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D2.4 – Understanding Wind for NBCC

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D2.5 – UFC Seismic, Wind, & Antiterrorism

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IBC SEISMIC

D2.1.1 – Introduction:

The purpose of this section is to provide design professionals, contractors, and building officials responsible for the nonstructural components (MEP – Mechanical, Electrical, and Plumbing) with the information and guidance required to ensure that the seismic restraints required for a specific project are selected and/or designed, and installed in accordance with the provisions code. This guide will be written in several easily referenced sections that deal with specific portions of the code.

This guide is based on the International Building Code (IBC). The 2000 IBC and the 2003 IBC are very similar, and in fact are almost identical. When they are referenced in this section, it will be as 2000/2003 IBC. The 2006 IBC and 2009 IBC are also nearly identical, and will be referenced in the section as 2006/2009 IBC. The latest version of the IBC is dated 2012 and is substantially different from the previous versions, particularly in respect to the attachment of components to concrete. The seismic provisions for all of the versions of the IBC for nonstructural components are found in ASCE 7. The IBC version with its corresponding ASCE 7 reference is shown in Table 2.1.1-1.

Table D2.1.1-1; IBC & ASCE 7 References

INTERNATIONAL BUILDING CODE YEAR (IBC)	ASCE 7 VERSION	ASCE 7 SEISMIC NON-STRUCTURAL COMPONENTS CHAPTER
2000	98	9
2003	02	9
2006	05	13
2009	05	13
2012	10	13

Since all versions of the IBC are still currently adopted by various states, they will all be discussed and covered in this section.

The following References are used throughout Section D2.1.

1. 2007 ASHRAE HANDBOOK – Heating, Ventilating, and Air-Conditioning Applications; American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E. Atlanta, GA 30329, 2007; Chapter 54 Pp 54-11 and 54-12.

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2. 2000 International Building Code; International Code Council, 5203 Leesburg Pike, Suite 708, Falls Church, Virginia, 22041-3401; 2000.

3. ASCE 7-98 Minimum Design Loads for Buildings and Other Structures; American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400, Chapter 9.

4. 2003 International Building Code; International Code Council, Inc., 4051 West Flossmoor Road, Country Club Hills, Illinois 60478-5795; 2002.

5. ASCE/SEI 7-02 Minimum Design Loads for Buildings and Other Structures; American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400, Chapter 9.

6. 2006 International Building Code; International Code Council, Inc., 4051 West Flossmoor Road, Country Club Hills, Illinois 60478-5795; 2006.

7. 2009 International Building Code; International Code Council, Inc., 4051 West Flossmoor Road, Country Club Hills, Illinois 60478-5795; 2009.

8. ASCE/SEI 7-05 Minimum Design Loads for Buildings and Other Structures; American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400, Chapters 1, 2, 11, 13, 20, and 21.

9. 2012 International Building Code; International Code Council, Inc., 4051 West Flossmoor Road, Country Club Hills, Illinois 60478-5795; 2012

10. ASCE/SEI 7-10 Minimum Design Loads for Buildings and Other Structures; American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400; 2010, Chapters 1, 2, 11, 13, 20, 21, 22 and 23.

11. Building Code Requirements for Structural Concrete (ACI 318-08) and Commentary – Appendix D; American Concrete Institute, 38800 Country Club Drive, Farmington Hills, MI 48331.

12. SMACNA, Seismic Restraint Manual – Guidelines for Mechanical Systems 3rd Edition; Sheet Metal and Air Conditioning Contractors' National Association, Inc., 4201 Lafayette Center Drive, Chantilly, Virginia 20151-1209; March, 2008.

The selection and installation of the proper seismic restraints for non-structural components requires good coordination with the design professionals and contractors involved with the building project. A good spirit of cooperation and coordination is especially required for projects that have been designated as essential facilities, such as hospitals, emergency response centers, police and fire stations. Coordination between the various design professionals and contractors

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will be a constant theme throughout this section. This coordination is vital for the following reasons.

1. The seismic restraints that are installed for a system can and will interfere with those of another unless restraint locations are well coordinated.

2. The space required for the installed restraints can cause problems if non-structural walls need to be penetrated, or other non-structural components are in the designed load path for the restraints.

The building end of the seismic restraints must always be attached to structure that is adequate to carry the code mandated design seismic loads. It is the responsibility of the structural engineer of record to verify this.

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REQUIRED BASIC PROJECT INFORMATION

D 2.1.2.1 Introduction:

As with any design job, there is certain basic information that is required before seismic restraints can be selected and placed. The building owner, architect, and structural engineer make the decisions that form the basis for the information required to select the seismic restraints for the mechanical and electrical systems in the building. This information should be included in the specification and bid package for the project. It also should appear on the first sheet of the structural drawings. For consistency, it is good practice to echo this information in the specification for each building system, and on the first sheet of the drawings for each system. In this fashion, this information is available to all of the contractors and suppliers that will have a need to know.

D2.1.2.2 Building Use – Nature of Occupancy (Section 1.5) [Section 1.5] {Section 1.5}[1]:

How a building is to be used greatly affects the level of seismic restraint that is required for the non-structural components. In 2012 IBC, the building use will be defined by Risk Category. In the 2006/2009 IBC the building use is defined through the Occupancy Category, which ranges from I to IV. Occupancy Category I is applied to buildings where failure presents a low hazard to human life. At the other end of the range, Occupancy Category IV is applied to buildings which are deemed to be essential. In 2012 IBC, the building use will be defined by Risk Category. The Risk Categories are assigned in exactly the same way as the Occupancy Categories in 2006/2009 IBC. In the first two versions of the IBC (2000/2003), the building use was defined though the Seismic Use Group which varied from I to III. Table 1-1 of ASCE 7-98/02 and ASCE 7-05 describes which types of buildings are assigned to which Occupancy Category. Table D2.1.2-1 below summarizes the information found in Tables 1-1 and 9.1.3 of ASCE 7-98/02, Table 1-1 of ASCE 7-05, and Table 1.5-1 of ASCE 7-10, and ties the Seismic Use Group from the previous versions of the IBC to the Occupancy Category. The nature of the building use, or its Occupancy Category, is determined by the building owner and the architect of record.

D2.1.2.3 Site Class – Soil Type (Sections 9.4.1.2.1, 9.4.1.2.2) [Section 11.4.2 & Chapter 20] {Section 11.4.2 & Chapter 20}:

The Site Class is related to the type of soil and rock strata that directly underlies the building site.

The Site Class ranges from A to F progressing from the stiffest to the softest strata. Table D2.1.2-2 lists the various Site Classes and their corresponding strata.

Generally the structural engineer is responsible for determining the Site Class for a project. If the structural engineer's firm does not have a geotechnical engineer on staff, this job will be

[1] References in brackets (Section 1.5), [Section 1.5], and {Section 1.5} apply to sections, tables, and/or equations in ASCE 7-98/02, ASCE 7-05, and ASCE 7-10 respectively which forms the basis for the seismic provisions in 2000/2003 IBC, 2006/2009 IBC, and 2012 respectively.

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contracted to a geotechnical firm. The Site Class is determined in accordance with the references stated above from ASCE 7-98/02, ASCE 7-05, and ASCE 7-10. The site profile is normally obtained by drilling several cores on the property. If there is insufficient information concerning the soil properties, then the default Site Class D is assigned to the project.

Table D2.1.2-1; Building Use vs. Occupancy Category, Risk Category, & Seismic Use Group (Table 1-1, Table 9.1.3), [Table 1-1], {Table 1.5-1}

SEISMIC USE GROUP 2000/2003 IBC	OCCUPANCY CATEGORY 2006/2009 IBC	RISK CATEGORY 2012 IBC	BUILDING USE
I	I	I	Buildings and other structures whose failures would pose a significant risk to human life.
	II	II	Buildings and other structures not listed in Occupancy/Risk Categories I, III, and IV or Seismic Use Groups II and III.
II	III	III	Buildings and other structures whose failure would pose a significant risk to human life, cause a significant economic impact, or cause mass disruption in the day-to-day life of civilians.
III	IV	IV	Buildings or other structures that are essential for post disaster recovery, whose failure would pose a substantial hazard to the community, or are used to process, store, or dispose of hazardous materials.

Table D2.1.2-2; Site Class vs. Soil Type (Table 9.4.1.2) [Table 20.3-1] {Table 20.3-1}

SITE CLASS	SOIL TYPE
A	Hard Rock
B	Rock
C	Very Dense Soil & Soft Rock
D	Stiff Soil (Default Site Class)
E	Soft Clay Soil
F	Liquefiable Soils, Quick Highly Sensitive Clays, Collapsible Weakly Cemented Soils, & etc. These require site response analysis.

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D2.1.2.4 Mapped Acceleration Parameters (Sections 9.4.1.2.4 & 9.4.1.2.5) [Sections 11.4.3 & 11.4.4 and Chapters 21 & 22] {Sections 11.4.3 & 11.4.4 and Chapters 21 & 22}

The United States Geological Survey, USGS, has mapped all of the known fault lines in the United States and its possessions. They have assigned ground level acceleration values to each location based on the Maximum Considered Earthquake, MCE, for two earthquake periods, 0.2 sec and 1.0 sec, at 5% damping. The mapped values are listed in terms of %g, where 1g is 32.2 ft/sec^2, 386.4 in/sec^2, 9.8 m/sec^2. The long period values are generally applied to the buildings and other structures since they react more strongly to the long period excitation due to their relatively high mass and low stiffness. The code specifies the use of short period values when evaluating non-structural components, which include pipe and duct, as they respond more strongly to the short period excitation due to their relatively low mass and high stiffness.

The Mapped Acceleration Parameters are available in ASCE 7-98/02 for 2000/2003 IBC, ASCE 7-05 for 2006/2009 IBC and ASCE 7-10 for 2012 IBC, or may be obtained from the USGS cataloged by ZIP Code. The short period Mapped Acceleration Parameter is usually denoted as S_S and the Long period Mapped Acceleration Parameter is denoted as S_1. Note that the values for S_S and S_1 may be different for 2000/2003 IBC, the 2006/2009 IBC or the 2012 IBC. Be sure the correct values are being used for the code that is in force in your jurisdiction.

<u>Special Note:</u> For the purpose of making preliminary estimates, the long and short period mapped acceleration parameters for selected U. S. cities are given in Table D2.1.2-3 (the values for 2012 IBC have not been published at this time as indicated by TBP on Table D2.1.2-3). For the U. S. cities please refer to the data compiled by the USGS by ZIP CODE. For international locations, local geological assessments should be sought from reputable sources at that location.

The Site Class information is then used to determine the Design Spectral Acceleration Parameters, S_{DS} and S_{D1}, for the short and long period MCE respectively. Eq D2.1.2-1 and Eq D2.1.2-2 may be used to estimate the Design Spectral Acceleration Parameters.

$$S_{DS} = \frac{2}{3} F_a S_S$$ **Eq D2.1.2-1 (9.4.1.2.4-1) [11.4-3] {11.4-3}**

And

$$S_{D1} = \frac{2}{3} F_v S_1$$ **Eq D2.1.2-2 (9.4.1.2.4-2) [11.4-4] {11.4-4}**

Where:

F_a = the short period Site Coefficient which is listed in Table D2.1.2-4. The values for F_a which correspond to values of S_S that fall between those listed in Table D2.1.2-4 may be obtained through linear interpolation.

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F_v = the long period Site Coefficient which is listed in Table D2.1.2-5. The values for F_v which correspond to values of S_1 that fall between those listed in Table D2.1.2-5 may be obtained through linear interpolation.

S_{DS} = the Design Short Period Spectral Acceleration Parameter which has been corrected for the Site Class.

S_{D1} = the Design Long Period Spectral Acceleration Parameter which has been corrected for the Site Class.

S_S = the Mapped Short Period Acceleration Parameter for the MCE @ 5% damping.

S_1 = the Mapped Long Period Acceleration Parameter for the MCE @ 5% damping.

If not otherwise listed for the project, the structural engineer should be contacted for the values of S_{DS} and S_{D1}. These values are not only required to determine the design accelerations, but also to determine the Seismic Design Category for the building, which will be discussed next.

D2.1.2.5 Seismic Design Category (Section 9.4.2.1) [Section 11.6] {Section 11.6}:

This parameter is of great importance to everyone involved with non-structural components. The Seismic Design Category to which a building has been assigned will determine whether seismic restraints are required or not, and if they qualify for exemption, which non-structural components may be exempted, and which will need to have seismic restraints selected and installed. The non-structural components within a building will be assigned to the same Seismic Design Category as the building itself. There are six Seismic Design Categories, A, B, C, D, E, and F. The level of restraint required increases from Seismic Design Category A through F. Up through Seismic Design Category D, the Seismic Design Category to which a building or structure is assigned is determined though the use of Tables D2.1.2-6 and D2.1.2-7.

To determine the Seismic Design Category both the Long (S_{D1}) and Short (S_{DS}) Period Design Response Acceleration Parameter must be determined. The most stringent Seismic Design Category, resulting from the two acceleration parameters, will be assigned to the project.

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Table D2.1.2-3; Mapped Acceleration Parameters for Selected U.S. Cities 2000/2003 IBC, 2006/2009 IBC, & 2012 IBC (TBP)

STATE, CITY	ZIP CODE	S_S 00	S_S 06	S_S 12	S_1 00	S_1 06	S_1 12
AL							
Birmingham	35217	0.33	0.31	0.27	0.12	0.10	0.11
Mobile	36610	0.13	0.12	0.11	0.06	0.05	0.06
Montgomery	36104	0.17	0.16	0.14	0.08	0.07	0.08
AR							
Little Rock	72205	0.48	0.50	0.41	0.18	0.16	0.17
AZ							
Phoenix	85034	0.23	0.19	0.18	0.07	0.06	0.06
Tucson	85739	0.33	0.29	0.28	0.09	0.08	0.08
CA							
Fresno	93706	0.76	0.78	0.95	0.30	0.29	0.34
Los Angeles	90026	1.55	2.25	2.78	0.60	0.83	0.99
Oakland	94621	1.98	1.97	2.27	0.87	0.77	0.95
Sacramento	95823	0.59	0.64	0.70	0.23	0.25	0.30
San Diego	92101	1.61	1.62	1.26	0.86	0.82	0.49
San Francisco	94114	1.50	1.61	1.64	0.86	0.82	0.76
San Jose	95139	2.17	1.60	1.50	0.78	0.60	0.60
CO							
Colorado Springs	80913	0.18	0.22	0.19	0.06	0.06	0.07
Denver	80239	0.19	0.21	0.18	0.06	0.06	0.06
CT							
Bridgeport	06606	0.34	0.27	0.21	0.09	0.06	0.07
Hartford	06120	0.27	0.24	0.18	0.09	0.06	0.07
New Haven	06511	0.29	0.25	0.19	0.08	0.06	0.07
Waterbury	06702	0.29	0.25	0.19	0.09	0.06	0.07
FL							
Ft. Lauderdale	33328	0.07	0.06	0.05	0.03	0.02	0.03
Jacksonville	32222	0.14	0.14	0.11	0.07	0.06	0.06
Miami	33133	0.06	0.05	0.05	0.02	0.02	0.02
St. Petersburg	33709	0.08	0.07	0.06	0.04	0.03	0.03
Tampa	33635	0.08	0.07	0.06	0.03	0.03	0.04
GA							
Atlanta	30314	0.26	0.23	0.19	0.11	0.09	0.09
Augusta	30904	0.42	0.38	0.30	0.15	0.12	0.12
Columbia	31907	0.17	0.15	0.13	0.09	0.07	0.08
Savannah	31404	0.42	0.43	0.33	0.15	0.13	0.13
IA							
Council Bluffs	41011	0.19	0.18	0.15	0.09	0.08	0.08
Davenport	52803	0.13	0.13	0.11	0.06	0.06	0.07
Des Moines	50310	0.07	0.08	0.07	0.04	0.04	0.05
ID							
Boise	83705	0.35	0.30	0.31	0.11	0.10	0.11
Pocatello	83201	0.60	0.63	0.57	0.18	0.19	0.18

STATE, CITY	ZIP CODE	S_S 00	S_S 06	S_S 12	S_1 00	S_1 06	S_1 12
IL							
Chicago	60620	0.19	0.17	0.14	0.07	0.06	0.07
Moline	61265	0.14	0.14	0.12	0.06	0.06	0.07
Peoria	61605	0.18	0.18	0.15	0.09	0.08	0.08
Rock Island	61201	0.13	0.13	0.11	0.06	0.06	0.07
Rockford	61108	0.17	0.15	0.13	0.06	0.06	0.06
Springfield	62703	0.27	0.29	0.22	0.12	0.11	0.11
IN							
Evansville	47712	0.82	0.72	0.62	0.23	0.21	0.22
Ft. Wayne	46835	0.17	0.15	0.12	0.06	0.06	0.06
Gary	46402	0.18	0.16	0.13	0.07	0.06	0.07
Indianapolis	46260	0.18	0.19	0.16	0.09	0.08	0.09
South Bend	46637	0.12	0.12	0.10	0.06	0.05	0.06
KS							
Kansas City	66103	0.12	0.13	0.12	0.06	0.06	0.07
Topeka	66614	0.19	0.17	0.15	0.06	0.05	0.06
Wichita	67217	0.14	0.14	0.11	0.06	0.05	0.06
KY							
Ashland	41101	0.22	0.19	0.16	0.09	0.07	0.08
Covington	41011	0.19	0.18	0.15	0.09	0.08	0.08
Louisville	40202	0.25	0.25	0.21	0.12	0.10	0.11
LA							
Baton Rouge	70807	0.14	0.12	0.11	0.06	0.05	0.06
New Orleans	70116	0.13	0.11	0.10	0.06	0.05	0.06
Shreveport	71106	0.17	0.15	0.13	0.08	0.07	0.07
MA							
Boston	02127	0.33	0.28	0.22	0.09	0.07	0.07
Lawrence	01843	0.38	0.33	0.25	0.09	0.07	0.08
Lowell	01851	0.36	0.31	0.24	0.09	0.07	0.08
New Bedford	02740	0.26	0.22	0.18	0.08	0.06	0.06
Springfield	01107	0.26	0.23	0.18	0.09	0.07	0.07
Worchester	01602	0.27	0.24	0.18	0.09	0.07	0.07
MY							
Baltimore	21218	0.20	0.17	0.14	0.06	0.05	0.06
ME							
Augusta	04330	0.33	0.30	0.24	0.10	0.08	0.08
Portland	04101	0.37	0.32	0.25	0.10	0.08	0.08
MI							
Detroit	48207	0.12	0.12	0.10	0.05	0.04	0.05
Flint	48506	0.09	0.09	0.08	0.04	0.04	0.05
Grand Rapids	49503	0.09	0.09	0.08	0.04	0.04	0.05
Kalamazoo	49001	0.12	0.11	0.09	0.05	0.05	0.05
Lansing	48910	0.11	0.10	0.09	0.04	0.04	0.05

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Table D2.1.2-3 Continued; Mapped Acceleration Parameters for Selected U.S. Cities 2000/2003 IBC, 2006/2009 IBC, & 2012 IBC (TBP)

STATE, CITY	ZIP CODE	S_S			S_1		
		00	06	12	00	06	12
MN							
Duluth	55803	0.06	0.06	0.05	0.02	0.02	0.02
Minneapolis	55422	0.06	0.06	0.05	0.03	0.03	0.03
Rochester	55901	0.06	0.06	0.05	0.03	0.03	0.04
St. Paul	55111	0.06	0.06	0.05	0.03	0.03	**003**
MO							
Carthage	64836	0.16	0.17	0.15	0.09	0.08	**0.09**
Columbia	65202	0.19	0.21	0.18	0.10	0.09	0.10
Jefferson City	65109	0.22	0.23	0.21	0.11	0.10	0.10
Joplin	64801	0.15	0.16	0.14	0.08	0.08	**0.09**
Kansas City	64108	0.15	0.13	0.12	0.06	0.06	0.07
Springfield	65801	0.21	0.22	0.21	0.10	0.10	0.11
St. Joseph	64501	0.12	0.12	0.10	0.05	0.05	0.06
St. Louis	63104	0.59	0.58	0.44	0.19	0.17	0.17
MS							
Jackson	39211	0.19	0.20	0.17	0.10	0.09	0.09
MT							
Billings	59101	0.16	0.17	0.16	0.06	0.07	0.07
Butte	59701	0.74	0.65	0.60	0.21	0.20	0.18
Great Falls	59404	0.29	0.26	0.22	0.09	0.09	0.08
NE							
Lincoln	68502	0.18	0.18	0.14	0.05	0.05	0.05
Omaha	68144	0.13	0.13	0.11	0.04	0.04	0.05
NV							
Las Vegas	89106	0.64	0.57	0.50	0.19	0.18	0.17
Reno	89509	1.36	1.92	2.12	0.50	0.77	0.73
NM							
Albuquerque	87105	0.63	0.59	0.49	0.19	0.18	0.15
Santa Fe	87507	0.62	0.54	0.52	0.19	0.17	0.16
NY							
Albany	12205	0.28	0.24	0.19	0.09	0.07	0.08
Binghamton	13903	0.19	0.17	0.13	0.07	0.06	0.06
Buffalo	14222	0.32	0.28	0.21	0.07	0.06	0.06
Elmira	14905	0.17	0.15	0.12	0.06	0.05	0.06
New York	10014	0.43	0.36	0.28	0.09	0.07	0.08
Niagara Falls	14303	0.31	0.28	0.21	0.07	0.06	0.06
Rochester	14619	0.25	0.21	0.17	0.07	0.06	0.06
Schenectady	12304	0.28	0.24	0.19	0.09	0.09	0.08
Syracuse	13219	0.19	0.18	0.15	0.08	0.06	0.07
Utica	13501	0.25	0.22	0.18	0.09	0.07	0.07
NC							
Charlotte	28216	0.35	0.32	0.24	0.14	0.11	0.10
Greensboro	27410	0.26	0.23	0.18	0.11	0.08	0.09
Raleigh	27610	0.22	0.21	0.16	0.10	0.08	0.08
Winston-Salem	27106	0.28	0.24	0.19	0.12	0.09	0.09
ND							
Fargo	58103	0.07	0.08	0.06	0.02	0.02	0.02
Grand Forks	58201	0.05	0.06	0.05	0.02	0.02	0.02
OH							
Akron	44312	0.18	0.17	0.16	0.06	0.05	0.06
Canton	44702	0.16	0.14	0.13	0.06	0.05	0.06
Cincinnati	45245	0.19	0.18	0.15	0.09	0.07	0.08
Cleveland	44130	0.20	0.19	0.17	0.06	0.05	0.06
Columbus	43217	0.17	0.15	0.12	0.07	0.06	0.07
Dayton	45440	0.21	0.18	0.15	0.08	0.07	0.08
Springfield	45502	0.26	0.21	0.17	0.08	0.07	0.07
Toledo	43608	0.17	0.16	0.13	0.06	0.05	0.06
Youngstown	44515	0.17	0.16	0.17	0.06	0.05	0.06
OK							
Oklahoma City	73145	0.34	0.33	0.26	0.09	0.07	0.08
Tulsa	74120	0.16	0.16	0.14	0.07	0.07	0.07
OR							
Portland	97222	1.05	0.99	0.99	0.35	0.34	0.43
Salem	97301	1.00	0.80	0.93	0.4	0.34	0.44
PA							
Allentown	18104	0.29	0.26	0.20	0.08	0.06	0.07
Bethlehem	18015	0.31	0.27	0.21	0.08	0.07	0.07
Erie	16511	0.17	0.16	0.16	0.05	0.05	0.06
Harrisburg	17111	0.23	0.20	0.15	0.07	0.05	0.06
Philadelphia	19125	0.33	0.27	0.21	0.08	0.06	0.06
Pittsburgh	15235	0.13	0.13	0.11	0.06	0.05	0.06
Reading	19610	0.30	0.26	0.20	0.08	0.06	0.06
Scranton	18504	0.23	0.20	0.16	0.08	0.06	0.06
RI							
Providence	02907	0.27	0.23	0.18	0.08	0.06	0.07
SC							
Charleston	29406	1.60	2.19	1.71	0.45	0.56	0.59
Columbia	29203	0.60	0.55	0.42	0.19	0.15	0.15
SD							
Rapid City	57703	0.16	0.17	0.13	0.04	0.04	0.05
Sioux Falls	57104	0.11	0.11	0.09	0.04	0.03	0.04
TN							
Chattanooga	37415	0.52	0.46	0.38	0.14	0.12	0.13
Knoxville	37920	0.59	0.53	0.43	0.15	0.12	0.13
Memphis	38109	1.40	1.40	1.04	0.42	0.38	0.37
Nashville	49503	0.09	0.09	0.08	0.04	0.04	0.05

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Table D2.1.2-3 Continued; Mapped Acceleration Parameters for Selected U.S. Cities 2000/2003 IBC, 2006/2009 IBC, & 2012 IBC (TBP)

STATE, CITY	ZIP CODE	S_S			S_1		
		00 03	06 09	12	00 03	06 09	12
TX							
Amarillo	79111	0.17	0.18	0.16	0.05	0.04	0.05
Austin	78703	0.09	0.08	0.07	0.04	0.03	0.04
Beaumont	77705	0.12	0.10	0.09	0.05	0.04	0.05
Corpus Christi	78418	0.10	0.08	0.07	0.02	0.02	0.02
Dallas	75233	0.12	0.11	0.10	0.06	0.05	0.05
El Paso	79932	0.37	0.33	0.31	0.11	0.11	0.10
Ft. Worth	76119	0.11	0.11	0.09	0.06	0.05	0.05
Houston	77044	0.11	0.10	0.08	0.05	0.04	0.04
Lubbock	79424	0.10	0.11	0.08	0.03	0.03	0.04
San Antonio	78235	0.14	0.12	0.09	0.03	0.03	0.03
Waco	76704	0.10	0.09	0.08	0.05	0.04	0.05
UT							
Salt Lake City	84111	1.82	1.71	1.50	0.78	0.09	0.55
VA							
Norfolk	23504	0.13	0.12	0.10	0.06	0.05	0.05
Richmond	23233	0.32	0.25	0.22	0.09	0.06	0.07
Roanoke	24017	0.30	0.26	0.20	0.10	0.08	0.08
VT							
Burlington	05401	0.47	0.40	0.37	0.13	0.10	0.11
WA							
Seattle	98108	1.56	1.57	1.54	0.54	0.54	0.59
Spokane	99201	0.38	0.40	0.34	0.09	0.11	0.12
Tacoma	98402	1.24	1.22	1.31	0.40	0.42	0.06
D.C.							
Washington	20002	0.18	0.15	0.12	0.06	0.05	0.05
WI							
Green Bay	54302	0.07	0.06	0.06	0.03	0.03	0.04
Kenosha	53140	0.14	0.12	0.10	0.05	0.05	0.06
Madison	53714	0.12	0.11	0.09	0.05	0.04	0.05
Milwaukee	53221	0.12	0.11	0.09	0.05	0.05	0.05
Racine	53402	0.13	0.12	0.10	0.05	0.05	0.05
Superior	54880	0.06	0.06	0.05	0.02	0.2	0.02
WV							
Charleston	25303	0.21	0.19	0.15	0.08	0.07	0.07
Huntington	25704	0.23	0.20	0.16	0.09	0.07	0.08
WY							
Casper	82601	0.38	0.39	0.30	0.08	0.08	0.08
Cheyenne	82001	0.19	0.20	0.19	0.06	0.05	0.06

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Table D2.1.2-4; Short Period Site Coefficient, F_a (Table 9.4.1.2.4a) [Table 11.4-1] {Table 11.4-1}

SITE CLASS	MAPPED MCE SHORT PERIOD SPECTRAL RESPONSE ACCELERATION PARAMETER				
	$S_S \leq 0.25$	$S_S = 0.50$	$S_S = 0.75$	$S_S = 1.00$	$S_S \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	These values to be determined by site response analysis.				

Table D2.1.2-5; Long Period Site Coefficient, F_v (Table 9.4.1.2.4b) [Table 11.4-2] {Table 11.4-2}

SITE CLASS	MAPPED MCE LONG PERIOD SPECTRAL RESPONSE ACCELERATION PARAMETER				
	$S_1 \leq 0.10$	$S_1 = 0.20$	$S_1 = 0.30$	$S_1 = 0.40$	$S_1 \geq 0.50$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	These values to be determined by site response analysis.				

For Occupancy/Risk Categories I, II, or III (Seismic Use Group I or II) structures, if the Mapped Spectral Response Acceleration Parameter is greater than or equal to 0.75, $S_1 \geq 0.75$, then the structure will be assigned to Seismic Design Category E. For Occupancy/Risk Category IV (Seismic Use Group III) structures, if the Mapped Spectral Response Acceleration Parameter is greater than or equal to 0.75, $S_1 \geq 0.75$, then the structure will be assigned to Seismic Design Category F. To ensure consistency, the Seismic Design Category should be determined by the structural engineer.

Table D2.1.2-6; Seismic Design Category Based on the Short Period Design Response Acceleration Parameter (Table 9.4.2.1a) [Table 11.6-1] {Table 11.6-1}

VALUE OF S_{DS}	OCCUPANCY/RISK		
	I or II	III	IV
$S_{DS} < 0.167$	A	A	A
$0.167 \leq S_{DS} < 0.33$	B	B	C
$0.33 \leq S_{DS} < 0.50$	C	C	D
$0.50 \leq S_{DS}$	D	D	D

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Table D2.1.2-7; Seismic Design Category Based on the Long Period Design Response Acceleration Parameter (Table 9.4.2.1b) [Table 11.6-2] {Table 11.6-2}

VALUE OF S_{D1}	OCCUPANCY/RISK		
	I or II	III	IV
$S_{D1} < 0.067$	A	A	A
$0.067 \le S_{D1} < 0.133$	B	B	C
$0.133 \le S_{D1} < 0.20$	C	C	D
$0.20 \le S_{D1}$	D	D	D

D2.1.2.6 Summary:

The following parameters will be required by the design professionals having responsibility for non-structural components in a building, and should be determined by the structural engineer of record.

1. Occupancy/RIsk Category (or Seismic Use Group for 2000/2003 IBC): This defines the building use and specifies which buildings are required for emergency response or disaster recovery.

2. Seismic Design Category: This determines whether or not seismic restraint is required.

3. Short Period Design Response Acceleration Parameter (S_{DS}): This value is used to compute the horizontal seismic force used to design and/or select seismic restraints required.

These parameters should be repeated in the specification and drawing package for the particular system, mechanical, electrical, or plumbing, in question.

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COMPONENT IMPORTANCE FACTOR

D2.1.3.1 Introduction:

MEP components and systems are categorized in ASCE 7-98/02, ASCE 7-05, and ASCE 7-10 as non-structural components. There are just two values for the Component Importance Factors for non-structural components, 1.0 and 1.5, which are not directly linked to the importance factor for the building structure. The Component Importance Factor is designated as I_P in the body of the code. All non-structural components must be assigned a component importance factor. The design professional that has responsibility for the MEP system in question is also responsible for assigning the Component Importance Factor to that system.

D2.1.3.2 Criteria for Assigning a Component Importance Factor (Sections 9.6.1 and 9.6.1.5) [Section 13.1.3] {Section 13.1.3}[1]:

For non-structural components, the Component Importance Factor (I_P) assigned to the components shall be determined as follows.

1. If the MEP system is required to remain in place and function for life-safety purposes following and earthquake the Component Importance Factor assigned to the non-structural component shall be 1.5. Some examples of this type of system would be;
    a. Fire sprinkler piping and fire suppression systems.
    b. Smoke removal and fresh air ventilation systems.
    c. Systems required for maintaining the proper air pressure in patient hospital rooms to prevent the transmission of infectious diseases.
    d. Systems that maintain proper air pressure, temperature, and humidity in surgical suites, bio-hazard labs, and clean rooms.
    e. Medical gas lines.
    f. Steam lines or high pressure hot water lines.
2. If the non-structural component contains or is used to transport hazardous materials, or materials that are toxic if released in quantities that exceed the exempted limits a Component Importance Factor of 1.5 shall be assigned to that component. Examples are as follows.
    a. Systems using natural gas.

[1] References in brackets (Sections 9.6.1 and 9.6.1.5), [Section 13.1.3], {Section 13.1.3} apply to sections, tables, and/or equations in ASCE 7-98/02, ASCE 7-05, and ASCE 7-10 respectively which forms the basis for the seismic provisions in 2000/2003 IBC, 2006/2009, and 2012 IBC respectively.

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b. Systems requiring fuel oil.

c. Systems used to exhaust laboratory fume hoods.

d. Boilers, furnaces and flue systems.

e. Systems that are used to ventilate bio-hazard areas and infectious patient rooms.

f. Chemical or by-product systems which are required for industrial processes.

3. If the non-structural component is in or attached to a building that has been assigned to Occupancy/Risk Category IV (Seismic Use Group III), i.e. essential or critical facilities, and is required for the continued operation of that facility following an earthquake, then a Component Importance Factor of 1.5 shall be assigned to that component. Hospitals, emergency response centers, police stations, fire stations, and etc. fall under Occupancy/Risk Category IV (Seismic Use Group III). The failure of any system could cause the portion of the building it serves to be evacuated and unusable would cause that system and its components to be assigned a Component Importance Factor of 1.5. Even the failure of domestic water lines can flood a building and render it uninhabitable. So, all of the items listed above under items 1 and 2 would apply to facilities in Occupancy/Risk Category IV (Seismic Use Group III).

4. If the non-structural component that is located in or attached to an Occupancy/Risk Category IV (Seismic Use Group III) facility and its failure would impair the operation of that facility, then a Component Importance Factor of 1.5 shall be assigned to that component. This implies that any non critical non-structural component that is located above a non-structural component with a Component Importance Factor of 1.5 must be assigned a Component Importance Factor of 1.5, or otherwise supported in a fashion that the more critical system would not be damaged.

5. All non-structural components that are not covered under items 1, 2, 3, or 4 may be assigned a Component Importance Factor of 1.0.

D2.1.3.3 Summary:

The Component Importance Factor is very important to the designer responsible for selecting and certifying the seismic restraints for a non-structural component. This factor is a direct multiplier for the horizontal seismic design force, which shall be discussed in a later section. The Component Importance Factor will also be a key indicator as to whether a particular component will qualify for an exemption or not. If a Component Importance Factor has not been assigned, the designer responsible for selecting the seismic restraints must assume that the Component Importance Factor is equal to 1.5. If the non-structural component could actually be assigned a Component Importance Factor of 1.0, this could result in a large increase in the size and number of restraints required along with a corresponding increase in the cost for the system.

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It is in the best interest of the design professionals responsible for the non-structural components to properly assign the Component Importance Factor to those components. The Component Importance Factor for each non-structural component should be clearly indicated on the drawings that are distributed to other design professionals, contractors, suppliers, and building officials.

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GENERAL EXEMPTIONS AND REQUIREMENTS

D2.1.4.1 Introduction:

The International Building Codes (IBC's) allow certain exemptions to be made for MEP (Mechanical, Electrical, and Plumbing) components and other non-structural components from the need for seismic restraint. These exemptions are based on the Seismic Design Category, the Component Importance Factor, the size, the weight, and the vertical location within the building of the components.

There are further general provisions in the IBC pertaining to MEP components and other non-structural components that must be acknowledged at the outset of a project. These are provisions ranging from the upper bound size for a component to the component certifications and documentation required.

This section will present the general exemptions for MEP components and other non-structural components and discuss the general requirements that apply to them.

D2.1.4.2 Exemptions for Seismic Design Categories A and B (Sections 9.6.1-1 & 9.6.1-3) [Sections 13.1.4-1 & 13.1.4-2] {Sections 11.7, 13.1.4-3, & 13.1.4-4}[1]:

MEP components that are located in or on buildings that have been assigned to Seismic Design Categories A and B, and other non-structural components that have been assigned to Seismic Design Category B, are exempt from the requirements for seismic restraints. These two exemptions point out the need for having the correct seismic deign in formation for the project available to all of the design professionals and contractors during the bidding stage of the project. Being able to use these exemptions can save the contractors as much as 10% to 15% in their costs.

For example, a critical piece of information required at the outset is the Site Class. If the Site Class has not been determined by a qualified geotechnical engineer, then Site Class D must be assumed. The resulting combination of the mapped acceleration parameters and soil profile of Site Class D may force the project to be assigned to Seismic Design Category C which in turn forces the requirement for seismic restraints. If instead the Site Class had been determined to be Site Class B by a qualified geotechnical engineer, then the project may have been found to fall into Seismic Design Category A or B, thus eliminating the need for seismic restraints for the nonstructural components.

[1] References in brackets (Section 9.6.1-1 & 9.6.1-2) [Section 13.1.4-1 & 13.1.4-2], {Sections 11.7, 13.1.4-3, & 13.1.4-4} apply to sections, tables, and/or equations in ASCE 7-98/02, ASCE 7-05, ASCE 7-12 respectively, which forms the basis for the seismic provisions in 2000/2003 IBC and 2006/2009 IBC, 2012 IBC respectively.

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D2.1.4.3 Exemptions for Seismic Design Category C (Section 9.6.1-4) [Section 13.1.4-3] {Section 13.1.4-5}:

MEP components that have been assigned to Seismic Design Category C, and that have also been assigned a Component Importance Factor of 1.0, are exempt from the requirements for seismic restraints. In this case it is very important that the design professionals responsible for the various MEP components assign the correct Component Importance Factors to those systems and components. If no Component Importance Factor is assigned, the installing contractor should prudently assume that the Component Importance Factor is equal to 1.5, and provide restraints for that system or component. This is particularly true of duct runs where it is very likely that the ventilation components may also be required for smoke control.

It is also critical to know which MEP systems and components have a component Importance Factor of 1.0 and which ones have a Component Importance Factor of 1.5. To the extent possible, those with Component Importance Factors equal to 1.5 should be installed above those with Component Importance Factors equal to 1.0 in order to reduce the over all number of restraints needed for the project.

D2.1.4.4 Exemptions for Seismic Design Categories D, E, and F

D2.1.4.4.1 ASCE 7-98/02 and ASCE 7-05 (Sections 9.6.1-5 and 9.1.6-6) [Sections 13.1.4-4 and 13.1.4-5] also ASCE 7-10, IBC 2012 with special conditions indicated in line item 3 below:

There are basically three exemptions that apply here.

1. MEP components that:
    a. Are in Seismic Design Categories D, E, and F.
    b. Have a Component Importance Factor equal to 1.0,
    c. Have flexible connections between the components and all associated duct, piping, conduit.
    d. Are mounted at 4 ft (1.22 m) or less above a floor level.
    e. And weigh 400 lbs (181 kg) or less.
2. MEP components that:
    a. Are in Seismic Design Categories D, E, and F.
    b. Have a Component Importance Factor equal to 1.0.
    c. Have flexible connections between the components and all associated duct, piping, conduit.

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d. And weigh 20 lbs (9.1 kg) or less.

3. MEP distribution systems that:

   a. Are in Seismic Design Categories D, E, and F.

   b. Have a Component Importance Factor equal to 1.0.

   c. Have flexible connections between the components and all associated duct, piping, conduit.

   d. And weigh 5 lbs/ft (2.6 kg/m) or less.

   (Note: In ASCE 7-10 and IBC 2012, there are no exemptions for Plumbing. Plumbing

   consists of all non HVAC related water piping and includes Drain, Waste and Vent Piping.)

No Seismic restraint is required for MEP components in Seismic Design Categories D, E, or F if all of the following criteria apply.

1. The Component Importance Factor is $I_P = 1.0$.

2. The MEP component is positively attached to the structure.

3. Flexible connections are used between the MEP component and any associated services, and either of the following apply;

   a. The component weighs 400 lb (181 kg) or less and has a center of mass located 4 ft (1.22 m) or less above the floor level.

   b. The component weighs 20 lb (9.1 kg) or less or, in the case of a distributed system, 5 lb/ft (2.3 kg/m).

D2.1.4.4.2 ASCE 7-10 (Sections 9.6.1-5 and 9.1.6-6) [Sections 13.1.4-4 and 13.1.4-5]:

D2.1.4.5 "Chandelier" Exemption (Section 9.6.3.2) [Section 13.6.1] {Section 13.6.1}:

This exemption applies to light fixtures, lighted signs, ceiling fans, and other components that are not connected to ducts or piping and which are supported by chains or other wise suspended from the structure by a method that allows the component to swing freely. These components will require no further seismic support provided that all of the following conditions are met.

1. The design load for these components shall be equal to:

   a. 3.0 times the operating load, applied as a gravity design load, for 2000/2003 IBC.

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b. 1.4 times the operating weight of the component acting downward with a simultaneous horizontal load that is also equal to 1.4 times the operating weight for 2006/2009 IBC and 2012 IBC. The horizontal load is to be applied in the direction that results in the most critical loading and thus the most conservative result.

2. The component shall not impact other components, systems, or structures as it swings through its projected range of motion.

3. The connection to the structure shall allow a 360° range of motion in the horizontal plane. In other words, this must be a “free swinging” connection.

D2.1.4.6 Component Size Relative to the Building Structure (Section 9.6.1) [Section 13.1.5] {Section 15.3.1}:

MEP components are treated as non-structural components by the code. However, if the MEP component is very large relative to the building it must be treated as a nonbuilding structure, which has a completely different set of design issues. For 2000/2003 IBC, If the weight of the MEP component is greater than or equal to 25% of the combined weight of the MEP Component and the supporting structure, the MEP component must be treated as a nonbuilding structure per Section 9.14 of ASCE 7-98/02. For 2006/2009 IBC, if the weight of the nonstructural component is greater than or equal to 25% of the effective seismic weight of the building as defined in Section 12.7.2 of ASCE 7-05, then that component must be classified as a nonbuilding structure and designed accordingly. For 2012 IBC, this provision is found in Section 15.3.1 of ASCE 7-10. Here it states that when the weight of the nonbuilding structure is less than 25% of the combined effective seismic weights of the nonbuilding structure and its supporting structure the nonbuilding structure will be treated like a non-structural component where the forces are determined in accordance with ASCE 7-10 Chapter 13.

When might this apply? This applies to very large pieces of MEP equipment such as large cooling towers, and the very large air handling units that are placed on the roofs of buildings employing lightweight design techniques. The structural engineer of record will have a value for the effective seismic weight of the building. This must be compared to the operating weight of the MEP component in question.

D2.1.4.7 Reference and Accepted Standards (Sections 9.6.1.1 and 9.6.1.2) and Reference Documents [Section 13.1.6] {Section 13.1.6}:

Typically reference standards, acceptance standards, and reference documents are other publications that will provide a basis for earthquake resistant design. Examples of reference documents currently in existence would be the SMACNA Seismic Restraint Manual, listed in Section 1.0 Introduction of the guide, and NFPA 13. These documents may be used with the approval of the jurisdiction having authority as long as the following conditions are met.

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1. The design earthquake forces used for the design and selection of the seismic restraints shall not be less that those specified in Section 9.6.1.3 of ASCE 7-98/02 and Section 13.3.1 of ASCE 7-05 and ASCE 7-10, which is also covered in Section 8.0 of this guide.

2. The seismic interaction of each MEP or non-structural component with all other components and building structures shall be accounted for in the design of the supports and restraints.

3. The MEP or other non-structural component must be able to accommodate drifts, deflections, and relative displacements that are defined in ASCE 7-05 and ASCE 7-10. This means that flexible connections for pipe, duct, and electrical cables for MEP components are in general, a good idea to prevent damage if the MEP component, and/or the pipe, duct, and electrical cables that are attached to it are unrestrained.

4. The MEP or other non-structural component anchorage requirements is not to be less than those covered in Section 13.4 of ASCE 7-10.

D2.1.4.8 Allowable Stress Design (Sections 2.3 and 2.4) [Sections 2.3, 2.4, and 13.1.7] {Sections 2.3, 2.4, and 13.1.7}:

Reference documents that use allowable stress design may be used as a basis for the design and selection of seismic restraints. However, the design earthquake loads determined in accordance with Section 9.6.1.3 of ASCE 7-98/02 and Section 13.3.1 of ASCE 7-05 and ASCE 7-10 must be multiplied by 0.7.

D2.1.4.9 Submittals and Construction Documents (Sections 9.6.3.6, 9.6.3.15 and A.9.3.4.5) [Sections 13.2.1, 13.2.5, 13.2.6, and 13.2.7] {Sections 13.2.1, 13.2.5, 13.2.6, and 13.2.7}:

Projects that require seismic restraints for MEP systems and components will require project specific certification that the design of the seismic restraints selected for the MEP systems and their components will meet the code, specification, or details which ever is most stringent. This certification is to be provided both in the submittals and in the construction documents.

For the submittal of seismic restraints and supports, the certification may be satisfied by one of the following means.

1. Project and site specific designs and documentation that are prepared and submitted by a registered design professional. Please note that a specific discipline is not mentioned regarding the registered design professional that is responsible for the design and signing and sealing of the documentation. However, it should be noted that certain states and local jurisdictions do specify a discipline for the registered design professional responsible for signing and sealing the documentation.

2. Manufacturer's certification accompanying the submittal the restraints are seismically qualified for the project and site. The certification may be made in any one of three ways as detailed below.

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a. Analysis – this is typical for the seismic restraints used for MEP systems and components. Manufacturers of these seismic restraint devices will normally have families of the various types of restraint devices that have different seismic force capacity ranges. The manufacturer will perform an analysis to determine the project and site specific seismic design loads, and then analyze the MEP system and/or components to determine the required restraint capacities at the restraint attachment points to the system and/or components. The proper restraint will be selected from the manufacturer's standard product offering, or a special restraint may be designed and built for the application. The manufacturer's certification will include a statement signed and seal by a registered design professional that the restraint devices will meet the appropriate code, specification, and/or details.

b. The manufacturer of the restraint devices may have them tested in accordance with ICC-ES AC 156 as outlined in Sections 9.6.3.6 and A.9.3.4.5 of ASCE 7-98/02 and Section 13.2.5 of ASCE 7-05 and ASCE 7-2012. They will then provide a signed and sealed certification document stating that the restraint devices will provide adequate protection for the MEP system and components.

c. Experience data per the requirements in Sections 9.6.3.6 and A.9.3.4.5 of ASCE 7-98/02 and Section 13.2.6 of ASCE 7-05 and ASCE 7-10. This is not a normal avenue for a manufacturer of seismic restraint devices to use to certify their products as being fit for a specific project. In using this method, the manufacturers would incur a great deal of liability.

Section A.9.3.4.5 of ASCE 7-98/02 and Section 13.2.7 of ASCE 7-05 and ASCE 7-2012 indicates that seismic restraints for MEP systems and components will require construction documents that are prepared and, signed and sealed by a registered design professional. Frequently, the submittal package provided by the manufacturer of the seismic restraints will also have enough information to fulfill this requirement.

The registered design professional mentioned above needs to be one with knowledge and experience in force analysis, stress and analysis, and the proper use of steel, aluminum, elastomers, and other engineering materials in the design of force resisting systems. There are several disciplines that may fulfill these requirements such as, structural engineers, civil engineers, and mechanical engineers involved in the area of machine design.

D2.1.4.10 Equipment Certification for Essential Facilities (Sections 9.6.3.6, 9.6.6.15, and A9.3.4.5) [Sections 13.2.2, 13.2.5, and 13.2.6] {Sections 13.2.2, 13.2.5, and 13.2.6}:

MEP components for buildings that have been assigned to Seismic Design Categories C, D, E, and F and have designated seismic systems that must remain functional will require certification. Designated seismic systems are those whose failure has the potential to cause loss of life or loss of function for buildings that were deemed essential for recovery following an earthquake. Typically essential facilities are those that have been assigned to Occupancy Category IV, see Section 2.2 of Section D2.0. For these types of systems, certification shall be provided as follows.

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1. For active MEP systems and components that must remain functional after an earthquake shall be certified by the supplier or manufacturer as being operable after the design level earthquake for the project site based on:

    a. Shake table testing such as that specified in ICC-ES AC 156 as described in Section A.9.3.4.5 of ASCE 7-98/02 and Section 13.2.5 of ASCE 7-05 and ASCE 7-10. Evidence of compliance is to be submitted to the jurisdiction having authority and the design professional of record for approval.

    b. Experience or historical data as outlined in Sections 9.6.3.6, 9.6.3.15 and A.9.3.4.5 of ASCE 7-98/02 and Section 13.2.6 of ASCE 7-05 and ASCE 7-10. This experience data is to come from a nationally recognized procedures and data base that is acceptable to the authority having jurisdiction. The substantiated seismic capacities from the experience data must meet or exceed the specific seismic requirements for the project. As in a. above evidence of compliance will need to be submitted to the design professional of record, and the jurisdiction having authority for approval.

2. MEP systems and components that contain hazardous materials must be certified as maintaining containment of the hazardous materials following an earth quake. Evidence of compliance must be submitted to the design professional of record and the jurisdiction having authority for approval. This certification may be made through:

    a. Analysis.

    b. Approved shake table testing specified in Section 9.6.3.6 of ASCE 7-98/02 and Section 13.2.5 of ASCE 7-05 and ASCE 7-10.

    c. Experience data as described in Section 9.6.3.6 of ASCE 7-98/02 and Section 13.2.6 of ASCE 7-05 and ASCE 7-10.

D2.1.4.11 Consequential or Collateral Damage (Section 9.6.1) [Section 13.2.3] {Section 13.2.3}:

The potential interaction of the MEP systems and components with surrounding systems, components or building structures must be considered when locating and restraining the MEP systems and components. The failure of an MEP system or component that has been assigned a Component Importance Factor equal to 1.0 must not cause the failure of an MEP system or component that has been assigned a Component Importance Factor equal to 1.5. This goes back to the issue of assigning a Component Importance Factor of 1.5 to MEP systems or components with a Component Importance Factor of 1.0 whose failure would cause the failure of a system or component with a Component Importance Factor of 1.5.

D2.1.4.12 Flexibility of Components and their Supports and Restraints (Sections 9.6.1 and 9.6.1.2) [Section 13.2.4] {Section 13.2.4}:

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All MEP systems and components that are constructed of normal engineering materials will have a certain amount of flexibility, or springiness. So how these systems and components behave during an earthquake will greatly affect their performance and survivability. The system or component could have a flexibility that would put it to resonance with the building and/or the earthquake, in which case the displacements and stresses in the system would be much larger than expected. Conversely the flexibility of the system or component could be such that it was not in resonance with either the building or the earthquake. In this case, the displacements and stresses may be much lower than a code based analysis would indicate. Therefore, the code indicates that the flexibility of the components and their supports be considered as well as the strength of the parts to ensure that the worst cases are considered.

D2.1.4.13 Temporary or Movable Equipment {Section 13.1.4-2}:

Only 2012 IBC addresses temporary and moveable equipment. This would include temporary air handlers, air conditioners, boilers, air purification systems, and etc. that have been brought in to handle the load during an outage, or other event. Section 13.1.4-2 of ASCE 7-10 exempts all temporary or movable equipment from the need for seismic restraint.

D2.1.4.14 Summary:

The exemptions and requirements outlined in this section are intended to assist the MEP design professionals and contractors in planning their project contribution efficiently. Also, they help define the limits of responsibility for each MEP design profession and trade.

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EXEMPTIONS FOR PIPING SYSTEMS

D2.1.5.1 Introduction:

The exemptions that apply specifically to piping are covered in Section 9.6.3.11.4 of ASCE 7-98/02 and Section 13.6.8 of ASCE 7-05 AND ASCE 7-10. The provisions of this section do not cover elevator system piping which is covered in Section 9.6.3.16 of ASCE 7-98/02 and Section 13.6.10 of ASCE 7-05 and ASCE 7-10. The piping considered in this section is assumed to be high-deformability piping. This implies pipes made from ductile materials that are joined by welding, brazing, or groove type couplings, similar to VICTAULIC, or groove type couplings, where the grooves in the pipe have been roll formed rather than cut. Limited deformability piping on the other hand, would be pipes made of ductile materials that are joined by threading, bonding, or the use of groove type couplings where the grooves in the pipe have been machine cut. Low deformability piping would be comprised of pipes made from relatively brittle materials such as cast iron, PVC, CPCV, or glass. Also not covered in this section is fire protection piping. Fire protection piping will be covered in a separate publication.

D2.1.5.2 The 12″ Rule (9.6.3.11.4-c) [Section 13.6.8-1] {Section 13.6.8-2}[1]:

No restraints will be required for piping that meets the requirements of the 12″ Rule for the entire piping run. The 12″ Rule will be said to apply to a piping run if:

1. The piping is supported by rod hangers.
   a. For single clevis supported pipe, all of the hangers in the piping run are 12 in. (305 mm) or less in length from the top of the pipe to the supporting structure.
   b. For trapeze supported pipe, all of the hangers in the piping run are 12 in. (305 mm) or less in length from the top of the trapeze bar to the supporting structure.
2. For 2000/2003 IBC The hanger rods and their attachments are not to be subjected to bending moments. For 2006/2009 IBC the hangers are to be detailed to avoid bending of the hangers and their attachments. This statement very is ambiguous. It does not clearly define the phrase “significant bending”, and leaves it up to the design professional responsible for the piping system, or worse, the contractor responsible for installing the piping system. The past practice by SMACNA and other recognized authorities in the industry to call for the connection between the hanger and the supporting structure to be “non-moment generating”. This means that the connector must be one that allows the piping run to swing freely on its hangers without introducing a bending moment in the hanger. 2012 IBC has clarified this

[1] References in brackets (9.6.3.11.4-c) [Section 13.6.8-1] {Section 13.6.8-2} apply to sections, tables, and/or equations in ASCE 7-98/02, ASCE 7-05, and ASCE 7-10 respectively which forms the basis for the seismic provisions in 2000/2003 IBC, 2006/2009 IBC, and 2012 IBC respectively.

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situation by stating that rod hangers are to be "equipped with swivels, eye nuts, or other devices to prevent bending in the rod".

3. There must be sufficient space around the piping run to accommodate the expected motion of the pipe as it sways back and forth with the earthquake motion in the building.

4. Connections between the piping and the interfacing components must be designed and/or selected to accept the full range of motion expected for both the pipe and the interfacing component.

D2.1.5.3 Single Clevis Supported Pipe in Seismic Design Categories A and B (Sections 9.6.1-1 and 9.6.1-3) [Sections 13.1.4-1 and 13.1.4-2] {Sections 11.7 and 13.1.4-4}:

No seismic restraints are required for piping in building assigned to Seismic Design Categories A and B. This is implied in ASCE 7-05 for Seismic Design Category A by the general exemptions found in Section 13.1.4-1 and 13.1.4-2. For ASCE 7-10, it is specified in Section 11.7.

D2.1.5.4 Single Clevis Supported Pipe in Seismic Design Category C (Sections 9.6.1-1 and 9.6.3.11.4-d2) [Sections 13.1.4-3 and 13.6.8-2b] {Sections 13.1.4-5 and 13.6.8.3-2a}:

1. For single clevis supported piping in buildings assigned to Seismic Design Category C for which the Component Importance Factor is equal to 1.0, no seismic restraint is required.

2. For piping in Buildings assigned to Seismic Design Category C, for which the Component Importance Factor is equal to 1.5, and for which the nominal size is 2 in. (51 mm) or less; no seismic restraint is required.

D2.1.5.5 Single Clevis Supported Pipe in Seismic Design Categories D, E, and F (Sections 9.6.3.11.4-d1 and 9.6.3.11.4-d3) [Sections 13.6.8-2a and 13.6.8-2c] {Sections 13.6.8.3-3b and 13.6.8.3-3c}:

1. For single clevis supported piping in buildings assigned to Seismic Design Categories D, E, and F, for which the Component Importance Factor is equal to 1.5, and for which the nominal size is 1 in. (25 mm) or less; no seismic restraint is required.

2. For single clevis supported piping in buildings assigned to Seismic Design Categories D, E, and F, for which the Component Importance Factor is equal to 1.0, and for which the nominal size is 3 in. (76 mm) or less; no seismic restraint is required.

Special Note: ***For 2012 IBC the exemptions described in Sections D2.1.5.4 and D2.1.5.5 above do not apply to piping having*** $R_P \leq 4.5$ ***per ASCE 7-10 Section 13.6.8.3-3. Plumbing piping will fall under this category for 2012 IBC because it has been given an*** $R_P = 2.5$ ***in Table 13.6-1. Per ICC, All Drain, Waste and Vent piping is to be considered to be plumbing.***

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D2.1.5.6 Exemptions for Trapeze Supported Pipe per VISCMA Recommendations {Section 13.6.8.3-1}:

Neither ASCE 7-98/02 nor ASCE 7-05 specifies how the piping is to be supported. The point is that many pipes of the exempted size may be supported on a common trapeze bar using hanger rods of the same size as would be specified for a single clevis supported pipe. Keep in mind that the purpose of the seismic restraints is to make sure the pipe moves with the building. The amount of force that the hanger rod must carry will be a direct function of the weight of pipe being supported. It is apparent that there must be some limit to how much weight a trapeze bar can support for a given hanger rod size before seismic restraint is required. VISCMA (Vibration Isolation and Seismic Control Manufacturer's Association) has investigated this issue and makes recommendations in a paper, *Seismic Exemptions for Suspended Trapeze Supported pipe – IBC 2006/ASCE7-05 (SUMMARY)*, which is published on their web site, www.viscma.com.

2012 IBC contains language that directly deals with trapeze supported pipe exemptions. This is found in ASCE 7-10 Section 13.6.8.3-1. For piping that falls within the limits discussed above in Sections D2.1.5.4 and D2.1.5.5, the trapeze assembly will be exempt if the piping supported by the trapeze bar is less than 10 lb/ft (4.5 kg/m).

D2.1.5.7 Summary:

The exemptions and allowances outlined in this section can, with careful planning save a lot of time and money. They may also mean the difference between making a profit on a project and breaking even, or worse, losing money. In order to take proper advantage of these exemptions, the Seismic Design Category to which the project has been assigned must be known. This is readily available from the structural engineer. Also, the design professional who is responsible for the piping system must assign an appropriate Component Importance Factor to the system.

As a sidebar to the previous statement, it should be noted that the specification for the building may increase the Seismic Design Category in order to ensure an adequate safety margin and the continued operation of the facility. This is a common practice with schools, government buildings, and certain manufacturing facilities. Also, the building owner has the prerogative, through the specification, to require all of the piping systems to be seismically restrained. So, careful attention to the specification must be paid, as some or all of the exemptions in this section may be nullified by specification requirements that are more stringent than those provided by the code.

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EXEMPTIONS FOR HVAC DUCTWORK

D2.1.6.1 Introduction:

The 2000/2003/2006/2009/2012 IBC have some general exemptions that apply to HVAC ductwork based on Component Importance Factor and the size of the duct. At present, there are not as many exemptions for ductwork as there are for piping. The number of exemptions for ductwork changed with SMACNA being dropped as a reference document in the 2003/2006 IBC. This will be discussed below in the appropriate section.

<u>Note:</u> For 2012 IBC, the exemptions for ductwork that are to be discussed do not apply if the duct is designed to carry toxic, highly toxic, or flammable gases or used for smoke control.

D2.1.6.2 The 12″ Rule (Section 9.6.3.10-a) [Section 13.6.7-a] {Section 13.6.7-1b}[1]:

No seismic restraints will be required for ductwork with a Component Importance Factor equal to 1.0 that meets the requirements of the 12″ Rule for the entire run of ductwork. The 12″ Rule is said to apply to a run of ductwork if:

1. The HVAC ducts a suspended for hangers that are 12″ (305 mm) or less in length for the entire run of ductwork. This is usually measured from the supporting structure to the top of the trapeze bar that is supporting the ductwork.

2. The hangers have been detailed and constructed in order to avoid significant bending of the hanger and its attachments. As with the 12″ rule applied to piping, the industry generally interprets this to mean that the connection of the hanger to the structure must be "non-moment generating", or free swinging. For 2012 IBC ASCE 7-10 plainly states that, hanger rods must be "equipped with swivels to prevent inelastic bending of the hanger rod".

Section 1613.6.8-1 of 2009 IBC allows the 12″ Rule to be applied to ductwork having a Component Importance Factor equal to 1.5.

ASCE 7-10 and 2012 IBC will also allow the 12″ Rule to be applied to ductwork having a Component Importance Factor equal to 1.5.

D2.1.6.3 Size Exemption (Section 9.6.3.10-b) [Section 13.6.7-b] {Section 13.6.7-2}:

For 2000/2003/2006 IBC, no seismic restraints are required for ductwork with a Component Importance Factor equal to 1.0 if the cross-sectional area is less than 6 ft^2 (0.557 m^2). There is no specific exemption for ducts whose Component Importance Factor is equal to 1.5. However, 2000

[1] References in brackets (Section 9.6.3.10-a) [Section 13.6.7-a] {Section 13.6.7-1b} apply to sections, tables, and/or equations in ASCE 7-98/02, ASCE 7-05, and ASCE 7-10 respectively which forms the basis for the seismic provisions in 2000/2003 IBC, 2006/2009 IBC, and 2012 IBC respectively.

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IBC has the SMACNA; Seismic Restraint Manual – Guidelines for Mechanical Systems 2nd Edition[2] directly referenced in Section 1621.3.9 as meeting the lateral bracing requirements of the code, does allow the exemption of duct with a cross-sectional area of less than 6 ft^2 (0.557 m^2) exemption to be made for all ductwork regardless of its Component Importance Factor. For 2003/2006 IBC, there are no exemptions for ductwork with a Component Importance Factor equal to 1.5. They simply state that; "HVAC duct systems fabricated and installed in accordance with a standards approved by the authority having jurisdiction shall be deemed to meet the lateral bracing requirements of this section (of the code)". This statement does open the door to permitting the SMACNA Seismic Restraint Manual to be used as a standard, thus permitting the 6 ft^2 (0.557 m^2) exemption.

Section 1613.6.8-2 of 2009 IBC allows the 6 ft^2 (0.557 m^2) exemption to be made for all ductwork with a Component Importance Factor of 1.5 as well as ductwork whose Component Importance Factor is equal to 1.0.

ASCE 7-10 and 2012 IBC will also allow the 6 ft^2 (0.557 m^2) exemption to be made for all ductwork regardless of the Component Importance Factor that has been assigned to it. Also, there is a weight limit assigned to this exemption in ASCE 7-10 of 17 lb/ft (7.7 kg/m) or less. So, the duct work is exempt if has either a cross-sectional area of less than 6 ft^2 (0.557 m^2) or a weight of 17 lb/ft (7.7 kg/m) or less.

D2.1.6.4 Trapeze Supported Ductwork {Section 13.6.7-1a}:

In this section, there is a new exemption for trapeze supported duct that is independent of the Component Importance Factor. Trapeze supported ductwork that weighs less than 10 lb/ft (4.5 kg/m) is exempt from the need for seismic restraint.

D2.1.6.5 Restraint Allowance for In-Line Components (Section 9.6.3.10) [Section 13.6.7] {Section 13.6.7}:

This allowance deals with components, such as fans, heat exchangers, humidifiers, VAV boxes, and the like, that are installed in-line with the ductwork. Components that have an operating weight of 75 lbs (334 N) or less may be supported and laterally, seismically, braced as part of the duct system. Where the lateral braces, seismic restraints, have been designed and sized to meet the requirements of ASCE 7-98/02 Section 9.6.1.3 or ASCE 7-05/10 Section 13.3.1. The following requirements will also apply to these components.

1. At least one end of the component must be hard, rigidly, attached to the ductwork. The other end may have a flex connector or be open. The flex connected, or open end, of the component must be supported and laterally braced. This requirement is not mentioned as part of ASCE 7-98, -02, -05, or -10, but is a requirement that is born out of common sense.

[2] SMACNA; Seismic Restraint Manual – Guidelines for Mechanical Systems 2nd Edition; Sheet Metal and Air Conditioning Contractors' National Association, In.; 4201 Lafayette Center Drive, Chantilly, VA 20151-1209

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2. Devices such as diffusers, louvers, and dampers shall be positively attached with mechanical fasteners.

3. Unbraced piping and electrical power and control lines that are attached to in-line components must be attached with flex connections that allow adequate motion to accommodate the expected differential motions.

D2.1.6.6 Summary:

As with the piping exemptions these exemptions and allowances, with careful planning, can save the contractor and the building owner a great deal of effort and money. There is also a great advantage to petition the local building authority to allow the SMACNA Seismic Design Manual to become a reference document for the project. This will allow the exemptions spelled out in the SMACNA Seismic Design Manual to be utilized to best advantage

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EXEMPTIONS FOR ELECTRICAL

D2.1.7.1 Introduction:

The equipment exemptions mentioned in ASCE 7-98/02, ASCE 7-05, and ASCE 7-10 are actually implied exemptions that are stated as requirements. The exemptions for electrical distribution systems are better defined at least in ASCE -05 and ASCE -10. This section is an attempt to more fully define these provisions for the design professional responsible for the design of the electrical components and distribution systems, and also for the installing contractor who is responsible for bidding and installing the restraints.

D2.1.7.2 "Implied" Blanket Exemption Based on Component Importance Factor I_P (Section 9.6.3.14) [Sections 13.6.4 and 13.6.5] {Sections 13.6.4 and 13.6.5}[1]:

Section 9.6.3.14 of ASCE 7-98/02 states that;

"Attachments and supports for electrical equipment shall meet the force and displacement provisions of Sections 9.6.1.3 and 9.6.1.4 and the additional provisions of this Section. In addition to their attachments and supports, electrical equipment designated as having $I_P = 1.5$, itself, shall be designed to meet the force and displacement provisions of Sections 9.6.1.3 and 9.6.1.4 and the additional provisions of this Section."

In this statement, there really are no implied exemptions for electrical equipment, except that if the supports for the equipment have been designed by the manufacturer to meet the seismic load requirements with the specified mounting hardware, no further analysis and restraint will be required.

In Section 13.6.4 of ASCE 7-05 and ASCE 7-10, the text reads as follows.

"Electrical components with I_P greater than 1.0 shall be designed for the seismic forces and relative displacements defined in Sections 13.3.1 and 13.3.2 …."

ASCE 7-05 Section 13.6.5 states the following;

"Mechanical and electrical component supports (including those with $I_P = 1.0$) and the means by which they are attached to the component shall be designed for the forces and displacements determined in Sections 13.3.1 and 13.3.2. Such supports including structural members, braces, frames, skirts, legs, saddles, pedestals, cables, guys, stays, snubbers, and tethers, as well as elements forged or cast as part of the mechanical or electrical component."

[1] References in brackets (Section 9.6.3.14) [Sections 13.6.4 and 13.6.5] {Sections 13.6.4 and 13.6.5} apply to sections, tables, and/or equations in ASCE 7-98/02, ASCE 7-05, ASCE 7-10 respectively which forms the basis for the seismic provisions in 2000/2003 IBC, 2006/2009 IBC, 2012 IBC respectively.

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ASCE 7-05 and ASCE 7-10 Section 13.6.4 implies that electrical components that have been assigned a Component Importance Factor equal to 1.0, regardless of the Seismic Design Category to which they have been assigned, will not require seismic restraints beyond the attachment provisions normally included with the component, provided that a qualified component is selected. This means that if the component has four mounting feet with holes for Φ3/8″ mounting hardware, then the component should be attached to the structure with four Φ3/8″ bolts, or anchors. Beyond that nothing further is required.

However, ASCE 7-05 Section 13.6.5 insists that the supports must be designed to withstand the code mounted forces and displacements. So, as with ASCE 7-98/02 this is not a general blanket exemption. The manufacturer of the component must be able to certify that the supports designed as part of the component will withstand the seismic requirements for the project using hardware of the appropriate size and strength.

So, while additional analysis and restraint may not be required for electrical components with $I_P = 1.0$, the supports for this equipment must be designed by the manufacturer with sufficient strength to meet the code mandated requirements. After this the design professional of record for a project and the contractor may provide attachment hardware of the appropriate type, size, and strength, as recommended by the manufacturer of the equipment, without doing any further analysis, or providing any further restraint.

While this sounds rather “wishy-washy”, it’s really not. If the manufacturer of the equipment and its supports certifies that is was design to handle accelerations in excess of the design acceleration for the project, then it may be exempted from the need for further seismic restraint or analysis.

D2.1.7.3 Conduit Size Exemption [13.6.5.5-6a] {13.6.5.5-2}:

There are no specific size exemptions for electrical conduit in 2000/2003 IBC, ASCE 7-98/02. However, 2006/2009 IBC and ASCE 7-05, and 2012 IBC and ASCE 7-10 do have exemptions for electrical conduit. They seem to follow the exemptions, in terms size, that are used for piping. Therefore, it is reasonable to use the exemptions in 2006/2009/2012 IBC for 2000/2003 IBC since it is the most recent version, and takes into account any new testing or analysis.

For 2006/2009 IBC and ASCE 7-05, and 2012 IBC and ASCE 7-10, seismic restraints are not required for conduit that has been assigned a Component Importance Factor equal to 1.5, and whose trade size is 2.5 in. (64mm) or less. When sizing and selecting restraints for electrical conduit, that the weight per linear foot of conduit varies greatly depending on the exact type of conduit being used. Also, when computing the total weight per foot of the conduit plus the cabling, it standard practice to assume that there will be ~40% copper fill for the cabling.

D2.1.7.4 Trapeze Supported Electrical Distribution Systems [13.6.5.5-6b] [13.6.5.6-1a]:

As with conduit, no specific exemptions for trapeze supported electrical distribution systems exist in 2000/2003 IBC, ASCE 7-98/02. However, an exemption is allowed under 2006/2009 IBC and ASCE 7-05, and 2012 and ASCE 7-10. It makes sense to argue for the use of this exemption in

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2000/2003 IBC as well. The exemption matches the weight limits proposed for trapeze supported pipe in Section 5.6 of this guide.

No restraints are required for conduit, bus ducts, or cable trays (termed in ASCE 7-10 as raceways) that are supported on trapeze bars, that have been assigned a Component Importance Factor equal to 1.5, and that have a total weight that is 10 lb/ft (4.5 kg/m) or less. This total weight includes not only the conduit, bus duct, or cable trays, but also includes the trapeze bars as well. In ASCE 7-10, there is no Component Importance Factor stated, so this will apply to both a Component Importance Factor of 1.0, and 1.5 for 2012 IBC.

D2.1.7.5 The 12″ Rule {Section 13.6.5.6-1b}:

In ASCE 7-10, the 12″ Rule has been applied to electrical raceways (conduit, bus ducts, or cable trays. The raceway run will be exempt fro the need for seismic restraints if every hanger supporting the raceway run is 12 in (305 mm) or less in length from the raceway attachment point to the supporting structure. If hanger rods are used to support the raceway, they must be equipped with swivels to prevent inelastic bending of the hanger rod.

D2.1.7.5 Summary:

All of the implied exemptions above are made without regard for the Seismic Design Category to which the building has been assigned. Further, a complete reading of the project specification is in order to ensure that these exemptions have not been negated by the wishes of the building owner.

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SESIMIC DESIGN FORCES

D2.1.8.1 Introduction:

The code based horizontal seismic force requirements for MEP systems and components are either calculated by the seismic restraint manufacturer as a part of the selection and certification process, or may be determined by the design professional of record for the MEP systems under consideration.

This is an informational section. It will discuss the code based horizontal seismic force demand equations and the variables that go into them. This discussion will provide a deeper understanding for the designer responsible for selecting the seismic restraints for MEP systems and their components and the nature of the seismic forces and the factors that affect them.

D2.1.8.2 Horizontal Seismic Design Force (Section 9.6.1.3) [Section 13.3.1] {Section 13.3.1}[1]:

The seismic force is based on the mass, or weight, of the MEP component and as such is applied to the MEP component at its center of gravity. Keep in mind that the earthquake ground motion moves the base of the building first. Then the motion of the building will accelerate the MEP component through its supports and/or seismic restraints. The horizontal seismic force acting on an MEP component will be determined in accordance with Equation 9.6.1.3-1 of ASCE 7-98/02 and Equation 13.3-1 of ASCE 7-05 and ASCE 7-10.

$$F_P = \frac{0.4 a_P S_{DS} W_P}{\left(\frac{R_P}{I_P}\right)}\left(1 + 2\frac{z}{h}\right)$$ **Eq D2.1.8-1 (9.6.1.3-1) [13.3-1] {13.3-1}**

ASCE 7-98/02, -05, and -10 define an upper and lower bound for the horizontal force that is to be applied to the center of gravity of a component. The horizontal seismic force acting on an MEP component is not required to be greater than;

$$F_P = 1.6 S_{DS} I_P W_P$$ **Eq D2.1.8-2 (9.6.1.3-2) [13.3-2] {13.3-2}**

And the horizontal seismic force acting on an MEP component is not to be less than;

$$F_P = 0.3 S_{DS} I_P W_P$$ **Eq D2.1.8-3 (9.6.1.3-3) [13.3-3] {13.3-3}**

Where:

[1] References in brackets (Section 9.6.1.3) [Section 13.3.1] {Section 13.3.1} refer to sections and/or tables in ASCE 7-98/02, ASCE 7-05, and ASCE7-10 respectively which forms the basis for the seismic provisions in 2000/2003 IBC, 2006/2009 IBC, and 2012 IBC respectively.

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F_P = the design horizontal seismic force acting on an MEP component at its center of gravity.

S_{DS} = the short period design spectral acceleration.

a_P =the component amplification factor. This factor is a measure of how close to the natural period of the building the natural period of the component is expected to be. The closer the natural period of the component is to that of the building, the larger a_P will be. Conversely, the further the natural period of the component is away from that of the building, the smaller a_P will be. Typically a_P will vary from 1.0 to 2.5, and is specified by component type in ASCE 7-98, -02, -05, and -10 and is listed in Tables D2.1.8-1, D2.1.8-2, D2.1.8-3, and D2.1.8-4 respectively.

I_P = the component importance factor which be either 1.0 or 1.5.

W_P = the operating weight of the MEP system or component that is being restrained.

R_P = the response modification factor which varies from 1.25 to 5.0 in ASCE 7-98, 1.5 to 5.0 in ASCE 7-02, and 1.50 to 12.0 in ASCE 7-05 and -10 by component type. This factor is a measure of the ability of the component and its attachments to the structure to absorb energy. It is really a measure of how ductile or brittle the component and its attachments are. The more flexible, ductile the component and its supports and/or restraints are the larger R_P will be. And conversely, the more brittle and inflexible the component and its supports and/or restraints are, the smaller R_P will be. The values are specified by component type in Table D2.1.8-1 for ASCE 7-98, Table D2.1.8-2 for ASCE 7-02, Table D2.1.8-3 for ASCE 7-05, and Table D2.1.8-4 for ASCE 7-10.

z = the structural attachment mounting height of the MEP component in the building relative to the grade line of the building.

h = the average height of the building roof as measured from the grade line of the building.

The **0.4** factor was introduced as a modifier for S_{DS} as a recognition that the MEP components inside the building would react more strongly to the long period earthquake ground motion than to the short period motion. The **0.4** factor brings the design level acceleration for the MEP components more in line with the design level acceleration that is applied to the building structure itself.

The $\left(1+2\frac{z}{h}\right)$ term in Equation D2.1.8-1 is recognition of the fact that all buildings and structures become more flexible as they increase in height. That is they are much stiffer, stronger, at the foundation level than the roof. Since the ground motion from an earthquake enters the building structure at the foundation level, the actual accelerations imparted an MEP component will be greater the higher in the building they are attached. A building may be likened to a vertically mounted cantilever beam that is being shaken by the bottom. It is a vibrating system that will have

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a certain natural period that is, in a general fashion, based on its mass and stiffness. If the natural period of the building is at, or close too, the earthquake period, the motion of the building could be extreme. This was the case in the Mexico City earthquake of September 19, 1985.

The horizontal seismic design force must be applied to the component along it's least resistant axis. This is likely not one of the primary axes. The horizontal seismic design force must also be applied in conjunction with all of the expected dead loads and service loads. The idea here is that the horizontal seismic design force is to be applied in the direction that causes the highest stress in the supports and restraints, and thus produces the most conservative results. Load combination equations are provided in the various versions of the IBC that indicate all of the various load considerations that must be addressed.

D2.1.8.3 Vertical Seismic Design Force (Sections 9.5.2.7 and 9.6.1.3) [Sections 12.4.2.2 and 13.3.1] {Sections 12.4.2.2 and 13.3.1}:

The MEP component, its supports, and its restraints must also be designed for a vertical seismic design force that acts concurrently with the horizontal seismic design force. This vertical seismic design force must be directed such that it also produces the highest stress in the supports and restraints, thus producing the most conservative result. This vertical seismic design force is defined as follows.

$$F_V = \pm 0.2 S_{DS} W_P$$ **Eq D2.1.8-4 (9.5.2.1-1/-2) [12.4-4] {12.4-4}**

Where:

F_V = the vertical seismic design force.

D2.1.8.4 The Evolution of a_P and R_P Factors (Sections 9.6.1.3 and 9.6.3.2 and Table 9.6.3.2) [Sections 13.3.1 and 13.6.1 and Table 13.6-1]:

The a_p and R_p factors represent respectively the dynamic response of the attachment method and the durability level of the restrained piece of equipment. The component amplification factor (a_p) increases the seismic force for conditions where the looseness in the mounting system can create pounding or where the attachment can possibly resonate with the motion generated by a seismic event. This number will increase as the attachment becomes more resilient.

The component response modification factor (R_p) is a measure of how much energy the restrained component along with its supports and attachments can absorb without sustaining crippling damage. A common term used throughout the HVAC industry for this factor is the fragility level. For R_p = 1.0 the component is extremely fragile. For R_p = 12.0, on the other hand, the component would be very robust.

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The values for a_P and R_P are assigned by the ASCE 7 committee based on accumulated experience throughout the building industry. The evolution of these factors may be traced through Tables D2.1.8-1; D2.1.8-2, D2.1.8-3, and D2.1.8-4 which represent 2000 IBC, ASCE 7-98; 2003 IBC, ASCE 7-02; 2006/2009 IBC, ASCE 7-05; and 2012 IBC, ASCE 7-10 respectively. The different values for the same items in the three tables indicate the lack of knowledge and understanding concerning these components throughout the industry. Only time, experience, and shake table testing will produce true usable values for a_P and R_P .

D2.1.8.5 LRFD versus ASD: (Sections 2.3 and 2.4) [Sections 2.3, 2.4 and 13.1.7] {Sections 2.3, 2.4 and 13.1.7}:

This topic was briefly touched upon in Section D2.1.4.8 of this guide. However, more should be said about it in this section dealing the design seismic forces that will be applied to the MEP components. The Civil and Structural Engineering community has adopted the LRFD, Load Resistance Factor Design, philosophy. With this design philosophy the factors controlling the serviceability of the structure as assigned to the design loads. ASD, Allowable Stress Design, is the design philosophy which preceded LRFD. In ASD, the factors controlling the serviceability of the structure are assigned to the yield strength or to the ultimate strength of the material. Traditionally the factors controlling the serviceability of the structure have been known as the Safety Factors, or Factors of Safety.

The forces calculated using Equations D2.1.8-1, D2.1.8-2, D2.1.8-3, and D2.1.8-4 will have magnitudes that correspond to LRFD. Many standard components such a concrete anchors, bolts, screws, and etc. will have their capacities listed as ASD values. Components whose capacities are listed as ASD values may be compared to the LRFD results from Equations D2.1.8-1 through D2.1.8-4 by multiplying the ASD values by 1.4.

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Table D2.1.8-1; Component Amplification and Response Modification Factors for 2000 IBC (Table 9.6.3.2)

MECHANICAL & ELECTRICAL COMPONENT[2]	a_P [3]	R_P [4]
General Mechanical Equipment	-----	-----
Boilers and furnaces.	1.0	2.5
Pressure vessels on skirts and free-standing.	2.5	2.5
Stacks & cantilevered chimneys	2.5	2.5
Other	1.0	2.5
Piping Systems	-----	-----
High deformability elements and attachments (welded steel pipe & brazed copper pipe).	1.0	3.5
Limited deformability elements and attachments (steel pipe with screwed connections, no hub connections, and Victaulic type connections).	1.0	2.5
Low deformability elements and attachments (iron pipe with screwed connections, and glass lined pipe).	1.0	1.25
HVAC Systems	-----	-----
Vibration isolated.	2.5	2.5
Non-vibration isolated.	1.0	2.5
Mounted-in-line with ductwork.	1.0	2.5
Other	1.0	2.5
General Electrical	-----	-----
Distributed systems (bus ducts, conduit, and cable trays).	2.5	5.0
Equipment.	1.0	2.5
Lighting fixtures.	1.0	1.25

[2] Components mounted on vibration isolators shall be restrained in each horizontal direction with bumpers or snubbers, and the horizontal seismic design force shall be equal to $2F_P$.
[3] The value for a_P shall not be less than 1.0. Lower values shall not be used unless justified by a detailed dynamic analysis. A value of a_P=1.0 is to be applied to equipment that is rigid or rigidly attached. A value of a_P=2.5 is to be applied to equipment regarded as flexible or flexibly attached.
[4] A value of R_P=1.25 is to be used for component anchorage design with expansion anchor bolts, shallow chemical anchor, shall low deformability cast in place anchors, or when the component is constructed of brittle materials. Shallow anchors are those with an embedment depth to nominal diameter ratio that is less than 8.

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Table D2.1.8-2; Component Amplification and Response Modification Factors for 2003 IBC (Table 9.6.3.2)

MECHANICAL & ELECTRICAL COMPONENT[5]	a_P [6]	R_P
General Mechanical Equipment	-----	-----
Boilers and furnaces.	1.0	2.5
Pressure vessels on skirts and free standing.	2.5	2.5
Stacks and cantilevered chimneys.	2.5	2.5
Other	1.0	2.5
Piping Systems	-----	-----
High deformability elements and attachments (welded steel pipe & brazed copper pipe).	1.0	3.5
Limited deformability elements and attachments (steel pipe with screwed connections, no hub connections, and Victaulic type connections).	1.0	2.5
Low deformability elements and attachments (iron pipe with screwed connections, and glass lined pipe).	1.0	1.5
HVAC Systems	-----	-----
Vibration isolated.	2.5	2.5
Non-vibration isolated.	1.0	2.5
Mounted-in-line with ductwork.	1.0	2.5
Other	1.0	2.5
General Electrical	-----	-----
Distribution systems (bus ducts, conduit, and cable trays).	2.5	5.0
Equipment	1.0	2.5
Lighting fixtures.	1.0	1.5

[5] Components mounted on vibration isolators shall be restrained in each horizontal direction with bumpers or snubbers. If the maximum bumper/snubber clearance, or air gap, is greater than 1/4 in., the horizontal seismic design force shall be equal to $2F_P$. If the maximum bumper/snubber clearance, air gap, is less than or equal to 1/4 in., the horizontal seismic design force shall be taken as F_P.

[6] The value for a_P shall not be less than 1.0. Lower values shall not be used unless justified by a detailed dynamic analysis. A value of a_P=1.0 is to be applied to equipment that is rigid or rigidly attached. A value of a_P=2.5 is to be applied to equipment regarded as flexible or flexibly attached.

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Table D2.1.8-3; Component Amplification and Response Modification Factors for 2006/2009 IBC [Table 13.6-1]

MECHANICAL AND ELECTRICAL COMPONENTS	a_P [7]	R_P [8]
Air-side HVAC – fans, air handlers, and other mechanical components with sheet metal framing.	2.5	6.0
Wet-side HVAC – boilers, chillers, & other mechanical components constructed of ductile materials.	1.0	2.5
Engines, turbines, pumps compressors, and pressure vessels not supported on skirts.	1.0	2.5
Skirt supported pressure vessels.	2.5	2.5
Generators, batteries, transformers, motors, & other electrical components made of ductile materials.	1.0	2.5
Motor control cabinets, switchgear, & other components constructed of sheet metal framing.	2.5	6.0
Communication equipment, computers, instrumentation and controls.	1.0	2.5
Roof-mounted chimneys, stacks, cooling and electrical towers braced below their C.G.	2.5	3.0
Roof-mounted chimneys, stacks, cooling and electrical towers braced below their C.G.	1.0	2.5
Lighting fixtures.	1.0	1.5
Other mechanical & electrical components.	1.0	1.5
Vibration Isolated Components & Systems	-----	-----
Components & systems isolated using neoprene elements & neoprene isolated floors with elastomeric snubbers or resilient perimeter stops	2.5	2.5
Spring isolated components & systems & vibration isolated floors closely restrained with elastomeric snubbing devices or resilient perimeter stops.	2.5	2.0
Internally isolated components or systems.	2.5	2.0
Suspended vibration isolated equipment including in-line duct devices & suspended internally isolated components.	2.5	2.5
Distribution Systems	-----	-----
Piping in accordance with ASME B31, this includes in-line components, with joints made by welding or brazing.	2.5	12.0
Piping in accordance with ASME B31, this includes in-line components, constructed of high or limited deformability materials with joints made by threading, bonding, compression couplings, or grooved couplings.	2.5	6.0
Piping & tubing that is not in accordance with ASME B31, this includes in-line components, constructed with high deformability materials with joints made by welding or brazing.	2.5	9.0
Piping & tubing that is not in accordance with ASME B31, this includes in-line components, constructed of high or limited deformability materials with joints made by threading, bonding, compression couplings, or grooved couplings.	2.5	4.5
Piping & tubing of low deformability materials, such as cast iron, glass, or non-ductile plastics.	2.5	3.0

---

[7] The value for a_P shall not be less than 1.0. Lower values shall not be used unless justified by a detailed dynamic analysis. A value of a_P=1.0 is to be applied to components that are rigid or rigidly attached. A value of a_P=2.5 is to be applied to components regarded as flexible or flexibly attached.

[8] Components mounted on vibration isolators shall be restrained in each horizontal direction with bumpers or snubbers. If the maximum bumper/snubber clearance, or air gap, is greater than 1/4 in., the horizontal seismic design force shall be equal to 2F_P. If the maximum bumper/snubber clearance, air gap, is less than or equal to 1/4 in., the horizontal seismic design force shall be taken as F_P.

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Ductwork, including in-line components, constructed of high deformability materials, with joints made by welding or brazing.	2.5	9.0
Ductwork, including in-line components, constructed of high or limited deformability materials, with joints made by means other than welding or brazing.	2.5	6.0
Duct work constructed of low deformability materials such as cast iron, glass, or non-ductile plastics.	2.5	3.0
Electrical conduit, bus ducts, rigidly mounted cable trays, & plumbing.	1.0	2.5
Suspended cable trays.	2.5	6.0

Table D2.1.8-4; Component Amplification and Response Modification Factors for 2012 IBC {Table 13.6-1}

MECHANICAL AND ELECTRICAL COMPONENTS	a_P [9]	R_P [10]
Air-side HVAC – fans, air handlers, and other mechanical components with sheet metal framing.	2.5	6.0
Wet-side HVAC – boilers, chillers, & other mechanical components constructed of ductile materials.	1.0	2.5
Engines, turbines, pumps compressors, and pressure vessels not supported on skirts.	1.0	2.5
Skirt supported pressure vessels.	2.5	2.5
Generators, batteries, transformers, motors, & other electrical components made of ductile materials.	1.0	2.5
Motor control cabinets, switchgear, & other components constructed of sheet metal framing.	2.5	6.0
Communication equipment, computers, instrumentation and controls.	1.0	2.5
Roof-mounted chimneys, stacks, cooling and electrical towers braced below their C.G.	2.5	3.0
Roof-mounted chimneys, stacks, cooling and electrical towers braced below their C.G.	1.0	2.5
Lighting fixtures.	1.0	1.5
Other mechanical & electrical components.	1.0	1.5
Vibration Isolated Components & Systems	-----	-----
Components & systems isolated using neoprene elements & neoprene isolated floors with elastomeric snubbers or resilient perimeter stops	2.5	2.5
Spring isolated components & systems & vibration isolated floors closely restrained with elastomeric snubbing devices or resilient perimeter stops.	2.5	2.0
Internally isolated components or systems.	2.5	2.0
Suspended vibration isolated equipment including in-line duct devices & suspended internally isolated components.	2.5	2.5

[9] The value for a_P shall not be less than 1.0. Lower values shall not be used unless justified by a detailed dynamic analysis. A value of a_P=1.0 is to be applied to components that are rigid or rigidly attached. A value of a_P=2.5 is to be applied to components regarded as flexible or flexibly attached.

[10] Components mounted on vibration isolators shall be restrained in each horizontal direction with bumpers or snubbers. If the maximum bumper/snubber clearance, or air gap, is greater than 1/4 in., the horizontal seismic design force shall be equal to $2F_P$. If the maximum bumper/snubber clearance, air gap, is less than or equal to 1/4 in., the horizontal seismic design force shall be taken as F_P.

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Distribution Systems	-----	-----
Piping in accordance with ASME B31, this includes in-line components, with joints made by welding or brazing.	2.5	12.0
Piping in accordance with ASME B31, this includes in-line components, constructed of high or limited deformability materials with joints made by threading, bonding, compression couplings, or grooved couplings.	2.5	6.0
Piping & tubing that is not in accordance with ASME B31, this includes in-line components, constructed with high deformability materials with joints made by welding or brazing.	2.5	9.0
Piping & tubing that is not in accordance with ASME B31, this includes in-line components, constructed of high or limited deformability materials with joints made by threading, bonding, compression couplings, or grooved couplings.	2.5	4.5
Piping & tubing of low deformability materials, such as cast iron, glass, or non-ductile plastics.	2.5	3.0
Ductwork, including in-line components, constructed of high deformability materials, with joints made by welding or brazing.	2.5	9.0
Ductwork, including in-line components, constructed of high or limited deformability materials, with joints made by means other than welding or brazing.	2.5	6.0
Duct work constructed of low deformability materials such as cast iron, glass, or non-ductile plastics.	2.5	3.0
Electrical conduit and cable trays	2.5	6.0
Bus ducts	1.0	2.5
Plumbing	1.0	2.5

D2.1.8.6 Summary:

This section has provided an insight into the way in which the seismic design forces for MEP systems and components are to be computed. It is generally not necessary for a designer to actually run the computations for the seismic design forces. These forces are normally computed by the manufacturer of the seismic restraint devices as part of the selection and certification process to ensure that the proper components are selected per the code and the specification.

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ANCHORAGE OF MEP COMPONENTS TO THE BUILDING STRUCTURE

D2.1.9.1 Introduction:

The anchorage, or attachment, of the MEP components and their seismic restraints to the building structure has always been a gray area generally left to the installing contractor with little or no guidance from the design professionals responsible for the MEP systems or the building structure. ASCE 7 does give some general guidance for the making these attachments. However, the design professionals involved with the MEP systems and the building structure must share the responsibility for ensuring the adequacy of these attachments. This section will cover the guidance provided to the design professionals of record in ASCE 7.

D2.1.9.2 General Guidelines for MEP Component Anchorage (Section 9.6.1.6 and 9.6.3.4) [Section 13.4] {Section 13.4 and Section 13.4.1}[1]:

1. The MEP component, its supports, and seismic restraints must be positively attached to the building structure without relying on frictional resistance generated by the dead weight of the component. The following are some of the acceptable ways and means of attachment.

    a. Bolting

    b. Welding

    c. Post installed concrete anchors

    d. Cast in place concrete anchors

2. There must be a continuous load path of sufficient strength and stiffness between the component and the building structure to withstand the expected seismic loads and displacements. This means that when cable restraints are used for distributed MEP systems, the cables can not bend or wrap around any other component or structure in a straight line path between the component and the structure.

3. The local areas of the building structure must be designed with sufficient strength and stiffness to resist and transfer the seismic restraint forces from the MEP systems and components to the main force resisting structure of the building. It is at this point that the design professional of record, and the installing contractor for the MEP system must work closely with the structural engineer of record to make sure that the intended anchorage points for the MEP system seismic restraints have sufficient capacity.

[1] References in brackets (Sections 9.6.1.6 and 9.6.3.4) [Section 13.4] {Section 13.4} apply to sections, tables, and/or equations in ASCE 7-98/02, ASCE 7-05, and ASCE 7-10 respectively which forms the basis for the seismic provisions in 2000/2003 IBC, 2006/2009 IBC, and 2012 IBC respectively.

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Special Notes:

1. **The design documents need to contain enough information pertaining to the attachments to allow a design professional to verify the compliance with the code.**

2. **In ASCE 7-10 Section 13.4.1, the design forces and displacements are to be determined according to Sections 13.3.1 and 13.3.2 as in previous versions except that $R_P \leq 6.0$. Thus, the design forces for certain pipe and duct systems will be higher than what would be indicated from using the R_P values found in Table 13.6-1of ASCE 7-10.**

D2.1.9.3 Anchorage in (Cracked) Concrete and Masonry (Section 9.6.1.6) [Section 13.4.2] {Section 13.4.2.1 and Section 13.4.2.3}:

1. Anchors for MEP component seismic restraints and supports are to be designed and proportioned to carry the least of the following:

   a. A force equal to 1.3 times the seismic design forces acting on the component and its supports and restraints.

   b. The maximum force that can be transferred to the anchor by the component and its supports.

2. $R_P \leq 1.5$ will be used to determine the component forces unless:

   a. The design anchorage of the component and/or its restraints is governed by the strength of a ductile steel element.

   b. The design of post installed anchors in concrete used for the anchorage of the component supports and restraints is prequalified for seismic applications according to ACI 355.2.

      i. Anchors that have been prequalified per AC 193[2] (ACI 355.2) will have an ICC-ES ESR Report issued for that anchor stating the fact that it is suitable for seismic applications for the current version of IBC. It will also give the allowable loads, embedments, and edge distances pertinent to the allowable loads.

      ii. Anchors from different manufacturers may not be directly substituted on a one-to-one basis. Each manufacturer will have a different design that will have different allowable loads when tested under AC 193 (ACI 355.2). The allowable loads for equivalent anchor sizes may be radically different.

[2] AC 193 is the Acceptance Criteria used by ICC ES to evaluate and pre-qualify the concrete anchors for use in cracked concrete. It is base directly on ACI 355.2.

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c. The anchor is designed in accordance with Section 14.2.2.14 of ASCE 7-05.

For 2000 IBC, ASCE 7-98, the “cracked” concrete anchors are not required, and standard post installed wedge type anchors may be used for seismic restraint as long as there is an ICC Legacy report stating that the anchors may be used in seismic applications. For 2003 IBC, ASCE 7-02, there are no specific statements in ASCE 7-02 that require the use of “cracked” concrete anchors in seismic applications. However, ASCE 7-02 Section 9.9 adopts ACI 318-02 as a reference document. ACI 318-02 specifies that the post installed anchors meet ACI 355.2 and “are required to be qualified for moderate or high seismic risk zone usage.” ACI 355.2 is the test standard by which post installed anchors are to be pre-qualified for seismic applications in cracked concrete. So, by inference, “cracked” concrete anchors should also be used for 2003 IBC. However, that has not yet been widely enforced since few if any post installed anchors had been qualified to this standard before 2006/2009 IBC was issued.

There are new and special wrinkles for concrete anchors in ASCE 7-10 which will be picked up by 2012 IBC. ASCE 7-10 Section 13.4.2.1 requires the concrete anchors to be designed per ACI 318 Appendix D. ACI 318-08 Section D.3.3.4 specifies that the anchors must be designed such that their failure is to be governed by a ductile steel element. So, the ductile steel element needs to fail before the concrete fails. The intent of the code is to prevent an unpredictable brittle failure in the concrete by having a predictable ductile failure in the steel of the anchor. There is an alternative to this requirement in ACI 318-08 Section D.3.3.6 which requires that, instead of the ductile failure in the steel of the anchor, that the allowable strength of the anchors may be reduced by 60%. This will create problems throughout the industry for MEP contractors who must use post installed concrete anchors to attach the restraints for MEP components to the building structure because the standard offering of wedge type anchors, typically, do not meet the ductility requirement of the code. To meet the requirement of the code, the steel element must have an elongation of at least 14% and a reduction in area of at least 30%. It may be possible to achieve this with adhesive type post installed anchors, but not in all cases. The result is that more anchors will be required to attach the restraints to the building than before. This means more “real estate” will be required for each anchor point.

Masonry anchors are now discussed more fully in ASCE 7-10 Sections 13.4.2.2 and 13.4.2.3. ASCE 7-10 Section 13.4.2.2 requires that the design of masonry anchors be per TMS 402/ACI 503/ASCE5, and that the design be governed by the failure of a ductile steel element or that the allowable strength of the anchor be reduced by 60%. Also, ASCE 7-10 Section 13.4.2.3 requires that the anchors used in masonry be prequalified for seismic applications per approved qualification standards (which do not yet exist). This will cause problems with application and inspection when 2012 IBC is implemented. There will be no acceptance criteria for pre-qualifying anchors for seismic applications in masonry, and thus, no pre-qualified anchors with an ICC-ESR.

D2.1.9.4 Undercut Anchors (Section 9.6.3.13.2-c) [Section 13.6.5.5-5] {Section 13.6.5.5-5}:

For both 2000 IBC, ASCE 7-98, and 2006/2009 IBC, ASCE 7-05, post installed expansion, wedge, anchors may not be used for non-vibration isolated mechanical equipment rated over 10 hp (7.45

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kW). However, post installed undercut expansion anchors may be used. Also, because they are not specifically prohibited, adhesive anchors may be used.

For 2003 IBC, ASCE 7-02, post installed expansion, wedge, anchors may not be used for non-vibration isolated mechanical equipment. However, post installed undercut expansion anchors are permitted. Again, adhesive anchors may be used because they are not specifically prohibited.

ASCE 7-10 Section 13.6.5.5-5 simply states that anchors used for non-vibration isolated equipment rated over 10 Hp (7.45 kW) are to be qualified per ACI 355.2 (AC 193). The requirement for undercut wedge anchors is removed.

D2.1.9.5 Prying of Bolts and Anchors (Section 9.6.1.6.3) [Section 13.4.3] {Section 13.4.3}:

The design of the attachment of the MEP component supports and restraints must take into account the mounting conditions such as eccentricity in the supports and brackets, and prying of the bolts or anchors.

D2.1.9.6 Power Actuated or Driven Fasteners (Section 9.6.1.6.5) [Section 13.4.5] {Section 13.4.5}:

Power actuated or driven fasteners, such as powder shot pins, may not be used for tensile load applications in Seismic Design Categories D, E, and F unless specifically approved for this application.

The language in ASCE 7-10 Section 13.4.5 has been made more restrictive. Power actuated fasteners in concrete or steel are not to be used sustained tension loads or brace (seismic restraint) applications in Seismic Design Categories D, E, or F unless they have been approved for seismic applications. Power actuated fasteners are not to be used in masonry unless approved for seismic applications.

D2.1.9.7 Friction Clips (Section 9.6.3.13.2-b) [Section 13.4.6] {Section 13.4.6}:

Friction clips may not be used to attach seismic restraints to the component or the building structure. A typical example would be the attachment of a cable restraint to a structural beam with a standard beam clamp. A beam clamp with a restraint strap or safety strap, capable of resisting the applied seismic load that will ensure that the clamp will be prevented from walking off the beam may be used.

ASCE 7-10 Section 13.4.6 has clarified the application of friction type clips for attaching seismic restraints to the building structure. They are not to be used for supporting sustained loads as well as seismic loads in Seismic Design Categories D, E, or F. The implication is that they can be used for seismic loads alone. C-type beam and large flange clamps can be used for hangers if they are equipped with safety straps. In all cases the bolts providing the clamping force that generates the friction load must be equipped with lock nuts or the equivalent to prevent the loosening of the threaded connections.

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D2.1.9.8 Summary:

Attachment of the MEP components and their seismic restraints to the building structure is of the utmost importance to maintaining the building function following an earthquake. It is the responsibility of the design professionals of record for the MEP systems to work with the structural engineer of record and the architect of record for the building to ensure that the anchorage points for the MEP component supports and restraints have been properly designed to transfer the design seismic loads as well as any other dead weight and service loads.

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IBC Wind

D2.2.1 - Introduction:

The need for the seismic restraint of equipment has been well recognized for many years. It even appears in most specifications. The need for the wind restraint of exposed roof top equipment, however, has been largely ignored. It very seldom appears as a specification item, and when it does it is placed in an obscure portion of the specification, almost as an after thought. Hurricane Katrina and the other recent hurricanes in Florida and the Gulf of Mexico have focused FEMA's attention on the ability of roof top equipment to withstand forces generated by high wind events. Of particular interest are the attachments of the equipment to the building structure. This paper will center on the different versions of the International Building Code (IBC), which are based on the wind provisions of ASCE 7, and how they apply to the wind loads acting on roof top equipment. Table 2.2.1-1 shows the IBC code year along with its ASCE 7 reference version.

Table D2.2.1-1; IBC & ASCE 7 Wind Load References

INTERNATIONAL BUILDING CODE YEAR (IBC)	IBC WIND LOAD SECTION	ASCE 7 VERSION	ASCE 7 WIND LOAD CHAPTER FOR ROOFTOP EQUIPMENT
2000	1609	98	6
2003	1609	02	6
2006	1609	05	6
2009	1609	05	6
2012	TBD	10	29

The following references are used throughout Section D2.2

1. 2000 International Building Code; International Code Council, 5203 Leesburg Pike, Suite 708, Falls Church, Virginia, 22041-3401; 2000.

2. ASCE 7-98 Minimum Design Loads for Buildings and Other Structures; American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400, Chapter 9.

3. 2003 International Building Code; International Code Council, Inc., 4051 West Flossmoor Road, Country Club Hills, Illinois 60478-5795; 2002.

4. ASCE/SEI 7-02 Minimum Design Loads for Buildings and Other Structures; American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400, Chapter 9.

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5. 2006 International Building Code; International Code Council, Inc., 4051 West Flossmoor Road, Country Club Hills, Illinois 60478-5795; 2006.

6. 2009 International Building Code; International Code Council, Inc., 4051 West Flossmoor Road, Country Club Hills, Illinois 60478-5795; 2009.

7. ASCE/SEI 7-05 Minimum Design Loads for Buildings and Other Structures; American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400, Chapters 1, 2, 11, 13, 20, and 21.

8. 2012 International Building Code; International Code Council, Inc., 4051 West Flossmoor Road, Country Club Hills, Illinois 60478-5795; ***Not Yet Published***.

9. ASCE/SEI 7-10 Minimum Design Loads for Buildings and Other Structures; American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400; 2010, Chapters 1, 2, 11, 13, 20, 21, 22 and 23.

10. Reinhold, Timothy A.; "Wind Loads and Anchorage Requirements for Rooftop Equipment"; ASHRAE Journal March 2006, www.ashrae.org.

When applying wind restraints to rooftop equipment, it is important to keep the following things in mind.

1. Wind loads are a real and constant threat in all locations in the country.

2. In many cases the wind loads acting on a piece of rooftop equipment will be more severe than the seismic loads.

3. There must be a continuous load path between the rooftop equipment and the building structure.

4. The building structure must be strong enough to carry, not only the dead weight of the equipment, but also carry the design wind loads calculated according to the code provisions.

5. Design calculations and submittals for wind restraints must be forwarded to the Structural Engineer of Record for evaluation and approval.

6. For curb mounted equipment, not only must the equipment be properly attached to the curb, but the curb itself must be properly attached to the building structure that supports it.

7. The restraint types used for isolated equipment may cause the isolation to be "shorted out", or ineffective, for extended periods of time during low to moderate wind conditions.

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CODE OVERVIEW & BASIC INFORMATION

D2.2.2.1 – Introduction

IBC code years 2000 thru 2009 have been published and are current. IBC 2012 has not yet been published. However, ASCE 7-10 has been published and will, no doubt, form the basis of the wind load requirements for IBC 2012. IBC 2000 and 2003, ASCE 7-98 and -02, are, for all intents and purposes, the same in regards to wind loading. They do not specifically mention equipment, and only have provisions for horizontal wind loads. IBC 2006, ASCE 7-05, is similar to IBC 2000 and 2003, but it does specifically mention equipment in a new section (Section 6.5.15.1), and it recommends consideration of wind generated uplift forces acting on the equipment in the Commentary (Page 300). IBC 2012 will have entirely new language and structure as pertains to wind loads. ASCE 7-10 has broken the wind load section up into 6 new chapters. As seen in Table D2.2.1-1, Chapter 29 deals specifically with roof top equipment. Also, the basic 3 second gust wind speeds are being increased significantly, by 30 mph.

D2.2.2.2 – Wind Restraint for Rooftop Equipment

For all current published versions of the IBC, 2000 thru 2009, Sections 1609.1 and 1609.1.1 require that all parts of buildings and structures be designed to withstand the minimum wind loads prescribed by the version of ASCE 7 that corresponds to the IBC code year in force. Section 1609.1 also states that wind loads acting on rooftop equipment may not be reduced through the shielding effects of other structures. These sections of the IBC will impact rooftop equipment in the following ways.

1. It requires that all exposed, outside, equipment and their attachment to the building structure be designed to resist the code mandated wind loads.

2. Barrier walls, screens, parapets, overhangs, and other shielding structures can not be counted on to protect exposed, outside, equipment. The equipment and its attachments to the structure must be designed to withstand the full force of the code mandated wind loads.

D2.2.2.3 – Building Classification for Wind Design:

The magnitude of the design wind loads will depend on the classification and use of the building. The basic building classifications have remained the same over the various versions of the IBC and ASCE 7. However, the designations of those classifications have changed over the various versions of the code. Table D2.2.2-1 shows how the building classifications have changed over the years, and is based on Table 1-1 of ASCE 7-98/-02, Table 1-1 of ASCE 7-05, and Table 1.5-1 of ASCE 7-10.

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Table D2.2.2-1; Building Use vs. Building Category, Occupancy Category, and Risk Category

BUILDING CATEGORY 2000/2003 IBC	OCCUPANCY CATEGORY 2006/2009 IBC	RISK CATEGORY 2012 IBC	BUILDING USE
I	I	I	Buildings and other structures whose failures would pose a significant risk to human life.
II	II	II	Buildings and other structures not listed in Occupancy/Risk Categories I, III, and IV or Seismic Use Groups II and III.
II	III	III	Buildings and other structures whose failure would pose a significant risk to human life, cause a significant economic impact, or cause mass disruption in the day-to-day life of civilians.
III	IV	IV	Buildings or other structures that are essential for post disaster recovery, whose failure would pose a substantial hazard to the community, or are used to process, store, or dispose of hazardous materials.

Building, Occupancy, or Risk Category is assigned by the Architect and/or structural engineer and is specified on the first sheet of the structural drawings.

D2.2.2.4 – Basic Wind Speed & Wind Importance Factor:

The Basic Wind Speed is used to compute the design wind loads that are applied to the rooftop equipment. For IBC 2000/2003 the Basic Wind Speed for each location in the United States is given in Figures 6-1 and 6-1a through -1c of ASCE 7-98/-02. Notice that for the bulk of the United States, the Basic Wind Speed is 90 mph. This wind speed corresponds to a Category 1 hurricane. Coastal areas have much higher basic wind speeds that increase with decreasing distance to the coast. For IBC 2006/2009, the basic wind speeds are given in Figures 6-1 and 6-1A through 6-1C of ASCE 7-05. The values shown on these maps did not change from those for ASCE 7-98/-02.

For IBC 2000/2003/2006/2009, the building classification is accounted for through the use of a Wind Importance Factor. The Wind Importance Factor is matched to the building classification by Table 6-1 of ASCE 7-98/-02/-05, which is repeated in Table D2.2.2-2 below.

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Table D2.2.2-2; Importance Factors for Wind Based on Building Occupancy
ASCE 7-98/-02/-05 Table 6-1

BUILDING, OCCUPANCY, OR RISK CATEGORY	NON-HURRICANE PRONE REGIONS AND HURRICANE PRONE REGIONS WITH $V = 85 - 100 \ mph$ AND ALASKA	HURRICANE PRONE REGIONS WITH $V > 100 \ mph$
I	0.87	0.77
II	1.00	1.00
III	1.15	1.15
IV	1.15	1.15

As will be seen in a later Section D2.2.3 of this manual, the Wind Importance Factor will be a direct multiplier of the calculated wind load based in the Basic Wind Speed.

In ASCE 7-10, all of this has changed dramatically. The Basic Wind Speeds are now found in Figures 26.5-1A through -1C. The Wind Importance Factor has been eliminated. The Basic Wind Speed will now be a function of the Risk Category that has been assigned to the building. From this point forward; this manual will deal only with Risk Category III and IV buildings. Most of the buildings that require large pieces of rooftop equipment will fall into one of these two Risk Categories. For Risk Category III and IV buildings, the Basic Wind Speeds have all been increased by 30 mph. So now, the bulk of the United States will have a Design Wind Speed of 120 mph, which corresponds to a Category 3 hurricane. The design wind loads are a function of the square of the Basic Wind Speed, so it may be expected that the design wind loads will increase dramatically across the board.

D2.2.2.5 – Exposure Categories:

The Exposure Category takes into account the surrounding terrain and structures. This is generally assigned to the building by the structural engineer and is listed on the first sheet of the structural drawings. Table D2.2.2-3 will help with understanding the assignment of the Exposure Category to a particular building, and is based on Section 6.5.6 of ASCE 7-98/-02/-05 and Section 26.7 of ASCE 7-10. Exposure Category A was dropped with ASCE 7-02, and will not be included in Table D2.2.2-3.

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Table D2.2.2-3; Importance Factors for Wind Based on Building Occupancy
ASCE 7-98/-02/-05 Section 6.5.6 and ASCE 7-10 Section 26.7

BUILDING, OCCUPANCY, OR RISK CATEGORY	SURROUNDING TERRAIN & STRUCTURES
B	Urban and Suburban areas, wooded areas, or other terrain with many closely spaced obstructions of single family dwelling size or larger.
C	Open terrain with scattered obstructions generally 30 ft or less in height; including flat open country, grasslands, and all water surfaces in hurricane-prone regions.
D	Fat unobstructed areas and water surfaces outside hurricane-prone regions; includes smooth mud flats, salt flats, and unbroken ice.

D2.2.2.6 – Mean Roof Height:

The design wind loads acting on the rooftop equipment will depend on the mean roof height of the building on which the equipment is setting. Generally speaking, the design wind loads increase with increasing roof height. So, it is critical that the actual roof height at the equipment mounting location be determined. This should be available from both the architectural drawings and the structural drawings.

D2.2.2.7 – Summary

The basic pieces of information that are required to determine the design wind loads on a piece of equipment are as follows.

1. The Building, Occupancy, or Risk Category; which is available from the first sheet of the structural drawings.
2. The Basic Wind Speed; this may be determined from the figure listed in Section D2.2.2.4 for the various versions of IBC and ASCE 7, or may be available from the first sheet of the structural drawings.
3. The Exposure Category; which is available from the first sheet of the structural drawings.
4. Mean roof height at the equipment mounting location; this may be found in the structural drawings or the architectural drawings.

Wind loads must be taken seriously. They are a real and constant threat to the building envelope integrity. For the bulk of the country the design wind speeds will be equivalent to either a Category 1 hurricane, IBC 2000/2003/2006/2009, or a Category 3 hurricane, IBC 2012. The fact that rooftop equipment and their attachments must be designed to meet these wind loads is not usually spelled out in the specifications for the various trades and disciplines as are the seismic

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design requirements. However, the code does require that rooftop equipment and its attachments to the building be designed to meet these wind loads.

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Evolution of Design Wind Loads

D2.2.3.1 – Introduction:

Over the various versions of ASCE 7, the design wind loads acting on rooftop equipment have gone from being very ambiguous and difficult to calculate to being fairly well defined and straightforward. The purpose of this section will be to cover the equations and constants that apply to wind loads acting on rooftop equipment and standardized worst case load values for differing conditions.

D2.2.3.2 – Velocity Pressure:

This parameter is common to all versions of ASCE 7 in one of two forms. For ASCE 7-98/-02/-05, it is expressed as Equation 6-13 in ASCE 7-98, Equation 6-15 in ASCE 7-02, and Equation 6-15 in ASCE 7-05, and is shown below in Equation D2.2.3-1.

$$q_z = 0.00256 K_z K_{zt} K_d V^2 I \qquad \textbf{Eq 2.2.3-1}$$

Where:

q_z = the velocity pressure at height z of the centroid of the area being impacted (psf). In this section it will be evaluated at the mean roof height of the building, and z will be taken to be the mean roof height at the equipment mounting location.

K_z = the velocity pressure exposure coefficient.

K_{zt} = the topographic factor.

K_d = the wind directionality factor.

V = the Design Wind Speed.

I = the Wind Importance Factor, see Table D2.2.2-2

For ASCE 7-10, the velocity pressure is defined in Equation 29.3-1, and show below in Equation D2.2.3-2. Notice that the only difference is that the Wind Importance Factor has been removed.

$$q_z = 0.00256 K_z K_{zt} K_d V^2 \qquad \textbf{Eq 2.2.3-2}$$

D2.2.3.2.1 – Velocity Pressure Exposure Coefficient:

The value of this parameter is defined in Tables 6-5 and 6-4 of ASCE 7-98, Tables 6-3 and 6-2 of ASCE 7-02/-05, and Tables 29.3-1 and 26.9-1 of ASCE 7-10. For the purposes of this analysis the

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equations listed in Note 1 of the tables will be used to compute the values for K_{zt} rather than trying to use tabulated data. The equation used in this section will be;

$$K_z = 2.01\left(\frac{z}{z_g}\right)^{\frac{2}{\alpha}} \text{ Where } 15 \le z \le z_g$$ **Eq 2.2.3-3**

Where:

z = the mean roof height of the building at the equipment mounting location (ft) and $z = 15$ for mean roof heights less than 15 ft.

The constants z_g and α are defined in Table 6-4 of ASCE 7-98, Table 6-2 of ASCE 7-02/-05, and Table 26.9-1 of ASCE 7-10 and are repeated below in Table D2.2.3-1 for convenience.

Table D2.2.3-1; Constants by Exposure Category for Computing K_z

EXPOSURE CATEGORY	α	z_g (FT)
B	7.0	1200
C	9.5	900
D	11.5	700

D2.2.3.2.2 – Topographic Factor:

This factor accounts for the wind speed-up effect that occurs when wind flows over a hill of an escarpment. It is defined by Equation 6-1 and Figure 6-2 of ASCE 7-98, Equation 6-3 and Figure 6-4 of ASCE 7-02/-05, and Equation 26.8-1 and Table 26.8-1 of ASCE 7-10. The values are the same over all four version of ASCE 7. Rarely are the exact topographic conditions surrounding a building site known to the suppliers of restraints for rooftop equipment. So, for the purposes of making a reasonable estimate of the design wind loads it will be assumed that;

$$K_{zt} = 1.0$$

D2.2.3.2.3 – Wind Directionality Factor:

This factor accounts for how the wind strikes the object, whether the wind can strike the object from only one direction, or whether it can strike the object from any direction. It allows for a reduction in the magnitude of the design wind loads to account for the reduced probability that the highest winds will strike the equipment from the worst possible direction. The values for this factor

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are given in Table 6-4 of ASCE 7-98/-05, Table 6-6 of ASCE 7-02, and Table 26.6-1 of ASCE 7-10. Timothy Reinhold in his ASHRAE Journal paper "Wind Loads and Anchorage Requirements for Rooftop Equipment", see Section D2.2.1 of this manual for the reference, recommends that the Wind Directionality Factor be given the following Value for rooftop equipment.

$$K_d = 0.85$$

This is the value given in the ASCE 7 tables listed above that is applied most frequently to objects that can be struck by the wind from any direction.

D2.2.3.3 – IBC 2000 & 2003 (ASCE 7-98 & -02):

The equation for the design wind load for ASCE 7-98 and ASCE 7-02 is found in Section 6.5.13 which is titled "Design Wind Loads on Open Buildings and Other Structures". In ASCE 7-98 the equation used is Equation 6-20, and in ASCE 7-02 it is 6-25. Both equations are identical and are shown below.

$$F = q_z G C_f A_f \qquad \textbf{Eq D2.2.3-4}$$

Where:

F = the horizontal design wind load (lbs).

G = the gust effect factor.

C_f = the net force coefficient.

A_f = the projected area normal to the wind (ft^2).

For the purposes of this manual it will be more convenient to express the design wind load as a design wind pressure. In this way the manual will be more generically applicable. So, then Equation D2.2.3-4 will have the following form.

$$p_h = q_z G C_f \qquad \textbf{Eq D2.2.3-5}$$

Where:

p_h = the horizontal design wind pressure (psf).

D2.2.3.3.1 – Gust Effect Factor:

The gust effect factor takes into account the turbulence and the resilience of the structure, and there are procedures for calculating the gust effect factor. However, the code provides only one

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value for rigid structures in Section 6.5.8.1 of ASCE 7-98/-02, and this is the value that has typically been used for rooftop equipment.

$$G = 0.85$$

There is some thought that the gust effect factor should be higher than 0.85, say on the order of 1.0 or 1.1, for roof top equipment since the equipment is small enough to be completely enveloped by a wind gust. However, there was no research available at the time ASCE 7-02 was published to allow a recommendation to be made on an acceptable value for the gust coefficient. Therefore, for ASCE 7-98/-02, the gust coefficient will remain at a value of 0.85.

D2.2.3.3.2 – Net Force Coefficient:

The net force coefficient is determined form Table 6-10 of ASCE 7-98 and Table 6-19 of ASCE 7-02. Most rooftop equipment is square or rectangular. Kinetics Noise Control performs its calculations with the wind acting on the gross diagonal area. The worst case for a square, rectangular, unit with the wind acting along the diagonal will produce a value for the net force coefficient of;

$$C_f = 1.5$$

This will also cover all of the cases of round rooftop stacks.

D2.2.3.3.3 – Design Wind Pressures for IBC 2000 & 2003:

Table D2.2.3-2 presents horizontal design wind pressures based on the equations and values for the various coefficients and factors given above. These design wind pressures are for Category III and IV buildings where $I = 1.15$.

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Table D2.2.3-2; Design Horizontal Wind Pressures on Rooftop Equipment for IBC 2000 & 2003 Category III & IV Buildings

Building Height (ft)		15	30	45	60	100	200
Design Wind Speed (mph)	Exposure Category	Horz. Press. p_h (psf)	Horz. Press. p_h (psf)	Horz. Press. p_h (psf)	Horz. Press. p_h (psf)	Horz. Press. p_h (psf)	Horz. Press. p_h (psf)
85	B	13.2	16.1	18.1	19.7	22.8	27.8
	C	19.6	22.6	24.7	26.2	29.2	33.8
	D	23.7	26.8	28.7	30.2	33.0	37.3
90	B	14.9	18.1	20.3	22.1	25.5	31.1
	C	21.9	25.4	27.6	29.4	32.7	37.8
	D	26.6	30.0	32.2	33.9	37.0	41.8
100	B	18.3	22.4	25.1	27.2	31.5	38.4
	C	27.1	31.3	34.1	36.3	40.4	46.7
	D	32.9	37.1	39.8	41.8	45.7	51.6
110	B	22.2	27.0	30.4	33.0	38.2	46.5
	C	32.8	37.9	41.3	43.9	48.9	56.5
	D	39.8	44.9	48.1	50.6	55.3	62.4
120	B	26.4	32.2	36.1	39.2	45.4	55.3
	C	39.0	45.1	49.2	52.2	58.1	67.3
	D	47.3	53.4	57.3	60.2	65.8	74.3
130	B	31.0	37.8	42.4	46.0	53.3	65.0
	C	45.8	53.0	57.7	61.3	68.2	79.0
	D	55.6	62.7	67.2	70.7	77.3	87.2
140	B	35.9	43.8	49.2	53.4	61.8	75.3
	C	53.1	61.4	66.9	71.1	79.1	91.6
	D	64.4	72.7	78.0	82.0	89.6	101.1
150	B	41.3	50.3	56.5	61.3	70.9	86.5
	C	60.9	70.5	76.8	81.6	90.9	105.1
	D	74.0	83.4	89.5	94.1	102.9	116.0

D2.2.3.4 – IBC 2006 & 2009 (ASCE 7-05):

The design wind load for ASCE 7-05 is described in Sections 6.5.15 and 6.5.15.1. The basic equation specified for computing the design wind load is identical to that used in ASCE 7-98/-02, and is shown in Equation D2.2.3-4. However, it is to be modified for the mean roof height of the building at the mounting location for the rooftop equipment. The factor used to modify Equation D2.2.3-4 for building heights less than or equal to sixty feet varies from 1.9 down to 1.0 in a linear fashion based on the size of the equipment relative to the building size. Since the overall building dimensions are not always known, the maximum value of 1.9 will be used in this manual as a worst case condition. Timothy Reinhold's ASHRAE Journal paper, see Section D.2.2.3-1 of this manual, recommended that Equation D2.2.3-4 be increased by a factor of 1.6 for buildings over sixty feet in height. Thus, the equations used to determine the horizontal design wind loads for ASCE 7-05 will be as follows.

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$F = 1.9 q_z G C_f A_f$ For $z \leq 60'$ **Eq D2.2.3-6**

And;

$F = 1.6 q_z G C_f A_f$ For $z > 60'$ **Eq D2.2.3-7**

Expressing Equations D2.2.3-6 and D2.2.3-7 as horizontal design wind pressures as in the previous section will lead to;

$p_h = 1.9 q_z G C_f$ For $z \leq 60'$ **Eq D2.2.3-8**

And;

$p_h = 1.6 q_z G C_f$ For $z > 60'$ **Eq D2.2.3-9**

The values for the gust effect factor G and the net force coefficient C_f will remain the same as those for ASCE 7-98/-02.

In the commentary of ASCE 7-05 (page 300) there is a strong recommendation to include uplift loads in the design of the attachments for rooftop equipment. No guidance is given in this version of the code as to how the uplift forces should be calculated. Timothy Reinhold in his ASHRAE Journal paper cited in Section D2.2.1 of this manual recommends the following form for the equations to compute the uplift design wind force acting on the rooftop equipment.

$F_v = 1.9 q_z G C_p A$ For $z \leq 60'$ **Eq D2.2.3-10**

And;

$F_v = 1.6 q_z G C_p A$ For $z > 60'$ **Eq D2.2.3-11**

Where:

F_v = the uplift design wind load (lbs).

C_p = the external pressure coefficient.

A = the horizontal projected area of the rooftop equipment (ft^2).

Expressing Equations D2.2.3-10 and D2.2.3-11 as horizontal design wind pressures as in the previous section will lead to;

$p_v = 1.9 q_z G C_p$ For $z \leq 60'$ **Eq D2.2.3-12**

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And;

$p_v = 1.6 q_z G C_p$ For $z > 60'$ **Eq D2.2.3-13**

Where:

p_v = the vertical, uplift, design wind pressure (psf).

D2.2.3.4.1 – External Pressure Coefficient:

The value for this coefficient is to be found in ASCE 7-05 Table 6-6. It will be assumed that the roof slope is less than or equal to 10° and that the wind is acting normal to the roof ridge. The values listed for C_p are negative because the act outward away from the roof. By convention the negative sign will be dropped in this manual, and the uplift design wind load will be assume to always act upward away from the roof surface. Then; the value for the external pressure coefficient will be taken to be;

$C_p = 0.9$

D2.2.3.4.2 – Design Wind Pressures for IBC 2006 & 2009:

Table D2.2.3-3 presents horizontal and uplift design wind pressures based on the equations and values for the various coefficients and factors given above. These design wind pressures are for Category III and IV buildings where $I = 1.15$.

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Table D2.3.3-3; Horizontal & Uplift Design Wind Pressures on Rooftop Equipment for IBC 2006 & 2009 – Occupancy Category III & IV Buildings

Building Height (ft)		15		30		45		60		100		200	
Design Wind Speed (mph)	Exposure Category	Horz Press p_h (psf)	Vert Press p_v (psf)	Horz Press p_h (psf)	Vert Press p_v (psf)	Horz Press p_h (psf)	Vert Press p_v (psf)	Horz Press p_h (psf)	Vert Press p_v (psf)	Horz Press p_h (psf)	Vert Press p_v (psf)	Horz Press p_h (psf)	Vert Press p_v (psf)
85	B	25.2	15.1	30.7	18.4	34.5	20.7	37.4	22.4	36.4	21.9	44.4	26.7
	C	37.2	22.3	43.0	25.8	46.9	28.1	49.8	29.9	46.7	28.0	54.0	32.4
	D	45.1	27.1	50.9	30.5	54.6	32.8	57.4	34.5	52.9	31.7	59.6	35.8
90	B	28.2	16.9	34.4	20.6	38.6	23.2	41.9	25.2	40.9	24.5	49.8	29.9
	C	41.7	25.0	48.2	28.9	52.5	31.5	55.8	33.5	52.3	31.4	60.6	36.3
	D	50.6	30.4	57.1	34.2	61.2	36.7	64.4	38.6	59.3	35.6	66.8	40.1
100	B	34.8	20.9	42.5	25.5	47.7	28.6	51.8	31.1	50.4	30.3	61.5	36.9
	C	51.5	30.9	59.5	35.7	64.9	38.9	68.9	41.3	64.6	38.8	74.8	44.9
	D	62.5	37.5	70.5	42.3	75.6	45.4	79.5	47.7	73.1	43.9	82.5	49.5
110	B	42.2	25.3	51.4	30.8	57.7	34.6	62.6	37.6	61.0	36.6	74.4	44.6
	C	62.3	37.4	72.0	43.2	78.5	47.1	83.4	50.0	78.2	46.9	90.5	54.3
	D	75.6	45.3	85.2	51.1	91.5	54.9	96.2	57.7	88.5	53.1	99.8	59.9
120	B	50.2	30.1	61.2	36.7	68.7	41.2	74.6	44.7	72.6	43.6	88.6	53.1
	C	74.1	44.5	85.7	51.4	93.4	56.0	99.2	59.5	93.0	55.8	107.7	64.6
	D	89.9	54.0	101.5	60.9	108.9	65.3	114.5	68.7	105.3	63.2	118.8	71.3
130	B	58.9	35.3	71.8	43.1	80.6	48.4	87.5	52.5	85.3	51.2	103.9	62.4
	C	87.0	52.2	100.6	60.4	109.6	65.8	116.4	69.9	109.2	65.5	126.3	75.8
	D	105.5	63.3	119.1	71.4	127.8	76.7	134.3	80.6	123.6	74.2	139.5	83.7
140	B	68.3	41.0	83.2	49.9	93.5	56.1	101.5	60.9	98.9	59.3	120.5	72.3
	C	100.9	60.5	116.7	70.0	127.1	76.3	135.0	81.0	126.6	76.0	146.5	87.9
	D	122.4	73.4	138.1	82.9	148.2	88.9	155.8	93.5	143.4	86.0	161.7	97.0
150	B	78.4	47.0	95.6	57.3	107.3	64.4	116.5	69.9	113.5	68.1	138.4	83.0
	C	115.8	69.5	134.0	80.4	145.9	87.5	155.0	93.0	145.4	87.2	168.2	100.9
	D	140.5	84.3	158.5	95.1	170.1	102.1	178.8	107.3	164.6	98.8	185.7	111.4

D2.2.3.5 – IBC 2012 (ASCE 7-10):

ASCE 7-10 does count for the wind effects on rooftop equipment in Sections 29.5 and 29.5.1. Section 29.5.1 deals with buildings whose mean roof height is sixty feet or less, and Section 29.5 covers buildings whose mean roof height is greater than sixty feet.

D2.2.3.5.1 – Buildings with $h \leq 60'$:

For buildings whose mean roof height is sixty feet or less, the horizontal design wind load is given by ASCE 7-10 Equation 29.5-2.

$$F_h = q_h (GC_f) A_f \quad \text{For } h \leq 60' \qquad \text{Eq D2.2.3-14}$$

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Where:

F_h = the horizontal design wind load (lbs).

q_h = the velocity pressure evaluated at the mean roof height (psf). For the purposes of this manual this value will be computed as q_z using Equation D2.2.3-2.

(GC_f) = 1.9 for rooftop equipment. This is allowed to vary in a linear fashion from 1.9 for equipment that is small compared to the size of the building to 1.0 for equipment that is approaching the same size as the building. IN this manual it will be taken as 1.9 for a worst case.

The uplift design wind load is given by ASCE 7-10 Equation 29.5-3.

$F_v = q_h (GC_r) A_r$ For $h \leq 60'$ **Eq D2.2.3- 15**

Where:

(GC_r) = 1.5 for rooftop equipment. Here again this is allowed to vary in a linear fashion from 1.5 for equipment that is small compared to the size of the building to 1.0 for equipment that is approaching the same size as the building. I this manual the worst case value of 1.5 will be used.

A_r = the horizontal projected area of the rooftop equipment (ft2).

The design loads presented in Equations D2.2.3-14 and D2.2.3-15 may be expressed as design pressures as follows.

$p_h = q_h (GC_f)$ For $h \leq 60'$ **Eq D2.2.3-16**

And;

$p_v = q_h (GC_r)$ For $h \leq 60'$ **Eq D2.2.3- 17**

D2.2.3.5.2 – Buildings with $h > 60'$:

For buildings whose mean roof height exceeds sixty feet, the neither the code nor the commentary mentions an uplift design wind load requirement. For buildings whose mean roof height exceeds sixty feet no design uplift wind load will be considered, and the horizontal design wind load is given by Equation 29.5.1 of ASCE 7-10.

$F = q_z GC_f A_f$ For $h > 60'$ **Eq D2.2.3-18**

And the horizontal design wind pressure is;

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$$p_h = q_z G C_f \text{ For } h > 60' \qquad \textbf{Eq D2.2.3-19}$$

For this manual, the value of q will be evaluated using Equation D2.2.3-1 at the mean roof height of the building. The values of G and C_f will be as before for ASCE 7-98/02/05.

D2.2.3.5.3 – Design Wind Pressures for IBC 2012 (ASCE 7-10):

The design wind pressures for IBC 2012 (ASCE 7-10) are presented below in Table D2.2.3-4. Note that there are no vertical uplift pressures listed for mean roof heights exceeding sixty feet. This table reflects the 30 mph increase across the board in design wind loads.

Table D2.2.3-4; Design Wind Pressures on Rooftop Equipment for IBC 2012 (ASCE 7-10) Risk Category III & IV Buildings

Building Height (ft)		15		30		45		60		100		200	
Design Wind Speed (mph)	Exposure Category	Horz Press p_h (psf)	Vert Press p_v (psf)	Horz Press p_h (psf)	Vert Press p_v (psf)	Horz Press p_h (psf)	Vert Press p_v (psf)	Horz Press p_h (psf)	Vert Press p_v (psf)	Horz Press p_h (psf)	Vert Press p_v [a] (psf)	Horz Press p_h (psf)	Vert Press p_v [a] (psf)
115	B	31.4	24.8	38.3	30.2	43.0	34.0	46.7	36.9	36.3	0.0	44.2	0.0
	C	46.4	36.6	53.7	42.4	58.5	46.2	62.1	49.1	46.4	0.0	53.7	0.0
	D	56.3	44.5	63.5	50.2	68.2	53.8	71.7	56.6	52.6	0.0	59.3	0.0
120	B	34.2	27.0	41.7	32.9	46.8	37.0	50.8	40.1	39.5	0.0	48.1	0.0
	C	50.5	39.9	58.5	46.2	63.7	50.3	67.7	53.4	50.6	0.0	58.5	0.0
	D	61.3	48.4	69.2	54.6	74.2	58.6	78.1	61.6	57.2	0.0	64.6	0.0
130	B	40.2	31.7	49.0	38.6	55.0	43.4	59.7	47.1	46.3	0.0	56.5	0.0
	C	59.3	46.8	68.6	54.2	74.7	59.0	79.4	62.7	59.3	0.0	68.7	0.0
	D	72.0	56.8	81.2	64.1	87.1	68.8	91.6	72.3	67.2	0.0	75.8	0.0
140	B	46.6	36.8	56.8	44.8	63.7	50.3	69.2	54.6	53.7	0.0	65.5	0.0
	C	68.8	54.3	79.6	62.8	86.7	68.4	92.1	72.7	68.8	0.0	79.6	0.0
	D	83.5	65.9	94.2	74.4	101.1	79.8	106.2	83.9	77.9	0.0	87.9	0.0
150	B	53.5	42.2	65.2	51.5	73.2	57.8	79.4	62.7	61.7	0.0	75.2	0.0
	C	79.0	62.3	91.4	72.1	99.5	78.6	105.7	83.5	79.0	0.0	91.4	0.0
	D	95.8	75.7	108.1	85.4	116.0	91.6	122.0	96.3	89.4	0.0	100.9	0.0
160	B	60.8	48.0	74.2	58.5	83.3	65.7	90.4	71.4	70.2	0.0	85.6	0.0
	C	89.8	70.9	104.0	82.1	113.2	89.4	120.3	95.0	89.9	0.0	104.0	0.0
	D	109.0	86.1	123.0	97.1	132.0	104.2	138.8	109.6	101.8	0.0	114.8	0.0
170	B	68.7	54.2	83.7	66.1	94.0	74.2	102.0	80.6	79.2	0.0	96.6	0.0
	C	101.4	80.1	117.4	92.7	127.8	100.9	135.8	107.2	101.5	0.0	117.4	0.0
	D	123.1	97.2	138.9	109.6	149.0	117.6	156.7	123.7	114.9	0.0	129.6	0.0
180	B	77.0	60.8	93.8	74.1	105.4	83.2	114.4	90.3	88.8	0.0	108.3	0.0
	C	113.7	89.8	131.6	103.9	143.3	113.1	152.2	120.2	113.8	0.0	131.6	0.0
	D	138.0	109.0	155.7	122.9	167.1	131.9	175.6	138.7	128.8	0.0	145.3	0.0
190	B	85.8	67.7	104.6	82.6	117.4	92.7	127.5	100.6	99.0	0.0	120.7	0.0
	C	126.7	100.0	146.6	115.7	159.7	126.1	169.6	133.9	126.8	0.0	146.7	0.0
	D	153.8	121.4	173.5	136.9	186.1	146.9	195.7	154.5	143.5	0.0	161.9	0.0
200	B	95.0	75.0	115.9	91.5	130.1	102.7	141.2	111.5	109.7	0.0	133.7	0.0
	C	140.4	110.8	162.4	128.2	176.9	139.7	188.0	148.4	140.5	0.0	162.5	0.0
	D	170.4	134.5	192.2	151.7	206.2	162.8	216.8	171.2	159.0	0.0	179.4	0.0

a. ASCE 7-10 does not require uplift for rooftop euipment on buildings over 60' in height.

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D2.3.3.6 – Summary:

1. The design wind loads increased greatly across the board between IBC 2000/2003 and IBC 2006/2009. The design wind loads also increased between IBC 2006/2009 and IBC 2012. However, the increase was smaller for the lower brackets of the Design Wind Speed, and the increase was much greater at the higher brackets of the Design Wind Speed.

2. IBC 2006/2009 saw the addition of a design uplift load requirement in the commentary of ASCE 7-05. For IBC 2012 this design uplift load requirement is specified in the body of the code in ASCE 7-10 in Chapter 29. For IBC 2006/2009 the uplift load requirement was not limited to a mean roof height of sixty feet or less. For IBC 2012, the design uplift load requirement applies only to buildings whose mean roof height is sixty feet or less.

3. The design wind pressures given in Tables D2.2.3-2, D2.2.3-3, and D2.2.3-4 may be used to ***estimate*** the wind loadings on rooftop equipment in order to make preliminary selections of wind restraint devices. The actual selection of the restraint devices must be reviewed and approved by Kinetics Noise Control and the Structural Engineer of Record.

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NBCC-OBC SEISMIC

D2.3.1 – Introduction:

The purpose of this guide is to provide design professionals, contractors, and building officials responsible for the MEP, Mechanical, Electrical, and Plumbing, with the information and guidance required to ensure that the seismic restraints required for a specific project are selected and/or designed, and installed in accordance with the code provisions. This guide will be written in several easily referenced sections that deal with specific portions of the code.

This guide is based on the National Building Code of Canada 2005 (NBCC 2005). The NBCC 2005 appears to be very different in the formulation of the design forces than the previous NBCC 1995 version. This document will be based entirely on the newer NBCC 2005 version.

1. National Building Code of Canada 2005; Canadian Commission on Building and Fire Codes and National Research Council of Canada, 1200 Montreal RD, Ottawa, ON K1A 9Z9 Chapter Division B – Part 4 Structural Design.

The selection and installation of the proper seismic restraints for MEP systems requires good coordination with the design professionals and contractors involved with the building project. A good spirit of cooperation and coordination is especially required for projects that have been designated as post-disaster buildings, such as hospitals, emergency response centers, police and fire stations. Coordination between the various design professionals and contractors will be a constant theme throughout this guide. This coordination is vital for the following reasons.

1. The seismic restraints that are installed for a system can and will interfere with those of another unless restraint locations are well coordinated.

2. The space required for the installed restraints can cause problems if non-structural walls need to be penetrated, or other MEP components are in the designed load path for the restraints.

3. The building end of the seismic restraints must always be attached to structure that is adequate to carry the code mandated design seismic loads. It is the responsibility of the structural engineer of record to verify this.

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REQUIRED BASIC PROJECT INFORMATION

D2.3.2.1 – Introduction:

As with any design job, there is certain basic information that is required before seismic restraints can be selected and placed. The building owner, architect, and structural engineer make the decisions that form the basis for the information required to select the seismic restraints for the pipe and duct systems in the building. This is information that should be included in the specification and bid package for the project. It also should appear on the first sheet of the structural drawings. For consistency, it is good practice to echo this information in the specification for each building system, and on the first sheet of the drawings for each system. In this fashion, this information is available to all of the contractors and suppliers that will have a need to know.

D2.3.2.2 – Building Use-Nature of Occupancy [Sentence 4.1.2.1][1]:

How a building is to be used greatly affects the level of seismic restraint that is required for the MEP (Mechanical, Electrical, and Plumbing) components. In the NBCC 2005 the building use is defined through the Importance Category, which ranges in four stages from Low to Post-Disaster. Table D2.3.2-1 below summarizes the information found in Tables 4.1.2.1 of the NBCC 2005. The nature of the building use, or its Occupancy Category, is determined by the building owner and the architect of record.

D2.3.2.3 – Site Class-Soil Type [Sentences 4.1.8.4.(2) and 4.1.8.1.(3)]:

The Site Class is related to the type of soil and rock strata that directly underlies the building site.

The Site Class ranges from A to F progressing from the stiffest to the softest strata. Table D2.3.2-2 lists the various Site Classes and their corresponding strata.

Generally the structural engineer is responsible for determining the Site Class for a project. If the structural engineer's firm does not have a geotechnical engineer on staff, this job will be contracted to a geotechnical firm. The site profile is normally obtained by drilling several cores on the property. Unlike the U. S. building codes, there is no published default Site Class that may be that can be substituted for the actual Site Class that is determined from soils testing performed at the actual project location.

[1] References in brackets [Sentence 4.1.2.1 and Table 4.1.2.1] apply to sections, tables, and/or equations in the National Building Code of Canada 2005.

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Table D2.3.2-1; Importance Category vs. Building Use and Occupancy [Table 4.1.2.1]

IMPORTANCE CATEGORY	BUILDING USE OR NATURE OF OCCUPANCY
Low	Buildings whose failure will present a low direct or indirect hazard to human life ➢ Low human occupancy buildings where structural collapse is unlikely to cause injury or other serious consequences. ➢ Minor storage buildings and structures.
Normal	Buildings not listed as Importance Category Low, High, or Post-Disaster.
High	Buildings which are likely to be used in Post-Disaster situations as shelters, which will include the following building types: ➢ Elementary, middle, or secondary schools. ➢ Community centers. Manufacturing and storage facilities which contain toxic, explosive, or hazardous materials in sufficient quantities to pose a hazard to the public is released, such as: ➢ Petrochemical facilities. ➢ Fuel storage facilities ➢ Manufacturing and storage facilities for dangerous goods.
Post-Disaster	Buildings and structures which are designated as essential facilities which include but are not limited to: ➢ Hospitals, emergency treatment facilities, and blood banks. ➢ Emergency response facilities, fire, rescue, ambulance, and police stations, housing for emergency response equipment, and communications facilities including radio and television, unless exempted by the jurisdiction having authority). ➢ Power generating stations and sub-stations. ➢ Control centers for air land and marine transportation. ➢ Water treatment, storage, and pumping facilities. ➢ Sewage treatment facilities and buildings or structures required for national defense.

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Table D2.3.2-2; Site Class vs. Soil Type [Table 4.1.8.4A]

SITE CLASS	SOIL TYPE
A	Hard Rock
B	Rock
C	Very Dense Soil & Soft Rock
D	Stiff Soil
E	Soft Soil
F	Liquefiable Soils, Quick Highly Sensitive Clays, Collapsible Weakly Cemented Soils, & etc. These require site-specific evaluation.

D2.3.2.4 – Spectral Response Acceleration Value at 0.2 Second [Sentence 4.1.8.4.(1) and Table C-2]

The Spectral Response Acceleration Values at 0.2 Second, which are denoted as $S_{a(0.2)}$, have been determined for selected location in Canada and documented in the Canadian Journal of Civil Engineering, Volume 10, Number 4, pp 670-680, 1983. These values for selected location in Canada are presented in Table C-2 of the NBCC 2005, and are repeated for convenience below in Table D2.3.2-3

D2.3.2.5 – Importance Factor for Earthquake Loads [Sentence 4.1.8.5 and Table 4.1.8.5]:

The Importance Factor for Earthquake Loads (I_E) for the building is assigned based on the Importance Category of the building. It may be prudent to request both the assigned Importance Category and the Importance Factor for Earthquake Loads. The Importance Factor for Earthquake Loads may be specified more stringently than the Importance Category of the building would indicate in order to artificially provide increased protection for the building and its contents. The Importance Factor for Earthquake Loads is assigned as shown in Table D2.3.2-4

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Table D2.3.2-3; Spectral Response Acceleration Value at 0.2 Second for Selected Locations in Canada [Table C-2]

PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$
British Columbia	------	Masset	0.53	Langley	1.10
100 Mile House	0.28	McBride	0.27	New Westminster	0.99
Abbotsford	0.92	Mcleod Lake	0.18	North Vancouver	0.88
Agassiz	0.67	Merrit	0.32	Richmond	1.10
Alberi	0.75	Mission City	0.93	Surrey (88 Ave & 156 St.)	1.10
Ashcroft	0.33	Montrose	0.27	Vancouver	0.94
Beatton River	0.12	Nakusp	0.27	Vancouver (Granville & 41 Ave)	0.88
Burns Lake	0.12	Nanaimo	1.00	Vernon	0.27
Cache Creek	0.33	Nelson	0.27	***Victoria Region***	------
Campbell River	0.62	Ocean Falls	0.38	Victoria (Gonzales Hts.)	1.20
Carmi	0.28	Osoyoos	0.28	Victoria (Mt. Tolmie)	1.20
Castlegar	0.27	Penticton	0.28	Victoria	1.20
Chetwynd	0.24	Port Alberni	0.75	Williams Lake	0.28
Chilliwack	0.73	Port Hardy	0.43	Youbou	1.00
Comox	0.66	Port McNeill	0.43	**Alberta**	------
Courtenay	0.65	Powell River	0.67	Athabasca	0.12
Cranbrook	0.27	Prince George	0.13	Banff	0.24
Crescent Valley	0.27	Prince Rupert	0.38	Barrhead	0.12
Crofton	1.10	Princeton	0.42	Beaverlodge	0.13
Dawson Creek	0.12	Qualicum Beach	0.82	Brooks	0.12
Dog Creek	0.32	Quesnel	0.27	Calgary	0.15
Duncan	1.10	Revelstoke	0.27	Campsie	0.12
Elko	0.27	Salmon Arm	0.27	Camrose	0.12
Fernie	0.27	Sandspit	0.56	Cardston	0.18
Fort Nelson	0.12	Sidney	1.20	Claresholm	0.15
Fort St. John	0.12	Smith River	0.52	Cold Lake	0.12
Glacier	0.27	Smithers	0.12	Coleman	0.24
Golden	0.26	Squamish	0.72	Coronation	0.12
Grand Forks	0.27	Stewart	0.30	Cowley	0.20
Hope	0.63	Taylor	0.12	Drumheller	0.12
Kamloops	0.28	Terrace	0.34	Edmonton	0.12
Kaslo	0.27	Tofino	1.20	Edson	0.15
Kelowna	0.28	Trail	0.27	Embarras Portage	0.12
Kimberley	0.27	Ucluelet	1.20	Fairview	0.12
Kitimat Plant	0.37	***Vancouver Region***	------	Fort MacLeod	0.16
Kitimat Townsite	0.37	Burnaby (Simon Fraser Univ.)	0.94	Fort McMurray	0.12
Lilooet	0.60	Cloverdale	1.00	Fort Saskatchewan	0.12
Lytton	0.60	Haney	0.97	Fort Vermilion	0.12
Mackenzie	0.23	Ladner	1.10	Grande Prairie	0.12

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Table D2.3.2-3 Continued; Spectral Response Acceleration Value at 0.2 Second for Selected Locations in Canada [Table C-2]

PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$
Alberta	------	Humboldt Bay	0.12	Selkirk	0.12
Habay	0.12	Island Falls	0.12	Spit Lake	0.12
Hardisty	0.12	Kamsack	0.12	Steinbach	0.12
High River	0.15	Kindersley	0.12	Swan River	0.12
Hinton	0.24	Lloydminster	0.12	The Pas	0.12
Jasper	0.24	Maple Creek	0.12	Virden	0.12
Keg River	0.12	Meadow Lake	0.12	Winnipeg	0.12
Lac la Bishe	0.12	Melfort	0.12	**Ontario**	------
Lacombe	0.12	Melville	0.12	Ailsa Craig	0.16
Lethbridge	0.15	Moose Jaw	0.12	Ajax	0.22
Manning	0.12	Nipawin	0.12	Alexandria	0.68
Medicine Hat	0.12	North Battleford	0.12	Alliston	0.17
Peace River	0.12	Prince Albert	0.12	Almonte	0.58
Pincher Creek	0.19	Qu' Appelle	0.12	Armstrong	0.12
Ranfurly	0.12	Regina	0.12	Arnprior	0.64
Red Deer	0.12	Rosetown	0.12	Atikokan	0.12
Rocky Mountain House	0.15	Saskatoon	0.12	Aurora	0.19
Slave Lake	0.12	Scott	0.12	Bancroft	0.26
Stettler	0.12	Strasbourg	0.12	Barrie	0.16
Stony Plain	0.12	Swift Current	0.12	Beaverton	0.16
Suffield	0.12	Uranium City	0.12	Belleville	0.26
Taber	0.12	Weyburn	0.23	Belmont	0.20
Turner Valley	0.15	Yorktown	0.12	Big Trout Lake	0.12
Valleyview	0.12	**Manitoba**	------	CFB Borden	0.16
Vegreville	0.12	Beausejour	0.12	Bracebridge	0.18
Vermilion	0.12	Boussevain	0.12	Bradford	0.18
Wagner	0.12	Churchill	0.12	Brampton	0.26
Wainwright	0.12	Dauphin	0.12	Brantford	0.24
Wetaskiwin	0.12	Flin Flon	0.12	Brighton	0.25
Whitecourt	0.12	Gimli	0.12	Brockton	0.40
Wimborne	0.12	Island Lake	0.12	Burk's Falls	0.21
Saskatchewan	------	Lac du Bonnet	0.12	Burlington	0.36
Assiniboia	0.17	Lynn Lake	0.12	Cambridge	0.22
Battrum	0.12	Morden	0.12	Campbellford	0.23
Biggar	0.12	Neepawa	0.12	Cannington	0.17
Broadview	0.12	Pine Falls	0.12	Carleton Place	0.52
Dafoe	0.12	Portage la Prairie	0.12	Cavan	0.20
Dundurn	0.12	Rivers	0.12	Centralia	0.14
Estevan	0.15	Sandilands	0.12	Chapleau	0.12

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Table D2.3.2-3 Continued; Spectral Response Acceleration Value at 0.2 Second for Selected Locations in Canada [Table C-2]

PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$
Ontario	------	Grimsby	0.40	Mattawa	0.51
Chatham	0.20	Guelph	0.21	Midland	0.15
Chesley	0.13	Guthrie	0.16	Milton	0.30
Clinton	0.13	Haileybury	0.29	Milverton	0.15
Coboconk	0.18	Haldimand (Caledonia)	0.34	Minden	0.19
Cobourg	0.24	Haldimand (Hagersville)	0.29	Mississauga	0.31
Cochrane	0.21	Haliburton	0.21	Mississauga (Port Credit)	0.32
Colborne	0.24	Halton Hills (Georgetown)	0.25	Mitchell	0.14
Collingwood	0.14	Hamilton	0.33	Moosonee	0.15
Cornwall	0.67	Hanover	0.13	Morrisburg	0.63
Corunna	0.14	Hastings	0.23	Mount Forest	0.15
Deep River	0.66	Hawkesbury	0.65	Nakina	0.12
Deseronto	0.27	Hearst	0.12	Nanticoke (Jarvis)	0.26
Dorchester	0.19	Honey Harbour	0.15	Nanticoke (Port Dover)	0.23
Dorion	0.12	Hornepayne	0.12	Napanee	0.28
Dresden	0.18	Huntsville	0.20	New Liskeard	0.29
Dryden	0.12	Ingersoll	0.19	Newcastle	0.22
Dunnville	0.35	Iroquois Falls	0.21	Newcastle (Bowmanville)	0.21
Durham	0.14	Jellicoe	0.12	Newmarket	0.19
Dutton	0.20	Kapuskasing	0.14	Niagara Falls	0.41
Earlton	0.26	Kemptville	0.60	North Bay	0.29
Edison	0.12	Kenora	0.12	Norwood	0.22
Elmvale	0.15	Killaloe	0.48	Oakville	0.35
Embro	0.18	Kincardine	0.12	Orangeville	0.18
Englehart	0.25	Kingston	0.30	Orillia	0.16
Espanola	0.12	Kinmount	0.19	Oshawa	0.21
Exeter	0.14	Kirkland Lake	0.24	Ottawa	0.66
Fenelon Falls	0.18	Kitchener	0.19	Owen Sound	0.13
Fergus	0.18	Lakefield	0.20	Pagwa River	0.12
Forest	0.14	Lansdowne House Leamington	0.20	Paris	0.22
Fort Erie	0.40	Lindsay	0.18	Parkhill	0.15
Fort Erie (Ridgeway)	0.39	Lion's Head	0.15	Parry Sound	0.16
Gananoque	0.31	London	0.18	Pelham (Fonthill)	0.40
Geraldton	0.12	Lucan	0.16	Pembroke	0.66
Glencoe	0.19	Maitland	0.41	Penetanguishene	0.15
Goderich	0.12	Markdale	0.14	Perth	0.39
Gore Bay	0.12	Markham	0.22	Petawawa	0.66
Graham	0.12	Martin	0.12	Peterborough	0.20
Gravehurst (Muskoka Airport)	0.17	Matheson	0.22	Petrolia	0.16

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Table D2.3.2-3 Continued; Spectral Response Acceleration Value at 0.2 Second for Selected Locations in Canada [Table C-2]

PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$
Ontario	------	Temagami	0.30	Beauport	0.60
Pickering (Dunbarton)	0.23	Thamesford	0.18	Bedford	0.60
Picton	0.26	Thedford	0.14	Beloeil	0.67
Plattsville	0.18	Thunder Bay	0.12	Brome	0.42
Point Alexander	0.66	Tillsonburg	0.20	Brossard	0.68
Port Burwell	0.21	Timmins	0.17	Buckingham	0.68
Port Colborne	0.38	Timmins (Porcupine)	0.19	Campbell's Bay	0.67
Port Elgin	0.12	***Toronto (Metropolitan)***	------	Chambly	0.67
Port Hope	0.23	Etobicoke	0.26	Chicoutimi	0.62
Port Perry	0.19	North York	0.24	Chicoutimi (Bagotville)	0.63
Port Stanley	0.20	Scarborough	0.24	Chicoutimi (Kenogami)	0.62
Prescott	0.44	Toronto	0.26	Coaticook	0.41
Princeton	0.20	Trenton	0.25	Contrecoeur	0.66
Raith	0.12	Trout Creek	0.25	Cowansville	0.48
Rayside-Balfour (Chelmsford)	0.14	Uxbridge	0.19	Deux-Montagnes	0.68
Red Lake	0.12	Vaughan (Woodbridge)	0.24	Dolbeau	0.31
Renfrew	0.63	Vittoria	0.21	Drummondville	0.50
Richmond Hill	0.22	Walkerton	0.13	Farnham	0.59
Rockland	0.66	Wallaceburg	0.18	Fort-coulonge	0.67
Sault Ste. Marie	0.12	Waterloo	0.19	Gagon	0.12
Schreiber	0.12	Watford	0.16	Gaspé	0.22
Seaforth	0.14	Wawa	0.12	Gatineau	0.68
Simcoe	0.22	Welland	0.40	Gracefield	0.62
Sioux Lookout	0.12	West Lorne	0.20	Granby	0.48
Smith Falls	0.42	Whitby	0.21	Harrington-Harbour	0.12
Smithville	0.40	Whitby (Brooklin)	0.20	Harve-St-Pierre	0.33
Smooth Rock Falls	0.19	White River	0.12	Hemmingford	0.68
South River	0.23	Wiarton	0.12	Hull	0.68
Southhampton	0.12	Windsor	0.18	Iberville	0.66
St. Catharines	0.41	Wingham	0.13	Inukjuak	0.12
St. Mary's	0.16	Woodstock	0.19	Joliette	0.63
St. Thomas	0.20	Wyoming	0.15	Jonquiére	0.62
Stirling	0.25	**Québec**	------	Kuujjuaq	0.12
Stratford	0.16	Acton-Vale	0.45	Kuujjuarapik	0.12
Strathroy	0.17	Alma	0.59	La-Malbaie	2.30
Sturgeon Falls	0.23	Amos	0.17	La-Tuque	0.29
Sudbury	0.15	Asbestos	0.37	Lac-Mégantic	0.40
Sundridge	0.22	Aylmer	0.67	Lachute	0.64
Tavistock	0.17	Baie-Comeau	0.66	Lennoxville	0.38

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Table D2.3.2-3 Continued; Spectral Response Acceleration Value at 0.2 Second for Selected Locations in Canada [Table C-2]

PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$
Québec	------	Richmond	0.38	**New Brunswick**	------
Léry	0.70	Rimouski	0.63	Alma	0.27
Loretteville	0.63	Rivière-du-loup	1.10	Bathhurst	0.41
Louisevilee	0.63	Roberval	0.43	Campbellton	0.39
Magog	0.38	Rock-Island	0.42	Chatham	0.41
Malartic	0.21	Rosemère	0.68	Edmundston	0.41
Maniwaki	0.66	Rouyn	0.20	Fredericton	0.39
Masson	0.66	Salaberry-de-Valleyfield	0.69	Gagetown	0.34
Matane	0.68	Schefferville	0.12	Grand Falls	0.42
Mont-Joli	0.62	Senneterre	0.20	Moncton	0.30
Mont-Laurier	0.66	Sept-Îles	0.37	Oromocto	0.36
Montmagny	0.89	Shawinigan	0.58	Sackville	0.25
Montréal Region	------	Shawville	0.67	Saint John	0.34
Beaconsfield	0.69	Sherbrooke	0.37	Shippagan	0.34
Dorval	0.69	Sorel	0.65	St. Stephen	0.66
Laval	0.68	St-Félicien	0.31	Woodstock	0.41
Montréal	0.69	St-Georges-de-Cacouna	0.98	**Nova Scotia**	------
Montréal-Est	0.68	St-Hubert	0.68	Amherst	0.24
Montréal-Nord	0.69	St-hubert-de-Temiscouata	0.64	Antigonish	0.19
Outremont	0.69	St-Hyacinthe	0.59	Bridgewater	0.23
Pierrefonds	0.69	St-jean	0.69	Canso	0.24
St-Lambert	0.69	St-Jérôme	0.64	Debert	0.22
St-Laurent	0.69	St-Jovite	0.63	Digby	0.26
Ste-Anne-de-Bellevue	0.69	St-Nicolas	0.59	Greenwood (CFB)	0.25
Verdun	0.69	Ste-Agathe-des-Monts	0.59	***Halifax Region***	------
Nicolet (Gentilly)	0.64	Sutton	0.44	Dartmouth	0.23
Nitchequon	0.12	Tadoussac	0.84	Halifax	0.23
Noranda	0.20	Témiscaming	0.59	Kentville	0.24
Percé	0.20	Thetford Mines	0.35	Liverpool	0.24
Pincourt	0.69	Thurso	0.63	Lockeport	0.26
Plessisville	0.45	Trois-Rivières	0.64	Louisburg	0.22
Port-Cartier	0.46	Val-d'Or	0.22	Lunenburg	0.23
Povungnituk	0.22	Varennes	0.68	New Glasgow	0.18
Québec City Region	------	Verchères	0.67	North Sydney	0.19
Ancienne-Lorette	0.60	Victoriaville	0.43	Pictou	0.18
Levis	0.58	Ville-Marie	0.33	Port Hawkesbury	0.21
Québec	0.59	Waterloo	0.41	Springhill	0.24
Sillery	0.58	Windsor	0.36	Stewiacke	0.22
Ste-Foy	0.59	------------------------------	------	Sydney	0.20

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Table D2.3.2-3 Continued; Spectral Response Acceleration Value at 0.2 Second for Selected Locations in Canada [Table C-2]

PROVINCE & LOCATION	$S_{A(0.2)}$	PROVINCE & LOCATION	$S_{A(0.2)}$
Nova Scotia	------	Echo Bay / Port Radium	0.12
Tatamagouche	0.19	Fort Good Hope	0.15
Truro	0.21	Fort Providence	0.12
Wolfville	0.25	Fort Resolution	0.12
Yarmouth	0.23	Fort Simpson	0.12
Prince Edward Island	------	Fort Smith	0.12
Charlottetown	0.19	Hay River	0.12
Souris	0.15	Holman	0.12
Summerside	0.19	Inuvik	0.12
Tignish	0.22	Mould Bay	0.35
Newfoundland	------	Norman Wells	0.51
Argentia	0.18	Rae-Edzo	0.12
Bonavista	0.17	Tungsten	0.51
Buchans	0.15	Yellowknife	0.12
Cape Harrison	0.24	**Nunavut**	------
Cape Race	0.20	Alert	0.12
Channel-Port aux Basques	0.15	Arctic Bay	0.18
Corner Brook	0.14	Arviat / Eskimo Point	0.18
Gander	0.16	Baker Lake	0.12
Grand Bank	0.18	Cambridge Bay	0.12
Grand Falls	0.15	Chesterfield Inlet	0.16
Happy Valley-Goose Bay	0.15	Clyde River	0.50
Labrador City	0.12	Coppermine	0.12
St. Anthony	0.15	Coral Harbour	0.24
St. John’s	0.18	Eureka	0.33
Stephenville	0.14	Iqaluit	0.13
Twin Falls	0.12	Isachsen	0.40
Wabana	0.12	Nottingham Island	0.24
Wabush	0.12	Rankin Inlet	0.12
Yukon	------	Resolute	0.35
Aishihik	0.26	Resolution Island	0.44
Dawson	0.54	------------------------------	------
Destruction Bay	0.73	------------------------------	------
Snag	0.61	------------------------------	------
Teslin	0.19	------------------------------	------
Watson Lake	0.45	------------------------------	------
Whitehorse	0.22	------------------------------	------
Northwest Territories	------	------------------------------	------
Aklavik	0.18	------------------------------	------

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Table D2.3.2-4; Importance Factor for Earthquake Loads by Importance Category [Table 4.1.8.5]

IMPORTANCE CATEGORY	IMPORTANCE FACTOR FOR EARTHQUAKE LOADS I_E
Low	0.8
Normal	1.0
High	1.3
Post-Disaster	1.5

D2.3.2.6 Summary:

The following parameters will be required by the design professionals having responsibility for MEP systems in a building, and should be determined by the structural engineer of record.

1. Importance Category: This defines the building use and specifies which buildings are required for emergency response or disaster recovery.
2. Spectral Response Acceleration Value at 0.2 Second: This is used to determine the actual Lateral Design Seismic Force.
3. Importance Factor for Earthquake Loads: This is a numerical value that translates the building usage into the Lateral Design Seismic Force used to design and/or select seismic restraints for non-structural components. This value used in conjunction with the Spectral Response Acceleration Value at 0.2 Second will determine whether seismic restraints are required for non-structural components or not.

These parameters should be repeated in the specification and drawing package for the particular system, mechanical, electrical, or plumbing, in question.

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DESIGN SESIMIC FORCES

D2.3.3.1 – Introduction:

The code based horizontal seismic force requirements for MEP systems and components are either calculated by the seismic restraint manufacturer as a part of the selection and certification process, or may be determined by the design professional of record for the MEP systems under consideration.

This is an informational section. It will discuss the code based horizontal seismic force demand equations and the variables that go into them. This discussion will provide a deeper understanding for the designer responsible for selecting the seismic restraints for MEP systems and their components and the nature of the seismic forces and the factors that affect them.

D2.3.3.2 – Lateral Design Seismic Force [Sentence 4.1.8.17.(1)][1]:

The seismic force is a mass, or weight, based force, and as such is applied to the MEP component at its center of gravity. Keep in mind that the earthquake ground motion moves the base of the building first. Then the motion of the building will accelerate the MEP component through its supports and/or seismic restraints. The lateral seismic force acting on an MEP component will be determined in accordance with the following set of equations from NBCC 2005.

$$V_P = 0.3 F_a S_{a(0.2)} I_E S_P W_P \qquad \textbf{Eq D2.3.3-1}$$

Where:

V_P = the Lateral Design Seismic Force

F_a = the acceleration based site coefficient. Values for this coefficient are given in Table D2.3.3-1 based on the site class. Linear interpolation between these values is permitted.

I_E = the Importance Factor for Earthquake Loads for the building. See Section D2.3.2.5 of this manual.

S_P = the horizontal force factor for the non-structural component and its anchorage to the building.

W_P = the weight of the non-structural component.

The value for S_P is computed in the following fashion.

[1] References in brackets [Sentence 4.1.8.17.(1)] apply to sections, tables, and/or equations in the National Building Code of Canada 2005.

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$$S_P = \frac{C_P A_r A_x}{R_P}$$ **Eq D2.3.3-2**

Where:

C_P = the seismic coefficient for mechanical and electrical equipment. These values are given per component category in Table D2.3.3-2.

A_r = the response amplification factor used to account for the type of attachment of the mechanical or electrical component to the building listed by component category in Table D2.3.3-2.

A_x = the amplification factor at the elevation of the component attachment point in the building. It is used to account for the increasing flexibility of the building from grade level to roof level.

R_P = the element or component response modification factor listed by component category in Table D2.3.3-2.

A_x is computed as follows.

$$A_x = \left(1 + 2\frac{h_x}{h_n}\right)$$ **Eq D2.3.3-3**

Where:

h_x = the elevation of the attachment point to the structure of the non-structural component.

h_n = the elevation of the roof line.

The values for S_P must remain within the following limits.

$$0.7 \le S_P \le 4.0$$ **Eq D2.3.3-4**

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Table D2.3.3-1; Acceleration Based Site Coefficient, F_a [Table 4.1.8.4]

SITE CLASS	SPECTRAL RESPONSE ACCELERATION VALUE AT 0.2 SECOND (LINEAR INTERPOLATION IS PERMITTED)				
	$S_{a(0.2)} \leq 0.25$	$S_{a(0.2)} = 0.50$	$S_{a(0.2)} = 0.75$	$S_{a(0.2)} = 1.00$	$S_{a(0.2)} \geq 1.25$
A	0.7	0.7	0.8	0.8	0.8
B	0.8	0.8	0.9	1.0	1.0
C	1.0	1.0	1.0	1.0	1.0
D	1.3	1.2	1.1	1.1	1.0
E	2.1	1.4	1.1	0.9	0.9
F	These values to be determined by site response analysis.				

D2.3.3.3 – Basis of Design for NBCC 2005 [Sentences 4.1.3.1.(1a), 4.1.3.2.(4), 4.1.3.2.(6), 4.1.3.2.(7), and 4.1.3.2.(8) and Table 4.1.3.2]:

The design of seismic restraints in the NBCC 2005 is based on the Ultimate Limit State. This limit state is used for design when life safety is at issue to prevent building or system collapse. This design basis along with the prescribed loads for earthquake design will produce results which are consistent with LRFD design techniques. Therefore; LRFD allowable loads may be used for the design and selection of seismic restraints for MEP components.

D2.3.3.4 – Summary:

This section has provided an insight into the way in which the seismic design forces for MEP systems and components are to be computed. It is generally not necessary for a designer to actually run the computations for the seismic design forces. These forces are normally computed by the manufacturer of the seismic restraint devices as part of the selection and certification process to ensure that the proper components are selected per the code and the specification.

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Table D2.3.3-2; Seismic Coefficient, Response Amplification Factor, and Response Modification Factor NBCC 2005 [Table 4.1.8.17]

CATEGORY	NON-STRUCTURAL COMPONENT	C_P	A_r	R_P
7	Suspended light fixtures with independent vertical support	1.00	1.00	2.50
11	Machinery, fixtures, equipment, ducts, and tanks (including contents):	-----	------	------
	That are rigidly connected.	1.00	1.00	1.25
	That are flexible or flexibly connected.	1.00	2.50	2.50
12	Machinery, fixtures, equipment, ducts, and tanks (including contents) containing toxic or explosive materials, materials having a flash point below 38°C or firefighting fluids:	-----	------	------
	That are rigidly connected.	1.50	1.00	1.25
	That are flexible or flexibly connected.	1.50	2.50	2.50
13	Flat bottom tanks (including contents) that are attached directly to the floor at or below grade within a building.	0.70	1.00	2.50
14	Flat bottom tanks (including contents) that are attached directly to the floor at or below grade within a building that contain toxic or explosive materials, materials that have a flash point below 38°C or firefighting materials.	1.00	1.00	2.50
15	Pipes, ducts, cable trays (including contents)	1.00	1.00	3.00
16	Pipes, ducts, cable trays (including contents) containing toxic or explosive materials.	1.50	1.00	3.00
17	Electrical cable trays, bus ducts, conduits.	1.00	2.50	5.00
18	Rigid components with ductile material and Connections.	1.00	1.00	2.50
19	Rigid components with non-ductile material or Connections.	1.00	1.00	1.00
20	Flexible components with ductile material and Connections.	1.00	2.50	2.50
21	Flexible components with non-ductile material or Connections.	1.00	2.50	1.00

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GENERAL EXEMPTIONS AND REQUIREMENTS

D2.3.4.1 – Introduction:

The National Building Code of Canada has limited exemptions for MEP components written in to it. The SMACNA Seismic Restraint Manual – Guidelines for Mechanical Systems, 2nd Edition with Addendum No. 1, 1998; is not directly referenced in the NBCC. Therefore, it is safe to assume that any exemptions in the SMACNA manual that have been previously taken are no longer allowed.

There are, however, some general exemptions for MEP components which will be covered in this section. Along with the exemptions, this section will the requirements for flexible/flexibly connected (isolated) components, direction of seismic design force application, structural connections, deflections, transfer of seismic forces to the building structure, and hanger rods for MEP components.

D2.3.4.2 - General Acceleration Based Exemption for MEP Components [Sentences 4.1.8.1, and 4.1.8.17.(2)][1]

Sentence 4.1.8.1 is a general exemption for building, and also applies to those buildings that have been assigned to the Importance Category classified as Post Disaster. The deflections and loads due to earthquake motion as specified in Sentence 4.1.8.17, do not apply to MEP Components when $S_{a(0.2)} \leq 0.12$. Under this condition seismic restraints will not be required for MEP components.

The next general exemption is found in Sentence 4.1.8.17.(2) and applies to buildings that have been assigned to Importance Categories Low, Normal, and High. Section D2.3.3 of this manual covered the seismic design forces specified by the NBCC. The basic acceleration term multiplying the weight (mass) of the MEP component is $I_E F_a S_{a(0.2)}$. This term includes the importance of the building, the effects of the ground upon which the project is being built, and the expected horizontal acceleration produced by the design earthquake for the project location. This general exemption for MEP components is based on the value of this term. If $I_E F_a S_{a(0.2)} < 0.35$, then MEP components that fall into categories 7 through 21 in Table D2.3.3-2 of this manual do not require seismic restraint for buildings assigned to Importance Categories Low, Normal, and High.

[1] References in brackets [Sentence 4.1.8.17.(2)] apply to sections, tables, and/or equations in the National Building Code of Canada 2005.

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D2.3.4.3 – "Chandelier" Exemption [Sentence 4.1.8.17.(13)]

This exemption does not read exactly as the companion exemption in the International Building Code (IBC); see Kinetic's Guide to Understanding IBC Seismic for MEP, Section D2.1.4.5. So, for clarity it will be directly quoted below.

> Isolated suspended equipment and components, such as pendant lights, may be designed as a pendulum system provided that adequate chains or cables capable of supporting 2.0 times the weight of the suspended component are provided and the deflection requirements of Sentence 4.1.8.17.(11) are satisfied.

D2.3.4.4 – Isolated vs. Rigidly Connected Components [Sentence 4.1.8.17.(4)]:

The NBCC basically says that MEP components that can be defined by Categories 11 and 12 in Table D2.3.3-2 of this Guide are to be treated as flexible/flexibly connected (isolated) components. If, however, the fundamental period of the component and its connections to the building structure can be shown to be less than or equal to 0.06 second, it mat be treated as though it were a rigid or rigidly connected component.

D2.3.4.5 – Design Horizontal Seismic Load Application [Sentence 4.1.8.17.(7)]:

The design horizontal seismic loads are to be applied in the direction the results in the most critical loading for the MEP component and its attachment to the structure. This will ensure that the most conservative design and selection of seismic restraints for the MEP component has been made.

D2.3.4.6 – Connection of MEP Components to the Building Structure [Sentence 4.1.8.17.(8)]:

Connections for the MEP components to the building structure must be designed to resist gravity loads, meet the requirements of Sentence 4.1.8.1 of the NBCC, and also satisfy the following additional requirements.

1. Friction due to gravity loads may not be used to resist seismic forces.
2. The R_p value for non-ductile fasteners such as adhesives, powder shot pins, and other power actuated fasteners must be taken as 1.0.
3. Shallow embedment anchors, shallow expansion, chemical, epoxy, or cast-in-place, are those whose embedment depth to nominal diameter ratio is less than 8:1. For these types of anchors the value for R_p shall be taken as 1.5.
4. Drop in anchors and power actuated fasteners, such as powder shot pins, are not to be used in tensile applications.

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D2.3.4.7 – Lateral Deflections of MEP Components [Sentence 4.1.8.17.(10)]:

The lateral deflections based on design horizontal seismic force specified the Sentence 4.1.8.17.(1), see Section D2.3.3 of this manual, need to be multiplied by a factor of $\boldsymbol{R_P}/\boldsymbol{I_E}$ to yield more realistic values for the anticipated deflections. The values of $\boldsymbol{R_P}$ and $\boldsymbol{I_E}$ are used to artificially inflate the loads to ensure the selection of seismic restraints and attachments that will meet the Post-Disaster criteria.

D2.3.4.8 – Transfer of Seismic Restraint Forces [Sentence 4.1.8.17.(11)]:

This provision is intended to engender co-operation between the MEP design professionals and the structural engineering professionals. It is basically saying that the MEP components and their attachments to the building structure must be designed in such away that they do not transfer any loads to the structure that were not anticipated by the structural engineer. This means that the MEP design professionals must inform the structural engineer of the anticipated dead loads and seismic restraint forces at the restraint attachment points as soon as the MEP component selections have been finalized. Conversely, the structural engineer needs to make him or her self available to the MEP design professionals to work out issues surrounding the seismic loads and the attachment points for the seismic restraints used for the MEP components.

D2.3.4.9 – Seismic Restraints for Suspended MEP Components & Hanger Rods [Sentence 4.1.8.17.(12)]:

The seismic restraints for suspended MEP equipment, pipes, ducts, electrical cable trays, bus ducts, and so on, must meet the force and displacement conditions of Sentence 4.1.8.17, and be designed in such away that they do not place the hanger rods in bending.

D2.3.4.13 - Summary:

The exemptions and requirements outlined in this section are intended to assist the MEP design professionals and contractors in planning their project contribution efficiently. Also, they help define the limits of responsibility for each MEP design profession and trade.

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UFC ANTI-TERRORISM

D2.5.1 – Introduction:

The United States Department of Defense has developed a set of standards for the design of new and existing buildings. These are called Unified Facilities Criteria (UFC). For seismic and wind restraint, and antiterrorism provisions for nonstructural components are found in three separate UFC documents which are listed below.

1. UFC-3-310-04 Dated 22 June 2007 Including Change Dated 01 May 2012 SESISMIC DESIGN FOR BUILDINGS.
2. UFC-3-301-01 Dated 27 January 2010 STRUCTURAL ENGINEERING.
3. UFC-4-010-01 Dated 8 October 2003 Including Change Dated 22 January 2007 DoD MINIMUM ANTITERRORISM STANDARDS FOR BUILDINGS.

These documents are available via the internet. They may be down loaded in PDF format by "GOOGLING" the UFC number.

This document will deal with each of the sub-headings one at a time. Antiterrorism will be the first sub-heading discussed since it seems to show up in specifications more often than the other two. Also, the provisions for restraint in the antiterrorism standard will "trump" those of the seismic design standard if the design acceleration level for the seismic design falls below that required for the antiterrorism standard.

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UFC-4-010-01 ANTITERRORISM

D2.5.2 - UFC-4-010-01:

Only one Section B-4.5 – **Standard 20. Equipment Bracing** of this document will apply to the restraint of MEP (Mechanical, Electrical, and Plumbing) components. It is quoted in its entirety below.

Mount all overhead utilities and other fixtures weighing 14 kilograms (31 pounds) or more (excluding distributed systems such as piping networks that collectively exceed that weight) to minimize the likelihood that they will fall and injure building occupants. Design all equipment mountings to resist forces of 0.5 times the equipment weight in any horizontal direction and 1.5 times the equipment weight in the downward direction. This standard does not preclude the need to design equipment mountings for forces required by other criteria such as seismic standards.

Piping, ductwork, cable trays, conduit, and bus bars appear to be exempt from the provisions of this standard. The reasoning appears to be that distributed systems such as these will have many hangers supporting them. Equipment, on the other hand, will have only four or perhaps six hangers. Losing one or two hangers in a distributed system would not be likely to bring down the entire system, whereas, losing one or two hangers on a piece of equipment would pretty much guarantee that it would fall.

Some specifications do impose the provisions of this standard on piping and ductwork. In these cases the following items need to be considered.

All hangers and their anchors will need to be evaluated for the increased vertical loads mandated by this standard. That is the deadweight of the pipe or duct plus 0.5 times the deadweight of the pipe or duct.

The hanger spacing and the restraint spacing may need to be reduced to protect the pipe or duct from the increased vertical and horizontal loads mandated by this standard.

The first sentence of the standard indicates that it applies only to overhead equipment and fixtures. These components will need to be braced to resist 0.5 time the deadweight of the equipment (0.5 G) horizontally in any direction and 0.5 times the deadweight of the equipment plus the deadweight of the equipment (1.5 G total) in the downward direction. The second sentence says that ***all*** equipment must be braced to this standard. However the 1.5 G total downward would seem to indicate that only suspended equipment and fixtures are covered under this standard. So, a clear interpretation of that provision will need to come from the specification and/or the Engineer of Record.

In many buildings where UFC 4-010-01 is specified, seismic restraint of MEP components may not be required by the building code. This horizontal restraint requirement of this standard will "trump" the seismic restraint requirements of the code up to the point where the code requirements exceed the 0.5 G horizontal load specified by this standard. A careful reading of the

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specification will be needed to obtain the proper interpretation of this standard for a project, and to see what if any components have been made exempt from the provisions of this standard.

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UFC-3-310-04 SEISMIC DESIGN & UFC-3-301-01 STRUCTURAL ENGINEERING

D2.5.3.1 – Introduction

This standard is a replacement for TI 809-04 and TI 809-05. It adopts the seismic design provisions of 2003 IBC and ASCE 7-02, with some modification. This standard is meant to work in conjunction with UFC 3-301-01 Structural Engineering. UFC 3-301-01 has adopted the provisions of 2006 IBC and ASCE 7-05. Some of the provisions of ASCE 7-02 in UFC 3-310-04 have been replaced by the provisions of ASCE 7-05. If this seems confusing, it is. This document will attempt to cover the provisions that apply to MEP components and concisely as possible.

D2.5.3.2 – Building Occupancy:

UFC 3-301-01 uses Occupancy Category to classify buildings and structures in a manner similar to 2006 IBC. However, it adds a fifth occupancy category for national strategic military assets. These are buildings that are considered to be irreplaceable and must be kept functioning at all costs. The example given was National Missile Defense facilities. UFC 3-310-04 still uses the Seismic Use Group (SUG) to classify buildings and structures. It adds a fourth SUG that corresponds to the fifth Occupancy Category of UFC 3-301-01. Occupancy Category and SUG will be defined below. For detailed examples of each refer to UFC 3-301-01 Table 2-2.

1. SUG I (Occupancy Categories I & II) – Buildings and other structures that represent a low hazard to human life in the event of failure.
2. SUG II (Occupancy Category III) – Buildings and other structures that represent a substantial hazard to human life or represent a significant economic loss in the event of failure.
3. SUG III (Occupancy Category IV) – Buildings and other structures designed as essential facilities.
4. SUG IV (Occupancy Category V) – Facilities designed as national strategic military assets.

D2.5.3.3 – Design for Wind Loads:

The design for wind loading of exterior exposed MEP components will be per 2003 IBC and ASCE 7-02. The 3-sec gust design wind speed may be found in UFC 3-301-01 Table E-1 for installations in the United States, its territories, and possessions. For facilities located outside the United States, its territories, and possessions, the 3-sec gust design wind speed may be found in UFC 3-301-01 Table F-1. The Wind Importance Factor, I_W, will depend on the Occupancy Category of the building or structure as shown in Table D2.5.3-1.

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Table D2.5.3-1; Wind Importance Factor per Occupancy Category

OCCUPANCY CATEGORY	SUG	WIND IMPORTANCE FACTOR
I	I	0.87
II	I	1.00
III	II	1.15
IV	III	1.15
V	IV	1.70

D2.5.3.4 – SUG I, II, & III Buildings & Structures:

The seismic and wind restraint design for MEP components appears to be Identical to the provisions specified in 2003 IBC and ASCE 7-02. So, the process of selecting, sizing and quoting seismic and wind restraints for these facilities will be identical to that of similar civilian buildings and structures.

Be sure to check the specification for the facility to see if UFC 4-010-01 has been listed. It may well require restraints for buildings that would not normally require seismic restraint for MEP components. For those buildings that would normally need seismic restraints, the size and cost of the restraints may be increased by the requirements of UFC 4-010-01.

Exemptions per Seismic Design Category would appear to apply to UFC 3-310-04. However, check the specification to see if particular exempts are allowed or disallowed.

D2.5.3.5 – SUG IV Buildings & Structures:

As mentioned before, these facilities are national strategic military assets that are required to function at all costs. As such, they are subjected to more rigorous design and analysis. Components inside these facilities are broken down into three categories.

1. Mission-Critical Level 1 (MC-1) – These are components that are critical to the mission of the facility and must be operational immediately following the maximum considered earthquake. They must be certified as being such per 1621.1.9 of Appendix B of UFC 3-310-04.

2. Mission-Critical Level 2 (MC-2) – These are components that are allowed to sustain minor damage and would be repairable within three days with parts that are stocked at or near the facility.

3. Non-mission Critical Components (NMC) – These are components that can incur damage during the maximum considered earthquake.

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These designations apparently replace the Component Importance Factor that would normally be assigned to the MEP components in the facility.

The seismic forces specified for MC-1, MC-2 MEP components in ASCE 7-02 do not apply to SUG IV facilities. The response spectrum, acceleration, is computed using ASCE 4-98, and the actual forces are computed per equation E-15 of UFC 3-310-04. The seismic forces for the NMC MEP components are calculated using the normal equations found in ASCE 7-02.

Quoting restraints for SUG IV facilities will require close coordination with the Structural Engineer of Record, and the Architect of Record to ensure that the proper designation is assigned to each component and that the proper seismic parameters are transmitted to Kinetics Noise Control.

Carefully reading the specification will indicate whether any exemptions may be applied to piping and ductwork. Also the specification will indicate whether additional safety factors will be required.

D2.5.3.6 – Ground Acceleration Values:

The values of S_S and S_1 for installations that lie within the United States may be obtained form Table E-2 of UFC 3-301-01, and for installations that lie outside the United States, the values for S_S and S_1 may be obtained from Tables F-2 and G-1 of UFC 3-301-01. These values should also be available in the specification and on the first sheet of the structural drawing package. In the provisions for SUG III & IV buildings more stringent values for S_S and S_1 may be required.

D2.5.3.7 – Component Importance Factor:

For SUG I, II, and III facilities, the Component Importance Factor is assigned to MEP components, unless UFC 3-310-04 Appendix D is used for the design of an SUG III facility. The Component Importance Factor will be either 1.0 or 1.5 similar to 2003 IBC. If Appendix D is used for the design of SUG III facilities, no Component Importance Factors will be assigned to MEP components. This is because the acceleration factors used to compute the seismic forces are 1.5 times greater than those normally used for 2003 IBC. So, if Appendix D is referenced for the design of an SUG III facility treat all components as if they had a Component Importance Factor equal to 1.5.

As seen in Section D2.5.3.5 of this document, SUG IV facilities will not have Component Importance Factors assigned to the MEP Components.

D2.5.3.8 – SMACNA:

SMACNA is directly referenced in UFC 3-310-04. However, it is the new SMACNA seismic manual that is referenced.

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ANSI/SMACNA 001-2008 Seismic Restraint Manual, Guidelines for Mechanical Systems 3rd Edition; Sheet Metal and Air Conditioning Contractors' National Association, 4201 Lafayette Center Drive, Chantilly, Virginia 20151-1219.

This has consequences for the engineers and contractors since this version of the SMACNA manual does not allow the 6 ft^2 exemption for ducts assigned a Component Importance Factor of 1.5. Thus for SUG III & IV buildings there will be no exemptions for ductwork, and everything will need to be restrained. Again, it is important to check the specification to see if it will allow the size exemptions for ductwork.

D2.5.3.9 – Inspections:

Walk-down inspections are required for all MEP components in all SUG III and IV facilities as well as all facilities assigned to Seismic Design Categories D, E, and F, prior to facility commissioning. The inspectors are to be registered design professionals who are familiar with the construction and installation of MEP components. The selection of these inspectors must be approved by the headquarters of the authorizing design agency. While this inspection is to be carried out a special selected team of design professionals, representatives from Kinetics Noise Control may be required to participate per the specification. Therefore, any quotations to supply restraints should include the cost of time and travel to cover the inspection(s).

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UFC ANTITERRORISM

D2.5.4 – Summary:

1. UFC 4-010-01 (Antiterrorism) appears to apply only to equipment. Piping and ductwork are excluded. Check the specification to see if piping and ductwork have been included under the provisions of this UFC, occasionally they are.

2. UFC 4-010-01 mentions suspended equipment, and then states that all equipment is to be braced. Check the specification to see if floor and roof mounted equipment is included for consideration.

3. UFC 4-010-01 requires that equipment be braced to withstand 0.5 G in any horizontal direction and 1.5 G total in the downward direction. This requirement will “trump” the seismic provisions of UFC 3-310-04 up to the point where they exceed 0.5 G.

4. UFC 3-301-01 (Structural Engineering) Table 2-2 defines the Building Occupancy Categories used in the UFC standards. A new Building Occupancy Category (V) has been established; see Section 3.1 of this document.

5. UFC 3-301-01 (Structural Engineering) Table E-1 will give the 3-sec gust design wind speed for facilities in the United States, its territories, and possessions. While Table F-1 will give the 3-sec gust design wind speed for facilities outside the United States, its territories, and possessions.

6. UFC 3-301-01 (Structural Engineering) Table E-2 will give the seismic data for facilities in the United States, its territories, and possessions.

7. UFC 3-301-01 (Structural Engineering) Tables F-2 and G-1 will give the seismic data for facilities outside the United States, its territories, and possessions.

8. UFC 3-310-04 (Seismic Design) is based on the provisions of 2003 IBC (ASCE 7-02).

9. UFC 3-310-04 (Seismic Design) establishes a new Seismic Use Group (SUG), see Section D2.5.3.1 of this document.

10. For SUG I, II, and III facilities, the seismic restraint of MEP components is carried out in a manner similar to 2003 IBC (ASCE 7-02). The exception would be if the design of an SUG III facility was specified as using UFC 3-310-04 Appendix D, see section D2.5.3.7 of this document.

11. SUG IV facilities will require special consideration and design for the seismic restraints for MEP components. Contact Kinetics Noise Control before quoting the seismic restraints for a facility designate as SUG IV or Occupancy Category V.

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12. It is important to obtain and read the specification for all Department of Defense facilities or other facilities that reference UFC 4-010-01 or UFC 3-310-04.

    a. The specifications will indicated the exact design standards being employed.

    b. The specifications may increase the requirements beyond the UFC standards. They may require that UFC-4-010-01 be applied to floor and roof mounted equipment, and also to piping and ductwork. They specifications may also increase the minimum safety factor, sometimes to 3:1 or even 4:1. This will significantly affect the number and size of restraints required.

    c. The specification will indicate whether representatives from Kinetics Noise Control are to participate in the mandated walk-down inspections of SUG III and IV facilities. Also, walk-down inspections appear to be required for all facilities assigned to Seismic Design Categories D, E, and F. Quotations to supply seismic restraints to these projects must include the cost of time and travel for the inspections.

    d. Finally, the specifications may indicate the exemptions that will apply to piping, ductwork and electrical distribution systems.

13. Note that the Wind Importance Factor for Occupancy V facilities has been raised to 1.7, which means that more restraint is required for exposed outside equipment.

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