Vibration Durability Considerations for HVAC Equipment and Piping

This document contains resources for vibration durability, including seismic activity, as it relates to refrigerant piping used in HVACR and water heating equipment.

AC units must meet shipping, steady-state operational vibration, and seismic event requirements where applicable. UL/CSA 60335-2-40 requires that all A2L AC units, including VRF, must be shown to be leak free following 180-minute transport per ASTM D4728-06 standard simulation vibration testing and drop testing. Following installation, the unit must be shown to be leak free following 960 operation cycles. Copper tubing is not rigidly mounted to allow for expansion, and vibration is further mitigated by expansion loops for thermal conditions and seismic isolators (required in California Building Code, where applicable). In addition, VRF also requires vibration testing for piping located in the space.

International Building Code (IBC) and California Building Code (CBC) Requirements

- Only Category IV buildings (e.g., hospitals, disaster relief) require certificate of seismic code compliance
- Certificate of seismic code compliance may be required for equipment anchorage and restraint systems in some Category III buildings (e.g., high occupancy buildings, power generation facilities)
- There are no seismic requirements for boilers in residential dwellings
- Water heaters must be secured in residential settings

Standards and Resources to Properly Design and Install Equipment to Withstand Vibrational Activity

AHRI Standard 1270 - 2015 Requirements for Seismic Qualification of HVACR Equipment	• Design and installation requirements consistent with ASCE Standard 7-10 (previous edition of ASCE 7). • Complementary to the 2012 International Building Code (IBC), which includes a number of provisions for seismic design and certification of nonstructural components. • Standard scheduled for reaffirmation in 2020.
Manufacturer Shipping Qualifications	• HVACR manufacturers perform shipping and vibration qualification tests and other voluntary tests when designing equipment. These are based on ASTM D4728-06 but with added testing defined by manufactures. • HPAC Engineering published an article on building design considerations and how HVACR equipment can be tested as a single "black box." The "black box" concept explains that during the shipping of equipment, any components inside the "black box" that survive shipment would likely survive an earthquake.
ASCE/SEI Standard 7-16 American Society of Civil Engineers (ASCE) / Structural Engineering Institute (SEI) Minimum Design Loads and Associated Criteria for Buildings and Other Structures	• Standard for determining minimum design loads and associated criteria for buildings and other structures. • Standard includes procedures for the qualification by analysis (calculation), shaker table test, and extrapolation. • Seismic design provisions created to withstand seismic activity. • AHRI Standard 1270 (2010) is incorporated by reference in ASCE/SEI Standard 7-16.

2018 IBC International Building Code (IBC) 2018 IMC International Mechanical Code (IMC)	• Chapters 16 and 17 of the 2018 International Building Code (IBC) provide procedures and criteria for testing equipment and establishes where additional inspections and testing must be provided, especially regarding seismic activity (Exhibit 2). • IBC Sections 1603 and 1605 specify load requirements for building design. • IBC Section 1613 specifies earthquake load requirements. • IBC Sections 1704 and 1705 include special inspections instructions and considerations for carrying out seismic resistance. • 2018 IBC refers to ASCE/SEI Standard 7-16. • 2018 IMC Section 301.18 says mechanical system supports shall be designed and installed for seismic forces in accordance with the IBC.
NEHRP Recommended Seismic Provisions for New Buildings and Other Structures. National Earthquake Hazards Reduction Program (FEMA) Recommended Seismic Provisions for New Buildings and Other Structures	• The Federal Emergency Management Authority (FEMA) committed under the National Earthquake Hazard Reduction Program (NEHRP) to improve seismic design and building practices in the U.S. • The 2015 NEHRP Provisions are a knowledge-based resource document and adopts ASCE 7-10 by reference. A 2020 version is in progress as of June 2020. • Chapter 13 addresses non-structural components, including HVAC equipment.
UL 60335-2-40 3rd edition Household and Similar Electrical Appliances - Safety - Part 2-40: Particular Requirements for Electrical Heat Pumps, Air-Conditioners and Dehumidifiers	• UL/CSA 60335-2-40 requires that all A2L AC units, including VRF, must be shown to be leak free following 180-minute transport per ASTM D4728-06 standard simulation vibration testing and drop testing. • Following installation, the unit must be shown to be leak free following 960 operation cycles.
California Building Code (CBC): Title 24, California Code of Regulations (Office of Statewide Health Planning and Development – OSHPD)	• California's seismic codes are managed by OSHPD • Chapters 16 and 17 of the 2019 California Building Code (CBC) provides a variety of procedures and criteria for testing equipment and establishes where additional inspections and testing must be provided, especially regarding seismic activity. • Sections 1603 and 1605 specify load requirements for building design. Section 1613 specifies earthquake load requirements. • Sections 1704 and 1705 include special inspections instructions and considerations for carrying out seismic resistance. • 2019 CBC refers to ASCE/SEI Standard 7-16.
Oregon Codes and Standards	• Adopted the 2018 IBC and IMC.
Washington State Building Code (SBC)	• Adopted the 2015 IBC into its SBC. Recently adopted the 2018 IBC to become effective July 2020, but may be moved to February 1, 2021.

New Madrid Seismic Zone (NMSZ)	• AR, IN, KY, and TN have statewide seismic building codes. IL, MI, and MO do not have statewide seismic building codes. • Arkansas - Adopted 2012 IBC and 2009 International Mechanical Code (IMC). • Illinois - Adopted 2015 IBC and IMC for state-owned buildings. No state-wide codes. • Indiana - Adopted 2012 IBC and IMC. • Kentucky - Adopted the 2015 editions of IBC and IRC. In the KBC (Kentucky Building Code) the state has adopted by reference the 2015 edition of the IMC and 2012 IECC. • Mississippi - Adopted the 2018 IBC and IMC. • Missouri - Adopted the 2012 IBC and IMC on state office space and Sec. 107 of the 2012 IBC to be used when there are no local codes. • Tennessee - Adopted 2012 International Building Code and the 2012 International Property Maintenance Code. Counties are permitted to adopt later editions of the code.

Standards and Resources to Properly Design and Install Piping for HVAC Equipment

AHRI Standard 1270 - 2015 Requirements for Seismic Qualification of HVACR Equipment	• Seismic requirements consistent with ASCE 7-10 (previous edition of ASCE 7). • Functional compliance testing includes tolerances for allowable outcomes as defined in Table 6 (Exhibit 1). • Standard scheduled for reaffirmation in 2020.
ANSI/ASHRAE Standard 15 (2019) Safety Standard for Refrigeration Systems	• Establishes procedures for design, construction, installation, inspection, testing, and operation of the equipment and systems using refrigerants. • 2019 version includes guidance for Class A2L refrigerants
ASHRAE Standard 15.2 (Proposed)	• ASHRAE 15.2 includes refrigerant piping safeguards, including reference to ASME 31.5. – Special requirements for A2L refrigerants in section 8. • This proposed standard is targeted for completion by December 2020.
ASHRAE Practical Guide to Seismic Restraint (Second Edition)	• Design guide to mechanical, plumbing, and electrical systems for earthquakes. – Consistent with 2009 IBC, ASCE 7-10, and 2010 California Building Code. • Covers piping connections and includes information on the advantages of different types of flexible connectors, the importance of proper connector orientation, and the need for flexible connector testing to develop accurate stiffness at operating pressure.
ASME B31.5 (2019) Refrigeration Piping and Heat Transfer Components	• Standard for safety and best practices for refrigerant, heat transfer components, and secondary coolant piping. • Complements ASME B31.1 (2018) – Power Piping, which includes design, materials, fabrication, erection, test, inspection, operation, and maintenance requirements and has a section on seismic activity.
UL 60335-2-40 3rd edition Household and Similar Electrical Appliances - Safety - Part 2-40: Particular Requirements for Electrical Heat Pumps, Air Conditioners and Dehumidifiers	• Stringent safety requirements for piping. Design and installation requirements for A2L piping more robust than A1. • Includes safety requirements associated with A1, B1, A2L, A2, and A3 refrigerants, include *in situ* and transportation guidance. A3 refrigerants have the most stringent requirements. Toxicity Class B2 and B3 refrigerants are not included in scope. • VRF installation requires vibration testing for installed piping.

UL 60335-2-89 1st edition Household and Similar Electrical Appliances - Safety - Part 2-89: Particular Requirements for Commercial Refrigerating Appliances with an Incorporated or Remote Refrigerant Unit or Compressor (Proposed)	• Stringent safety requirements for piping. Design and installation requirements for A2L piping more robust than A1. • Includes safety requirements associated with A1, A2L, A2, and A3 refrigerants, include *in situ* and transportation guidance. A3 refrigerants have the most stringent requirements. Ammonia refrigerants are not included in scope. • New edition of 2-89 targeted for review in fall 2020. Targeted publication April or May 2021.

Exhibit 1

ANSI/AHRI STANDARD 1270 (I-P)-2015

Table 6. Allowable Minor Damage States for Designated Seismic Systems

Equipment	Allowable Minor Damage States[1,2]
Vertical Packaged AC Units Packaged Terminal AC Units Water Source Heat Pumps Unitary Small AC Units Unitary Large AC Units (above 65,000 BTUH) Dehumidifiers	Component freely rotates and has no visible deformation of the Component's Equipment Force Resistance System (EFRS). Equipment that provides airflow has no visible deformation of the EFRS/housing (envelope) and no visible separation of access doors or EFRS/housing (envelope). No visible or minimal deformation of the piping systems (with no leakage), refrigerant retaining Components and EFRS. No visible deformation of the piping system, water retaining Components and EFRS. Failure of personnel lighting and minor deformation of electrical power/control conduit. Minor deformation of standing seam construction is allowed only if the deformation does not affect the functionality of any required Component.

IBC Code Seismic Requirements

Seismic Use Group	Building Occupancy	Seismic Design Category (1)	Equipment Importance Factor (2)	Cetificate of Compliance
I	Buildings and other structures that represent a low hazard to human life in the event of failure including, but not limited to: - Agricultural facilities - Certain temporary facilities - Minor storage facilities	A, B	1.0 or 1.5	Not required
II	Buildings and other structures except those listed in Categories I, III and IV	A, B, C	1.0	Only Required only for life safety equipment
III	Buildings and other structures that represent a substantial hazard to human life in the event of failure including, but not limited to: - Buildings and other structures where more than 300 people congregate in one area - Buildings and other structures with elementary school, secondary school or day care facilities with an occupant load greater than 250 - Buildings and other structures with an occupant load greater than 500 for colleges or adult education facilities - Health care facilities with an occupant load of 50 or more resident patients but not having surgery or emergency treatment facilities - Jails and detention facilities - Any other occupancy with an occupant load greater than 5,000 - Power-generating stations, water treatment for potable water, waste water treatment facilities and other public utility facilities not included in Category IV - Buildings and other structures not included in Category IV containing sufficient quantities of toxic or explosive substances to be dangerous to the public if released	C, D, E, F	1.0	May be required for equipment anchorage and restraint system
IV	Buildings and other structures designed as essential facilities including, but not limited to: - Hospitals and other health care facilities having surgery or emergency treatment facilities - Fire, rescue and police stations and emergency vehicle garages - Designated earthquake, hurricane or other emergency shelters - Designated emergency preparedness, communication, and operation centers and other facilities required for emergency response - Power-generating stations and other public utility facilities required as emergency backup facilities for Category IV structures - Structures containing highly toxic materials as defined by Section 307 where the quantity of the material exceeds the maximum allowable quantities of Table 307.7(2) - Aviation control towers, air traffic control centers and emergency aircraft hangars - Buildings and other structures having critical national defense functions - Water treatment facilities required to maintain water pressure for fire suppression	C, D, E, F	1.5	Required
	1- All structures shall be assigned to a seismic design category based on their seismic use group and the design spectral response acceleration coefficients, SDS and SD1, determined in accordance with Section 1615.1.3 or 1615.2.5 of the IBC. S_{ds} is the spectral response and is a function of the location and soil composition			
	2 - Equipment importance factor (Ip) shall be 1.0 except for the following and then shall be set to 1.5; - Life-safety component is required to function after earthquake - Component contains hazardous or flammable material in quantities that exceed the exempted amounts for open system listed in chapter 4 -Storage racks in occupancies open to general public (e.g warehouse retails stores) All Seismic use group III shall have an Ip =1.5			

TABLE 1616.3(1)
SEISMIC DESIGN CATEGORY BASED ON
SHORT-PERIOD RESPONSE ACCELERATIONS

VALUE OF S_{DS}	SEISMIC USE GROUP		
	I	II	III
$S_{DS} < 0.167g$	A	A	A
$0.167g \le S_{DS} < 0.33g$	B	B	C
$0.33g \le S_{DS} < 0.50g$	C	C	D
$0.50g \le S_{DS}$	D[a]	D[a]	D[a]

a. Seismic Use Group I and II structures located on sites with mapped maximum considered earthquake spectral response acceleration at 1-second period, S_1, equal to or greater than 0.75g, shall be assigned to Seismic Design Category E, and Seismic Use Group III structures located on such sites shall be assigned to Seismic Design Category F.

Exhibit 2

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