced spray, flood, and fire interaction sources should be evaluated. Example sources to watch for include:
  - Hazardous/flammable material stored in unanchored drums.
  - Nonductile fluid-carrying pipe (such as cast-iron or PVC pipe).
  - Fire protection piping with inadequate clearance around fusible link sprinkler heads (see Figure 9-39).
  - Unanchored and poorly anchored tanks with nonflexible attached piping (see Figure 9-40).

9.6 Building Structure Review

The walkdown screening evaluation should also include facility building structures. This is especially true when the building structure forms a confinement barrier for hazardous materials. For complex building structures, it is advantageous for a separate walkdown team to concentrate solely on the building structure. As a minimum, the following should be reviewed:

- Lateral-force-resisting System. The lateral-force-resisting system of the building structure (including roof system and floor diaphragms) should be identified and reviewed for strength, stiffness, and ductility. It is important to concentrate on the connection details between structural members (e.g., beam-to-column and roof diaphragm-to-wall connections). For the overall structure, any irregularities in stiffness or mass that could result in excessive torsional loading should be examined. Irregularities in the load-resisting path such as a weak first story or diaphragm or shear wall discontinuities should be evaluated.

- Foundation. The type of foundation and the anchorage of the building to the foundation should be evaluated. Inadequate foundation and anchorage can result in the loss of a facility.

- Exterior Walls. The type of exterior cladding and its attachment to the building structure should be identified and evaluated. Use of unreinforced masonry, especially if in the lateral-load-resisting path, should be reviewed in detail by methods other than a walkthrough screening evaluation.

- Soil Conditions. Soil conditions that may affect the integrity of the facility should be identified for further review. Example conditions to check for include liquefiable soils, unstable slopes, and possible uneven settling. If geotechnical reports are not available, a soils evaluation specialist should be consulted.

10. Extreme Wind/Tornado Screening Evaluation

During the walkthrough screening evaluations, the potential effects of high winds and tornadoes at the facility should be evaluated. Areas of concern include response to wind loading of the structure and nonstructural components, and the effects of wind-borne missiles, as follows:

- Wind Loading on Structures. High winds result in pressure loading of structures and components, causing overturning forces and base shears. The pressure loads may result in large uplift forces for open structures or long roof overhangs. Pressure loads may also be large enough to fail individual structural and nonstructural components such as walls, beams, and columns. Lightweight structures, especially trailers and other temporary structures not tied down, are highly vulnerable; building weight contributes directly to holddown resistance.

  Tall structures are also highly vulnerable to wind pressure loads because wind speed increases with height. Examples of vulnerable structures include stacks, chimneys, and transmission towers. Narrow items subject to high winds are also vulnerable to vortex shedding, which may induce dynamic effects such as galloping.

- Wind Loading on Nonstructural Components. Wind pressure loading puts high forces on nonstructural elements such as cladding, windows, and roofing materials. These items and their attachment to the structural system should be reviewed. Venting of the structure must be checked for tornadoes; the steep drop in atmospheric pressure with tornadoes can result in large pressure loadings on internal components such as walls and doors. Note that wind and rain exposure damage may occur following an event if cladding is lost.

- Wind-borne Missiles. Objects may be picked up by high-speed wind and thrown into structures or outdoor equipment. Potential missile sources in the vicinity of the facility should be identified during the walkthrough. Example sources include loose wooden planks, spare structural steel framing (such as angle iron), and steel piping. Any facility with a high wind/tornado speed in excess of 90 mph should consider a 2x4 wood plank missile. The structure should be reviewed for its missile penetrating resistance, especially in areas that contain essential equipment or that provide confinement of hazardous material.

11. Flood Screening Evaluation

The potential effects of flooding should be considered during the walkthrough screening evaluation. The highest credible flood elevation should be determined prior to the walkthrough. This flood level can be a severe problem if it is above the critical flood elevation for the facility, which is the level at which performance goals cannot be met. Examples of items that may establish the critical flood level for facility include:

- Electrical Devices. Water levels may rise high enough during flood conditions to short out electrical devices or components.

- Important Documents. Inundation of a facility due to high floodwater can damage important facility design documents or mission-dependent research files. Damaged documents may require costly and time-consuming cleanup or replacement.

- Drainage Systems. Drainage and sump-pump systems should have adequate capacity to keep floodwater levels inside a facility to a minimum. Drainage routes should be reviewed for spillage concerns. Floor drains that empty into other rooms or passageways may present follow-on flooding concerns that should be checked. Cable troughs and other potential water flow paths should similarly be checked. The operability of sump pumps (e.g., is an emergency power source available) should be reviewed when sumps are absolutely needed.

- Open Hatches/Door. Lower elevation hatches and doors that may be below floodwater levels should be sealed shut and maintained by site procedural requirements. If hatches are left open, then the lower elevations of a facility are directly exposed to flooding.

  In addition to the inundation hazards associated with flood, consideration should also be given to the imposed structural loads. Flooding can impose severe lateral loads on a structure. In addition to lateral loads, vertical live loads on roofs and floors due to ponding, or uplift forces on buried tanks, walls, and foundations can occur that may lead to structural failure. Where floodwater levels are above grade, a check of the structure design criteria should be performed to verify if flooding was considered.

12. Guidance for Prioritizing Recommendations from the Review

The walkthrough screening evaluations will identify potential NPH concerns that warrant upgrade or further evaluations. Some of these will involve only simple quick-fixes; any facility improvements that can be made at negligible cost (e.g., by regular maintenance staff activity) should be made immediately. However, some of the identified potential concerns may invoke the need for costly studies or expensive modifications (e.g., requiring many engineering hours, extensive construction effort, or considerable facility downtime). These more costly recommendations should be prioritized to assist facility management and DOE oversight decision making.

Although beyond the scope of a walkthrough screening evaluation, an effective means of ranking these items is in terms of estimated cost and approximate reduction in risk, in quantitative probabilistic terms, of ability to achieve the designated performance goal. This can be accomplished by determining the following information for each recommendation:

1. Estimate Cost. Estimate the cost, including all costs required to bring the facility system or component up to its designated performance goal.

2. Estimate Capacity. Using the evaluation methods somewhat consistent with UCRL-15910 (Reference 4), estimate the approximate capacity of the item in question. This approximate capacity should be estimated in terms consistent with the site hazard curves (i.e., peak ground acceleration, wind speed, or flood elevation).

3. Obtain Capacity Mean Hazard Exceedance Probability. For the capacity estimated in Step 2, obtain the associated exceedance probability from the site mean hazard curve.

4. Obtain Performance Goal Mean Hazard Exceedance Probability. The hazard exceedance probability associated with the facility system or component performance goal is defined in UCRL-15910 (Reference 4).

   Note that the hazard exceedance probabilities (for each performance category) in UCRL-15910 work together with the evaluation method factors of safety in order to achieve the desired performance goal. This is why in Step 2 above the capacity estimates need to be somewhat consistent with UCRL-15910 rules.

5. Approximate Risk Reduction. The approximate reduction in risk can be approximated by dividing the "capacity" hazard exceedance probability in Step 3 by the "performance goal" hazard exceedance probability of Step 4.

For each facility performance goal, a simplified table can be made that ranks review recommendations by cost (Step 1) versus approximate risk reduction (Step 5). The high-priority items, within each performance goal, will be the largest risk reductions at lowest costs. Be sure to designate which recommendations need to work together. For example, the walkthrough screening may identify concerns with the standby generator start batteries and also the standby generator fuel day tank. Obviously, both concerns need to be addressed together in order to have standby power available.

This approximate method will assist prioritization of concerns within each performance goal. Prioritization between different performance goals should be left to facility management and DOE.

•

13. References for Screening Evaluation Guidance

1. U.S. Department of Energy (DOE). January 15, 1993. "Natural Phenomena Hazards Mitigation for Department of Energy Facilities." Order 5480.28.

DOE Order 5480.28 establishes the requirements that are consistent for all DOE facilities and for all natural phenomena hazards (NPHs) and that are appropriate for the characteristics and objectives of the facilities, when using a graded approach. These requirements are put in place to protect DOE facilities, workers, the public, and the environment from NPHs, such as earthquake, wind, tornado, and flood.

2. Lawrence Livermore National Laboratory and EQE Engineering Consultants. November 1992. "Program Plan for the Evaluation of Systems and Components in Existing DOE Facilities Subject to Natural Phenomena Hazards." Prepared for DOE Office of Engineering and Operations Support, Defense Programs; Office of Risk Analysis and Technology, Environment, Safety, and Health; and Office of Nuclear Safety Policy and Standards, Nuclear Energy.

The program plan outlines the overall approach for DOE facility existing systems and component evaluation. Major elements include short-range tasks to get immediate risk reduction, long-range tasks to establish a consistent graded approach for all the DOE complex, and transfer of NPH evaluation technology to the DOE sites.

3. U.S. Department of Energy (DOE). December 1992. "Natural Phenomena Hazards Performance Categorization Criteria for Structures, Systems, and Components." DOE-STD-1021-92.

This DOE standard provides the guidelines for facilities to establish performance goals and associated performance categories for structures, systems, and components. This standard establishes the basis for the graded approach for assessment of natural phenomena hazards.

4. Kennedy, R.P., S.A. Short, J.R. McDonald, M. W. McCann Jr., R.C. Murray, and J.R. Hill. June 1990. "Design and Evaluation Guidelines for Department of Energy Facilities Subjected to Natural Phenomena Hazards." UCRL-15910. Prepared for the Assistant Secretary for Environment, Safety and Health, Office of Safety Appraisals, United States Department of Energy.

The UCRL-15910 guidelines provide the basic criteria for NPH evaluations of DOE facilities. UCRL-15910 specifies NPH loading levels, acceptable methods for evaluation, and permissible response levels. Performance goals and natural hazard levels are expressed in probabilistic terms, and design and evaluation procedures are presented in deterministic terms. The report is undergoing general revision and is planned to be issued as DOE-STD-1020-92.

5. Winston and Strawn, EQE Incorporated, MPR Associates Inc., Stevenson & Associates, and URS Corporation. February 1992. "Generic Implementation Procedure (GIP) for Seismic Verification of Nuclear Plant Equipment." Revision 2, Corrected 2/14/92.

"Seismic Qualification of Mechanical and Electrical Equipment in Operating Nuclear Power Plants" was designated by the United States Nuclear Regulatory Commission (NRC) as Unresolved Safety Issue (USI) A-46 in December 1980. SQUG was formed in 1982 to pursue the use of earthquake experience data as a primary basis for evaluating the seismic adequacy of equipment. SQUG, EPRI, SSRAP, and the NRC

worked steadily to establish the GIP, which contains the experience-based acceptance criteria and implementation procedure using realistic capacity and demand estimates, with consistent factors of safety.

The SQUG GIP seismic evaluation guidelines consist of four primary criteria: (1) verifying that the seismic demand response spectrum is enveloped by the capacity bounding spectrum; (2) reviewing the equipment by inclusion rules and caveats; (3) evaluating the adequacy of the anchorage; and (4) checking that there are no seismic interaction concerns that may adversely affect equipment functionality.

These criteria are in the form of screening guidelines. Items not passing the four criteria are not necessarily inadequate; they are "outliers" and may be further reviewed by other methods. NRC's acceptance of the GIP is documented in a May 1992 Supplementary Safety Evaluation Report (SSER), Reference 6.

The SQUG GIP addresses 20 generic classes of mechanical and electrical equipment, plus vertical flat-bottom storage tanks, horizontal tanks, heat exchangers, and conduit and cable tray raceway systems and supports. The scope includes commercial nuclear power plant components required to achieve hot shutdown condition and maintain it for 72 hours. The primary steps in the SQUG GIP include selecting evaluation personnel, identifying required equipment, detailed evaluation, and the documentation process. Much of the seismic evaluation effort relies on engineering judgment exercised during in-plant evaluations. For this reason, SQUG established guidelines for the qualifications of engineers using the GIP, including a minimum of five years of related seismic qualification experience and a professional engineering license. SQUG also provides a week-long training program for applying the GIP.

6. U.S. Nuclear Regulatory Commission. May 1992. "Supplemental Safety Evaluation Report No. 2 on Seismic Qualification Utility Group's Generic Implementation Procedure, Revision 2, Corrected February 14, 1992 for Implementation of GL 87-02 (USI A-46), Verification of Seismic Adequacy of Equipment in Older Operating Nuclear Plants." Attachment to Supplement No. 1 to Generic Letter (GL) 87-02.

In this supplemental safety evaluation report (SSER), the NRC staff concludes that SQUG GIP Revision 2, dated February 1992, supplemented by the staff positions, clarifications, and interpretations, stated in the SSER for each section of the GIP, constitutes an acceptable method for the implementation of the resolution of USI A-46 as specified in Generic Letter 87-02.

7. URS Corporation/John A. Blume & Associates, Engineers. June 1991. "Seismic Verification of Nuclear Plant Equipment Anchorage." Volumes 1, 2, and 3. Revision 1. EPRI Report NP-5228. Prepared for Electric Power Research Institute, Palo Alto, CA.

NP-5228 Volume 1 is the key reference for the anchorage evaluation guidelines in the SQUG GIP. It includes capacity and demand criteria for expansion anchors, cast-in-place anchors, and welded connections. Inspection procedures are also explained. The report provides detailed discussion of the basis for the anchor criteria.

NP-5228 Volume 2 provides inspection checklists and screening criteria that can be used as tools for verifying the adequacy of the anchorage of various types of equipment during plant inspections. The inspection checklists provide a field procedure for recording and documenting the verification of anchorage adequacy. The screening criteria are tables and charts that give the seismic capacity as a function of key anchorage parameters.

NP-5228 Volume 3 provides documentation for the computer program EBAC (EPRI - Blume Anchorage Code). The computer program EBAC was developed to perform evaluation of the structural adequacy of equipment anchorage for seismic and gravity loading. The program features an interactive input format and can be used to evaluate a wide variety of anchorage conditions. The program is capable of determining the seismic capacity of a given equipment anchorage configuration and of evaluating a configuration for a specified input seismic acceleration.

8. URS Corporation/John A. Blume & Associates, Engineers. June 1991. "Seismic Verification of Nuclear Plant Equipment Anchorage." Volume 4. "Guidelines for Tanks and Heat Exchangers." Revision 1. EPRI Report NP-5228. Prepared for Electric Power Research Institute, Palo Alto, CA.

Volume 4 of NP-5228 describes the SQUG GIP methodology for evaluation of tanks and heat exchangers. Considerable discussion is provided on the basis for the developed criteria. The theoretical approach and the analytical methods used to generate the simplified GIP approach are presented.

9. Senior Seismic Review and Advisory Panel (SSRAP). February 28, 1991. "Use of Seismic Experience Data to Show Ruggedness of Equipment in Nuclear Power Plants." Revision 4.

The Senior Seismic Review and Advisory Panel (SSRAP) served as the independent review body for SQUG and the NRC during development of the SQUG GIP. This report is a summary of their review of the experience data and their conclusions and recommendations. It provides considerable background information on the basis for many of the technical guidelines of the SQUG GIP. The four primary criteria, capacity versus demand, data base inclusion rules and caveats, anchorage adequacy, and seismic interaction are discussed in detail.

10. EQE Engineering. March 1991. "Summary of the Seismic Adequacy of Twenty Classes of Equipment Required for Safe Shutdown of Nuclear Plants." EPRI Report NP-7149. Prepared for Electric Power Research Institute, Palo Alto, CA.

NP-7149 summarizes the earthquake experience data on mechanical and electrical equipment that form the basis for much of the SQUG GIP. The report defines the 20 generic classes of equipment that are represented by the earthquake experience data, and describes the sources of damage to these equipment from past earthquakes. The report discusses equipment parameters to use to demonstrate representation and bounding of nuclear plant safe shutdown equipment by the SQUG seismic experience data base.

11. ANCO Engineers, Inc. February 1991. "Generic Seismic Ruggedness of Power Plant Equipment in Nuclear Power Plants." Revision 1. EPRI Report NP-5223. Prepared for Electric Power Research Institute, Palo Alto, CA.

NP-5223 summarizes the shake-table test experience data base on electrical and mechanical equipment that forms the basis for the Generic Equipment Ruggedness Spectra (GERS) of the SQUG GIP. The report defines the classes of equipment represented in the shake-table test data base, describes any instances of damage, and provides background discussion on how the GERS and the related GIP inclusion rules were developed.

12. MPR Associates, Inc. December 1990. "Procedure for Evaluating Nuclear Power Plant Relay Seismic Functionality." EPRI Report NP-7148. Prepared for Electric Power Research Institute, Palo Alto, CA.

NP-7148 describes in detail the SQUG systems and electrical circuit evaluation procedure (summarized in the GIP) for establishing which relays are essential for safe shutdown and require a seismic verification. The screening approach starts with all plant relays and works down to the final list of relays whose chatter or malfunction results in adverse effects on nuclear plant safe shutdown function.

13. ANCO Engineers, Inc. February 1991. "Seismic Ruggedness of Relays." EPRI Report NP-7147. Prepared for Electric Power Research Institute, Palo Alto, CA.

NP-7147 summarizes the data base of fragility level shake-table tests on relays. The report includes ruggedness spectra for many individual makes and models of relays included in nuclear plant safe shutdown systems. The ruggedness spectra capacities defined in the report are for use with the SQUG GIP methodology.

14. Stevenson & Associates. December 1990. "Development of In-Cabinet Amplified Response Spectra for Electrical Benchboards and Panels." EPRI Report NP-7146. Prepared for Electric Power Research Institute, Palo Alto, CA.

NP-7146 provides information in addition to that contained in the SQUG GIP on determination of in-cabinet amplified response spectra. The report provides the basis for and an evaluation method for determining seismic demand on relays in control panels and benchboard assemblies. The GENRS computer code is presented and described in detail.

15. EQE Engineering. March 1991. "Cable Tray and Conduit System Seismic Evaluation Guidelines." EPRI Report NP-7151. Prepared for Electric Power Research Institute, Palo Alto, CA.

NP-7151 describes the SQUG GIP methodology for seismic evaluation of cable tray and conduit systems, based on earthquake experience data and shake-table tests.

16. Senior Seismic Review and Advisory Panel (SSRAP). March 1, 1991. "Review Procedure to Assess Seismic Ruggedness of Cantilever Bracket Cable Tray Supports." Revision 3.

This report summarizes the SSRAP review of cantilever bracket cable tray systems, and provides considerable background discussion and philosophy regarding the SQUG GIP raceway evaluation guidelines.

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

NP-7150 summarizes the earthquake experience data and shake-table test data forming the basis for the raceway evaluation guidelines of the SQUG GIP.

18. EQE Engineering. March 1991. "Longitudinal Load Resistance in Seismic Experience Data Base Raceway Systems." EPRI Report NP-7153. Prepared for Electric Power Research Institute, Palo Alto, CA.

NP-7153 provides additional details of earthquake experience data supporting the lack of rigorous longitudinal load evaluation requirements for suspended raceway systems of the SQUG GIP.

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

NP-7152 provides the basis for the rod hanger fatigue evaluation guidelines of the SQUG GIP. The report includes the fatigue test data and describes the fatigue analysis methodology used to generate the screening charts in the GIP.

20. Antaki, G.A., G.S. Hardy, and G. Rigamonti. 1991. "Screening Criteria for the Verification of Seismic Adequacy of Piping Systems." In *American Society of Mechanical Engineers Piping and Pressure Vessel Conference Proceedings*, PVP-Vol. 214, DOE Facilities Programs and Systems Interaction with Linear and Non-Linear Techniques, pp. 103-105.

Piping system screening criteria are presented for use by engineering walkdown teams for the evaluation of seismic adequacy of piping systems. The application of the screening criteria to a nuclear facility is described and compared to the results achieved using conventional analytical techniques. The screening criteria for the evaluation of the seismic adequacy of existing piping systems are confirmed by rigorous analyses of the piping systems.

21. Benda, B., R.W. Cushing, and G.E. Driesen. 1991. "Guidelines for the Seismic Design of Fire Protection Systems." In *American Society of Mechanical Engineers Piping and Pressure Vessel Conference Proceedings*, PVP-Vol. 214, DOE Facilities Programs and Systems Interaction with Linear and Non-Linear Techniques, pp. 111-117.

The engineering knowledge gained from earthquake experience data surveys of fire protection system components is combined with analytical evaluation results to develop guidelines for the design of seismically rugged fire protection distribution piping. The seismic design guidelines of the National Fire Protection Association Standard NFPA-13 are reviewed, augmented, and summarized to define an efficient method for the seismic design of fire protection piping systems.

22. Dizon, J.O., and S.J. Eder. 1991. "Advancement in Design Standards for Raceway Supports and Its Applicability to Piping Systems." In *American Society of Mechanical Engineers PVP, Codes and Standards and Applications for Design and Analysis of Pressure Vessel and Piping Components*, pp. 143-148.

As a result of the development of SQUG guidelines for cable tray and conduit supports, ductile support design was determined to be the best solution. This paper provides background on the ductile design approach from review of experience data; describes the ductile design approach for raceway supports (simplified rules); discusses applicability to low-energy (low-pressure, low-temperature) piping systems; and recommends support design guidelines for piping systems.

23. Campbell, R.D., L.W. Tiong, and J.O. Dizon. 1989. "Response Prediction Guidelines for Piping Systems Which Have Experienced Strong-motion Earthquakes." In *American Society of Mechanical Engineers Piping and Pressure Vessel Conference Proceedings*, pp. 87 to 102.

This paper examines the margins in standard non-seismic design piping systems by comparing the computed responses of piping systems that have experienced strong-motion earthquakes to ASME code allowables. In some cases, very high stresses were anticipated due to undesirable design features that are easily detectable in a plant walkdown. In other cases, stresses exceeding code allowables were anticipated but, because of the lack of known undesirable features, these exceedances were of no consequence. The major conclusion reached is that it is not necessary to conduct expensive dynamic analysis and install excessive supports to result in a safe design. Vulnerable designs can be determined by walkdowns and piping layout reviews.

24. Stevenson and Associates, and EQE Engineering. April 1990. "Procedure for Seismic Evaluation and Design of Small Bore Piping (NCIG-14)." EPRI Report No. NP-6628. Electric Power Research Institute, Palo Alto, CA.

NP-6628 presents a procedure and supporting information for designing and evaluating seismic small-bore piping. This procedure defines an experience-based reference spectrum and limitations governing the construction of piping. If the reference spectrum envelops the safe shutdown earthquake (SSE) ground response spectrum for the site and the limitations are met, then the small-bore piping is qualified for seismic inertial loads without further evaluation. The limitations include requirements to qualify the piping for other applicable design loads, seismic anchor movement effects, spatial interaction, and concentrated loads. An in-plant walkdown of the as-constructed piping is required to ensure that the piping system is properly evaluated.

25. Bragagnolo, L.J., J-P Conoscente, and S.J. Eder. 1991. "A Proposed Methodology for the Seismic Design of Rectangular Duct Systems." In Applied Technology Council (ATC)-29, *Seismic Design and Performance of Equipment and Nonstructural Elements in Buildings and Industrial Structures.*

Guidelines for duct design and construction published by the Sheet Metal and Air Conditioning Contractors National Association, Inc. (SMACNA), size a system based on performance characteristics and the allowable stresses caused by operating pressure loads; no provisions exist for incorporating seismic loads into the design of a duct system. This paper proposes a methodology similar to and based upon the SMACNA requirements, but with the ability to actively design for seismic loads. The result is an easy-to-use, conservative, and flexible approach to incorporating seismic design into a duct system.

26. NTS Engineering and RPK Consulting. July 1991. "A Methodology for Assessment of Nuclear Power Plant Seismic Margin." Revision 1. EPRI Report NP-6041. Prepared for Electric Power Research Institute, Palo Alto, CA. Long Beach and Yorba Linda, CA.

Reassessments of seismicity in the eastern United States and the NRC Reassessment of Severe Accident policy have created interest in defining the inherent seismic design margin of operating nuclear power plants.

The NP-6041 seismic margin methodology enables utility engineers to quantify a nuclear power plant's ability to withstand an earthquake greater than design and still safely shut down for at least 72 hours. The methodology uses generic screening of systems and component seismic ruggedness and does not require probabilistic calculations.

The approach includes systems and experience-based seismic ruggedness screening guidelines, detailed plant walkdown procedures to verify component screening, and analytic methods for evaluating unscreened components. These methods are used to determine the seismic capacity for which there is a high confidence of a low probability of failure (HCLPF).

The seismic margin methodology enables engineers to choose a functional success path and several alternatives to shut down the plant and to identify the subset of plant structures and components associated with the path selected. Methodology procedures determine the weakest-link components and establish the HCLPF level of ground motion for which the plant can safely shut down. Detailed methods for calculating HCLPF values for an extensive variety of components is provided.

27. Hom, S., R. Kincaid, and P.I. Yanev. 1986. "Practical Equipment Seismic Upgrade and Strengthening Guidelines." Prepared for Lawrence Livermore National Laboratory by EQE, UCRL-15815, P/O 9227705.

UCRL-15815 provides U.S. Department of Energy (DOE) facilities with practical guidelines for equipment strengthening and upgrading. The simple seismic upgrades presented in this manual are designed to be a cost-effective method of enhancing the seismic safety of facilities and reducing the potential for major economic loss that can result from equipment damaged or destroyed by an earthquake. Example details for seismic upgrade of common equipment types are provided.

28. Johnson, M.W., E.A. Smietana, J.D. Gillengerten, and S.K. Harris. 1991. "Structural Concepts and Details for Seismic Design." Prepared for DOE Office of the Assistant Secretary for Environment, Safety, and Health, Office of Safety Appraisals by EQE and LLNL, UCRL-CR-106554.

The UCRL-CR-106554 manual discusses building and building component behavior during earthquakes, and provides suggested details for seismic resistance that have been shown by experience to provide adequate performance during earthquakes. Special design and construction practices are also described. Special attention is given to describing the level of detailing appropriate for each seismic region. The UBC seismic criteria for all seismic zones are carefully examined, and many examples of connection details are given. The general scope of discussion is limited to materials and construction types common to Department of Energy (DOE) sites.

ATTACHMENT 1

FIELD DATA SHEET FOR SYSTEMS AND COMPONENTS WALKTHROUGH SCREENING EVALUATION

FIELD DATA SHEET FOR SYSTEMS AND COMPONENTS WALKTHROUGH SCREENING EVALUATION

DOE SITE: ______________________ **BY:** ______________________
FACILITY ______________________ **DATE:** ______________________
BUILDING NAME/NO: ______________________
PERFORMANCE GOAL: ______________________
REVIEW AREA OR SYSTEM: ______________________

DESCRIPTION OF REVIEW SCOPE:

Emergency Power Components: ______________________
Other Emergency Systems Components: ______________________
Reactor System Components: ______________________
Electrical Equipment: ______________________
Mechanical Equipment: ______________________
Mission Dependent Equipment: ______________________

Distribution Systems: ________ Piping ________ Tubing ________ Raceways ________ Ducting

Functional Requirements:

____ Operate During ____ Operate After Shaking
____ System Redundancy: ______________________
____ Failure Position: ______________________
____ Operator Intervention: ______________________

NPH DEMAND SUMMARY

Facility PGA: ______________________
Spectra Type: ______________________
Building Structure: ______________________
Elevation: ______________________
Exposure to Wind: ______________________
Exposure to Floodwater: ______________________

SPACE FOR NOTES AND SKETCHES

Notes:

FIELD DATA SHEET FOR SYSTEMS AND COMPONENTS (CONT.)
WALKTHROUGH SCREENING EVALUATION
DOE SITE: ____________________
BUILDING NAME/NO: ______________

SCREENING EVALUATION: ANCHORAGE

Noted Anchorage Concerns:

____ Installation Adequacy: ______________
____ Missing or Loose Bolts: ______________
____ Concrete Quality: ______________
____ Spacing/Edge Distance: ______________
____ Weld Quality: ______________
____ Corrosion: ______________
____ Other Concerns: ______________

Comments: ______________________________
____

SCREENING EVALUATION: LOAD PATH

Noted Load Path Concerns:

____ Connections to Components: ______________
____ Support Members: ______________
____ Missing or Loose Hardware: ______________
____ Other Concerns: ______________
____ Strength: ______________
____ Ductility: ______________
____ Stiffness: ______________

Comments: ______________________________
____

SCREENING EVALUATION: STRUCTURAL INTEGRITY

Noted Structural Integrity Concerns:

____ Internal Connections/Hardware: ______________
____ Internal Framing: ______________
____ Attached Item Load Path: ______________
____ Maintenance Concerns: ______________
____ Other Concerns: ______________
____ Strength: ______________
____ Ductility: ______________
____ Stiffness: ______________

Comments: ______________________________
____

FIELD DATA SHEET FOR SYSTEMS AND COMPONENTS (CONT.)
WALKTHROUGH SCREENING EVALUATION
DOE SITE: ______________________
BUILDING NAME/NO: ______________________

SCREENING EVALUATION: OPERABILITY REVIEW

Noted Operability Concerns:

____ Low-ruggedness Relays: ______________________
____ Other Sensitive Components: ______________________
____ Sloshing/Banging Trips: ______________________
____ Other: ______________________

Comments: ______________________
____

SCREENING EVALUATION: SYSTEMS INTERACTION

Noted Interaction Concerns:

____ Failure and Falling: ______________________
____ Proximity and Impact: ______________________
____ Differential Displacement: ______________________
____ Spray/Flood/Fire: ______________________

Comments: ______________________
____

ADDITIONAL NOTES

(Include High Wind/Tornado and Flooding Considerations)

END

DATE
FILMED
3/2/94