Appendix D

Seismic Interaction

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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 essential relays, as defined in Section 6, which are required for a safe shutdown function. Since relays are susceptible to chatter, any impact on an electrical cabinet which has such an essential relay in it should be considered an unacceptable seismic interaction and cause for identifying that electrical cabinet as an outlier.

D.2.1 Piping, Raceways, and Ductwork Deflections

The motion of piping, conduit, cable raceways, and other distribution lines may result in impact interactions with safe shutdown equipment. Non-safety-related piping is commonly supported with rod hangers or other forms of flexible dead load support, with little or no lateral restraint. Where adequate clearance with safe shutdown equipment is not provided, potential impact interaction may result. The integrity of the piping is typically not a concern. (Threaded fittings,

cast iron pipes and fittings, and victaulic couplings may be exceptions where large anchor movement is possible.) In general, impacts between distribution systems (piping, conduit, ducts, raceways) and safe shutdown equipment of comparable size are not a cause for concern; the potential for large relative motions between dissimilar size systems should be carefully evaluated to assure that a large system cannot carry away a smaller one.

Judgment should be exercised by the Seismic Capability Engineers in estimating potential motions of distribution systems in proximity to the safe shutdown equipment under evaluation. For screening purposes, a clearance of 2 inches for relatively rigid cable tray and conduit raceway systems and 6 inches for relatively flexible systems would normally be adequate to prevent impacts, subject to the judgment of the Seismic Capability Engineers.

Where potential interaction may involve systems with significant thermal movements during plant normal operating conditions, the thermal displacements should be evaluated along with those resulting from seismic deflections. Inter-equipment displacement limits may be developed from the applicable floor response spectra to assist in this effort.

D.2.2 Mechanical and Electrical Equipment Deflections

Inadequately anchored or inadequately braced mechanical and electrical equipment such as pumps, valves, vessels, cabinets, and switchgear may deflect or overturn during seismic loadings resulting in impact with nearby safe shutdown equipment. Certain items, such as tanks with high height-to-diameter aspect ratios, can deflect and impact nearby equipment. Electrical cabinets in proximity to each other may pound against each other.

The Seismic Capability Engineers should use judgment in such cases to evaluate the potential displacements and their potential effect on nearby safe shutdown equipment. Cabinets with essential relays warrant special concern as described above.

D.3 STRUCTURAL FAILURE AND FALLING

Safe shutdown equipment can be damaged and unable to accomplish its safe shutdown function due to impact caused by failure of overhead or adjacent equipment, systems, or structures. (This interaction hazard is commonly referred to as a Category II over Category I concern.) This seismic interaction effect can occur from nearby or overhead: (1) mechanical and electrical equipment; (2) piping, raceway, and HVAC systems; (3) architectural features; and (4) operations, maintenance, and safety equipment. The seismic interaction effects which are of concern for these types of equipment, systems, and structures are described below. It is the intent of this evaluation that realistic hazards be identified and corrected; failure of non-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 identify 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.
- The doors on electrical cabinets may swing and impact devices or cause relays to chatter.
- Inadequately anchored or braced equipment such as pumps, vessels, tanks, heat exchangers, cabinets, and switchgear may deflect or overturn and impact equipment.
- Architectural features such as suspended ceilings, ceiling components such as T-bars and acoustical panels, light fixtures, fluorescent tubes, partition walls, and plate glass may deflect, overturn or break and fall and impact equipment.
- Grating may slide or fall and impact equipment.
- Sheetrock may fall and impact equipment if it was previously water-damaged or if there is severe distortion of the building.
- Unanchored room heaters, air conditioning units, sinks, and water fountains may fall or slide into equipment.