AHRI Standard 1270 (I-P)

2011 Standard for

Requirements For Seismic Qualification of HVACR Equipment

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REQUIREMENTS FOR SEISMIC QUALIFICATION OF HVACR EQUIPMENT

Section 1. Purpose

1.1 *Purpose.* The purpose of this standard is to define the requirements for seismic qualification of mechanical HVACR Equipment. The International Building Code® (IBC) includes a number of provisions for seismic design and certification of nonstructural components. These provisions are intended to improve the performance of non-essential and essential nonstructural systems subject to strong ground shaking. Both the IBC and the American Society of Civil Engineers Standard SEI/ASCE 7 (ASCE 7) contain requirements for qualification of Equipment. The pertinent sections of the latest editions of IBC and ASCE 7 are characterized in Appendices C, D, E and F.

Section 2. Scope

2.1 *Scope*. This standard applies to the following Equipment: Fan Coil Units, Unit Ventilators, Air Handling Units, Coils, Air-to-Air Heat Exchangers, Vertical Packaged Air Conditioners and Heat Pumps, Packaged Terminal Equipment, Dehumidifiers, Flow and Contaminant Controls, Furnaces, Humidifiers, Liquid Chillers, Thermal Storage Equipment, Unitary Air Conditioners and Heat Pumps, and Water-Source Heat Pumps. This standard describes the methods for equipment qualification and the process to determine equipment Seismic Capacity.

Section 3. Definitions

Definitions . All terms in this document follow standard industry definitions in the current edition of *ASHRAE Terminology of Heating, Ventilation, Air Conditioning and Refrigeration* or the International Code Council Evaluation Services (ICC-ES) Acceptance Criteria AC156 (AC156), unless otherwise defined in this section.

3.1 *Allowable Stress Design (ASD).* A comparison of the stresses in the connections/elements defined in the Equipment Force-Resisting System (EFRS) determined by analysis from the effects of design loads to the allowable stresses for the material used in the EFRS.

3.2 *Attachments.* The devices or hardware used to secure or restrain the Equipment to the building structure. Attachments or restraints of the Equipment include anchor bolting, welded connections and mechanical fasteners.

3.3 *Attachment Point.* The point at which the Equipment is connected to the building structure. This connection point is designed to transfer seismic forces between the structure and the Equipment.

3.4 *Active Equipment.* Equipment that contains moving or rotating parts, electrical parts such as switches or relays, or other internal components that are sensitive to earthquake forces and critical to the functional performance of the Equipment.

3.5 *Certificate of Compliance.* A certificate stating the Seismic Capacity of Equipment determined using methods of this standard.

3.6 *Certification Response Spectrum (CRS).* For shake table testing, certification will be performed based on a Required Response Spectrum (RRS) which determines the input motion at the equipment attachment. For this application, the CRS is the RRS. For dynamic analysis certification of Equipment, the CRS defines the forcing function in terms of octaves used by the analysis program to define the input of motion at the equipment attachment. The CRS constitutes the Seismic Capacity of the Equipment if it satisfies the acceptance criteria as defined in this standard.

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3.7 *Component.* Devices that can be individually qualified per this standard and joined with other Pre-Qualified Components or EFRS qualified separately for multi-component Equipment such as motors, coils, fans, valves, dampers, and etc.

3.8 *Component Application Factor*. A factor for a component that is not attached to the Equipment's substructure at the base, but somewhere above in the unit. The unit may have some internal amplification because of the response to the dynamic forcing functions. For example, a fan on top of a cooling tower may see higher seismic shaking than if it was attached to the base. This higher demand must be defined so the fan (Component) will need to have a higher capacity in order for the cooling tower itself to be rated at the demand at the attachment point.

3.9 *Damping.* Energy dissipation mechanism that reduces amplification and broadens the vibratory response. Damping is expressed as a percentage of critical Damping applied near the natural frequency of the Equipment.

3.10 *Designated Seismic System.* The architectural, electrical and mechanical systems and their Equipment and components that require design in accordance with Chapter 13 of ASCE 7 and for which the importance factor, I_p, is equal to 1.5 in accordance with Section 13.1.3 of ASCE 7.

3.11 *Equipment.* Products manufactured to perform HVACR functions. These products are manufactured by combining components with an EFRS. In context of this standard, these products are evaluated to determine the maximum Seismic Demand that the HVACR Equipment will survive or function following a seismic event.

3.12 *Equipment Qualified by Test (EQT).* Equipment identified to be qualified by shake table test.

3.13 *Equipment Force-Resisting System (EFRS).* A system of elements within the Equipment that include brackets, braces, frames, and struts that provides the seismic load path transmitting seismic forces to the equipment Attachment Points.

3.14 *Flexible Equipment.* Equipment, including its attachment and force-resisting structural system, that has a fundamental period greater than 0.06 second (frequency less than 16.67 Hz).

3.15 *Functional Requirements.* High level actions that the Equipment must achieve that define the Equipment to be functional.

3.16 *Load and Resistance Factor Design (LRFD).* Comparison of the load on the connections/elements defined in the EFRS determined by analysis from the effects of design loads to the allowable strength for the configuration of the connection and material used in the EFRS.

3.17 *Performance Requirements.* Parameters that can be measured such as pressure, revolutions per minute (RPM), flow rates, and physical dimensions. The Performance Requirements are measured before and after a shake table test and must be equivalent or within tolerance for the functional requirements to be met.

3.18 *Pre-Qualified Component.* Active or energized components seismically pre-qualified to a specific g-level used in multi-component Equipment.

3.19 *Required Response Spectrum (RRS).* The response spectrum as defined by AC156 to create the required demand on the Equipment. The response spectrum is generated from formulas available in AC156 and is used as the Seismic Capacity in the certification of Equipment.

3.20 *Rigid Equipment.* Equipment, including its Attachments and EFRS, that has a fundamental period less than or equal to 0.06 second (frequency greater than or equal to 16.67 Hz).

3.21 *Rugged Component.* Component judged to survive a design basis earthquake without Significant Loss of Function and qualified by engineering judgment such that the Component does not require further testing or analysis.

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3.22 *Rugged Equipment.* Equipment judged to survive a design basis earthquake without Significant Loss of Function and qualified by engineering judgment such that the Equipment does not require further testing or analysis.

3.23 *Seismic Capacity.* The maximum analytical or test acceleration at which the Equipment can satisfy the performance criteria as defined in Section 5.

3.24 *Seismic Demand.* Seismic forces resulting from ground motion that are defined in the IBC. The maximum design acceleration of the seismic forces is the demand. The Seismic Demand can be a single value that corresponds to the maximum value of the RRS.

3.25 "Shall," "Should," "Recommended," or "It Is Recommended." "Shall," "should," "recommended," or "it is recommended" shall be interpreted as follows:

3.25.1 *Shall.* Where "shall" or "shall not" is used for a provision specified, that provision is mandatory if compliance with the standard is claimed.

3.25.2 *Should, Recommended, or It Is Recommended*. "Should," "recommended," or "it is recommended" is used to indicate provisions which are not mandatory but which are desirable as good practice.

3.26 *Significant Loss of Function*. The functional state of Equipment or Components that cannot be restored in a timely fashion to their original function by competent technicians after a design earthquake because the Equipment or components require parts that are not normally stocked locally or not readily available.

3.27 *Test Response Spectrum (TRS).* The acceleration response spectrum developed by the motion of the shake table to provide an input motion that simulates an earthquake for the qualification of Equipment. This motion is created to develop the CRS at the equipment attachment point. The TRS shall envelope the RRS with limited exceptions.

3.28 *Transmissibility.* A non-dimensional ratio that defines the force amplitude factor of load path in the EFRS in terms of steady-state forced vibration. The ratio may be expressed in terms of force, displacement, velocity, or acceleration and is used to characterize resonant modes of structural vibration.

3.29 *Zero Period Acceleration (ZPA).* The maximum peak acceleration used to derive a specific applied time history spectrum (the peak acceleration A_{FLX} is greater than the ZPA).

Section 4. Symbols

4.1 *Symbols.* The following symbols are used in this document. Refer to ASCE 7 and AC156 for additional information.

A_{FLX-H} = The probable maximum horizontal spectral acceleration that Flexible Equipment will experience in a seismic event defined by AC156.

A_{FLX-V} = The probable maximum vertical spectral acceleration that Flexible Equipment will experience in a seismic event defined by AC156.

a_p = In-structure equipment amplification factor. The a_p represents a comparison of the equipment's natural frequency to the fundamental frequency of the building structure as determined in ASCE 7 Section 13.6-1.

A_{RIG-H} = Horizontal spectral acceleration that Rigid Equipment will experience in a seismic event defined by AC156.

A_{RIG-V} = Vertical spectral acceleration that Rigid Equipment will experience in a seismic event defined by AC156.

D = Dead Load as used in the load combination formulas.

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F = Load due to fluids with well-defined pressures and maximum heights.
F_p = An equivalent horizontal static force that represents the dynamic accelerations of a seismic event used in the prescriptive method identified by ASCE 7 Section 13.3.1. The horizontal seismic design force is applied at the equipment's center of gravity.
H = Load due to lateral earth pressure, ground water pressure or pressure of bulk materials.
h = Average building/structure roof height with respect to grade as defined in ASCE 7 Section 13.3.1.
I_p = Equipment importance factor. I_p represents the life-safety importance factor of the Equipment or Component as defined in ASCE 7 Section 13.1.3.
L = Live load.
ρ = Redundancy factor based on the extent of structural redundancy present in a structure as defined in ASCE 7, Section 12.3.4. ρ = 1.0 for nonstructural components.
Q_E = Earthquake Load as used in the load combination formulas.
R_p = Equipment response modification factor. R_p represents the capability of the Equipment and attachment to absorb energy, as defined in ASCE 7 Section 13.6.1.
S = Snow load.
S_{DS} = Design spectral response acceleration at short period (0.2 secs), as determined in ASCE 7 Section 11.4.4.
W_p = Equipment operating weight, including all contents, as defined in ASCE 7 Section 13.3.1.
z = Height of the equipment attachment to the structure with respect to grade (ground level) as defined in ASCE 7 Section 13.3.1. For items at or below grade, z shall be 0.0 and not negative.

Section 5. Equipment

5.1 *Applicability.* Equipment shall be seismically qualified per the requirements contained in this standard. The qualification processes are shown in Figure 1. For each piece of Equipment, the seismic qualification method shall be identified as provided in Tables 1 and 2. As the complexity of Equipment increases, the methods allowed to qualify Equipment become more limited. Components can be qualified separately for multi-component Equipment. Component complexity may require the component to be qualified separately from the equipment EFRS especially for electronic components. Components that are deemed rugged are exempt from qualification.

For Equipment and Components to meet the special qualification requirements for Designated Seismic Systems, the device shall be shown to be functional after an earthquake as required by Section 13.2.2 in ASCE 7. When the Equipment is not part of a Designated Seismic System, the device's structural integrity shall be qualified in accordance with Table 1. In both cases, Attachments are not included in the qualification. The qualification of the Equipment shall include the loads applied at the Attachment Points.

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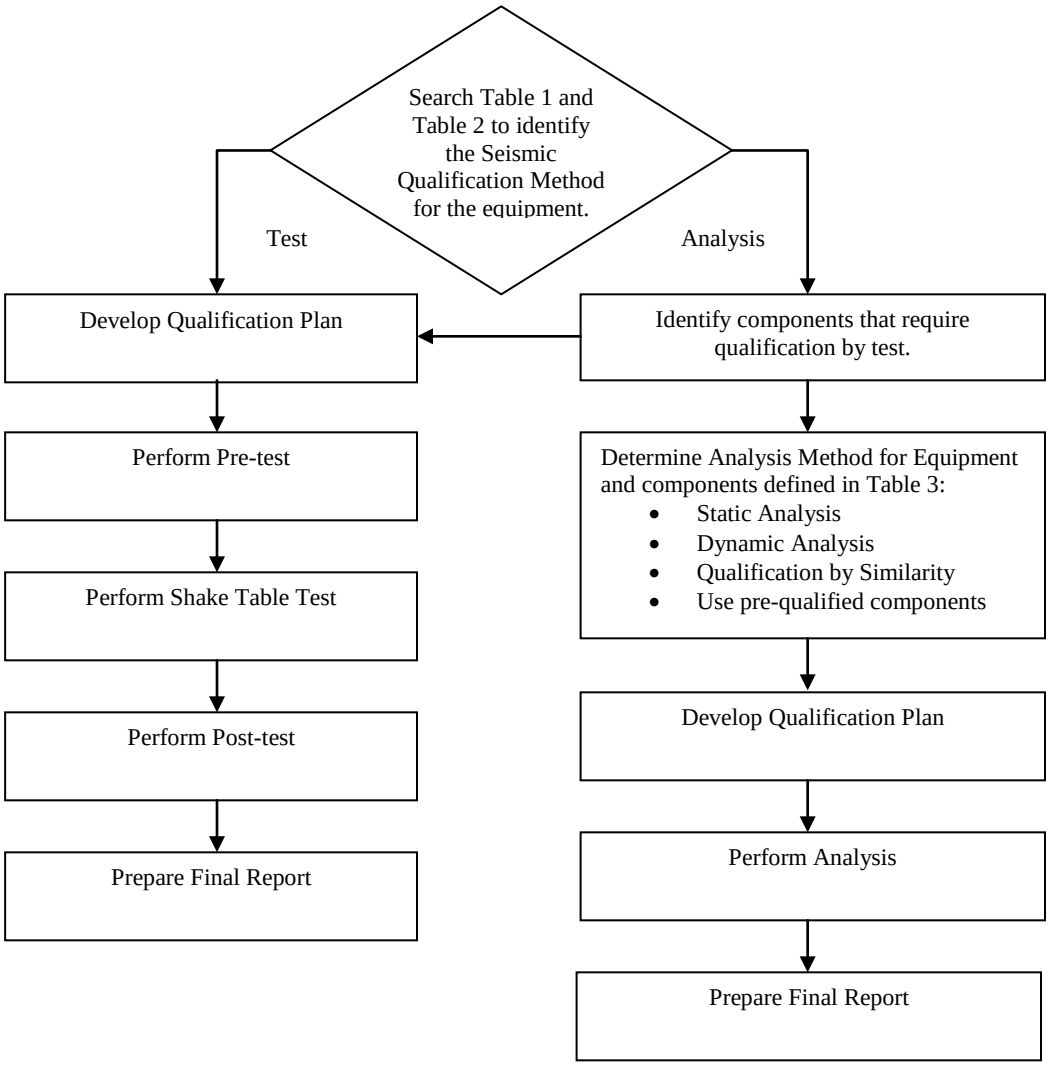


Figure 1. Qualification Flowchart

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Table 1. Seismic Performance Level[5]; Functionality (per ASCE 7 Section 13.2.2)					
Component Description	**Qualification Method**	**Qualification Focus**	**a_p**	**R_p**	**I_p**
Non-vibration Isolated Rugged Component[4]	Static Analysis	Attachment Point	1.0	See Note 6	1.5
	Dynamic Analysis	Attachment Point	RRS	See Note 6	1.5
	Shake Table Test	Attachment Point	per Standard AC156		
Vibration Isolated Rugged Component[4]	Static Analysis	Attachment Point	1.0	See Note 6	1.5
	Dynamic Analysis	Attachment Point	RRS	See Note 6	1.5
	Shake Table Test	Attachment Point	per Standard AC156		
Non-vibration Isolated Active or Energized Component	Shake Table Test[3]	Component Functionality and Attachment Point	per Standard AC156		
Vibration Isolated Active Component	Shake Table Test w/Isolation Mounts	Component Functionality and Attachment Point	Per Standard AC156		
Equipment Description	**Qualification Method**	**Qualification Focus**	**a_p**	**R_p**	**I_p**
Rugged Equipment[4]	Static Analysis	EFRS and Attachment Point	2.5	See Note 6	1.5
	Static Analysis w/Natural Frequency[1]	EFRS and Attachment Point	1.0 or 2.5[2]	See Note 6	1.5
	Dynamic Analysis	EFRS and Attachment Point	RRS	See Note 6	1.5
	Shake Table Test	EFRS and Attachment Point	per Standard AC156		
Non-vibration Isolated Active Equipment	Static Analysis of EFRS and Dynamic Analysis[4] (Component Qualification also required)	Equipment Functionality and Attachment Point	1.0 or 2.5[2]	See Note 6	1.5
	Dynamic Analysis of EFRS (Component Qualification also required)	Equipment Functionality and Attachment Point	RRS	See Note 6	1.5
	Shake Table Test	Equipment Functionality and Attachment Point	per Standard AC156		
Vibration Isolated Active Equipment	Shake Table Test w/Isolation Mounts	Equipment Functionality and Attachment Point	per Standard AC156		
Liquid Storage Tanks[4]	Static Analysis w/Sloshing Effects	Equipment Functionality and Attachment Point	Appendix F		
	Dynamic Analysis	Equipment Functionality and Attachment Point	Appendix F		

Notes:
1. Natural frequency can be determined by dynamic analysis or other means.
2. The value of a_p equal to 1.0 is for rigid Components and Equipment. The value of a_p equal to 2.5 is for flexible Components and Equipment. See Section 2 for definitions of rigid and flexible.
3. Dynamic analysis required to determine amplification factors for shake table testing of active or energized Components.
4. ASME pressure vessels are considered rugged but still require an evaluation of the EFRS
5. The local authority having jurisdiction may have more stringent requirements.
6. Refer to ASCE 7 Table 13.6-1

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Table 2. Seismic Performance Level[5]; Structural Integrity (per ASCE 7 Section 13.2.1)					
Component Description	**Qualification Method**	**Qualification Focus**	**a_p**	**R_p**	**I_p**
Non-vibration Isolated Rugged Component[4]	Static Analysis	Attachment Point	1.0	See Note 6	1.0
	Dynamic Analysis	Attachment Point	RRS	See Note 6	1.0
	Shake Table Test	Attachment Point	per Standard AC156		
Vibration Isolated Rugged Component[4]	Static Analysis	Attachment Point	1.0	See Note 6	1.0
	Dynamic Analysis	Attachment Point	RRS	See Note 6	1.0
	Shake Table Test	Attachment Point	per Standard AC156		
Non-vibration Isolated Active or Energized Component	Static Analysis	Attachment Point	2.5	See Note 6	1.0
	Static Analysis w/Natural Frequency[1]	Attachment Point	1.0 or 2.5[2]	See Note 6	1.0
	Dynamic Analysis	Attachment Point	RRS	See Note 6	1.0
	Shake Table Test	Attachment Point	per Standard AC156		
Vibration Isolated Active Component	Static Analysis	Attachment Point	2.5	2.0	1.0
	Dynamic Analysis	Attachment Point	RRS	2.0	1.0
	Shake Table Test[3]	Attachment Point	per Standard AC156		
Equipment Description	**Qualification Method**	**Qualification Focus**	**a_p**	**R_p**	**I_p**
Rugged Equipment[4] (motor HP < 10; heat transfer capacity < 200 MBH)	Static Analysis	Attachment Point	2.5	See Note 6	1.0
	Static Analysis w/Natural Frequency[1]	Attachment Point	1.0 or 2.5[2]	See Note 6	1.0
	Dynamic Analysis	Attachment Point	RRS	See Note 6	1.0
	Shake Table Test	Attachment Point	per Standard AC156		
Non-vibration Isolated Active Equipment	Static Analysis	EFRS and Attachment Point	2.5	See Note 6	1.0
	Static Analysis w/Natural Frequency[1]	EFRS and Attachment Point	1.0 or 2.5[2]	See Note 6	1.0
	Dynamic Analysis	EFRS and Attachment Point	RRS	See Note 6	1.0
	Shake Table Test	EFRS and Attachment Point	per Standard AC156		
Vibration Isolated Active Equipment	Static Analysis	EFRS and Attachment Point	2.5	2.0	1.0
	Dynamic Analysis	EFRS and Attachment Point	RRS	2.0	1.0
	Shake Table Test	EFRS and Attachment Point	per Standard AC156		
Liquid Storage Tanks[4]	Static Analysis w/Sloshing Effects	EFRS and Attachment Point	Appendix F		
	Dynamic Analysis	EFRS and Attachment Point	Appendix F		

Notes:
1. Natural frequency can be determined by dynamic analysis or other means.
2. The value of a_p equal to 1.0 is for rigid Components and Equipment. The value of a_p equal to 2.5 is for flexible Components and Equipment. See Section 2 for definitions of rigid and flexible.
3. Dynamic analysis required to determine amplification factors for shake table testing of active or energized Components.
4. ASME pressure vessels are considered rugged but still require an evaluation of the EFRS
5. The local authority having jurisdiction may have more stringent requirements.
6. Refer to ASCE 7 Table 13.6-1.

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Section 6. Seismic Demand

6.1 *Seismic Demand.* The Seismic Demand for Equipment is based on the design spectral response acceleration at short periods, S_{DS}. This acceleration value is modified based on many factors and results in the total horizontal acceleration at the center of gravity of Equipment and its Components in terms of g-levels. AC156 is the accepted document that defines the acceleration demand as shown in Figure 2, which is used for dynamic testing and dynamic analysis of Equipment. ASCE 7 defines an equivalent static horizontal force F_P based on the design spectral acceleration that is used in static analysis discussed later in this section. This section will provide guidance on how to use the reference criteria to determine the Seismic Demand. Additional explanation of how the demand is calculated is in Appendix E.

6.2 *Derivation of Seismic RRS.* The equipment earthquake response spectra for testing Equipment are defined in AC156 and are applied in the horizontal and vertical directions. The spectra are applied simultaneously at the Attachment Points of the Equipment. The shake table testing input is adjusted so that the response at the Attachment Points meets the criteria established in AC156. The RRS for horizontal and vertical accelerations shall be developed based on the normalized response spectra shown in Figure 2 (Reference from AC156). The RRS for the vertical direction shall be two-thirds of the horizontal acceleration at ground level. The horizontal accelerations (A_{FLX} and A_{RIG}) shall be calculated as specified in equations 1 through 4 (Reference AC156). The RRS has an assumed 5 percent damping value of critical Damping for Equipment.

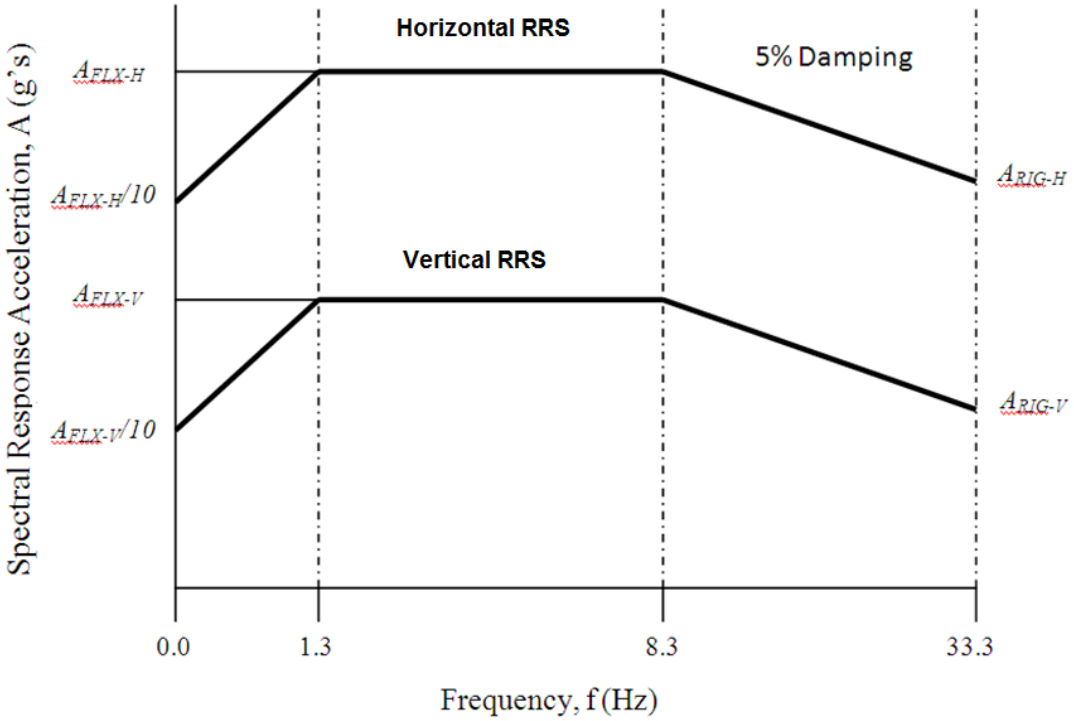


Figure 2. RRS, Normalized for Equipment

These assumptions allowed by AC156 result in normalizing the acceleration factors that define the horizontal acceleration RRS.

Horizontal: $A_{FLX-H} = S_{DS} \cdot (1 + 2z/h)$ 1

$A_{RIG-H} = 0.4\ S_{DS} \cdot (1 + 2z/h)$ 2

Vertical: $A_{FLX-V} = 2/3\ S_{DS}$ 3

$A_{RIG-V} = 0.4 \cdot 2/3\ S_{DS}$ 4

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A_{FLX-H} is limited to a maximum value of 1.6 times S_{DS} (equation 5). A_{RIG-H} is limited to 3 times 0.4 or 1.2 times S_{DS} (equation 6). The 1.2 times S_{DS} can be applied to Equipment that is considered rigid with a natural frequency above 33.3 Hz.

$$A_{FLX-H}\,(MAX) = 1.6 \cdot S_{DS} \quad 5$$

$$A_{RIG-H}\,(MAX) = 1.2 \cdot S_{DS} \quad 6$$

Logarithmic interpolation can be used between the A_{FLX-H} and A_{RIG-H} using the 1.6 and 1.2 factors for the acceleration with 8.3 Hz and 33.3 Hz for the frequency. A good approximation for Equipment that has a natural frequency of 16 Hz is 1.4 times S_{DS}. However, some Equipment may have a natural frequency above 16 Hz. This provides a small reduction in demand from the 1.6 times S_{DS} to 1.4 times S_{DS} as shown in equation 7.

$$A_{RIG-H}\,(MAX) = 1.4 \cdot S_{DS} \quad 7$$

For Equipment restricted to at grade locations, A_{FLX-H} is limited to a maximum value of 1.0 times S_{DS} as shown in Equation 8 where z in equation 1 is set at 0.0. For Rigid Equipment restricted to at grade locations, A_{RIG-H} is limited to a maximum value of 0.4 times 1.4 times S_{DS} resulting in Equation 9. For some applications, the Equipment may be restricted to be installed "at grade" to take advantage of lower demands if the Equipment does not have capacity that meets the criteria in Equations 5 and 6.

$$A_{FLX-H}\,(MAX \text{ at Grade}) = 1.0 \cdot S_{DS} \quad 8$$

$$A_{RIG-H}\,(MAX \text{ at Grade}) = 0.4 \cdot 1.4 \cdot S_{DS} = 0.56 \cdot S_{DS} \quad 9$$

The acceleration g-level demand to qualify Equipment is defined in Equations 5 and 8 for Flexible Equipment or Rigid Equipment installed on isolation springs. The acceleration g-level demand to qualify Equipment is defined in Equations 7 and 9 for Rigid Equipment (natural frequencies above 16 Hz) rigidly attached to the building structure. The vertical acceleration value is not used in the comparison for demand versus capacity. It is assumed that the vertical acceleration is included in the equipment qualification at a 2/3 fraction of the horizontal acceleration at ground level. So the capacity of the Equipment will be provided for the horizontal g-level that the Equipment can survive and, if necessary, function after the seismic event to be compared with the demand g-levels as determined by Equations 5 and 8 or Equations 7 and 9.

6.3 *Derivation of Seismic CRS.* The Seismic Demand of Equipment defined in Section 6.1 is based on AC156 for qualifying Equipment by test. Further discussion defines the Seismic Demand based on natural frequencies to be used to qualify Equipment by analysis. The Seismic Demand derived by the requirements in Section 6.1 for either test or analysis is defined as the CRS.

6.4 *Seismic Demand.* The seismic demand on the equipment is selected depending on the type of qualification.

6.4.1 *Demand for Qualification by Testing.* The demand will be provided by the motion of the shake table and the response measured at the equipment attachment. The measured response is the demand. This response shall be in terms of a spectrum as identified in Figure 2. Whereas the peak of the demand curve will be A_{FLX-H} . This qualification method allows the equipment to yield and approach the strength failure without loss of function.

6.4.2 *Demand for Qualification by Dynamic Analysis.* The maximum horizontal acceleration and coincident vertical acceleration is applied at the equipment attachment. As an example, the demand input for floor mounted equipment would be applied at the base. The dynamic analysis model will result in the applicable responses of the EFRS based on the natural frequencies of the equipment. The shape of the input demand shall match the demand as depicted in Figure 2. Whereas the peak of the demand curve will be A_{FLX-H} .

This method limits the stress levels below yield. Conservatism of this method to show operability maintains the structure below yield and results in a safety factor of 1.4 from the testing method. The

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