# 8. EQUIPMENT CLASS EVALUATIONS USING CAVEATS FOR THE REFERENCE SPECTRUM AND / OR GERS

*Chapter 8 contains a summary of equipment class descriptions based on earthquake experience data and generic seismic testing data. These descriptions and the rest of the information in Chapter 8 is from Appendix B of Revision 2 of the SQUG GIP (Ref. 1). Any modifications from the corresponding sections of Appendix B are denoted in Chapter 8 with words in italics (such as this introduction to Chapter 8). An item of equipment must have the same general characteristics as the equipment in the earthquake experience equipment class or the generic seismic testing equipment class to apply the methodology in Chapter 8. The intent of this rule is to preclude items of equipment with unusual designs and characteristics that have not demonstrated seismic adequacy in earthquakes or tests.*

*"Caveats" are defined as the set of inclusion and exclusion rules that represent specific characteristics and features particularly important for seismic adequacy of a particular class of equipment. Chapter 8 contains a summary of the caveats for the earthquake experience equipment class and for the generic seismic testing equipment class. If the caveats are satisfied, then the capacity of the equipment class can be represented by the Reference Spectrum and/or the GERS. For these equipment classes, extensive use of earthquake experience and test data permits the rigorous definition of the equipment capacity and evaluation of the seismic adequacy of the equipment. The equipment capacity determined in Chapter 8 is compared to the seismic demand using the provisions of Chapter 5.*

*The "intent" of the caveats should be met when evaluating an item of equipment as they are not fixed, inflexible rules. Engineering judgment may be used to determine whether the specific seismic concern addressed by the caveat is met. Chapter 8 provides brief discussions of the intent of the caveats. When specific cases are identified where the intent of the caveats are considered to be met, but the specific wording of the caveat rule is not, the reason for this conclusion should be documented.*

*Note that the caveats in Chapter 8 are not necessarily a complete list of every seismically vulnerable detail that may exist since it is impossible to cover all such situations by meaningful caveats. Instead, the SCEs should exercise their judgment and experience to seek out suspicious details or uncommon situations (not specifically covered by the caveats) which may make equipment vulnerable to earthquake effects. For example, the SCEs should note any areas of concern within the "box" which could be seismically vulnerable such as added attachments, missing or obviously inadequate anchorage of components, heavy objects mounted on the equipment, and components that are known to be seismically sensitive.*

*The summaries of the equipment class descriptions and caveats in Chapter 8 are based on information contained in References 19, 35, and 40. Additional information on seismic experience data is contained in Chapter 9d of Reference 32. The SCEs should use the summaries in Chapter 8 only after first thoroughly reviewing and understanding the background of the equipment classes and bases for the caveats as described in these references. These references provide more details (such as photographs of the data base equipment) and more discussion than summarized in Chapter 8. Note that in some cases, clarifying remarks have been included in Chapter 8 that are not contained in the reference documents. These clarifying remarks include such things as the reason for including a particular caveat, the intent of the caveat, and recommended allowable limits for stress analysis. The remarks are also based on experience gained during SQUG GIP reviews at operating nuclear power plants and DOE seismic evaluations at DOE facilities and they serve to help guide the SCEs in their judgment.*

*Certain important caveats from the reference documents are not included in Chapter 8 because they are covered in other sections of the DOE Seismic Evaluation Procedure. These caveats include:*

- *Equipment should be adequately anchored and base isolation should be carefully evaluated (see Chapter 6).*
- *Seismic interaction concerns, such as flexibility of attached lines, should not adversely affect the equipment (see Chapter 7).*
- *Relays for which chatter is not acceptable should be specifically evaluated. Note that although the primary responsibility for conducting the relay evaluation is the Lead Relay Reviewer, the SCEs should be alert for any seismically induced systems effects that may lead to loss of function or malfunction of the equipment being evaluated (see Chapter 11).*

*In addition, caveats discussing a limiting fundamental frequency of 8 Hz are not included in Chapter 8 because this limiting frequency does not apply with the provisions of Chapter 5. Table 8-1 lists the numbers of the SQUG GIP caveats which have been removed for Chapter 8 of the DOE Seismic Evaluation Procedure.*

**Table 8-1 SQUG GIP (Ref. 1) Caveats which are Removed for Chapter 8**

| *Section in DOE Seismic Evaluation Procedure* | *SQUG GIP (Ref. 1) Bounding Spectrum Caveats Removed for Chapter 8* | *SQUG GIP (Ref. 1) GERS Caveats Removed for Chapter 8* |
|---|---|---|
| *8.1.1* | *#9* | |
| *8.1.2* | *#9, #10, and #11* | |
| *8.1.3* | *#10 and #11* | *#6, #7, and #8* |
| *8.1.4* | *#10 and #11* | *#7, #8, and #9* |
| *8.1.5* | *#6 and #7* | |
| *8.1.6* | *#11 and #12* | |
| *8.1.7* | *#7 and #8* | |
| *8.1.8* | *#8, #9, and #10* | *N/A* |
| *8.1.9* | *#5, #6, #7, and #8* | |
| *8.1.10* | *#4* | *N/A* |
| *8.2.1* | *#8* | |
| *8.2.2* | *#7* | |
| *8.2.3* | *#5, #6, #7, and #8* | *N/A* |
| *8.2.4* | *#4, #5, and #6* | *N/A* |
| *8.2.5* | *#3, #4, and #5* | *N/A* |
| *8.2.6* | *#2, #3, #4, and #5* | *N/A* |
| *8.2.7* | *#3, #4, #5, and #6* | *N/A* |
| *8.2.8* | *#3, #4, #5, and #6* | *N/A* |
| *8.2.9* | *#5, #6, #7, and #8* | *N/A* |
| *8.2.10* | *#5, #6, and #7* | *N/A* |

*Chapter 8 is organized by equipment class as listed in Table 2.1-2. For each equipment class, the class description and the caveats applicable to the Reference Spectrum are given first. A plot of the Reference Spectrum is provided in Chapter 5. Next, the class description and the caveats applicable to the GERS are given, when available. Some equipment classes have more than one GERS while other classes have none. A plot of the GERS follows the caveats for each applicable equipment class. While the GERS typically define a higher capacity, the GERS caveats are more restrictive than the reference spectrum caveats.*

## 8.1 ELECTRICAL EQUIPMENT

### 8.1.1 BATTERIES ON RACKS[1]

*The seismic capacity for* the equipment class of Batteries on Racks (BAT) *(see Figure 8.1.1-1) may be* based on earthquake experience data, provided the intent of each of the caveats listed below is met. This equipment class includes both storage batteries and their supporting structures. Most battery systems consist of lead-acid storage batteries mounted in series on steel-frame racks or wooden racks.

A battery is a group of electro-chemical cells interconnected to supply a specified voltage of DC power. Individual battery weights typically range from about 50 to 450 pounds. Batteries are used to supply a steady source of DC power for circuits in control and instrumentation systems, to power DC starter motors for emergency engine-generators, and to provide DC power to inverters for uninterruptible power systems.

Lead-acid storage batteries are the most prevalent type of battery and are the subject of this equipment class. The basic components of a lead-acid battery cell are the electrode element, cell cover, cell jar, electrolyte, and flame arrestor. The electrode elements are the key components of the battery system.

There are four basic types of lead-acid storage batteries which are distinguished by the construction of their positive plates. These four types are: calcium flat plate, Planté or Manchex, antimony flat plate, and tubular. Since there are no examples of antimony flat plate and tubular batteries in experience data, they are excluded from the equipment class. The Planté or Manchex battery is one of the older designs of batteries. It is constructed of heavy lead plate with either a series of horizontal cross-ribs attached to the plate (Planté plate design), or a matrix of spiral buttons inserted into the plate (Manchex design).

Battery racks are normally frames of steel channels, angles, and struts that support the batteries above the floor. Racks can be multi-rowed, multi-tiered, or multi-stepped. Multi-rowed racks are adjacent rows of batteries all at the same level. Multi-tiered racks are vertical rows of batteries mounted directly above each other. Multi-stepped racks have each succeeding row of batteries located above and to the rear of the previous row.

The shelf that supports the batteries typically consists of steel channels running longitudinally that are, in turn, supported by transverse rectangular frames of steel angles. The racks are usually braced by diagonal struts along either the front or rear face for longitudinal support. The rack members are connected by a combination of welds and bolts.

Well-designed battery racks include a restraining rail running longitudinally along the front and the rear of the row of batteries and wrapping around the ends of the row. The rails are located at about mid-height of the battery, and can prevent accidental overturning of the batteries, or overturning from earthquake loadings.

The battery (including the cell jar and enclosed plates, the supporting rack, electrical connections between batteries (bus bar), and attached electrical cable) are included in the Batteries on Racks equipment class.

[1] Section B.15 of SQUG GIP (Ref. 1)

8.1.1.1 *Reference Spectrum Caveats - Batteries On Racks*

The *Reference* Spectrum (*R*S) represents the seismic capacity of Batteries on Racks (BAT) if the batteries and racks meet the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

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

BAT/*R*S Caveat 2 - Plates of the Battery Cells Are Lead-Calcium Flat-Plate or They Are of Planté or Manchex Design. The plates of the battery must be of the lead-calcium flat-plate or the Planté or Manchex design. These are the only battery cell types included in the earthquake experience equipment class.

BAT/*R*S Caveat 3 - Each Individual Battery Weighs Less Than 450 Pounds. Individual battery cells should weigh less than about 450 pounds. This is the upper bound weight of the battery cells included in the earthquake experience equipment class.

BAT/*R*S Caveat 4 - Close-Fitting, Crush-Resistant Spacers Between Cells. There should be close-fitting, crush-resistant spacers between the cells, which fill about two-thirds of the vertical space between the cells. The concern is that the batteries without spacers can rock and collide during the earthquake causing malfunction and damage.

BAT/*R*S Caveat 5 - Batteries Restrained by Side and End Rails. The battery racks should have end and side rails incorporated in the design. The end and side rails should also be close fitting against the cells (with shims, if needed). The concern is that batteries on racks without end and side rails may tip or slide off the rack.

BAT/*R*S Caveat 6 - Battery Racks Have Longitudinal Cross Bracing. The racks should have longitudinal cross bracing unless engineering judgment or analysis shows that such bracing is not needed. The concern is that racks without cross bracing may not be able to transfer the lateral seismic loads to the base support. Simple bounding hand calculations are recommended to show that the structural components of the rack are capable of transferring these loads. The capacity of rack steel members may be calculated following AISC Part 2 *(Ref. 81)* allowable stresses.

BAT/*R*S Caveat 7 - Racks Constructed of Wood To Be Evaluated. Battery racks constructed of wood should be specially evaluated. The concern is that racks constructed of wood may be more vulnerable to seismic loads than steel racks. Evaluation of the rack should consider industry accepted structural design standards for wood construction, using extreme load allowable stresses as appropriate.

BAT/*R*S Caveat 8 - Batteries Greater Than 10 Years Old To Be Evaluated. Batteries that are more than 10 years old should be identified as outliers. The concern with the aging of batteries is that some models have been shown by shake table testing to be susceptible to structural and or metallurgical changes with time that result in either structural failure or reduced capacity after vibration.

BAT/*R*S Caveat 9 - Any Other Concerns? *SCEs* should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the batteries on racks.

8.1.1.2 GERS *Caveats* - Batteries on Racks

*The seismic capacity for* the equipment class of Batteries on Racks (BAT) *may be* based on generic testing data, provided the intent of each of the caveats listed below is met. This equipment class includes storage battery sets of the lead-calcium type supported on racks with rail restraints. Each battery set consists of multiple lead-acid cells (nominal 2 volts each) interconnected by rigid bus connectors. Rows or groups of cells are connected by flexible bus connectors. The racks have either a two-step or single-tier configuration with longitudinal cross-braces. The racks have rail restraints to keep the batteries in place. There are snug-fitting spacers between the cells and, if needed, shims between the cells and rails. This equipment class covers typical stationary lead-acid battery cells used in *facilities.*

The GERS *(see Figure 8.1.1-2)* represent the seismic capacity of Batteries on Racks (BAT) if the batteries and racks meet the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

BAT/GERS Caveat 1 - Generic Seismic Testing Equipment Class. The batteries and racks should be similar to and bounded by the BAT class of equipment described above. The equipment class descriptions are general and the *SCEs* should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

BAT/GERS Caveat 2 - *Reference* Spectrum Caveats Apply. The batteries on racks should meet all the caveats given for the *Reference* Spectrum. This caveat is included to cover the vulnerabilities identified for the earthquake experience equipment class. Those GERS caveats which are the same as the *Reference* Spectrum caveats are not repeated below.

BAT/GERS Caveat 3 - Lead-Calcium Plates. The plates of the battery cell should be lead-calcium. Lead-calcium battery cells are the only type included in the generic seismic testing equipment class.

BAT/GERS Caveat 4 - Supported on Two-Step or Single-Tiered Racks with Longitudinal Cross-Braces. The batteries should be supported on two-step racks or single-tier racks which have longitudinal cross-braces as supplied by the battery manufacturer (review of manufacturer's submittals is sufficient). A row of batteries should be restrained by double rails in front, back and on the ends, symmetrically placed with respect to the cell center of gravity. The concerns addressed by this caveat are that racks may not be able to transfer the lateral seismic loads to the base support, and that the natural frequencies of the rack may be lower than those in the generic seismic testing equipment class.

If the battery rack is custom made and/or does not have longitudinal cross-braces supplied by the manufacturer, then the intent of this caveat can be satisfied by showing that the racks have adequate strength (i.e., within 1.6 times normal AISC allowable stress limits) and have natural frequencies above about 8 Hz horizontal and 20 Hz vertical. If the natural frequency of the rack is below these values, then a realistic amplification through the rack to the center of gravity of the batteries should be included when determining the amplified response of the batteries for comparison to the GERS (for this case the GERS represents the battery capacity).

If the racks only have a single rail, then this rail should be evaluated to determine whether it will hold the cells in place and prevent significant relative motion between cells.

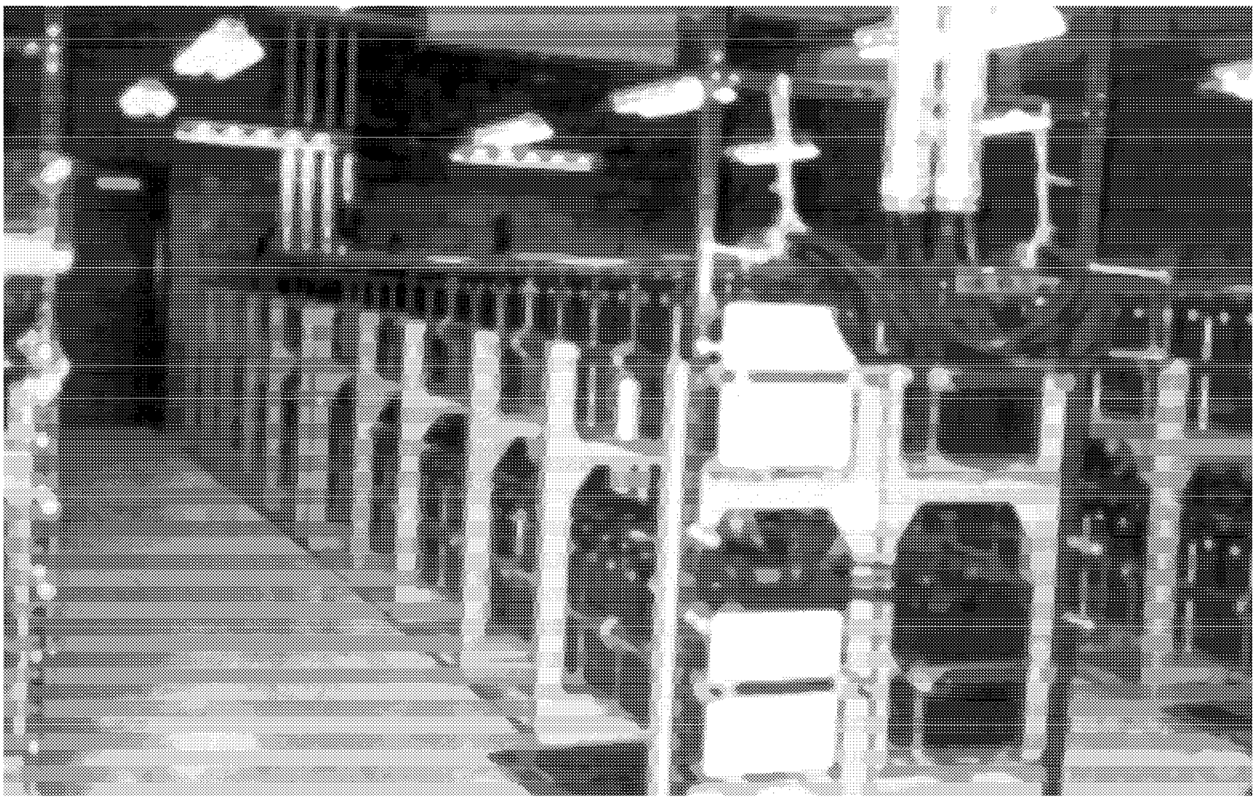
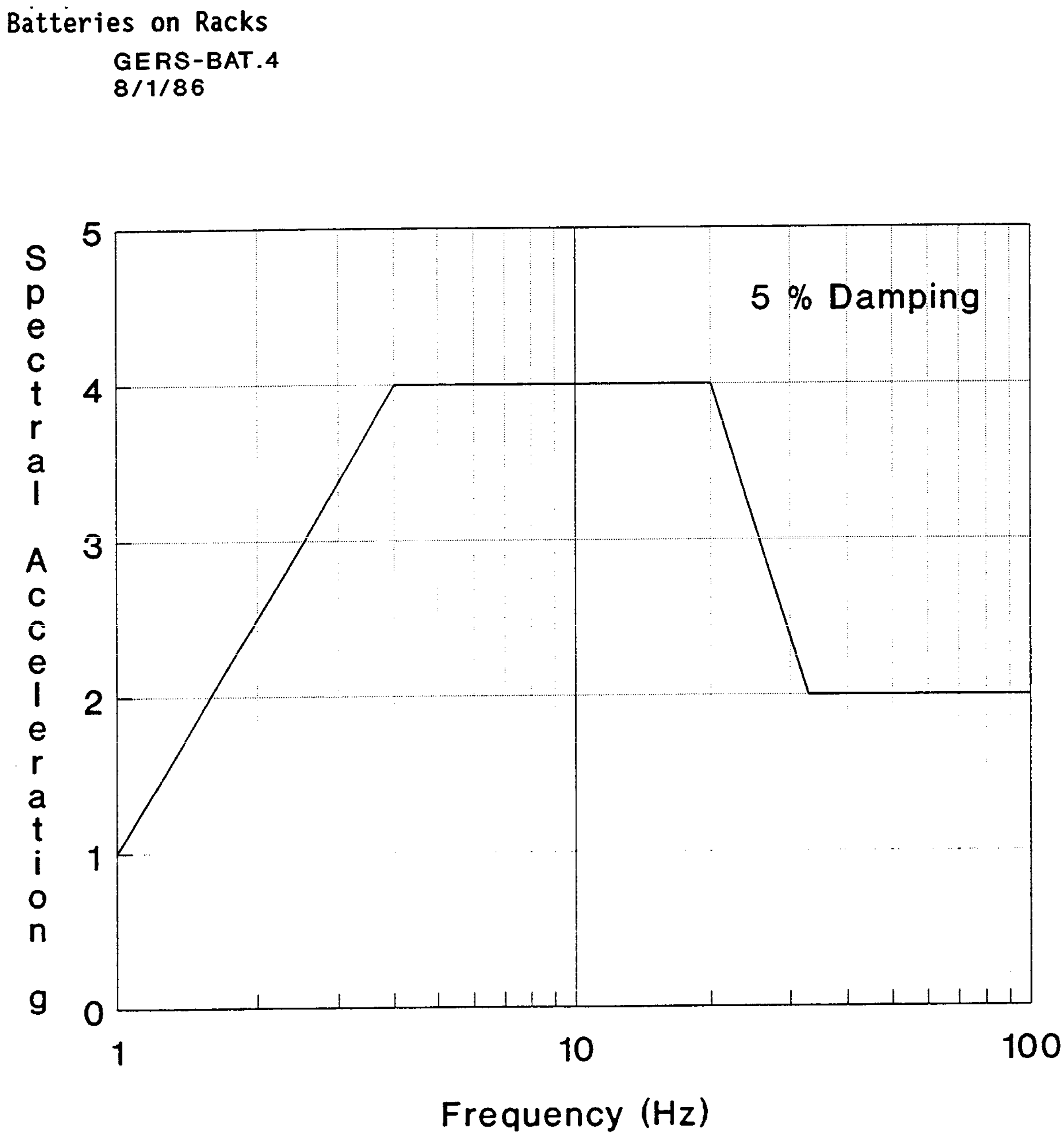


**Figure 8.1.1-1 Batteries on Racks from the Earthquake Experience Database**




| Frequency (Hz) | 1 | 4 | 20 | 33 |
|---|---|---|---|---|
| Batteries on Racks (g) | 1.0 | 4.0 | 4.0 | 2.0 |

**Figure 8.1.1-2 Generic Equipment Ruggedness Spectra (GERS) for Batteries on Racks (Reference 40) (Figure B.15-1 of SQUG GIP, Reference 1)**

## 8.1.2 MOTOR CONTROL CENTERS[2]

*The seismic capacity for* the equipment class of motor control centers (MCCs) *(see Figure 8.1.2-1) may be* based on earthquake experience data, provided the intent of each of the caveats listed below is met. This equipment class includes control and electrical fault protection systems for motors powered at 600 volts or less (typically 480 volts). Motor controllers are mounted in sheet metal cubicles with controller cubicles typically assembled into stacks which are lined up side-by-side and bolted together to form a motor control center. This equipment class includes motor controllers mounted in individual cubicles on racks or walls as well as freestanding MCCs.

Individual motor controllers are normally mounted in a sheet metal box that can be removed from its cubicle in the motor control center. Motor controllers are arranged in vertical stacks or sections attached to each other within the MCC assembly. The individual components of the motor controller are attached to the sides and rear face of the box. Motor controller cubicles typically include the following types of components: molded case circuit breaker (or disconnect switch), magnetic contactors, a control transformer, fuses, push buttons, and pilot lights.

The motor controller cubicles are typically arranged in vertical stacks within an MCC assembly. Each stack is a separate sheet metal enclosure, usually reinforced at its corners by overlapped sheet metal or steel angle framework. Stacks are bolted together through adjacent sheet metal side walls or steel framework.

Motor control centers may be either single- or double-sided. Double-sided MCCs have controller cubicles on both the front and rear face of the cabinet, with vertical bus bars routed through a center compartment between the front and rear stacks of controller cubicles. Single-sided MCCs typically route electrical connections through vertical raceways along the sides of each stack section.

Motor control centers may be either freestanding units or form part of a more complex assembly. In many cases, MCCs are included in an assembly with switchgear, distribution panels, and/or transformers. Another alternative to the freestanding motor control center is the wall- or rack-mounted motor control cubicle. Within these cubicles, motor control components are bolted to the inner faces of the wall in the same manner as in a small control or instrument cabinet. Access to the cubicle is usually through a swinging door that forms the front face of the cubicle.

MCC cabinet dimensions are generally standardized. Most MCC sections (stacks) are typically 20 to 24 inches wide, and 90 inches tall. The depth of each section typically varies from about 18 to 24 inches. Typical weight of each section is less than about 650 pounds.

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

The construction of motor control centers is typically governed by industry standards such as those developed by the National Electrical Manufacturers Association (NEMA) and Underwriters' Laboratories (UL) (e.g., NEMA ICS-6 *(Ref. 82)*, UL-508 *(Ref. 83))*. These standards define minimum sheet metal thickness as a function of wall area between reinforcement.

Motor control center assemblies represented in the equipment class contain motor starters (contactors), disconnect switches, and, in some cases, over-current relays. They also contain distribution panels, automatic transfer switches, and relay/instrumentation compartments, *and include attachments such as junction boxes, conduit and cables.* Motor controllers are represented

[2] Section B.1 of SQUG GIP (Ref. 1)

in a variety of mounting configurations ranging from individual mounted controllers to MCC assemblies in outdoor enclosures.

8.1.2.1 *Reference Spectrum Caveats - Motor Control Centers*

The *Reference* Spectrum (*R*S) represents the seismic capacity of a Motor Control Center (MCC) if the MCC meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

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

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

MCC/*R*S Caveat 3 - Adjacent Cabinets Bolted Together. Adjacent cabinets which are close enough to impact each other and sections of a multi-bay cabinet assembly should be bolted together if any of these cabinets contains essential relays as defined in *Chapter 11*. The concern addressed in this caveat is that unbolted cabinets could respond out of phase to one another and impact each other during an earthquake. This would cause impact loadings and high frequency vibration loadings which could cause any essential, impact-sensitive relays to chatter.

MCC/*R*S Caveat 4 - Attached Weight of 100 Pounds or Less. Equipment and their enclosures (but not conduit) mounted externally to cabinets and supported by them should have a weight less than about 100 pounds for a cabinet assembly, *i.e., a combination or a lineup of a number of individual adjacent cabinets, bays, or frames*. The concern is that the center of gravity of the cabinet will be raised too high, the total weight of the cabinets will be too large, or large eccentric weights will introduce excessive torsion. This concern is directed primarily toward equipment which is attached to the cabinet but is not normally supplied with the MCC and thereby possibly not included in the earthquake experience equipment class. The load path for the attached component through the cabinet should be carefully examined. In addition, its attachment should be reviewed to ascertain whether the attached component may become a seismic interaction hazard source. Conduit was deleted from this caveat since conduit supported above an MCC is well represented by the earthquake experience data. Additional support of the cabinet and attached equipment will alleviate these concerns and satisfy the intent of this caveat.

For the purposes of anchorage checking, the effective weight of any attached conduit and equipment should be included in the cabinet weight.

MCC/*R*S Caveat 5 - Externally Attached Items Rigidly Anchored. Externally attached items should be rigidly attached to the cabinet. The concern addressed by this caveat is that these items could impact the cabinet and possibly lead to relay chatter, or impact other components of the MCC as a seismic interaction hazard. As an example, some electrical cabinets have small, externally attached panels mounted on hinges to the main cabinet frame. During seismic motion the externally attached panel may swing and cause significant impact loading to the electrical panel.

MCC/*R*S Caveat 6 - General Configuration Similar to NEMA Standards. The general configuration of the cabinets should be similar to those constructed to NEMA Standards. The MCC does not have to conform exactly to the NEMA standards but should be similar with regard to the gage of the steel, internal structure and support. This caveat is intended to preclude unusual designs not covered by the equipment class (thin gage material, flimsy internal structure, etc.). In general, cabinets manufactured by the major manufacturers of MCCs conform to this caveat if they have not been modified. *Cabinets which are less than 18-inches tall and are not top braced are outliers.*

MCC/*R*S Caveat 7 - Cutouts Not Large. Cutouts in the lower half of the cabinet sheathing should be less than 6 inches wide and 12 inches high. A second concern is that the shear load from the earthquake will not be able to be transferred through the shear walls to the anchorage. There are many standard MCCs that exceed this caveat; however, in many cases, the area around the cutout is reinforced with additional plate or steel members alleviating the concern of shear transfer. This caveat is of more concern for cutouts modifying the standard design that are not reinforced.

MCC/*R*S Caveat 8 - Doors/Buckets Secured. All doors and drawout buckets should be secured by a latch or fastener. The concern addressed by this caveat is that the doors and drawout buckets could open during an earthquake and repeatedly impact the housing, causing internal components such as relays and contactors to malfunction or chatter.

MCC/*R*S Caveat 9 - Any Other Concerns? The *SCEs* should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the MCC.

#### 8.1.2.2 GERS *Caveats* - Motor Control Centers

*The seismic capacity for* the equipment class of MCCs *may be* based on generic testing data, provided the intent of each of the caveats listed below is met. This equipment class includes control and electrical fault protection systems for motors powered at 600 VAC (480 VAC nominal), 250 VDC, or less. MCCs in the testing equipment class typically include several enclosure sections which are normally about 20 inches wide, about 20 inches deep, and about 90 inches high. These sections are fabricated of 14 gage (0.0747 inches thick) or heavier steel sheets and are supported at the floor on base channels which are either integral with the MCC frame or are external members connected by internal bolts to the MCC frame. Multiple MCC sections may be grouped together to make widths to 120 inches or greater. The weight per section of these MCCs ranges from 200 to 800 pounds.

The types of components typically housed within MCCs in the equipment class include contactors, overload relays, various types of other relays, circuit breakers, disconnect switches, control or distribution transformers, and panelboards. MCCs may also have indicator lamps and meters mounted on them.

The GERS *(see Figure 8.1.2-2)* represent the seismic capacity of a Motor Control Center (MCC) if the MCC meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

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

MCC/GERS Caveat 2 - *Reference* Spectrum Caveats. The MCC should meet all the caveats given for the *Reference* Spectrum. This caveat is included to cover the vulnerabilities identified for the earthquake experience equipment class. Those GERS caveats which are the same as the *Reference* Spectrum caveats are not repeated below.

MCC/GERS Caveat 3 - Floor-Mounted Cabinet. The MCC should be floor-mounted. This is the mounting configuration for all MCCs in the generic seismic testing equipment class.

MCC/GERS Caveat 4 - Weight Less Than 800 Pounds. The maximum weight per vertical section should be less than about 800 pounds. This is the upper bound weight of MCCs in the generic seismic testing equipment class.

MCC/GERS Caveat 5 - Anchored Through Base Channel. The MCC should be anchored through a base channel integral to the MCC frame or an external base channel which is connected to the MCC frame by internal bolts. The intent of this caveat is to avoid anchoring MCCs through flimsy or flexible sections in which significant bending of sheet metal could occur during an earthquake.

MCC/GERS Caveat 6 - Load Path Check. To use the "Function After" GERS, the load transfer path from the anchorage to base frame of the MCC should be checked for strength and stiffness. In particular, the following load path elements should be checked for adequacy. There should be stiff anchorage connections for each section to secure the unit to the floor, e.g., 4 anchors for a single MCC cabinet or 2 anchors for interior cabinets in a multi-cabinet assembly if these anchors are located near the shear wall of the cabinet and adjacent cabinets are bolted together. If the MCC frame is connected to external base structural members provided by the manufacturer with internal mounting bolts, then there should be at least four of these internal mounting bolts per section, and these bolts should be at least 3/8 inches in diameter. Any sheet metal cabinet components used for anchorage should have reinforcement. Excessive eccentricities in the internal load path which allow significant bending of sheet metal should be evaluated separately for strength and stiffness.

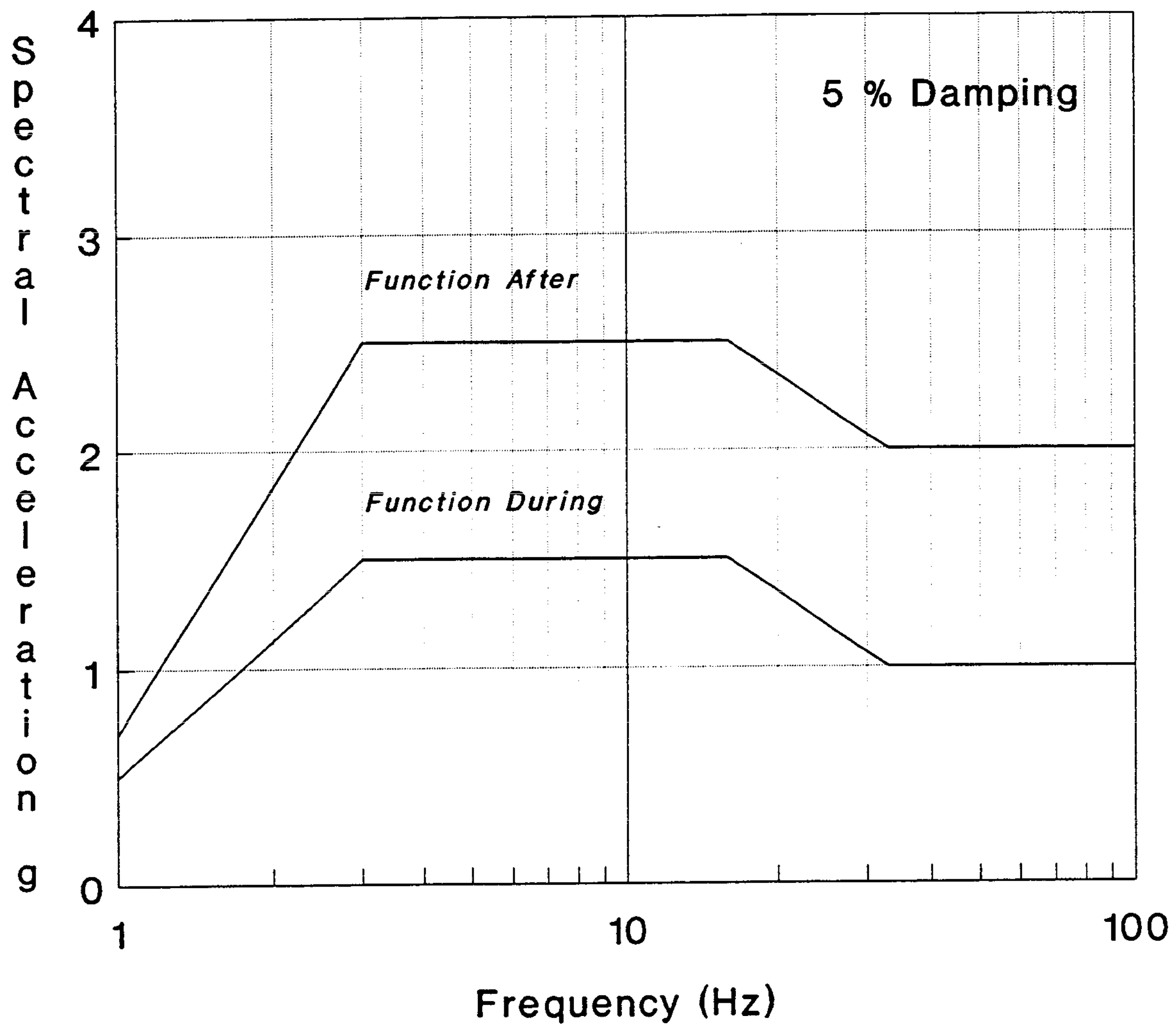
MCC/GERS Caveat 7 - "Function During" GERS. The "Function During" GERS can be used only if all the relays within the MCC have GERS greater than 4.5g within the amplified spectral region. For this caveat, the term "relays" does not include contactors and other starter components. Auxiliary contacts of contactors require a separate relay evaluation as described in *Chapter 11* if they are used for external control or lockout signals.

MCC/GERS Caveat 8 - "Function After" GERS. The "Function After" GERS can be used if it can be demonstrated that the starters can be reset. The Relay Functionality Review in *Chapter 11* describes the guidelines for evaluating the acceptability of resetting relays and starters. Note that, in general, both system tolerance of the changed state and operator availability for manual reset should be shown.

*MCC/GERS Caveat 9 - Adjacent Cabinets Bolted Together. Adjacent cabinets and sections of a multi-bay cabinet assembly should be bolted together, including those that do not contain essential relays. Adjacent cabinets and sections of multi-bay cabinet assemblies were bolted together when tested for this generic seismic testing equipment class.*


**Figure 8.1.2-1 Motor Control Center from the Earthquake Experience Database**

GERS-MCC.9
2/1/91




| Frequency (Hz) | 1 | 3 | 16 | 33 |
|---|---|---|---|---|
| Function After (g) | 0.7 | 2.5 | 2.5 | 2.0 |
| Function During (g) | 0.5 | 1.5 | 1.5 | 1.0 |

**Figure 8.1.2-2 Generic Equipment Ruggedness Spectra (GERS) for Motor Control Centers (Reference 40) (Figure B.1-1 of SQUG GIP, Reference 1)**

### 8.1.3 LOW-VOLTAGE SWITCHGEAR[3]

*The seismic capacity for* the equipment class of low voltage switchgear (LVS) assemblies *(see Figure 8.1.3-1) may be* based on earthquake experience data, provided the intent of each of the caveats listed below is met. This equipment class consists of one or more circuit breakers and associated control relays, instrumentation, disconnect switches, and distribution buses mounted in a sheet metal enclosure. The term "low voltage switchgear" is associated with circuits of 600 volts or less, typically 440 to 480 volts in modern *industrial* facilities.

Switchgear assemblies are composed of vertical sections which normally contain stacks of two to four circuit breaker cubicles. The vertical section is a sheet metal enclosure welded to a framework of steel angles or channels. Each section includes a circuit breaker or other control devices in a forward compartment and bus connections for the primary circuits in the rear compartment.

A section of a switchgear assembly is typically 90 inches in height and 60 inches in depth. The width of each section ranges from 20 to 36 inches, depending on the size of the circuit breaker it contains. A typical section weighs about 2000 pounds. Individual sections are bolted together through adjoining walls to form an assembly. LVS assemblies normally include at least one cubicle that serves as a metering compartment. The compartment typically contains ammeters, voltmeters, relays, and transformers.

Most low-voltage circuit breakers are the drawout type. They are mounted on a roller/rail support system that allows them to be disconnected from their primary contacts at the rear, and drawn forward out of their sheet metal enclosure for maintenance. While in operation, the circuit breaker clamps to bus bars in the rear of the switchgear assembly. Additional positive attachment of the breaker to its enclosure is made by a mechanical jack or racking mechanism which slides the breaker in or out of its operating position.

The circuit breaker can include the following types of components: spring-actuated electric contacts, a closing solenoid, various types of tripping devices (overcurrent, shunt, under voltage), fuses, and auxiliary switches.

Low-voltage breakers may be combined in assemblies with transformers, distribution panels, medium voltage breakers, and motor controllers. Circuit breakers, relays, instrumentation, the switchgear assembly enclosure, internal transformers, attachments such as junction boxes, and attached conduit and cables are included in the Low-Voltage Switchgear equipment class.

#### 8.1.3.1 *Reference Spectrum Caveats - Low-Voltage Switchgear*

The *Reference* Spectrum (*R*S) represents the seismic capacity of a Low-Voltage Switchgear (LVS) if the switchgear meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

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

LVS/*R*S Caveat 2 - Rating of 600 V or Less. The low voltage switchgear should have a 600 V rating or less. This is the upper bound voltage rating of LVS in the earthquake experience equipment class.

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[3] Section B.2 of SQUG GIP (Ref. 1)

LVS/*R*S Caveat 3 - Side-to-Side Restraint of Breaker. The support structure for circuit breakers of the drawout type should have side-to-side restraint to limit relative motion with respect to the cabinet. The concern is to prevent damage or disconnection of secondary contacts. Restraint may be provided by the breaker support structure or by a special lateral restraint device.

LVS/*R*S Caveat 4 - Adjacent Cabinets Bolted Together. Adjacent cabinets which are close enough to impact each other and sections of multi-bay cabinet assemblies should be bolted together if any of these cabinets contain essential relays as defined in *Chapter 11*. The concern addressed in this caveat is that unbolted cabinets could respond out of phase to one another and impact each other during an earthquake. This would cause additional impact loadings and high frequency vibration loadings which could cause any essential relays to chatter.

LVS/*R*S Caveat 5 - Attached Weight of 100 Pounds or Less. Equipment and their enclosures (but not conduit) mounted externally to cabinets and supported by them should have a weight less than about 100 pounds for a cabinet assembly, *i.e., a combination or a lineup of a number of individual adjacent cabinets, bays, or frames*. The concern is that the center of gravity of the cabinet will be raised too high, the total weight of the cabinets will be too large, or large eccentric weights will introduce excessive torsion. The concern is directed primarily for equipment not normally supplied with the switchgear and thereby possibly not included in the earthquake experience equipment class. The load path of the attached component through the cabinet should be carefully examined. In addition, its attachment should be reviewed to ascertain whether the attached component may become a seismic interaction hazard source. Conduit was deleted from the caveat since conduit supported above switchgear is well represented by the earthquake experience data. Additional support of the cabinet and attached equipment will alleviate these concerns and satisfy the intent of this caveat.

For the purposes of anchorage checking, the effective weight of any attached conduit and equipment should be included in the cabinet weight.

LVS/*R*S Caveat 6 - Externally Attached Items Rigidly Anchored. Externally attached items should be rigidly attached to the cabinet. The concern addressed by this caveat is that these items could impact the cabinet and possibly lead to relay chatter, or impact other components of the switchgear as a seismic interaction hazard. As an example, some electrical cabinets have small, externally attached panels mounted on hinges to the main cabinet frame. During seismic motion the externally attached panel may swing and cause significant impact loading to the electrical panel.

LVS/*R*S Caveat 7 - General Configuration Similar to ANSI C37.20 Standards. The general configuration of the cabinets should be similar to those constructed to ANSI C37.20 Standards *(Ref. 84)*. The switchgear does not have to conform exactly to ANSI standards but should be similar with regard to the gage of the steel, internal structure and support. This caveat is intended to preclude unusual designs not covered by the equipment class (thin gage material, flimsy internal structure, etc.) In general, cabinets manufactured by the major manufacturers of switchgear conform to this caveat if they have not been modified.

LVS/*R*S Caveat 8 - Cutouts Not Large. Cutouts in the lower half of cabinet sheathing should be less than 30% of the width of the side panel, and the height of the cutout should be less then 60% of the width of the side panel. This caveat also applies to side panels between multi-bay cabinets. Cutout restrictions do not apply to the bus transfer compartment if the remaining part of the enclosure conforms with the cutout limitation. The concern of this caveat is that the shear load from the earthquake will not be able to be transferred through the shear walls to the anchorage. Reinforcement around the cutout with additional plate or steel members may alleviate the concern of shear transfer.

LVS/RS Caveat 9 - Doors Secured. All doors should be secured by a latch or fastener. The concern addressed by this caveat is that loose doors could repeatedly impact the housing and be damaged or cause internal components such as relays to malfunction or chatter.

LVS/RS Caveat *10* - Any Other Concerns? *SCEs* should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the switchgear.

### 8.1.3.2 GERS *Caveats* - Low-Voltage Switchgear

*The seismic capacity for* the equipment class of LVS *may be* based on generic testing data, provided the intent of each of the caveats listed below is met. This equipment class includes steel enclosures containing several draw-out type circuit breakers, bus bars, protective/auxiliary relays, and meters. Units have a maximum rating of 600 VAC or 250 VDC. The metal enclosure sections are typically 20 to 30 inches wide, 60 inches deep, and 80 to 90 inches high. They are fabricated of 14 gage (0.0747 inches thick) or heavier steel sheet metal and framed with angles or other formed members, with anchorage provisions included in the base frame. The weight per section of the switchgear assembly ranges from 1000 to 1600 pounds. The units should be mounted within ANSI-type metal enclosures with either welded or bolted anchorage. To exclude specialty-type switchgear, the equipment class is limited to the following three manufacturers: ITE/Brown Boveri, Westinghouse, or General Electric.

The GERS *(see Figure 8.1.3-2)* represent the seismic capacity of a Low-Voltage Switchgear (LVS) if the switchgear meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

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

LVS/GERS Caveat 2 - *Reference* Spectrum Caveats Apply. The switchgear should meet all the caveats given for the *Reference* Spectrum. This caveat is included to cover the vulnerabilities identified for the earthquake experience equipment class. Those GERS caveats which are the same as the *Reference* Spectrum caveats are not repeated below.

LVS/GERS Caveat 3 - Floor-Mounted Switchgear. The low voltage switchgear must be housed within a floor-mounted ANSI-type enclosure. This ensures consistency with enclosures included in the generic seismic testing equipment class.

LVS/GERS Caveat 4 - No Specially-Designed Switchgear. The GERS are not applicable to specially-designed or custom made switchgear, such as those which have been used in some reactor trip systems. To preclude their use, the switchgear should be manufactured by either ITE/Brown Boveri, Westinghouse, or General Electric. These are the manufacturers which produced the switchgear included in the generic seismic testing equipment class.

LVS/GERS Caveat 5 - Weight Per Section Less than 1600 Pounds. The maximum weight per section should be less than about 1600 pounds. This is the upper bound weight limit of LVS in the generic seismic testing equipment class.

LVS/GERS Caveat *6* - Vertical Restraint in the Form of Stops or Brackets. To utilize the 2.5g GERS level, vertical restraint in the form of stops or brackets should be provided to prevent uplift of the circuit breaker so that the wheels do not come disengaged from rails.

LVS/GERS Caveat *7* - Reinforcement of Outside Corners of End Units. To utilize the 2.5g GERS level, the outside base frame corners of the outer switchgear cabinets in a lineup should have certain enhancements to improve their seismic ruggedness. For Westinghouse type switchgear, the outside base frame corners of the outer switchgear cabinets in a lineup should be reinforced. For the other types of switchgear, the manufacturers (GE, ITE) should be consulted to determine what enhancements, if any, should be included in their switchgear cabinets to give them this seismic ruggedness level and then check whether these enhancements have been included on these units.

*LVS/GERS Caveat 8 - Adjacent Cabinets Bolted Together. Adjacent cabinets and sections of a multi-bay cabinet assembly should be bolted together. Adjacent cabinets and sections of multi-bay cabinet assemblies were bolted together when tested for this generic seismic testing equipment class.*

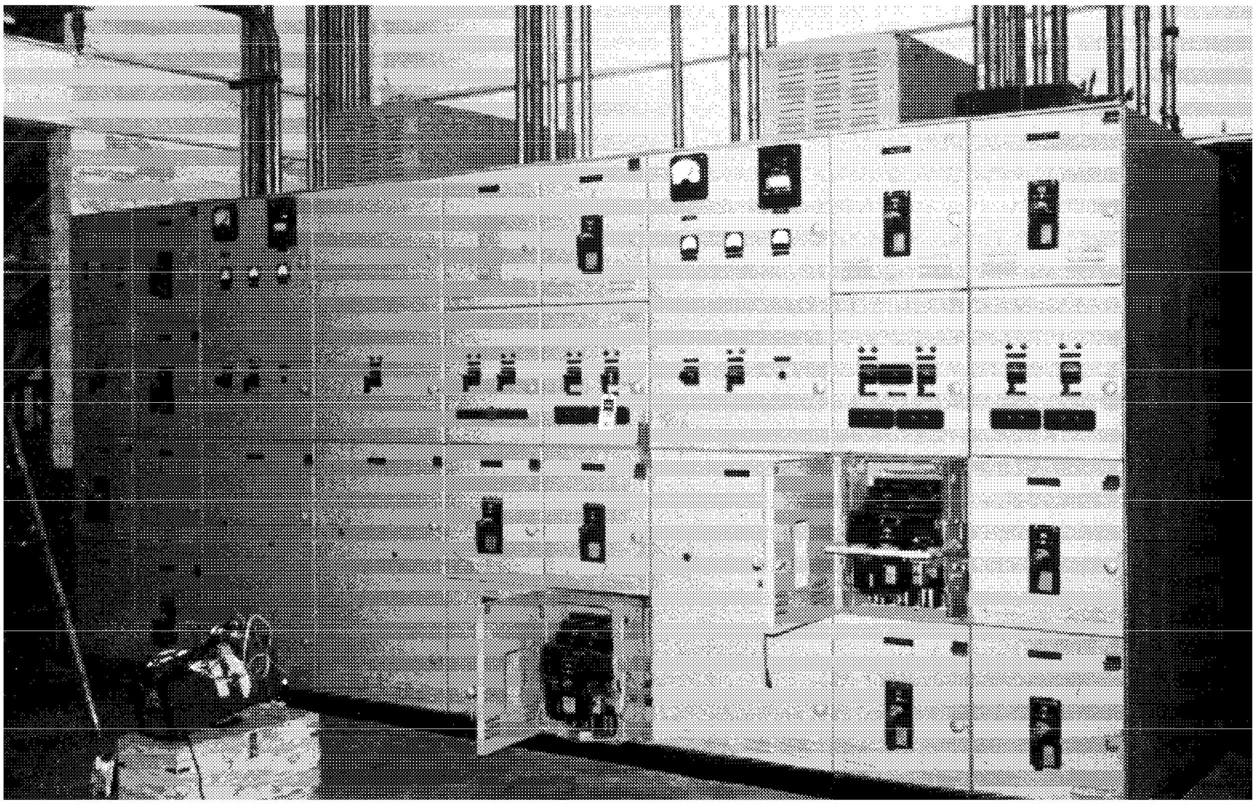
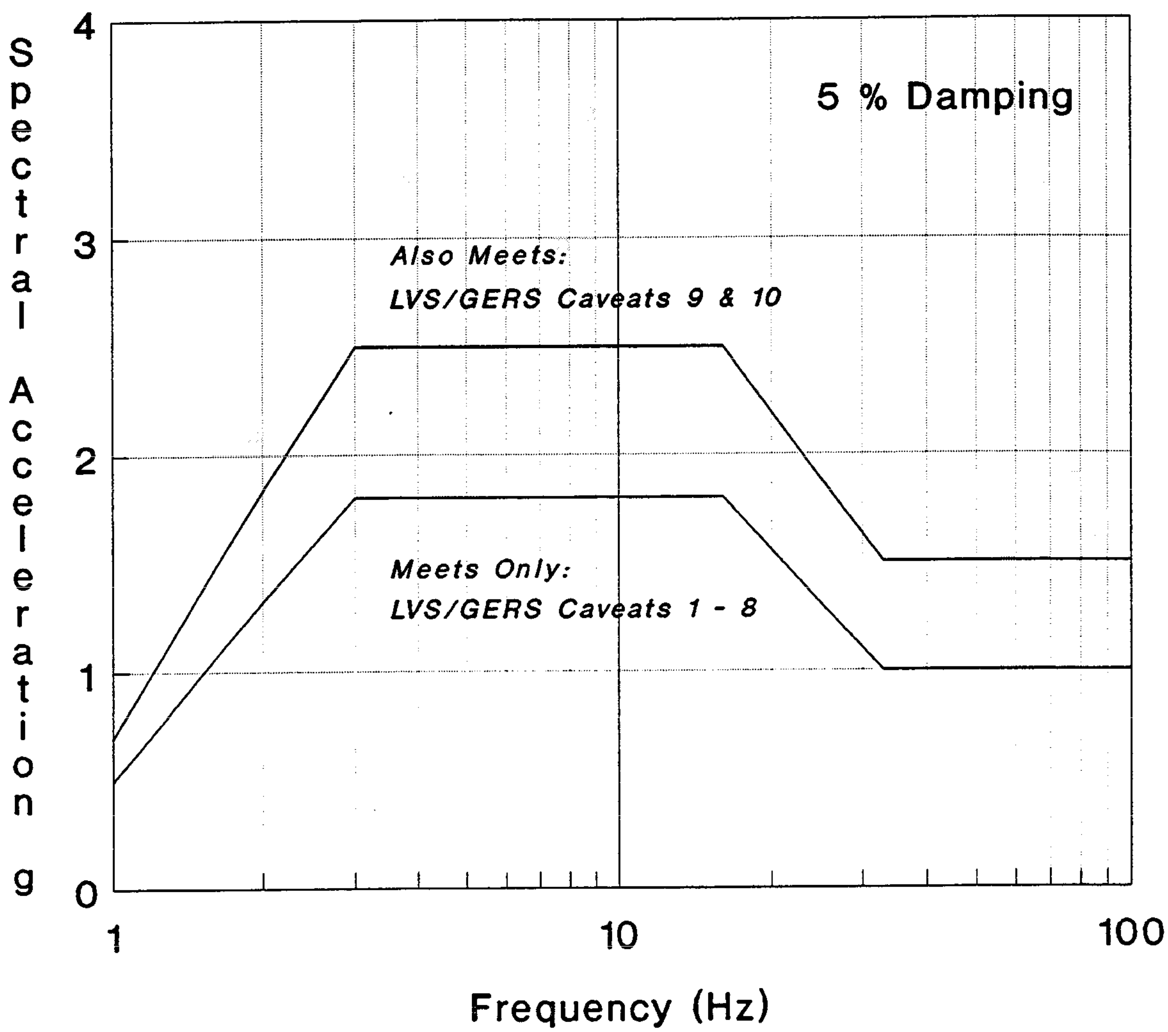


**Figure 8.1.3-1 Low-Voltage Switchgear from the Earthquake Experience Database**

Low Voltage Switchgear

GERS-MVS/LVS.7 (Low Voltage)
2/1/91




| Frequency (Hz) | 1 | 3 | 16 | 33 |
|---|---|---|---|---|
| Meets LVS/GERS Caveats 1 - 10 (g) | 0.7 | 2.5 | 2.5 | 1.5 |
| Meets LVS/GERS Caveats 1 - 8 (g) | 0.5 | 1.8 | 1.8 | 1.0 |

**Figure 8.1.3-2 Generic Equipment Ruggedness Spectra (GERS) for Low-Voltage Switchgear (Reference 40) (Figure B.2-1 of SQUG GIP, Reference 1)**

### 8.1.4 MEDIUM-VOLTAGE SWITCHGEAR[4]

*The seismic capacity for* the equipment class of medium voltage switchgear (MVS) assemblies *(see Figure 8.1.4-1) may be* based on earthquake experience data, provided the intent of each of the caveats listed below is met. This equipment class consists of one or more circuit breakers and associated control relays and instrumentation mounted in a sheet metal enclosure. The equipment class includes electrical switching and fault protection circuit breakers for systems powered between 2400 and 4160 volts. Medium-voltage circuit breakers are mounted in sheet metal cabinets which are bolted together, side-by-side, to form a switchgear assembly.

Medium-voltage circuit breakers or load interrupter switches are often integrated into unit substations that may include a transformer (typically 4160/480 volt), a set of low-voltage switchgear, or a distribution switchboard. The switchgear assembly also may include internal transformers, junction boxes, and attached conduit and cables. The basic component of a medium voltage switchgear assembly is a metal-clad enclosure, typically containing a circuit breaker compartment in a lower section and a metering compartment in an upper section. The rear of the enclosure is a separate compartment for primary electrical connections. The enclosure consists of sheet metal panels welded to a supporting frame of steel angles or channels. Individual enclosures are typically 90 inches in height and approximately 90 inches in depth. The width of an enclosure typically varies from 24 to 36 inches, depending on the size of the circuit breaker within. The weight of a metal-clad enclosure ranges from 2000 to 3000 pounds, with the circuit breaker itself weighing from 600 to 1200 pounds.

Electro-mechanical relays are mounted either to the swinging doors at the front of the enclosure, or to the interior of the metering compartment. Relays are typically inserted through cutouts in the door and secured by screws through a mounting flange into the sheet metal. The metering compartment may also contain components such as ammeters, voltmeters, hand switches, and small transformers.

The medium-voltage circuit breakers commonly used in *facility* applications include the drawout-type air-magnetic circuit breakers, and stationary load interrupter switches. Each type is discussed in this section.

Drawout, air-magnetic circuit breakers are mounted on rollers to allow them to be wheeled in and out of their individual sheet metal enclosures. There are two general types of drawout circuit breakers: the horizontally-racked model and the vertically-racked model.

The <u>horizontally-racked</u> model has clamping bus connections at its rear. It is racked into operating position by a mechanical jack that rolls the circuit breaker into contact with the bus connections at the rear of its enclosure and secures it in place. The weight of the circuit breaker rests on the floor.

<u>Vertically-racked</u> circuit breakers roll into position within their enclosure and are then engaged by a jack built into the walls of the enclosure. The jack lifts the circuit breaker several inches above the floor, until the clamping connections atop the circuit breaker contact the bus connections at the top of the enclosure. The weight of the circuit breaker is then supported on the framework of the sheet metal enclosure. Lateral restraint of the circuit breaker should be provided by the cabinet framing and not solely by the jack lifts.

Air-magnetic circuit breakers typically include the following types of components: spring-actuated contacts, tripping devices, auxiliary switches, and fuses. Typical capacities for medium voltage circuit breakers range from 1200 to 3000 amperes.

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4 Section B.3 of SQUG GIP (Ref. 1)

Load interrupter switches perform the load connecting and interrupting function of circuit breakers, but do not include the same capabilities of electrical fault protection. Interrupter switches are bolted into sheet metal enclosures and are therefore designated as stationary devices. Like air-magnetic circuit breakers, interrupter switches usually operate with spring-actuated contacts to ensure quick opening of the primary circuit.

8.1.4.1 *Reference Spectrum Caveats - Medium-Voltage Switchgear*

The *Reference* Spectrum (*R*S) represents the seismic capacity of a Medium-Voltage Switchgear (MVS) if the switchgear meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

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

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

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

MVS/*R*S Caveat 4 - Adjacent Cabinets Bolted Together. Adjacent cabinets which are close enough to impact each other and sections of multi-bay cabinet assemblies should be bolted together if any of these cabinets contain essential relays as defined in *Chapter 11*. The concern addressed in this caveat is that unbolted cabinets could respond out of phase to one another and impact each other during an earthquake. This would cause additional impact loadings and high frequency vibration loadings which could cause the essential relays to chatter.

MVS/*R*S Caveat 5 - Attached Weight of 100 Pounds or Less. Equipment and their enclosures (but not conduit) mounted externally to cabinets and supported by them should have a weight less than about 100 pounds for a cabinet assembly, *i.e., a combination or a lineup of a number of individual adjacent cabinets, bays, or frames*. The concern is that the center of gravity of the cabinet will be raised too high, the total weight of the cabinets will be too large, or large eccentric weights will introduce excessive torsion. The concern is directed primarily for equipment not normally supplied with the switchgear and thereby possibly not included in the earthquake experience equipment class. The load path for the attached component through the cabinet should be carefully examined. In addition, its attachment should be reviewed to ascertain whether the attached component may become a seismic interaction hazard source. Conduit was deleted from the caveat since conduit supported above switchgear is well represented in the seismic experience data base. Additional support of the cabinet and attached equipment will alleviate these concerns and satisfy the intent of this caveat.

For the purposes of anchorage checking, the effective weight of any attached conduit and equipment should be included in the cabinet weight.

MVS/*RS* Caveat 6 - Externally Attached Items Rigidly Anchored. Externally attached items should be rigidly attached to the cabinet. The concern addressed by this caveat is that these items could impact the cabinet and possibly lead to relay chatter or impact other components of the switchgear as a seismic interaction hazard. As an example, some electrical cabinets have small, externally attached panels mounted on hinges to the main cabinet frame. During seismic motion the externally attached panel may swing and cause significant impact loading to the electrical panel.

MVS/*RS* Caveat 7 - General Configuration Similar to ANSI C37.20 Standards. The general configuration of the cabinets should be similar to those constructed to ANSI C37.20 Standards *(Ref. 84).* The switchgear does not have to conform exactly to ANSI standards but should be similar with regard to the gage of the steel, internal structure and support. This caveat is intended to preclude unusual designs not covered by the equipment class (thin gage material, flimsy internal structure, etc.). In general, cabinets manufactured by the major manufacturers of switchgear conform to this caveat if they have not been modified.

MVS/*RS* Caveat 8 - Cutouts Not Large. Cutouts in the lower half of cabinet sheathing should be less than 30% of the width of the side panel, and the height of the cutout should be less than 60% of the width of the side panel. This caveat also applies to side panels between multi-bay cabinets. Cutout restrictions do not apply to the bus transfer compartment if the remaining part of the enclosure conforms with the cutout limitations. The concern of this caveat is that the shear load from the earthquake will not be able to be transferred through the shear walls to the anchorage. Reinforcement around the cutout with additional plate or steel members may alleviate the concern of shear transfer.

MVS/*RS* Caveat 9 - Doors Secured. All doors should be secured by a latch or fastener. The concern addressed by this caveat is that the doors could open during an earthquake, and the loose door could repeatedly impact the housing and be damaged or cause internal components such as relays to malfunction or chatter.

MVS/*RS* Caveat *10* - Any Other Concerns? *SCEs* should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the switchgear.

### 8.1.4.2 GERS *Caveats* - Medium-Voltage Switchgear

*The seismic capacity for* the equipment class of metal clad medium-voltage switchgear *may be* based on generic testing data, provided the intent of each of the caveats listed below is met. This equipment class includes steel panel enclosures containing several wheel-mounted draw-out type circuit breakers, bus bars, auxiliary/ protective relays, transformers, switches, and meters. Units are medium voltage rated at 5000 VAC. Circuit breakers which must be jacked up to engage (vertical lift) into the connected position are not included in this class. The equipment in the GERS equipment class include ANSI C37.20 enclosures whose nominal section sizes are 30 inches wide, 60 inches deep, and 90 inches high. They are fabricated of 12 gage (0.1046 inches thick) or heavier steel sheet metal and framed with angles or other formed members, with anchorage provisions included in the base frame. Widths of MVS can range between 24 inches and 42 inches. Some cubicles can be essentially empty, while other cubicles can house very heavy circuit breaker units. In general, a single cubicle which houses a circuit breaker can typically weigh between 3000 and 5000 pounds. The MVS GERS equipment class covers most medium voltage switchgear used in *facilities* for overcurrent protection in primary voltage (normally 4160 VAC) distribution systems.

The GERS *(see Figure 8.1.4-2)* represent the seismic capacity of a Medium-Voltage Switchgear (MVS) if the switchgear meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

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

MVS/GERS Caveat 2 - *Reference* Spectrum Caveats Apply. The switchgear should meet all the caveats given for the *Reference* Spectrum. This caveat is included to cover the vulnerabilities identified for the earthquake experience equipment class. Those GERS caveats which are the same as the *Reference* Spectrum caveats are not repeated below.

MVS/GERS Caveat 3 - Floor-Mounted Switchgear. The medium-voltage switchgear should be housed within a floor-mounted ANSI-type enclosure. This ensures consistency with the enclosures included in the generic seismic testing equipment class.

MVS/GERS Caveat 4 - No Specially-Designed Switchgear. The GERS are not applicable to specially-designed or custom made switchgear, such as those which have been used in some reactor trip systems. Specially-designed switchgear are not included in the generic seismic testing equipment class.

MVS/GERS Caveat 5 - No Jack-Up or Vertical-Lift Type Breakers. The breakers should be the wheel-mounted type and not a jack-up or vertical-lift type. This is the only breaker configuration represented in the generic seismic testing equipment class.

MVS/GERS Caveat 6 - Weight Per Section Less than 5000 Pounds. The maximum weight per vertical breaker section should be less than about 5000 pounds (review of manufacturer's submittals is sufficient). This is the upper bound weight limit of sections included in the generic seismic testing equipment class.

MVS/GERS Caveat *7* - Vertical Restraint of Breaker. To utilize the 2.5g GERS level, vertical restraint in the form of stops or brackets should be provided to prevent uplift of the circuit breaker so that the wheels do not become disengaged from the rails.

MVS/GERS Caveat *8* - Horizontal Restraint of Arc Chutes. To utilize the 2.5g GERS level, horizontal restraint of the circuit breaker arc chutes should be provided. This restraint may take the form of blocks between adjacent arc chutes and between arc chutes and the wall or frame of the cabinet.

MVS/GERS Caveat *9* - Relay Model Excluded. The 2.5g level GERS can not be used for Westinghouse medium-voltage switchgear if the "Y" anti-pump relay is a Beaver Type Z.

MVS/GERS Caveat *10* - Separate Evaluation of Racking Mechanism. Breaker positioning or racking mechanisms should be evaluated. There should be side-to-side restraint of the breaker to prevent secondary/auxiliary breaker contacts from opening. The evaluation may consist of a visual inspection by the *SCEs*. This caveat is intended to address potential damage or operational problems due to excessive relative motion between the drawout breaker and the switchgear cabinet frame as observed in an example from the generic seismic test data.

*MVS/GERS Caveat 11 - Adjacent Cabinets Bolted Together. Adjacent cabinets and sections of a multi-bay cabinet assembly should be bolted together. Adjacent cabinets and sections of multi-bay cabinet assemblies were bolted together when tested for this generic seismic testing equipment class.*

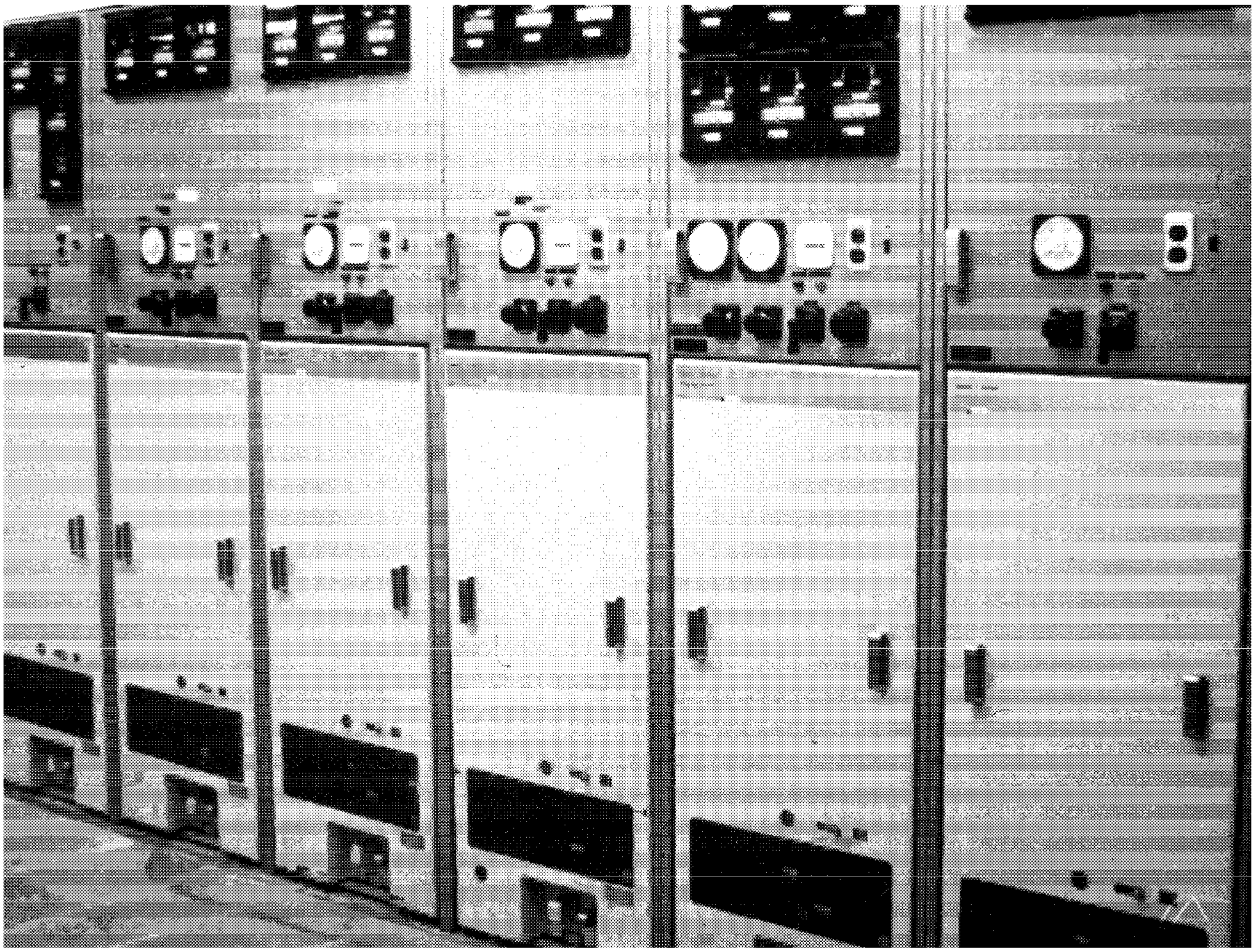
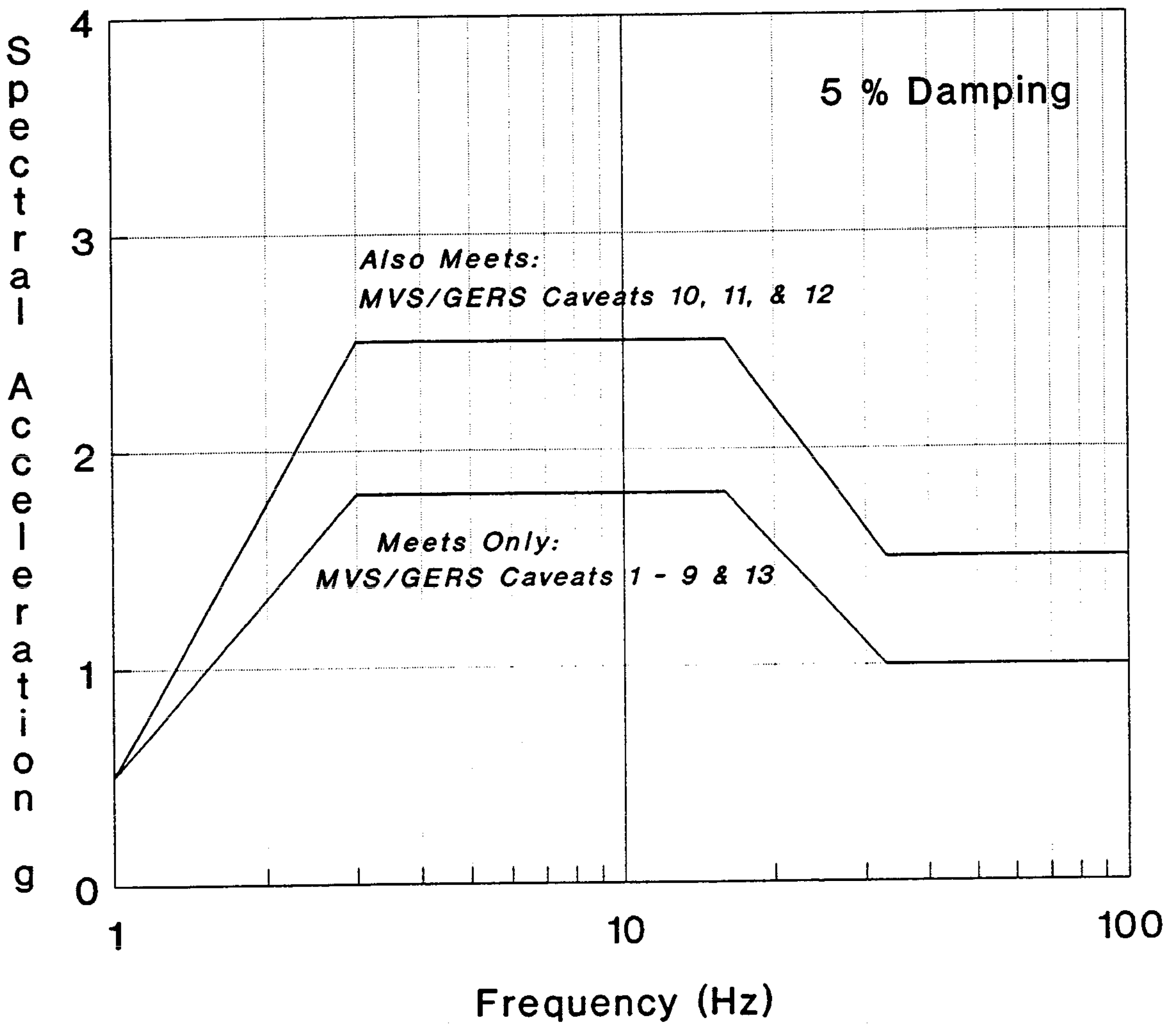


**Figure 8.1.4-1 Medium-Voltage Switchgear from the Earthquake Experience Database**

Medium Voltage Switchgear

GERS-MVS/LVS.7 (Medium Voltage)
2/1/91




| Frequency (Hz) | 1 | 3 | 16 | 33 |
|---|---|---|---|---|
| Meets MVS/GERS Caveats 1 - 13 (g) | 0.5 | 2.5 | 2.5 | 1.5 |
| Meets MVS/GERS Caveats 9 & 13 (g) | 0.5 | 1.8 | 1.8 | 1.0 |

**Figure 8.1.4-2 Generic Equipment Ruggedness Spectra (GERS) for Medium-Voltage Switchgear (Reference 40) (Figure B.3-1 of SQUG GIP, Reference 1)**

## 8.1.5 DISTRIBUTION PANELS[5]

*The seismic capacity for* the equipment class of Distribution Panels (DP) *(see Figure 8.1.5-1) may be* based on earthquake experience data, provided the intent of each of the caveats listed below is met. This equipment class consists of circuit breakers or fusible disconnect switches mounted in vertical stacks within sheet metal cabinets. The function of distribution panels is to distribute low voltage AC or DC power from a main circuit to branch circuits, and to provide overcurrent protection. Distribution panels typically serve AC power systems ranging up to 600 volts and DC power systems ranging up to 250 volts.

Two types of distribution panels are found in *facility* electrical systems: switchboards and panelboards. Although switchboards and panelboards perform the same function, they differ in construction and application. Switchboards are typically floor-mounted assemblies, while panelboards are usually wall-mounted. Switchboards usually distribute larger quantities of power than panelboards.

Distribution switchboards are freestanding cabinets containing stacks of circuit breakers or fusible switches. They have assemblies of circuit breakers or switches mounted into shelf-like cubicles. Electrical connections are normally routed through enclosed cable compartments in the rear of the cabinet. A switchboard will sometimes include a main circuit breaker and a power metering section mounted in separate compartments within the cabinet. Switchboards are often incorporated into substation assemblies that include motor control centers, transformers, and switchgear. In typical applications, the completely enclosed (safety) switchboard is almost exclusively used. These switchboards are completely enclosed in a sheet metal casing. Switchboard dimensions are standardized with individual sections ranging from 20 to 40 inches in depth and width. The height is generally 90 inches. Switchboard sections can weigh up to 500 pounds.

Distribution panelboards are defined by the National Electric Code (NEC) *(Ref. 85)* as panels which include buses, switches, and automatic protective devices designed for the control or distribution of power circuits. Panelboards are placed in a cabinet or cutout box which is mounted in or against a wall and accessible only from the front. The assembly of circuit breakers contained in a panelboard is normally bolted to a steel frame, which is in turn mounted to the rear or sides of the panelboard enclosure. Individual circuit breakers are either bolted or plugged into the steel chassis. A cable gutter typically runs along the side of the circuit breaker chassis. Panelboards have a wide range of cabinet sizes. Typical dimensions for wall-mounted units are 20 to 40 inches in height and width, and 6 to 12 inches in depth. Weights for wall-mounted panelboards typically range from 30 to 200 pounds.

Industry standards developed by the National Electrical Manufacturers Association and the Underwriters Laboratories (e.g., NEMA ICS-6 *(Ref. 82)*, UL-508 *(Ref. 83))*, are maintained for the construction of distribution panel enclosures. These standards determine the minimum structural framing and sheet metal thickness for distribution panel enclosures as a function of sheet metal area between supports or reinforcing.

The Distribution Panel equipment class includes the circuit breakers, fusible switches, metering compartments, switchboard/panelboard enclosure and internals, and attached conduit.

### 8.1.5.1 *Reference Spectrum Caveats - Distribution Panels*

The *Reference* Spectrum (*R*S) represents the seismic capacity of a Distribution Panel (DP) if the panel meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

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[5] Section B.14 of SQUG GIP (Ref. 1)

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

DP/*R*S Caveat 2 - Contains only Circuit Breakers and Switches. The distribution panel should only contain circuit breakers and switches. The concern is that other seismically vulnerable components not normally associated with a distribution panel may have been added. Other components contained within the panel should be evaluated on a case-by-case basis. This case-by-case evaluation may include use of earthquake experience, test data or component specific qualification data as discussed in *Chapter 12*, Outlier Evaluation.

DP/*R*S Caveat 3 - Doors Secured. All doors, latches or screwdriver-operated door fasteners should be secured. The concern addressed by this caveat is that the doors could open during an earthquake and the loose door could repeatedly impact the housing and be damaged or cause internal components to malfunction or chatter.

DP/*R*S Caveat 4 - Adjacent Cabinets Bolted Together. Adjacent cabinets which are close enough to impact each other and sections of multi-bay cabinet assemblies should be bolted together if any of these cabinets contain essential relays as defined in *Chapter 11*. The concern addressed in this caveat is that unbolted cabinets could respond out of phase to one another and impact each other during an earthquake. This would cause additional impact loadings and high frequency vibration loadings which may result in malfunction or chatter of internal components.

DP/*R*S Caveat 5 - General Configuration Similar to NEMA Standards. The general configuration of the distribution panel should be similar to those constructed to NEMA Standards. The unit does not have to conform exactly to NEMA Standards, but should be similar with regard to the gage of steel, internal structure and support. This caveat is intended to preclude unusual designs not covered by the equipment class (thin gage material, flimsy internal structure, etc.). In general, units manufactured by the major manufacturers of distribution panels conform to this caveat if they have not been modified.

DP/*R*S Caveat *6* - Any Other Concerns? *SCEs* should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the panel.

8.1.5.2 GERS *Caveats* - Distribution Panels

*The seismic capacity for* the equipment class of Distribution Panels (or load centers) *may be* based on generic testing data, provided the intent of each of the caveats listed below is met. This equipment class consists of individual molded-case circuit breakers and fused disconnect switches housed in NEMA-type floor and wall enclosures. Units are low voltage rated at 600 VAC (480 VAC nominal) or 250 VDC. A distribution panel receives its electrical power from the *facility* distribution system and distributes this power to each of the circuit breakers and fused disconnect switches by an internal arrangement of vertical and horizontal bus bars. This equipment class covers distribution panels which contain circuit breakers and switches. For panels which contain an occasional relay or motor starter, the GERS only applies to the remainder of the panel and components mounted on the panel, not to the relay or motor starter. The evaluation of relays and motor starters is covered in *Chapter 11*.

Floor-mounted (freestanding) distribution panels are denoted as Switchboards (NEMA Standard Publication No. PB2 *(Ref. 86)*). The typical floor enclosure is 90 inches high, 36 inches wide, and 20 inches deep.

Wall-mounted (either flush or surface mount) distribution panels are denoted as Panelboards (National Electrical Code NFPA/ANSI No. 70 *(Ref. 85)*). Wall-mounted enclosures vary in size, with nominal dimensions ranging up to 48 inches high, 24 inches wide, and 12 inches deep.

The GERS *(see Figure 8.1.5-2)* represent the seismic capacity of a Distribution Panel (DP) (Switchboard or Panelboard) if the panel meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

DP/GERS Caveat 1 - Generic Seismic Testing Equipment Class. The distribution panel should be similar to and bounded by the DP class of equipment described above. The equipment class descriptions are general and the *SCEs* should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

DP/GERS Caveat 2 - *Reference* Spectrum Caveats Apply. The panel should meet all the caveats given for the *Reference* Spectrum. This caveat is included to cover the vulnerabilities identified for the earthquake experience equipment class. Those GERS caveats which are the same as the *Reference* Spectrum caveats are not repeated below.

DP/GERS Caveat 3 - Freestanding, Designated Switchboard. The Switchboard GERS can be used only if the unit is freestanding and designated as a switchboard by the manufacturer; otherwise the Panelboard GERS should be used. A review of manufacturer's submittals and parts list is sufficient. These two subclasses (Switchboard and Panelboard) have different seismic capacity based on the generic seismic test data.

DP/GERS Caveat 4 - Circuit Breaker Model Excluded. The GERS cannot be used for distribution panels that contain the Westinghouse "Quicklag" Type E circuit breakers. This circuit breaker model has been shown to trip at levels below the 2.5g GERS. A review of manufacturer's submittals and parts listed is sufficient to determine whether this type of circuit breaker is used.

*DP/GERS Caveat 5 - Adjacent Cabinets Bolted Together. Adjacent cabinets and sections of a multi-bay cabinet assembly should be bolted together. Adjacent cabinets and sections of multi-bay cabinet assemblies were bolted together when tested for this generic seismic testing equipment class.*

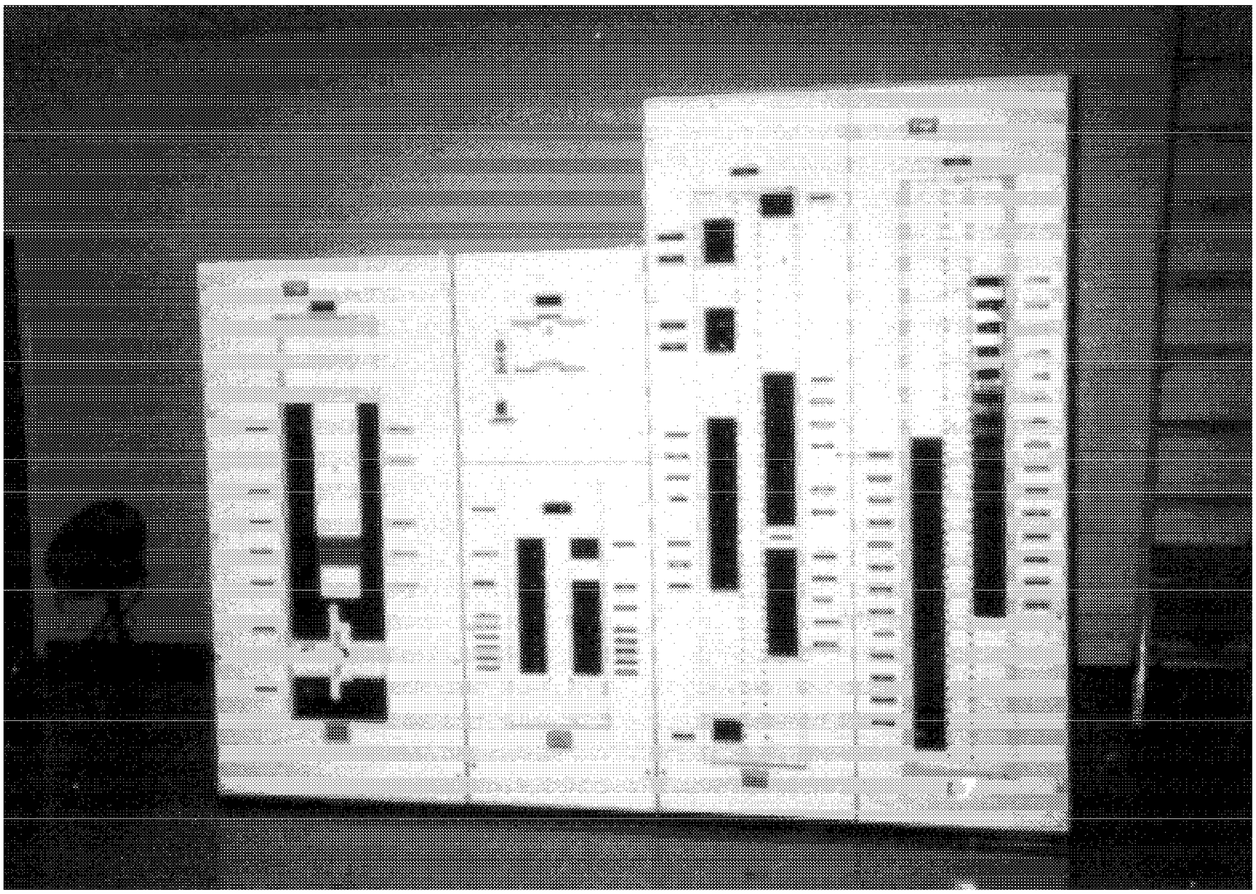
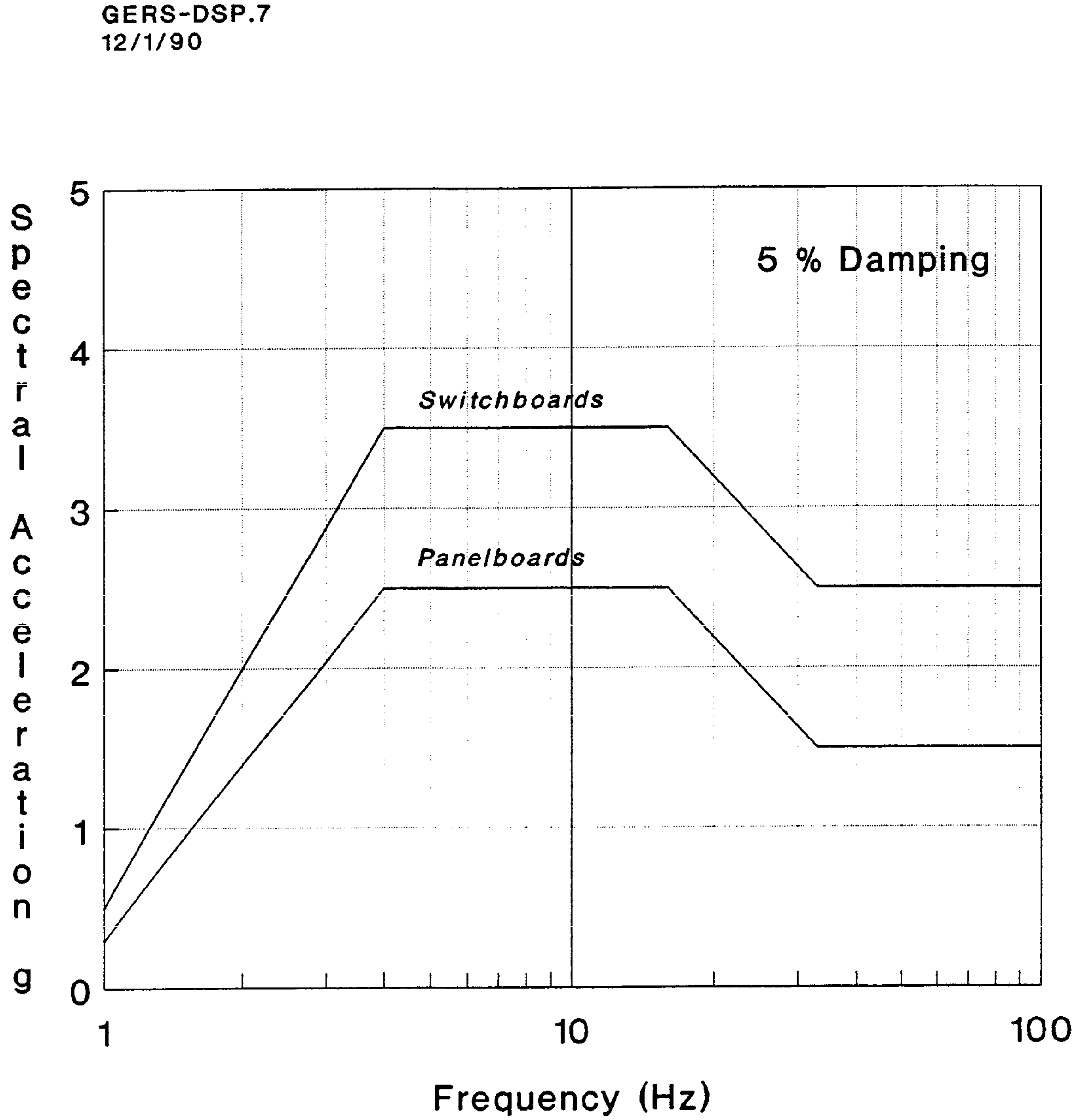


**Figure 8.1.5-1 Distribution Panels from the Earthquake Experience Database**




| Frequency (Hz) | 1 | 4 | 16 | 33 |
|---|---|---|---|---|
| Switchboards (g) | 0.5 | 3.5 | 3.5 | 2.5 |
| Panelboards (g) | 0.3 | 2.5 | 2.5 | 1.5 |

**Figure 8.1.5-2** **Generic Equipment Ruggedness Spectra (GERS) for Distribution Switchboards and Panelboards (Reference 40) (Figure B.14-1 of SQUG GIP, Reference 1)**

## 8.1.6 TRANSFORMERS[6]

*The seismic capacity for* the equipment class of transformers (TRN) *(see Figure 8.1.6-1) may be* based on earthquake experience data, provided the intent of each of the caveats listed below is met. This equipment class includes the unit substation type, typically 4160/480 volts, and the distribution type, typically 480/120 volts. Main power transformers with primary voltages greater than about 13,800 volts are not included in this equipment class. Small transformers that are components of electrical equipment, such as motor control centers or control panels, are also not included in this equipment class but are addressed as components of other classes of electrical equipment.

Unit substation transformers step power down from the medium voltage levels (typically 4160 volts for use in large mechanical equipment) to lower voltage levels (typically 480 volts) for use in smaller equipment. Distribution transformers usually step power from the 480 volt level to the 120 to 240 volt level to operate small mechanical equipment, battery chargers, or lighting systems.

Unit substation transformers included in the equipment class can be freestanding or attached to motor control centers or switchgear assemblies. They typically have primary voltages of 2400 to 4160 volts, and secondary voltages of 480 volts. This transformer type may be either liquid- or air-cooled. Liquid-cooled units typically consist of a rectangular steel tank filled with oil or a similar insulating fluid. The transformer coils are submerged in a liquid bath which provides cooling and insulation within the steel tank casing. Most liquid-filled transformers have one or more radiator coils attached to the side of the transformer.

Air-cooled or dry-type unit substation transformers are similar in size and construction to liquid-cooled units, except the transformer coils are mounted in a ventilated steel enclosure, rather than a liquid bath. Larger air-cooled unit substation transformers may have small fans mounted to their enclosures for forced air cooling.

The casings of both liquid-cooled and air-cooled unit substation transformers have typical overall dimensions of 60 to 100 inches in height, and 40 to 100 inches in width and depth. The weights of these units range from 2000 to 15,000 pounds.

Distribution transformers typically have primary voltages of 480 volts stepping down to secondary voltages of 120 to 240 volts. This type of transformer is almost always air-cooled. The construction of distribution transformers is essentially the same as that of unit substation transformers, except for a difference in size. The sizes of typical distribution transformers range from small wall-mounted or cabinet-mounted units that have overall dimensions of about 10 inches in height, width, and depth, and weights of 50 to 100 pounds; to larger units that are typically floor-mounted with dimensions ranging up to the size of unit substation transformers and weights ranging up to 5000 pounds.

The transformer equipment class includes the enclosure along with the internals and attached cable and conduit.

### 8.1.6.1 *Reference Spectrum Caveats - Transformers*

The *Reference* Spectrum (*R*S) represents the seismic capacity of a Transformer (TRN) if the transformer meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

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[6] Section B.4 of SQUG GIP (Ref. 1)

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

TRN/*RS* Caveat 2 - Rating of 4.16 KV or Less. The transformer should have a 4.16 KV rating or less. This is the upper bound voltage rating of transformers included in the earthquake experience equipment class.

TRN/*RS* Caveat 3 - Transformer Coils Positively Restrained Within Cabinet. For floor-mounted dry and oil-type units, the transformer coils should be positively restrained within their cabinet so that relative sliding and rocking motions between the transformer coil and their cabinet is kept to an acceptable level. The concern is that excessive relative motions may damage the wiring yoke, or that the coils may come in contact with their cabinet which may result in a short circuit or damage to the electrical insulation. This caveat especially applies to transformers whose installation procedure recommends that bolts used to anchor the coils during shipping be removed. If the unit is factory-sealed or constructed so that removing shipping anchors is precluded, no internal inspection is necessary.

TRN/*RS* Caveat 4 - Coils Top Braced or Analyzed for Large Transformers. Large transformers of 750 kVA or larger should also have the top of the coils braced by a structural frame or should be analyzed for adequate restraint. If the unit is factory-sealed or constructed so that removing shipping anchors is precluded, no internal inspection is necessary.

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

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

TRN/*RS* Caveat 7 - Wall-Mounted Units Anchored Close to Enclosure Support. The transformer coil contained in wall-mounted units should have engineered anchorage and be anchored to its enclosure near the enclosure support surface. The concern is that a well-engineered load path should exist for earthquake loadings from the transformer coil (which is relatively massive), through the enclosure, and to the enclosure support. If the transformer coil is not anchored to the enclosure near the enclosure support surface, a calculation can be performed to show that the earthquake loadings can be transferred to the anchorage.

TRN/*RS* Caveat 8 - Weak-Way Bending. The base assembly of floor-mounted units should be properly braced or stiffened such that lateral forces in any direction do not rely on weak-way bending of sheet metal or thin webs of structural steel shapes. If unbraced or unstiffened steel webs are used, they should be specially evaluated so that adequate strength and stiffness is ensured.

TRN/*RS* Caveat 9 - Adjacent Cabinets Bolted Together. Adjacent cabinets which are close enough to impact each other, and sections of multi-bay cabinet assemblies should be bolted together if any of these cabinets contains essential relays as defined in *Chapter 11*. The concern addressed in this caveat is that unbolted cabinets could respond out of phase to one another and cause impact loadings and high frequency vibration loadings which could cause any impact sensitive essential relays to chatter.

TRN/*RS* Caveat 10 - Doors Secured. All doors should be secured by a latch or fastener. The concern addressed by this caveat is that the doors could open during an earthquake, and the loose door could repeatedly impact the housing and be damaged or cause internal components such as relays to malfunction or chatter.

TRN/*RS* Caveat *11* - Any Other Concerns? *SCEs* should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the transformer.

8.1.6.2 GERS *Caveats* - Transformers

*The seismic capacity for* the equipment class of Transformers *may be* based on generic testing data, provided the intent of each of the caveats listed below is met. This equipment class includes only dry-type transformers. The equipment in the GERS equipment class is limited to units which range from 7.5 to 225 KVA capacity with either single- or three-phase voltage ratings of 120-480 volts AC. These transformers are housed in NEMA-type *(Ref. 82)* metal enclosures which can be either wall-mounted or floor-mounted.

The GERS *(see Figure 8.1.6-2)* represent the seismic capacity of a Transformer (TRN) if the transformer meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

TRN/GERS Caveat 1 - Generic Seismic Testing Equipment Class. The transformer should be similar to and bounded by the TRN class described above. The equipment class descriptions are general and the *SCEs* should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

TRN/GERS Caveat 2 - *Reference* Spectrum Caveats Apply. The transformer should meet all the caveats given for the *Reference* Spectrum. This caveat is included to cover the vulnerabilities identified for the earthquake experience equipment class. Those GERS caveats which are the same as the *Reference* Spectrum caveats are not repeated below.

TRN/GERS Caveat 3 - Only Dry-Type Transformer. The transformer should be a dry-type unit. Oil-filled units are excluded as they are not included in the generic seismic testing equipment class.

TRN/GERS Caveat 4 - NEMA-Type Enclosure. The transformer should be housed within a wall- or floor-mounted NEMA-type enclosure (review of manufacturer's submittals is sufficient). This is the enclosure type represented by the generic seismic testing equipment class.

TRN/GERS Caveat 5 - Voltage Rating of 120-480 VAC. The transformer should have a single- or three-phase voltage rating of 120-480 volts AC (review of manufacturer's submittals or transformer name-plate is sufficient).

TRN/GERS Caveat 6 - Capacity of 7.5 to 225 KVA. The transformer should have a capacity of 7.5 to 225 KVA (review of manufacturer's submittals or transformer name-plate is sufficient).

TRN/GERS Caveat 7 - Weight of 180-2000 Pounds. The transformer should weigh between 180 and 2000 pounds (review of the manufacturer's submittals or transformer name-plate is sufficient).

TRN/GERS Caveat 8 - Transformer Internal Supports. The internal supports should provide positive attachment of the transformer components (a force transfer path for seismic loads is necessary).

TRN/GERS Caveat 9 - *Sufficient* Clearance Between Bare Conductors and Enclosure. The clearance between any bare conductor and the transformer enclosure should be at least 3/8 inch. The concern is that without adequate clearance, transformers could be shorted out during the earthquake and thereby rendered inoperable.

*TRN/GERS Caveat 10 - Adjacent Cabinets Bolted Together. Adjacent cabinets and sections of a multi-bay cabinet assembly should be bolted together. Adjacent cabinets and sections of multi-bay cabinet assemblies were bolted together when tested for this generic seismic testing equipment class.*

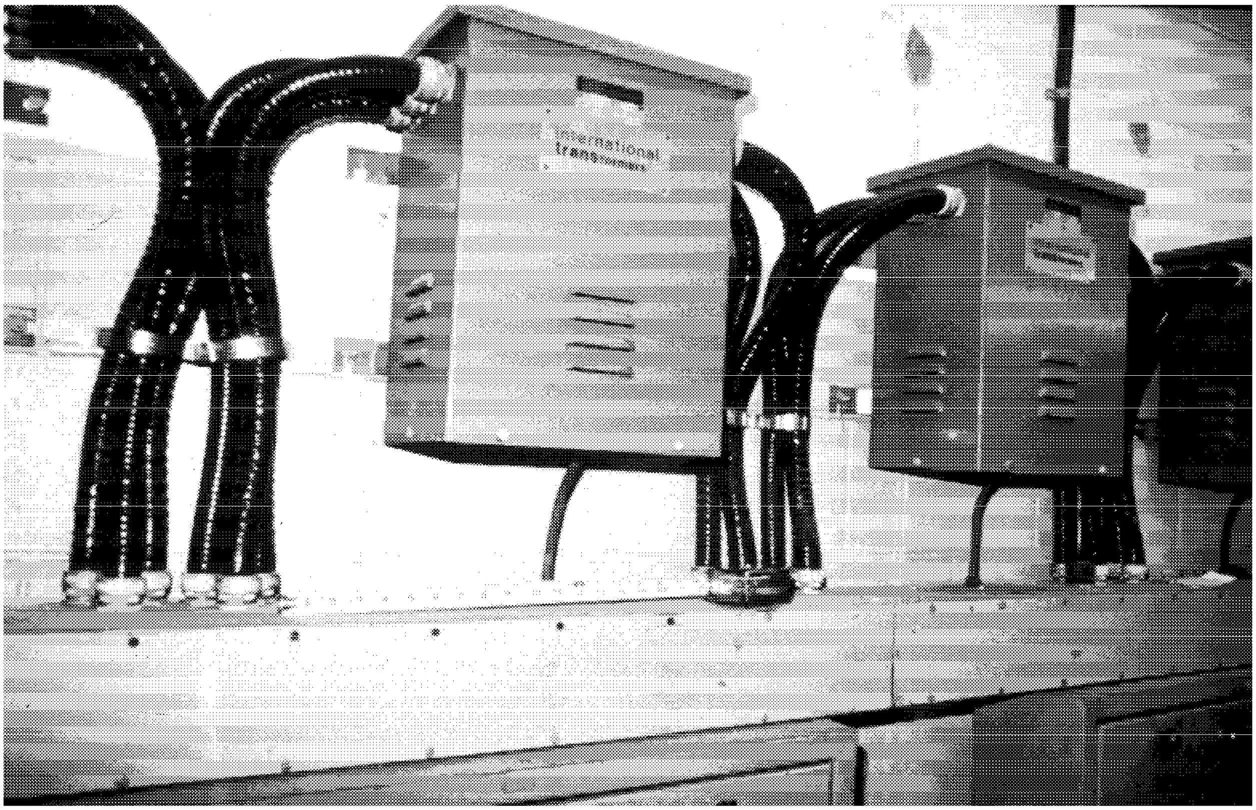
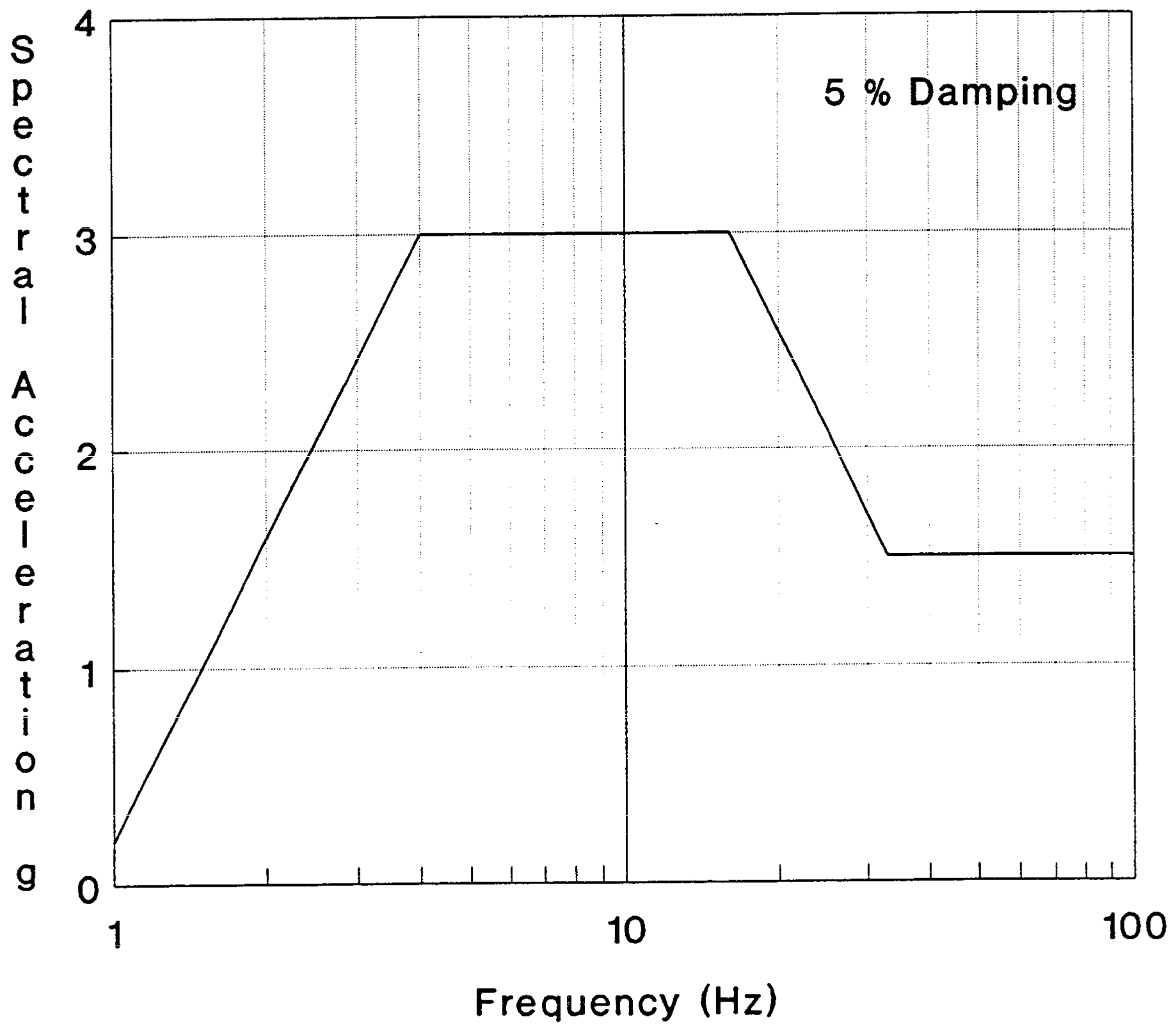



**Figure 8.1.6-1 Transformers from the Earthquake Experience Database**

GERS-TR.4
12/1/90




| Frequency (Hz) | 1 | 4 | 16 | 33 |
|---|---|---|---|---|
| Dry-Type Transformers (g) | 0.2 | 3.0 | 3.0 | 1.5 |

**Figure 8.1.6-2 Generic Equipment Ruggedness Spectra (GERS) for Dry-Type Transformers (Reference 40) (Figure B.4-1 of SQUG GIP, Reference 1)**

## 8.1.7 BATTERY CHARGERS AND INVERTERS[7]

*The seismic capacity for* the equipment class of Battery Chargers and Inverters (BCI) *(see Figure 8.1.7-1) may be* based on earthquake experience data, provided the intent of each of the caveats listed below is met. Chargers and Inverters are grouped into a single equipment class since they perform similar (although electrically inverse) functions, contain similar components, and are packaged in similar cabinets. Solid-state battery chargers are assemblies of electronic components whose function is to convert AC input into DC output. Inverters are assemblies whose function is to convert DC input into AC output. Battery chargers and inverters are normally housed in floor- or wall-mounted cabinets.

The most common applications for both battery chargers and inverters are as components of an uninterruptible power supply (UPS). A typical UPS consists of a solid-state inverter, a battery charger, a set of lead-acid storage batteries, and an automatic transfer switch. Chargers serve the station batteries which provide a DC power source to controls, instrumentation and switchgear. A portion of the DC power from the batteries is routed through inverters which provide a source of AC power to critical equipment.

The primary electrical function of a battery charger is accomplished using a rectifier. Most battery chargers are based on solid-state rectifiers consisting of semiconductors. This equipment class is limited to solid-state battery chargers and inverters.

The primary components of battery chargers include solid-state diodes, transformer coils, capacitors, electronic filters, and resistors. In addition, the primary components are usually protected from electrical faults by molded case circuit breakers and fuses. The internal components are normally bolted either to the rear panel or walls of a cabinet, or to interior panels or steel frames mounted within a cabinet. The front panel of the cabinet typically contains instrumentation and controls, including ammeters, voltmeters, switches, alarms, and control relays. Inverters contain primary components similar to those found in battery chargers. Virtually all inverters use solid state components.

Battery chargers and inverters are typically mounted in separate cabinets, but they are sometimes supplied as an assembly of two adjoining cabinets. The smallest units are wall-mounted or rack-mounted with typical dimensions of 10 to 20 inches in height, width, and depth, and typical weights of 50 to 200 pounds. Typical cabinet dimensions for larger floor-mounted units are 20 to 40 inches in width and depth, and 60 to 80 inches in height. The weights of the floor-mounted chargers and inverters range from several hundred to several thousand pounds. Typical AC voltages to battery chargers and from inverters range from 120 to 480 volts. Voltages in DC power typically range from 24 to 240 volts.

Industry standards are maintained for the construction of cabinets by the National Electrical Manufacturers Association *(Ref. 82)* and Underwriters Laboratories *(Ref. 83)*. These standards determine the minimum structural framing and sheet metal thickness for charger and inverter cabinetry as a function of size.

Solid-state inverters and battery chargers are included in the equipment class in freestanding, rack-mounted, and wall-mounted configurations. The Battery Charger and Inverter equipment class includes the sheet metal enclosure, all internal components, junction boxes, and attached cable or conduit.

[7] Section B.16 of SQUG GIP (Ref. 1)

8.1.7.1 *Reference Spectrum Caveats - Battery Chargers and Inverters*

The *Reference* Spectrum (*R*S) represents the seismic capacity of a Battery Charger or Inverter (BCI) if the equipment meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

BCI/*R*S Caveat 1 - Earthquake Experience Equipment Class. The battery charger or inverter should be similar to and bounded by the BCI class of equipment described above. The equipment class descriptions are general and the *SCEs* should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

BCI/*R*S Caveat 2 - Solid State Type. The battery charger or static inverter should be a solid-state type. The solid-state electrical construction is the primary type included in the earthquake experience equipment class. The concern is that electronics which are not of the solid state variety (glass tubes, etc.) are vulnerable to earthquake damage.

BCI/*R*S Caveat 3 - Transformer Mounted Near Base of Floor-Mounted Units. For floor-mounted units, the transformer, which is the heaviest component of this equipment, should be positively anchored and mounted near the base of the cabinet. If not mounted near the base, then the load path should be specially evaluated. The concern is that the lateral earthquake loads on the transformer will not be properly transferred to the equipment base. The load path evaluation may use judgment or simple calculations to ensure that the structure can transfer these loads.

BCI/*R*S Caveat 4 - No Reliance on Weak-Way Bending of Steel Plate or Structural Steel Shapes. The base assembly of floor-mounted units should be properly braced or stiffened such that lateral forces in any direction do not rely on weak-way bending of sheet metal or thin webs of structural steel shapes. If such unbraced or unstiffened steel webs exist, they should be investigated and *evaluated* for adequacy by the *SCEs* to check the strength and stiffness.

BCI/*R*S Caveat 5 - Load Path Check for Wall-Mounted Units. If the battery charger or inverter is a wall-mounted unit, the transformer supports and bracing should be visually reviewed for a proper load path to the rear cabinet wall. Lateral earthquake loads on the heavy transformer need to be properly transferred to the anchorage.

BCI/*R*S Caveat 6 - Doors Secured. All doors should be secured by a latch or fastener. The concern addressed by this caveat is that the doors could open during an earthquake and the loose door could impact the housing and be damaged or cause internal components to malfunction.

*BCI/RS Caveat 7 - Adjacent Cabinets Bolted Together. Adjacent cabinets which are close enough to impact each other, and sections of multi-bay cabinet assemblies should be bolted together if any of these cabinets contains essential relays as defined in Chapter 11. The concern addressed in this caveat is that unbolted cabinets could respond out of phase to one another and cause impact loadings and high frequency vibration loadings which could cause any impact sensitive essential relays to chatter.*

BCI/*R*S Caveat *8* - Any Other Concerns? *SCEs* should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the battery charger or inverter.

8.1.7.2 GERS *Caveats* - Battery Chargers and Inverters

*The seismic capacity for* the equipment class of both Battery Chargers and Inverters *may be* based on generic testing data, provided the intent of each of the caveats listed below is met. Battery charger units range from 25 to 600 amp capacity with either single- or three-phase voltage ratings of 24 to 250 volts DC and 120 to 480 Volts AC. The units utilize solid-state technology (silicon-controlled rectifier, SCR) in both the main circuits and the power controls. Major components include protective circuit breakers, transformers, power supply, SCR, filter, and various alarm relays, and control circuits. The units are housed in NEMA-type floor- or wall-mounted enclosures. This equipment class includes typical battery chargers used in *facilities* for float charging of lead-acid storage battery sets.

DC to AC inverter units included in the GERS data base range from 0.5 to 15 KVA capacity with either single- or three-phase voltage ratings of 120 volts DC and 120 to 480 volts AC. The units utilize solid-state technology (silicon-controlled rectifier, SCR), and have protective circuit breakers, transformers, frequency control circuitry, various alarm relays and SCR power control circuits as major components. The units are housed in NEMA-type floor-mounted enclosures. This equipment class covers typical 120 VDC inverters used in *facilities* for critical power supply.

The GERS *(see Figures 8.1.7-2 and 8.1.7-3)* represents the seismic capacity of a Battery Charger or Inverter (BCI) if the equipment meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

BCI/GERS Caveat 1 - Generic Seismic Testing Equipment Class. The battery charger or inverter should be similar to and bounded by the BCI class of equipment described above. The equipment class descriptions are general and the *SCEs* should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

BCI/GERS Caveat 2 - *Reference* Spectrum Caveats Apply. The battery charger or inverter should meet all the caveats given for the *Reference* Spectrum. This caveat is included to cover the vulnerabilities identified for the earthquake experience equipment class. Those GERS caveats which are the same as the *Reference* Spectrum caveats are not repeated below.

BCI/GERS Caveat 3 - SCR Power Controls Within NEMA-Type Enclosure. The battery charger or inverter should be a solid-state unit with SCR power controls (C&D, PCP, or Exide for battery chargers) (Elgar, Solid State Controls, Staticon for inverters). Battery charger units should be wall- or floor-mounted within a NEMA-type enclosure (review of manufacturer's submittals is sufficient). Only floor mounted inverter units are permitted. The enclosure does not have to conform exactly to NEMA standards but should be similar with regard to the gage of the steel, internal structure and support. The purpose of this caveat is to ensure similarity with the power controls and enclosure type of the generic seismic testing equipment class.

BCI/GERS Caveat 4 - Battery Charger Size and Capacity Range. Battery Charger size and capacity should be within the following range: 24 to 250 VDC, 120 to 480 VAC, 25 to 600 amps; and weight in the range of 150 to 2,850 pounds with wall-mounted units limited to 600 pounds (review of manufacturer's submittals or Battery Charger nameplate is sufficient). This represents the size and capacity limits of the generic seismic testing equipment class.

BCI/GERS Caveat 5 - Inverter Size and Capacity Range. Inverter size and capacity should be within the following range: 120 VDC, 120 to 480 VAC, 0.5 to 15 KVA; and weight in the range of 300 to 2,000 pounds. (Review of manufacturer's submittals or inverter nameplate is sufficient.) This represents the size and capacity range of the generic seismic testing equipment class.

BCI/GERS Caveat 6 - Cutouts Require Separate Evaluation. Heavy components should, in general, be located in the lower half of the enclosure height and either supported from the base or rear panel. If cutouts are adjacent to support points for heavy internal components, a separate evaluation is required. The concern is that the seismic load will not be able to be transferred through the shear panels to the anchorage.

*BCI/GERS Caveat 7 - Adjacent Cabinets Bolted Together. Adjacent cabinets and sections of a multi-bay cabinet assembly should be bolted together. Adjacent cabinets and sections of multi-bay cabinet assemblies were bolted together when tested for this generic seismic testing equipment class.*

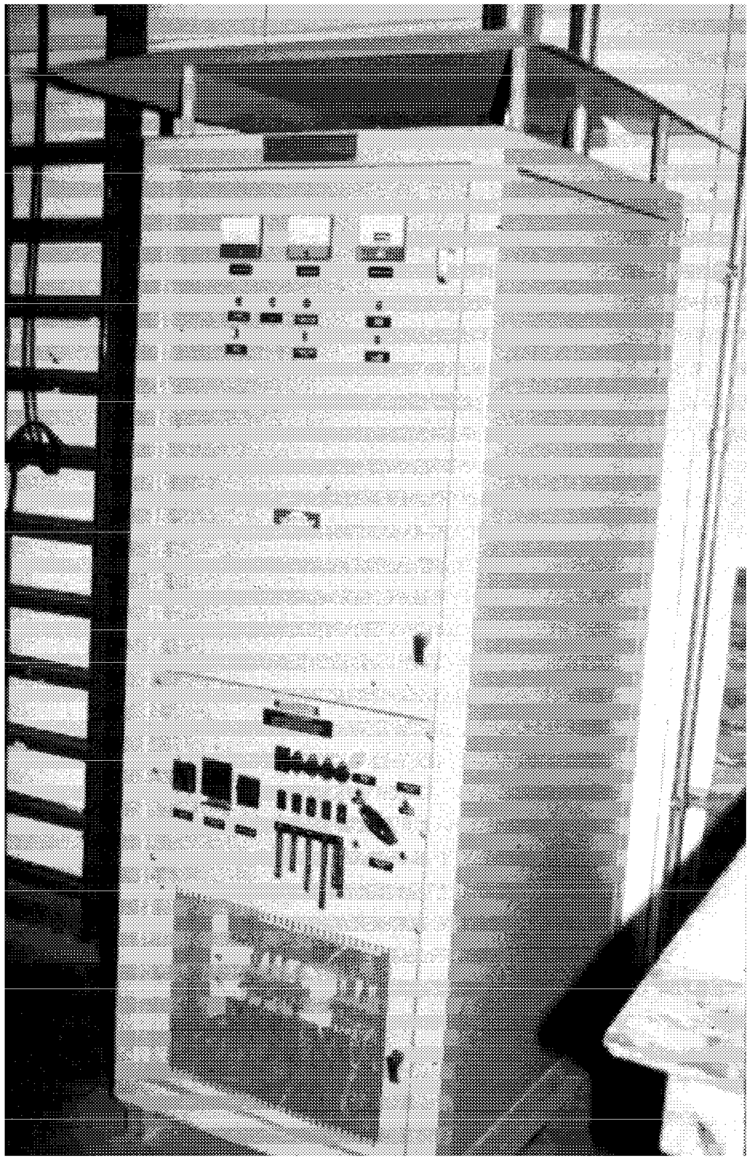
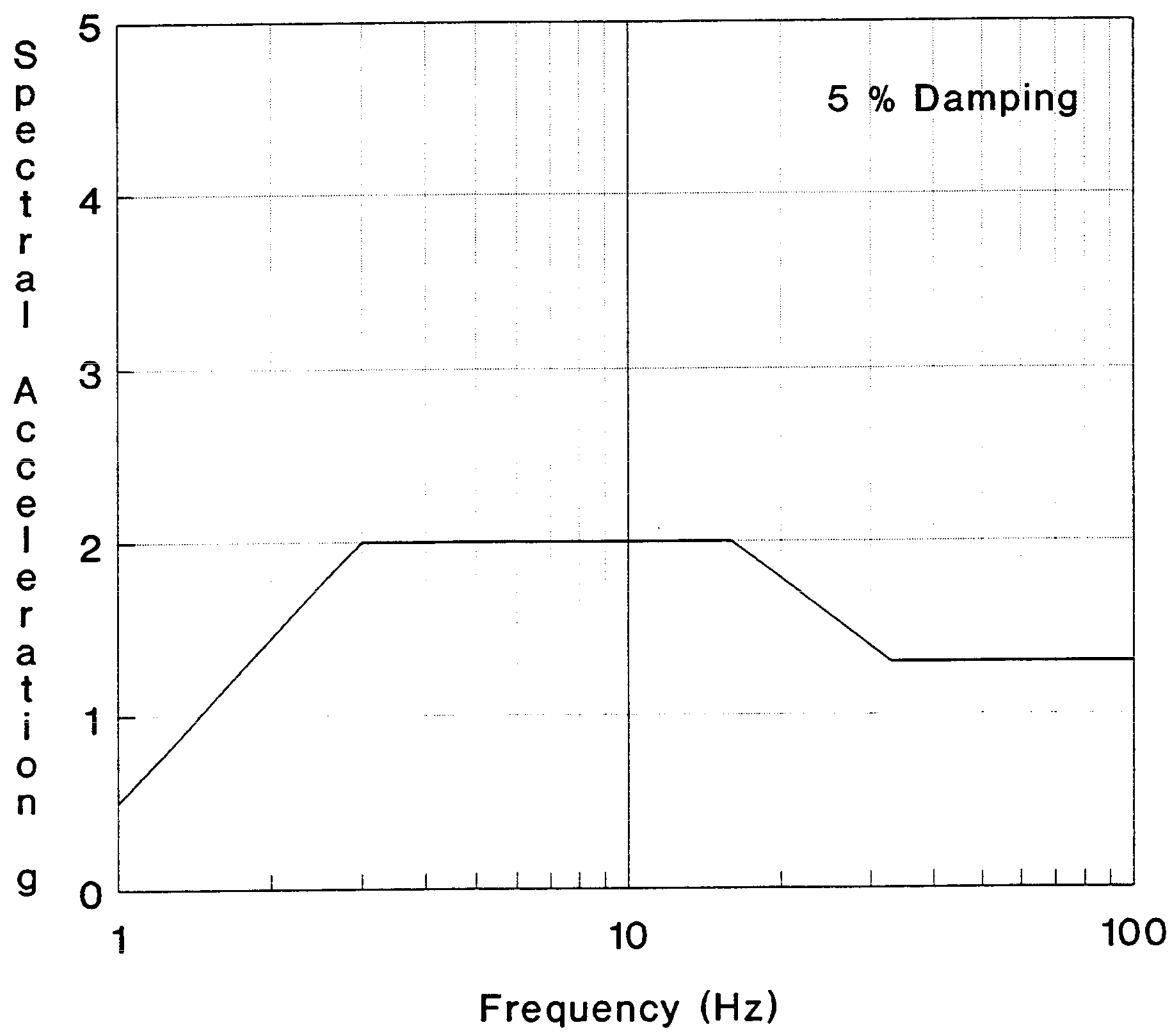


**Figure 8.1.7-1 Inverter from the Earthquake Experience Database**

Battery Chargers and Inverters

GERS-BC.3
6/1/88

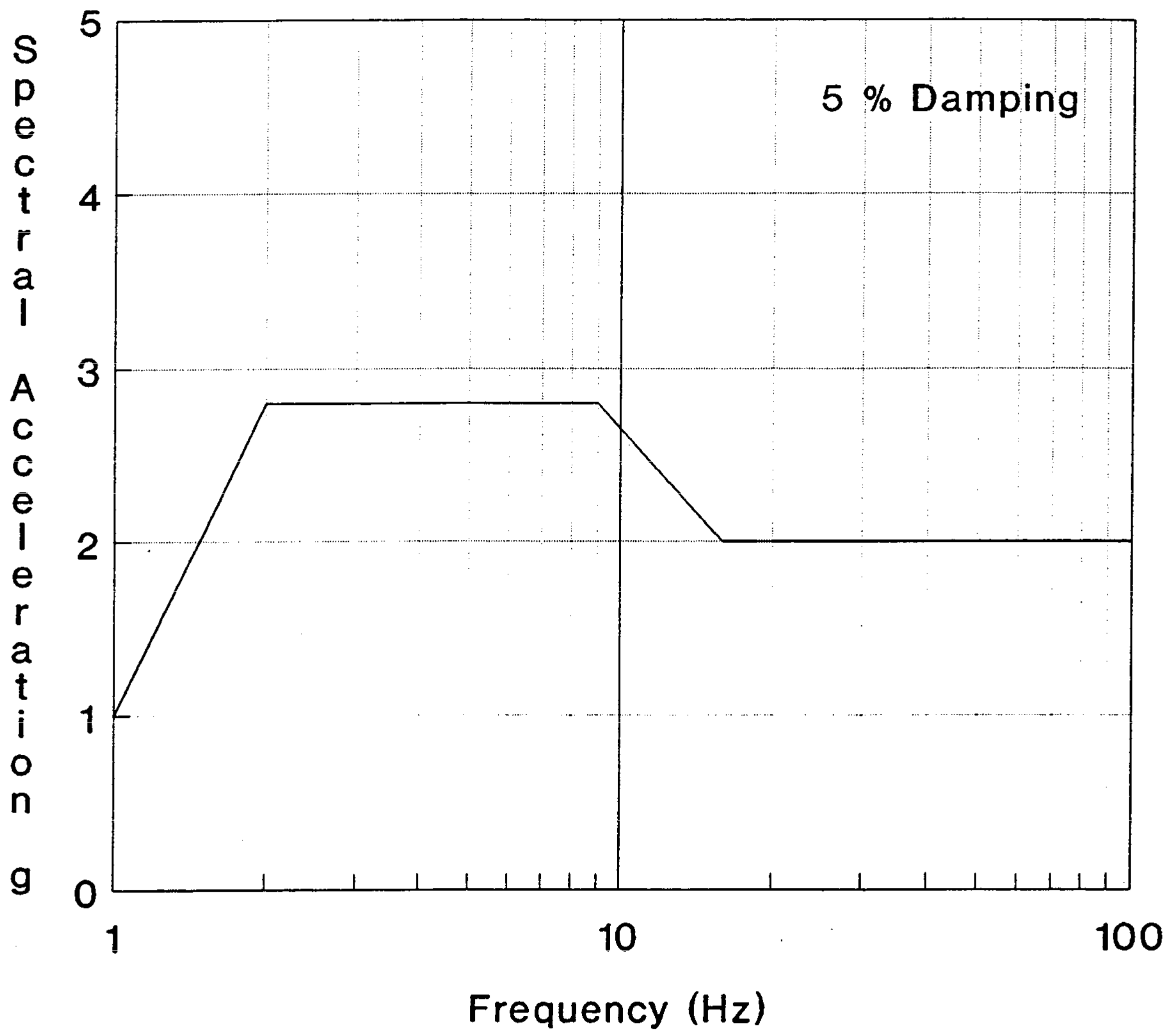



| Frequency (Hz) | 1 | 3 | 16 | 33 |
|---|---|---|---|---|
| Battery Chargers (g) | 0.5 | 2.0 | 2.0 | 1.3 |

**Figure 8.1.7-2 Generic Equipment Ruggedness Spectra (GERS) for Battery Chargers (Reference 40) (Figure B.16-1 of SQUG GIP, Reference 1)**

Battery Chargers and Inverters

GERS-INV.4
6/1/88




| Frequency (Hz) | 1 | 2 | 9 | 16 | 33 |
|---|---|---|---|---|---|
| Inverters (g) | 1.0 | 2.8 | 2.8 | 2.0 | 2.0 |

**Figure 8.1.7-3 Generic Equipment Ruggedness Spectra (GERS) for Inverters (Reference 40) (Figure B.16-2 of SQUG GIP, Reference 1)**

## 8.1.8 INSTRUMENTATION AND CONTROL PANELS[8]

*The seismic capacity for* the equipment class of Instrumentation and Control Panels (I&C) *(see Figure 8.1.8-1) may be* based on earthquake experience data, provided the intent of each of the caveats listed below is met. This equipment class includes all types of electrical panels that support instrumentation and controls. This equipment class includes both the sheet metal enclosure and typical control and instrumentation components mounted on or inside the enclosure. Instrumentation and control panels and cabinets create a centralized location for the control and monitoring of electrical and mechanical systems. In addition to main control panels, local instrumentation and control panels are sometimes distributed throughout the facilities, close to the systems they serve.

Instrumentation and control panels and cabinets have a wide diversity of sizes, types, functions, and components. Panel and cabinet structures generally consist of a steel frame supporting sheet metal panels to which instrumentation and control components are bolted or clamped. Cabinet structures range from a single panel, braced against or built into a wall, to a freestanding cabinet enclosure. These enclosures are generally categorized as either switchboards or benchboards as described below.

A vertical switchboard is a single reinforced sheet metal instrument panel, which is either braced against an adjacent wall or built into it. An enclosed switchboard is a freestanding enclosed sheet metal cabinet with components mounted on the front face, and possibly on the interior walls. The front or rear panel is usually hinged as a single or double swinging door to allow access to the interior. A dual switchboard consists of two vertical panels braced against each other to form a freestanding structure, with components mounted to both front and rear panels. The sides are usually open, and the two panels are joined by cross members spanning between their tops. A duplex switchboard is similar to a dual switchboard, except that it consists of a panel fully enclosed by sheet metal on all sides, with access through doors in the two side panels.

A benchboard consists of a control desk with an attached vertical panel. A control desk has components mounted on the desk top, and interior access through swinging doors in the rear. The single panel is similar to a vertical switchboard and is normally braced against or built into a wall. A dual benchboard is similar to a dual switchboard, but the lower half of the front panel is a desk console. A duplex benchboard is similar to a duplex switchboard, a totally enclosed panel, but with a desk console in the lower half of the front panel.

Panel and cabinet enclosures normally consist of steel angles, channels, or square tubes welded together, with sheet metal siding attached by spot welds. Large panels are typically made of individual sections bolted together through adjoining framing. The cabinet may or may not include a sheet metal floor or ceiling.

Electronic or pneumatic instrumentation or control devices attached to sheet metal panels or within sheet metal cabinets are included in the equipment class. The Instrumentation and Control Panels equipment class includes the sheet metal enclosure, switches, push buttons, panel lights, indicators, annunciators, gauges, meters, recorders, relays (provided they meet relay requirements), controllers, solid-state circuit boards, power supplies, tubing, wiring, and terminal blocks.

*There are no GERS for Instrumentation and Control Panels*

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[8] Section B.20 of SQUG GIP (Ref. 1)

8.1.8.1 *Reference Spectrum Caveats - Instrumentation and Control Panels*

The *Reference* Spectrum (*R*S) represents the seismic capacity of Instrumentation and Control Panels (I&C) if the panel or cabinet meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

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

I&C/*R*S Caveat 2 - Evaluate Computers and Programmable Controllers Separately. Computers and programmable controllers should be evaluated separately. The concern is that the subclass of computers and programmable controllers is so diverse that they may not be adequately represented by the earthquake experience data. Computers and programmable controllers should therefore be evaluated on a case-by-case basis.

I&C/*R*S Caveat 3 - Evaluate Strip Chart Recorders Separately. Strip chart recorders should be evaluated separately. The concern is that long, narrow recorders which are cantilevered off the panel may not have adequate structural support. Strip chart recorders are commonly supported on compression-type mounting brackets supplied by the manufacturer. These types of support brackets are inherently rugged and generally adequate for transfer of seismic loads. If there are no support brackets, or the support system appears to be a custom design, or the *SCEs* have any concerns regarding the adequacy of the bracket, then the support system should be subject to further evaluation.

I&C/*R*S Caveat 4 - Structural Adequacy. The steel frame and sheet metal should be evaluated for adequacy. Engineering judgment may be used to determine that an adequate load path exists to transfer the lateral earthquake loads to the foundation.

I&C/*R*S Caveat 5 - Adjacent Cabinets or Panels Bolted Together. Adjacent cabinets or panels which are close enough to impact each other and sections of multi-bay assemblies should be bolted together if any of these assemblies contain essential relays as defined in *Chapter 11*. The concern addressed in this caveat is that unbolted cabinets or panels could respond out of phase to one another and impact each other during an earthquake. This would cause additional impact loadings and high frequency vibration loadings which could cause any essential relays to chatter.

I&C/*R*S Caveat 6 - Drawers or Equipment on Slides Restrained. Drawers or equipment on slides should be restrained to prevent them from falling out during seismic motion. The concern is that the components in the drawer could slide and become damaged, or slide out and fall onto some other fragile essential component in the vicinity. A latch or fastener should secure these sliding components.

I&C/*R*S Caveat 7 - Doors Secured. All doors should be secured by a latch or fastener. The concern addressed by this caveat is that loose doors could repeatedly impact the housing and be damaged or cause internal components such as relays to malfunction or chatter.

I&C/*R*S Caveat *8* - Any Other Concerns? *SCEs* should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the cabinet or panel.

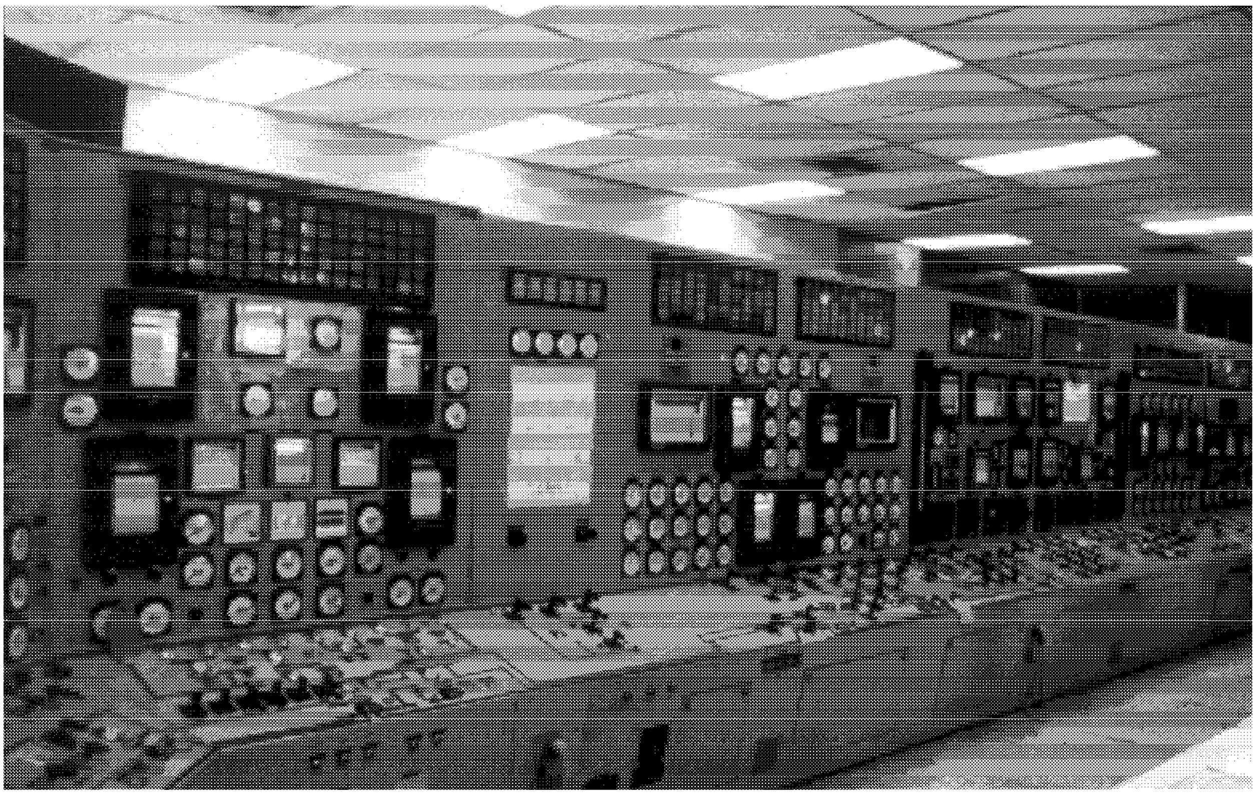

**Figure 8.1.8-1 Instrumentation and Control Panels from the Earthquake Experience Database**

## 8.1.9 INSTRUMENTS ON RACKS[9]

*The seismic capacity for* the equipment class of Instruments on Racks (IR) *(see Figure 8.1.9-1) may be* based on earthquake experience data, provided the intent of each of the caveats listed below is met. This equipment class consists of steel frames that provide mounting for local controls and instrumentation, such as signal transmitters to remote control panels. Instrument racks typically consolidate transducer or control signals from several equipment items in their immediate vicinity.

Instrument racks usually consist of steel members (typically steel angle, pipe, channel, or Unistrut) bolted or welded together into a frame. Components are attached either directly to the rack members or to metal panels that are welded or bolted to the rack. Floor-mounted instrument racks typically range from 4 to 8 feet in height, with widths varying from 3 to 10 feet, depending on the number of components supported on the rack. A simpler configuration of an instrument rack is a single floor-mounted post supporting one or two components. Wall-mounted and structural column-mounted racks are often used for supporting only a few components.

Control system components mounted on instrument racks may include electronic systems used for functions such as temperature monitoring, starting, stopping, and throttling electric motors, and monitoring electric power. Pneumatic system components mounted on instrument racks may be used for monitoring fluid pressure, liquid level, fluid flow, and for adjusting pneumatically-actuated control valves. Electronic control and instrumentation system components mounted on instrument racks include transmitters that convert a pneumatic signal from the transducer to an electric signal for transmission to the main control panel.

Typical components supported on instrument racks include: pressure switches, transmitters, gauges, recorders, hand switches, manifold valves, and solenoid valves. Attachments to instrument racks include steel or plastic tubing, conduit, and junction boxes.

Freestanding, wall-mounted, and structural column-mounted instrument racks of bolted and welded steel construction are included in the equipment class along with the components mounted on them. Both pneumatic and electronic components, as well as associated tubing, wiring, and junction boxes, are included in the Instruments on Racks equipment class.

### 8.1.9.1 <u>*Reference Spectrum Caveats - Instruments on Racks*</u>

The *Reference* Spectrum (*R*S) represents the seismic capacity of Instruments on Racks (IR) if the instruments and racks meet the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

<u>IR/*R*S Caveat 1 - Earthquake Experience Equipment Class.</u> The instruments and racks should be similar to and bounded by the IR class of equipment described above. The equipment class descriptions are general and the *SCEs* should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

<u>IR/*R*S Caveat 2 - Evaluate Computers and Programmable Controllers Separately.</u> Computers and programmable controllers should be evaluated separately. The concern is that the subclass of computers and programmable controllers is so diverse that they may not be adequately represented by the earthquake experience equipment class. Computers and programmable controllers should therefore be evaluated on a case-by-case basis. Component specific test data for computers and programmable controllers may be used to resolve this concern.

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9 Section B.18 of SQUG GIP (Ref. 1)

IR/*RS* Caveat 3 - Structure Adequate. The steel frame and sheet metal structure should be evaluated in the walkdown for adequacy. Engineering judgment may be used to determine that an adequate load path exists to transfer the lateral earthquake loads to the foundation.

IR/*RS* Caveat 4 - Adjacent Racks Bolted Together. Adjacent racks which are close enough to impact each other and sections of multi-bay assemblies should be bolted together if any of these assemblies contain essential relays as defined in *Chapter 11*. The concern addressed in this caveat is that adjacent, unbolted racks could respond out of phase to one another and impact each other during an earthquake. This would cause additional impact loadings and high frequency vibration loadings which could cause essential relays to chatter.

IR/*RS* Caveat 5 - Any Other Concerns? *SCEs* should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the instrument rack.

8.1.9.2 GERS *Caveats* - Instruments on Racks

*The seismic capacity for* the equipment class of Instruments on Racks *may be* based on generic testing data, provided the intent of each of the caveats listed below is met. This equipment class includes four kinds of transmitters: pressure, temperature, level, and flow. The racks for these instruments are not covered in the generic seismic testing equipment class. Transmitters are used to transmit signals received from transducers which monitor operating conditions. The transmitters send electric signals to control panels for use by safety systems, *facility* control systems, alarm systems and operator displays. Some transmitters are designed for remote rack or control panel mounting while others are mounted adjacent to the transducer. The term "transmitter" is also used for the transducer/signal conditioner combination when the transducer and signal conditioner are integral. This is the usual case for flow, pressure, and level transmitters. Temperature transmitters are usually remote from the transducer. In general, transmitters range in size from a few pounds to about 40 pounds; however, the majority of the transmitters weigh only a few pounds. The largest physical dimension of a transmitter is usually less than about 12 inches.

The GERS *(see Figure 8.1.9-2)* represent the seismic capacity of a pressure, temperature, level, or flow transmitter if the transmitter meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

IR/GERS Caveat 1 - Generic Seismic Testing Equipment Class. The transmitter should be similar to and bounded by the IR class of equipment described above. The equipment class descriptions are general and the *SCEs* should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

IR/GERS Caveat 2 - *Reference* Spectrum Caveats Apply. The transmitter and its supporting rack, when present, should meet all the caveats given for the *Reference* Spectrum. This caveat is included to cover the vulnerabilities identified for the earthquake experience equipment class. Those GERS caveats which are the same as the *Reference* Spectrum caveats are not repeated below.

IR/GERS Caveat 3 - Component is a Pressure, Temperature, Level, or Flow Transmitter. The component should be a pressure, temperature, level, or flow transmitter. These are the components included in the generic seismic testing equipment class.

IR/GERS Caveat 4 - Specific Transmitter Models Included. There is a wide diversity of transmitter types and mechanical properties. Specific manufacturer/models were tested for function during an earthquake. The tested transmitters in the generic seismic testing equipment class include: Foxboro E96, E13, E916; Devar 18-119; Rosemount 1151, 1152, 442; Robertshaw 161; Love 48, 54, 8100, 1106; Kepco PCX; Travis P8, P24.

This caveat may be satisfied for other models of transmitters by performing a case-by-case evaluation of similarity to one of the above models.

IR/GERS Caveat 5 - Seismic Induced System Changes Should be Evaluated. Transmitters are sometimes sensitive to system perturbations. The concern is that the earthquake may induce system changes (i.e., pressure, flow, and level variation) which may have the same effect on the system being controlled as if the transmitter malfunctioned. For example, a level switch used to measure the oil level in the crank case of an emergency diesel-generator (EDG) may be tripped during an earthquake when the oil is sloshing. This reading may inadvertently cause the EDG to trip off line. This caveat is also addressed in the Relay Functionality Review in *Chapter 11*.

IR/GERS Caveat 6 - No Vacuum Tubes. Vacuum tubes should not be used as internal electrical components. The concern is that glass tubes are especially vulnerable to earthquake damage.

IR/GERS Caveat 7 - All Mounting Bolts in Place. All external mounting bolts (transmitter to bracket and bracket to support) should be in place. This is the condition under which the transmitters were tested during the generic seismic tests.

IR/GERS Caveat 8 - Evaluation of Amplified Response. The transmitters which were tested were attached directly to the shake table. Therefore realistic amplification through the rack (or other supporting structure) to the transmitter should be included when determining the amplified response of the transmitter-to-rack interface for comparison to the GERS. The basis for this amplification factor should be documented.

IR/GERS Caveat 9 - Rack Requires Separate Evaluation. The transmitters were tested separately from the rack, therefore in order use the GERS capacity curves which are higher than the *Reference* Spectrum, an evaluation of the rack should be made. The evaluation should show that the structural components of the rack are capable of transferring the earthquake loads to the anchorage. This evaluation may depend upon the engineering judgment of the *SCEs* and may not require a formal calculation.

*IR/GERS Caveat 10 - Adjacent Racks Bolted Together. Adjacent racks and sections of multi-bay rack assemblies should be bolted together.*

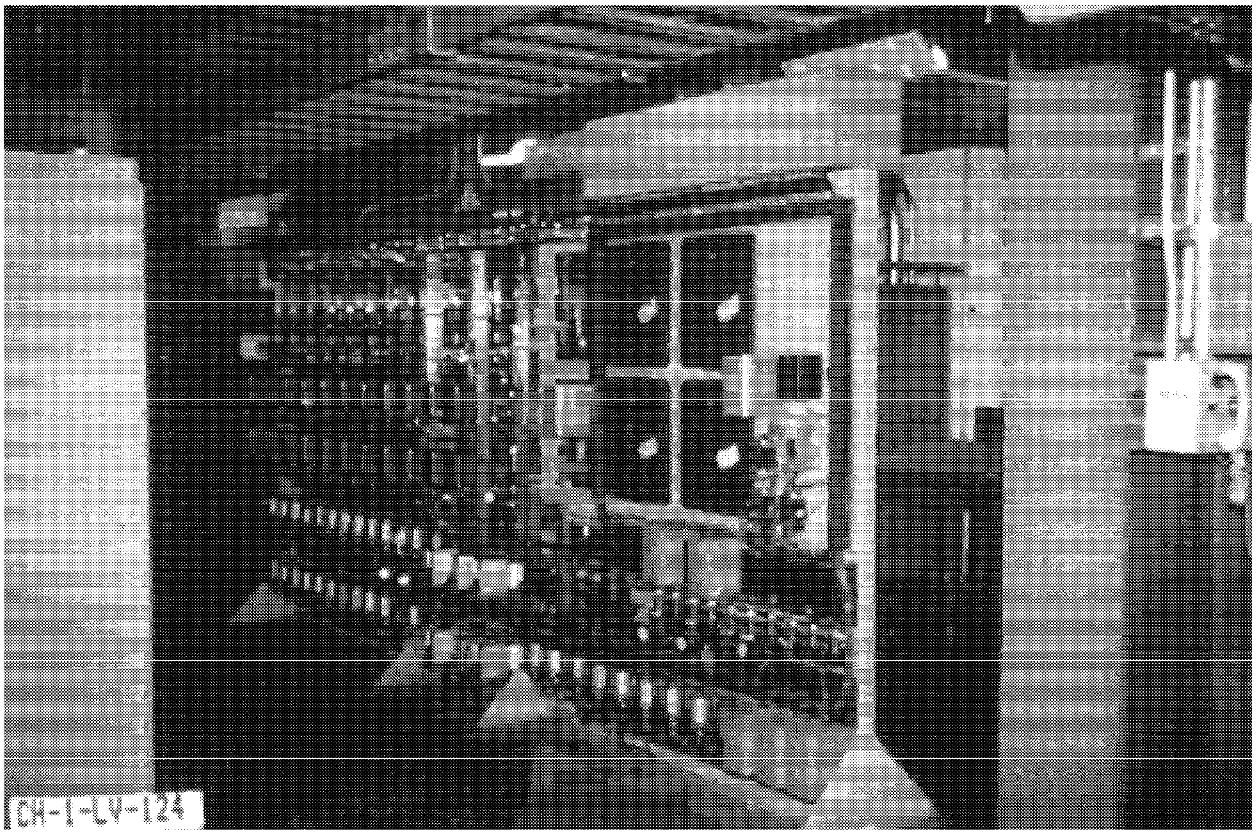
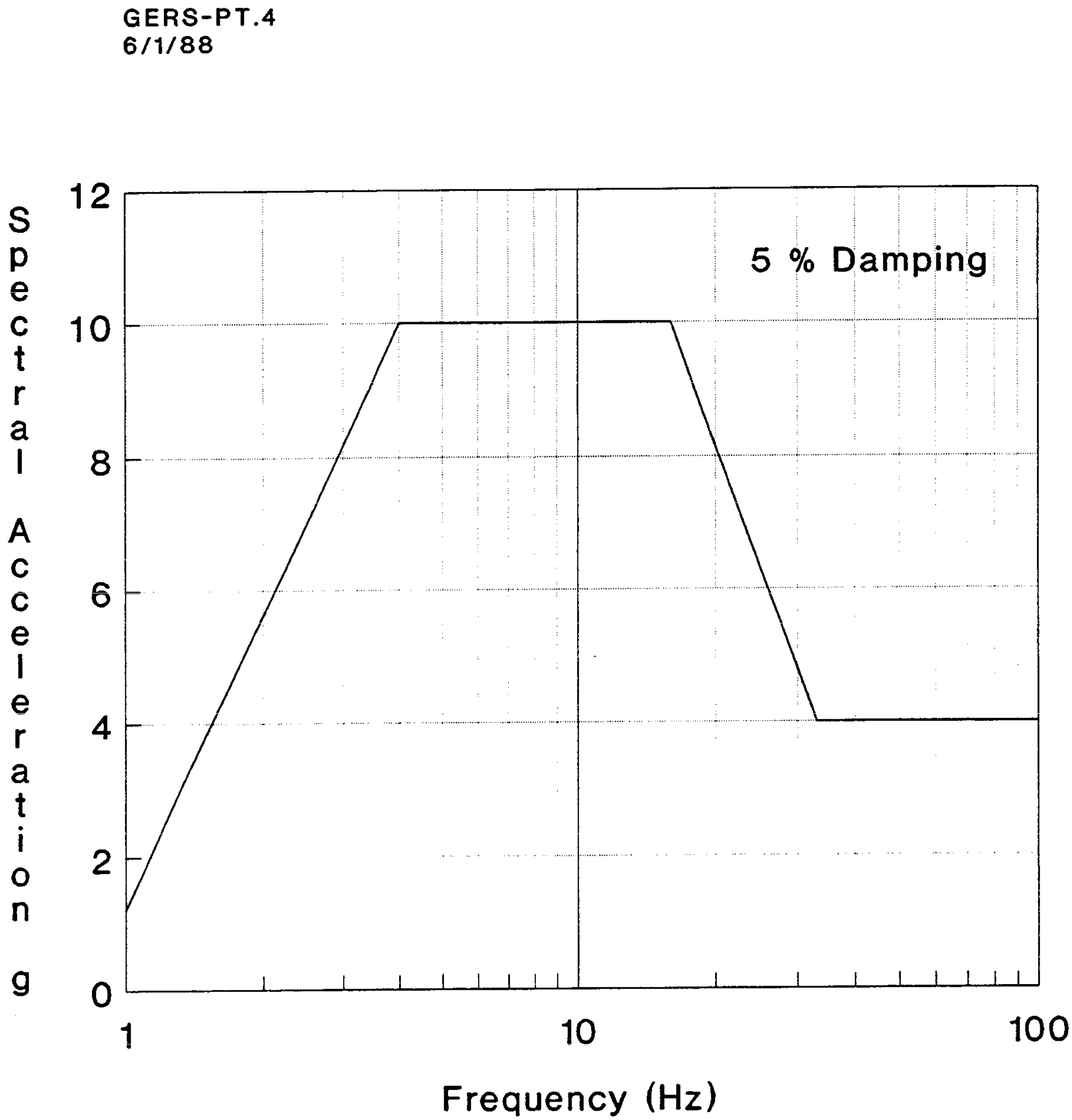



**Figure 8.1.9-1 Instruments on Racks from the Earthquake Experience Database**

Instruments on Racks




| Frequency (Hz) | 1 | 4 | 16 | 33 |
|---|---|---|---|---|
| Transmitters (g) | 1.2 | 10 | 10 | 4 |

**Figure 8.1.9-2 Generic Equipment Ruggedness Spectra (GERS) for Transmitters (Reference 40) (Figure B.18-1 of SQUG GIP, Reference 1)**

## 8.1.10 TEMPERATURE SENSORS[10]

*The seismic capacity for* the equipment class of Temperature Sensors (TS) *(see Figure 8.1.10-1) may be* based on earthquake experience data, provided the intent of each of the caveats listed below is met. This equipment class includes thermocouples and resistance temperature detectors (RTDs) that measure fluid temperature and typically are mounted within or on piping or tanks. Thermocouples are probes consisting of two dissimilar metal wires routed through a protective sleeve that produce a voltage output proportional to the difference in temperature between the hot junction and the lead wires (cold junction). RTDs are similar in construction to thermocouples, but their operation is based on variation in electrical resistance with temperature. RTDs and thermocouples are connected to pressure vessel boundaries (piping, tanks, heat exchangers, etc.) using threaded joints. The sensor's sheath will often be inserted into a thermowell or outer protective tube that is permanently mounted in the pipe or tank. A thermowell allows the thermocouple or RTD to be removed without breaking the pressure boundary of the pipe or tank.

Sensors are typically linked to transmitters mounted on nearby instrument racks, which amplify the electronic signal generated in the sensors, and transmit the signal to a remote instrument readout.

The Temperature Sensors equipment class includes the connection head, threaded fitting, sheath or protective tube, thermowell, and attached wires.

*There are no GERS for Temperature Sensors.*

### 8.1.10.1 *Reference Spectrum Caveats - Temperature Sensors*

The *Reference* Spectrum (*RS*) represents the seismic capacity of a Temperature Sensor (TS) if the sensor meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

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

TS/*RS* Caveat 2 - No Possibility of Detrimental Differential Displacement. Detrimental differential displacement between the mounting of the connection head and the mounting of the temperature sensor should not occur. The concern is that the differential displacement may cause the wiring to be pulled out of the sensor.

TS/*RS* Caveat 3 - Solid State Electronics. The electronics associated with the temperature sensor should be solid state (i.e., no vacuum tubes). The earthquake experience equipment class only includes solid-state electronics for temperature sensors. The concern is that electronics that are not of the solid-state variety (glass tubes, etc.) are vulnerable to earthquake damage.

TS/*RS* Caveat *4* - Any Other Concerns? *SCEs* should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the temperature sensor.

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10 Section B.19 of SQUG GIP (Ref. 1)

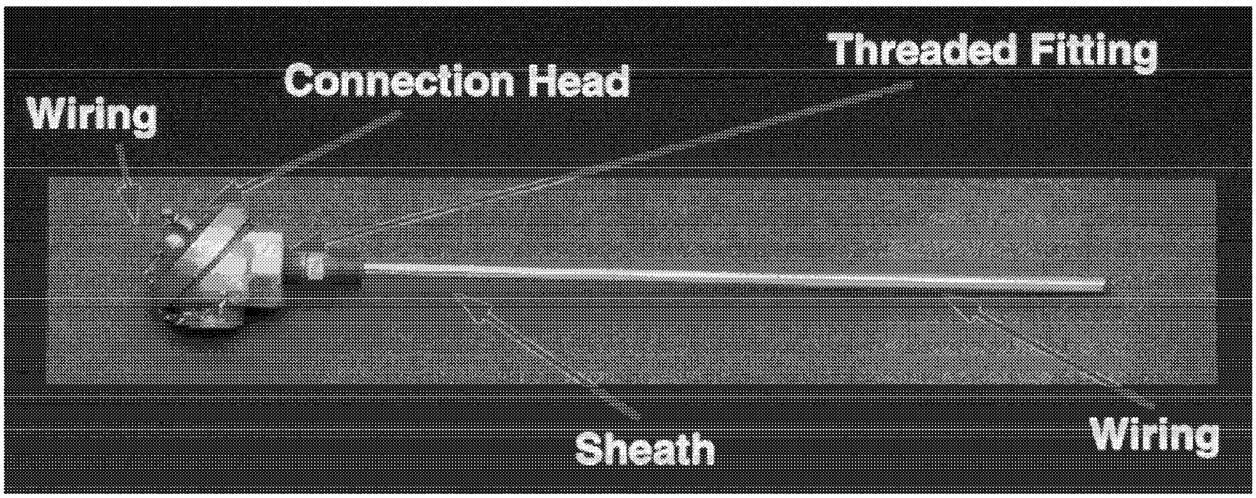


**Figure 8.1.10-1 Temperature Sensor**