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Understanding the 2000 IBC Code
(Architectural Components and Equipment Restraint)

May 27, 2005

The intent of this document is to offer some simplified guidance to understanding the above code and how it applies to non-structural components. Significantly more detailed information is provided in the code itself and, before applying the information documented here, the code should be reviewed for further clarification on many of the details that are presented here in general terms. Note: OSHPD is not addressed in this document as IBC is not their model code.

Section 1
General Information

The 2000 IBC includes new **Seismic Maps** with significantly more detail and higher acceleration factors than were used in the past. Current maps can be downloaded from the following websites: http://eqdesign.cr.usgs.gov/design/ibc/IBC1615-1us.pdf or short period acceleration (S_s) and http://eqdesign.cr.usgs.gov/design/ibc/IBC1615-2us.pdf for long period acceleration (S_1). For evaluating the attachment of Equipment and Architectural Components, the map of interest is the "-1" map which lists the Maximum Short Period Spectral Response (.2 second). The "-2" map identifying Maximum Long Period Spectral Response (1 second) is of interest to us only to determine if the structure can be exempted from seismic analysis.

It must be noted that the maps indicate the Maximum Spectral Response for long and short periods (S_S & S_l) and not the Design Spectral Response. The ground accelerations used for the design of Architectural and Equipment's attachment are the short period (.2 second) values only (S_S). These are multiplied by the site (soil) Classification Factor (F_a) from table 1615.1.2(1) and then multiplied by a factor of 2/3, per section 1615.1.3. This, the **Design Spectral Response at Short Periods** or S_{DS} is the final acceleration coefficient used in the design. The Site Factors for various soil types and mapped Acceleration Factors (S_S) are listed in the table below.

Site Factor (F_a) Based on Site Class and Mapped Spectral Response for Short Periods (S_s)[a]						
Site Class	Soil Type	Mapped Spectral Response Accel at Short Periods				
		$S_s \leq 0.25$	$S_s = 0.50$	$S_s = 0.75$	$S_s = 1.0$	$S_s \geq 1.25$
A	Hard Rock	0.8	0.8	0.8	0.8	0.8
B	Moderate Rock	1	1	1	1	1
C	Dense Soil, Soft Rock	1.2	1.2	1.1	1	1
D[c]	**Stiff Soil**	**1.6**	**1.4**	**1.2**	**1.1**	**1**
E	Soft Soil, Clay	2.5	1.7	1.2	0.9	Note b
F	Fill and Other	Note b	Note b	Note b	Note b	Note b

[a] Use straight line interpolation for intermediate values of mapped spectral acceleration

[b] Site specific geotechnical investigation and dynamic site response analyses shall be performed to determine values

[c] In lieu of geotechnical data an in cases where Site Class E or F are not expected, Site Class D shall be assumed.

A similar Table exists for Long Period Response S_{D1}. It is computed in the same manner (2/3 S_1 x F_v). For our purposes, this is a second screen that must be met to exempt a project from the need to perform a seismic analysis. The table is shown below.

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Site Factor (F_v) Based on Site Class and Mapped Spectral Response for Long Periods (S_1)[a]						
Site Class	**Soil Type**	**Mapped Spectral Response Accel at Short Periods**				
		$S_s \leq 0.1$	$S_s = 0.2$	$S_s = 0.3$	$S_s = 0.4$	$S_s \geq 0.5$
A	Hard Rock	0.8	0.8	0.8	0.8	0.8
B	Moderate Rock	1.0	1.0	1.0	1.0	1.0
C	Dense Soil, Soft Rock	1.7	1.6	1.5	1.4	1.3
D[c]	**Stiff Soil**	**2.4**	**2.0**	**1.8**	**1.6**	**1.5**
E	Soft Soil, Clay	3.5	3.2	2.8	2.4	Note b
F	Fill and Other	Note b	Note b	Note b	Note b	Note b

[a] Use straight line interpolation for intermediate values of mapped spectral acceleration

[b] Site specific geotechnical investigation and dynamic site response analyses shall be performed to determine values

[c] In lieu of geotechnical data an in cases where Site Class E or F are not expected, Site Class D shall be assumed.

Levels of Seismic Concern are identified in the new code as "**Seismic Design Category**". These are a function of the structure's end use and the ground acceleration coefficient. A rough definition of the 3 possible Use Groups (I, II and III) is as follows: Group III is an Emergency Treatment or Response Center (Hospitals, Fire Stations), an Essential Service structure (Emergency Phone, Backup Electric), or a structure containing potentially Hazardous Material. Group II is a high occupancy structure (Buildings where 300+ people can congregate, Schools, College Structures, Buildings with a total occupancy of 5000 or more) or non-Essential Utilities. Group I is what is left. Below are reprints of Tables 1616.3(1) and 1616.3(2) from the code indicating the Seismic Design Categories for various conditions. The Seismic Design Category appropriate for a project is the highest letter value obtained from the 2 tables below.

Seismic Design Category based on .2 Second Response Accelerations			
	Seismic Use Group		
S_{DS} Value	I	II	III
$S_{DS} < 0.167g$	A	A	A
$0.167g \leq S_{DS} < 0.33g$	B	B	C
$0.33 \leq S_{DS} < 0.50g$	C	C	D
$0.50g \leq S_{DS}$	D	D	D
$0.75g \leq S_1$[a]	E	E	F

[a]S_1 is Mapped Max Considered Spectral Response

Seismic Design Category based on 1.0 Second Response Accelerations			
	Seismic Use Group		
S_{D1} Value	I	II	III
$S_{D1} < 0.067g$	A	A	A
$0.067g \leq S_{D1} < 0.133g$	B	B	C
$0.133 \leq S_{D1} < 0.20g$	C	C	D
$0.20g \leq S_{D1}$	D	D	D
$0.75g \leq S_1$[a]	E	E	F

[a]S_1 is Mapped Max Considered Spectral Response

The **Importance Factor** in the IBC code is now tied more closely to the use of the equipment rather than the use of the structure as was primarily the case in the past. There are 2 levels of importance (1.0 and 1.5). The Importance Factor of 1.5 is used under the following conditions:

1) The component is a Life-Safety Component that must function after an Earthquake
2) The component contains hazardous or flammable material in excess of exempted limits.
3) Storage Racks in structures that are open to the public (Home Depot for example)
4) Components needed for continued operation of Group III Occupancy Structure.

All other conditions use an Importance Factor of 1.0.

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Section 2

When do I ***NOT*** need to worry about Seismic Restraint?

The Code includes several layers of exclusions that identify instances in which the restraint of equipment need not be designed. These begin with entire structures, then move into areas where equipment only is excluded and then finally, list by size and location, particular pieces of equipment or architectural elements that need not be reviewed under particular situations. This list is drawn from the following sections of the code: 1615.1, 1621.1.1, 1621.2.1, 1621.3.9, and 1621.3.10.2.1.

Entire Structures (and contents) that are exempted from Seismic review are:

1) Group R-3, Single family stand alone residential structures not more than 3 stories in height, in areas where the mapped S_{DS} value is less than .5g.
2) Agricultural storage structures intended only for incidental human occupancy.
3) All structures where the mapped S_{DS} value is less than .167g and the mapped S_{D1} value is less than .067g.

Mechanical Components and Architectural Elements exempted from Seismic review are:

1) All non-structural mechanical components and architectural elements in structures that fall into Seismic Design Category A or B.
2) All mechanical components in structures that fall into Seismic Design Category C and where the Importance Factor is1.0
3) All architectural elements in structures that fall into Seismic Design Category C and where the Importance Factor is1.0, and there are fewer than 3 stories.

Specific Component exemptions for Mechanical Equipment are:

1) Restraint systems for all components (no matter what Seismic Design Category) with an Importance Factor of 1.0 weighing less than 400 lb, mounted to the floor with legs under 4' in height, connected via flexible connections between components and associated ductwork, piping, etc. and not critical to the continued operation of the structure need not be designed (standard attachment hardware should be sufficient).
2) Mechanical and Electrical components in Seismic Design Categories D and E that weigh 20 lb or less (no matter where mounted), that are connected via flexible connections between components and associated ductwork, piping, etc., where the Importance Factor does not exceed 1.0.
3) Ductwork that is less than 6 sq ft in area for the full length of a run where the Importance Factor does not exceed 1.0 (no matter what Seismic Design Category) and the motion induced by a seismic event will not result in contact with other components.
4) All ductwork that is suspended on hangers 12" or less in length for the full length of a run equipped with non-moment generating connections to the structure and where the Importance Factor does not exceed 1.0 (no matter what Seismic Design Category) and motion induced by a seismic event will not result in contact with other components.
5) High deformability piping in all Seismic Design Categories that is 3.0 inches or less in diameter and has an Importance Factor of 1.0. (Note: High deformability is a measure of ductility as defined in the code section 1602.1.) (Note: if trapeze mounted

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and the accumulative total area of the pipes supported is less than 7 sq inches (the approximate area of a 3" pipe), no restraint is required.)

6) High deformability piping in Seismic Design Category C that is 2.0 inches or less in diameter with an Importance Factor of 1.5. (Note: if trapeze mounted and the accumulative total area of the pipes supported is less than 3 sq in, no restraint is required.)
7) High deformability piping in Seismic Design Category D or E that is 1.0 inch or less in diameter, with an Importance Factor of 1.5.
8) All piping that is suspended on hangers 12" or less in length (from the top of the pipe) with a non-moment generating (swivel) connection to the structure, for all Importance Factors and Seismic Design Categories.
9) Any component that is supported from above by chains or other non-moment generating connection provided it cannot be damaged by or cannot damage any other component and has a supporting connection designed to take at least 3 times the operating weight.

Specific Component exemptions for Architectural Elements are:

1) Components supported on chains or otherwise suspended from the structural system above, as long as they are capable of moving a minimum of 12" or a swing of 45 degrees without damage or contact with an obstruction, and as long as the gravity design load used, when sizing the attachment hardware, is 3g.
2) All Partitions under 6 ft in height or Partitions under 9 ft in height with an equivalent Seismic load of less than 5 psf.

Other

1) Equipment installed in line and hard mounted to the ductwork and that weighs 75 lb or less can be restrained as though it is part of the duct (no independent restraint system is required).

Section 3
How do I determine the Seismic design force that is appropriate?

The basic Design Force Equation used in this Code is:

$$F_p = ((0.4a_pS_{DS}W_p) / (R_p / I_p))(1 + 2z / h)$$

Where:

F_p is the Horizontal Design Seismic Load

a_p is the component amplification factor drawn from the Component Coefficient Table below (Table 1621.2 or 1621.3 in the code)

S_{DS} is the design spectral response at short periods (2/3 S_s x F_a) as previously determined in the "General Information" Section.

W_p is the component operating weight

R_p is the Component response modification factor drawn from the Component Coefficient Table below (Table 1621.2 or 1621.3 in the code)

I_p is the component importance factor as previously determined in the "General Information" Section.

z is the component elevation above grade in the building or structure

h is the average roof height of the structure above grade.

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Component Coefficients

Mechanical and Electrical Component or Element	a_p	R_p
General Mechanical		
Boilers and furnaces	1.0	2.5
Pres Vessels, Stacks, Cantilevered Chimneys	2.5	2.5
Other	1.0	2.5
Mfg and Process Equipment		
General	1.0	2.5
Conveyors	2.5	2.5
Piping		
High deformability elements and attachments	1.0	3.5
Limited deformability elements and attachments	1.0	2.5
Low deformability elements or attachments	1.0	1.25
HVAC Equipment		
Vibration isolated	2.5	2.5
Non-vibration isolated	1.0	2.5
Mounted in line with ductwork	1.0	2.5
Elevator & Escalator Components	1.0	2.5
Trussed Towers	2.5	2.5
General Electrical		
Distribution Systems	1.0	3.5
Equipment	1.0	2.5
Lighting Fixtures	1.0	1.25
Architectural Component or Element		
Interior Non-Structural Walls and Partitions		
Plain (unreinforced) masonry	1.0	1.25
Other	1.0	2.5
Ceilings	1.0	2.5
Access Floors		
Floors (built on and affixed to seismic frame)	1.0	2.5
Other	1.0	1.25
Flexible Components		
High Deformability	1.0	3.5
Limited Deformability	2.5	2.5
Low Deformability	2.5	1.25

When anchoring components to concrete using shallow embedment anchors (those with an embedment length to diameter ratio of less than 8), an R_p value of 1.5 is to be used and overides the value identified in the Component Coefficient table.

This equation can be simplified, altered to include the factors for Site and Design Acceleration, and then expressed in g's at the equipment with the following result:

$$F_p\ (g's) = (0.267 a_p S_S\ F_a\ I_p / R_p)(1 + 2z / h)$$

Where: S_S comes directly from the Short Period Acceleration Map
F_a comes from the Site Factor table in the "General Information" section.

Although the above is the prime equation used to determine the design force, the code also contains a maximum and minimum screen value that must be checked. The maximum design limit is:

$$F_p = 1.6\ S_{DS}\ I_p\ W_p$$

Which can also be expressed as:

$$F_p\ (g's) = 1.067\ S_S\ F_a\ I_p$$

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And the minimum design limit is:

$$F_p = 0.3\ S_{DS}\ I_p\ W_p$$

Which can also be expressed as:

$$\boldsymbol{F_p\ (g's) = .2\ S_S\ F_a\ I_p}$$

Vertical Force Component

For our purposes, it can be assumed that a vertical force component must be factored into the restraint analysis (see section 1617.1.1 in the code). Its value would be:

$$F_{pv} = 0.2\ S_{DS}\ W_p$$

Which can also be expressed as:

$$\boldsymbol{F_{pv}\ (g's) = .133\ S_S\ F_a}$$

Force Tailoring Factors

In order to apply the above forces, there are additional factors that may be applicable, depending on the component being analyzed and the method of attachment used.

1) The outputted forces from the above equations are "working strength" based figures (see also section 1605.3 in the code). Because of this, when combining the load with other design loads or when comparing this load to "working stress" based allowables, it can be reduced by a factor of 1.4. This reduction is not applicable when evaluating the hardware used to attach the componentry to steel structures if the current LRF (Load and Resistance Factor) is used to determine the fastener capacity. It does however, come into play when evaluating connections using the older ASD (Allowable Stress Design) bolt allowables, connections to timber with lag screws or connections to concrete with post installed anchors (where a "working stress" based rating system is still common).

2) Permitted design loads and resulting stresses in the attachment hardware can be increased by a factor of 1.33 for short term wind and seismic load applications when working with working stress based allowables. (This factor is increased to 1.6 when evaluating Screw connections to Timber (NDS table 2.3.2)).

3) Shallow embedment anchors must be sized to withstand 1.95 (or 1.3 x R_p (where R_p is equal to 1.5)) times the computed design load. (1621.1.7)

4) For Mechanical or Electrical equipment that is supported on vibration isolation systems, the Design Lateral force shall be taken as 2 F_p (1621.3.1).

All of this is understandably confusing. However, consolidating the above into simple more understandable equations, we get the following:

Using the previously determined design force F_p, steel and bolt and fastener allowables as per LFR, ASD and/or published post installed anchor allowables per ICBO

1) Rigid Equipment Connection to steel using LRF Bolt Allowables:

Lateral Design Load = F_p
Vertical Design Load = F_{pv}

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2) Rigid Equipment Connection via Through Bolts using the ASD Bolt Allowables:
Lateral Design Load = F_p / 1.4, but increase Bolt Allowables by multiplying by 4/3
Vertical Design Load = F_{pv}/ 1.4, but increase Bolt Allowables by multiplying by 4/3

3) Rigid Equipment Connection to Concrete with Post Installed Anchors using ICBO Anchor Ratings:
Shallow embed anchors (< 8 dias)
Lateral Design Load = 1.95 x F_p/ 1.4, but increase Anchor Allowables by multiplying by 4/3
Vertical Design Load = 1.95 x F_{pv}/ 1.4, but increase Anchor Allowables by multiplying by 4/3
Standard embed anchors (>= 8 dias)
Lateral Design Load = 1.3 x F_p/ 1.4, but increase Anchor Allowables by multiplying by 4/3
Vertical Design Load = 1.3 x F_{pv}/ 1.4, but increase Anchor Allowables by multiplying by 4/3

4) Rigid Equipment Connection to Concrete with Post Installed Anchors using ICBO Special Inspection Anchor Ratings:

Shallow embed anchors (< 8 dias)
Lateral Design Load = 1.95 x F_p/ 1.4
Vertical Design Load = 1.95 x F_{pv}/ 1.4
Standard embed anchors (>= 8 dias)
Lateral Design Load = 1.3 x F_p/ 1.4
Vertical Design Load = 1.3 x F_{pv}/ 1.4

5) Rigid Equipment Connection to wood with Lag Screws as rated per ASD:
Lateral Design Load = F_p/ 1.4, but increase Anchor Allowables by 1.6
Vertical Design Load = F_{pv}/ 1.4, but increase Anchor Allowables by 1.6

6) Isolated Equipment Connection to steel using LRF Bolt Allowables:
Lateral Design Load = 2 x F_p
Vertical Design Load =2 x F_{pv}

7) Isolated Equipment Connection via Through Bolts using the ASD Bolt Allowables:
Lateral Design Load = 2 x F_p / 1.4, but increase Bolt Allowables by multiplying by 4/3
Vertical Design Load = 2 x F_{pv}/ 1.4, but increase Bolt Allowables by multiplying by 4/3

8) Isolated Equipment Connection to Concrete with Post Installed Anchors using ICBO Anchor Ratings:
Shallow embed anchors (< 8 dias)
Lateral Design Load = 3.9 x F_p/ 1.4, but increase Anchor Allowables by multiplying by 4/3
Vertical Design Load = 3.9 x F_{pv}/ 1.4, but increase Anchor Allowables by multiplying by 4/3
Standard embed anchors (>= 8 dias)
Lateral Design Load = 2.6 x F_p/ 1.4, but increase Anchor Allowables by multiplying by 4/3
Vertical Design Load = 2.6 x F_{pv}/ 1.4, but increase Anchor Allowables by multiplying by 4/3

9) Isolated Equipment Connection to Concrete with Post Installed Anchors using ICBO Special Inspection Anchor Ratings:
Shallow embed anchors (< 8 dias)

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Lateral Design Load = 3.9 x F_p/ 1.4
Vertical Design Load = 3.9 x F_{pv}/ 1.4

Standard embed anchors (>= 8 dias)

Lateral Design Load = 2.6 x F_p/ 1.4
Vertical Design Load = 2.6 x F_{pv}/ 1.4

10) Isolated Equipment Connection to wood with Lag Screws as rated per ASD:

Lateral Design Load = 2 x F_p/ 1.4, but increase Anchor Allowables by 1.6
Vertical Design Load = 2 x F_{pv}/ 1.4, but increase Anchor Allowables by 1.6

Section 4
Are there any special Equipment Requirements?

Per section 1621.3.5, the equipment manufacturer must submit a certificate of compliance indicating that the equipment being installed can withstand the design seismic forces. This certificate must be provided to the appropriate building official for all applications.

Section 5
Are there any special Anchorage Requirements?

Per section 1621.3.12.2, with the exception of undercut anchors, expansion anchors shall not be used to attach non-vibration isolated equipment rated at over 10 hp. Conventional wedge type post-installed anchors are acceptable for isolated equipment as long as they meet the load requirements as defined here.

Restraints that are used in conjunction with Vibration Isolated Equipment must contain a layer of viscoelastic or similar material to dampen the shock of impact.

Section 6
What are the Requirements for HVAC Ductwork?

Except for those ducts previously excluded in Section 2, all ductwork must be restrained against the predicted design load. Included in the analysis should be a buckling review of the duct, an evaluation of tensile and compressive loads in the hanger rods or rigid bracing and an evaluation of the anchorage.

Section 1621.3.9 indicates that duct systems fabricated and installed per SMACNA, including Appendix B of the SMACNA restraint manual shall be deemed to meet the code requirement.

Section 7
What are the Requirements for Piping Systems?

Except for those pipes previously excluded in Section 2, All piping must be restrained against the predicted design load. Included in the analysis should be a buckling review of the pipe, an evaluation of tensile and compressive loads in the hanger rods or rigid bracing and an evaluation of the anchorage.

There is no direct link back to SMACNA with regard to piping system design. Instead, the following ASME documents are to be followed: B31.1 (Power), B31.3 (Process), B31.4 (Hydrocarbon, Ammonia and Alcohol), B31.5 (Refrigeration), B31.9 (Building Services), B31.11 (Slurries) and B31.8 (Gas). It should be noted that ASME B31.4 and B31.8 deal with "transportation" of gas and liquid petroleum (petrochemical plants, gas pipelines, utilities gas mains, etc.) Therefore it cannot be assumed that conformance to SMACNA necessarily means conformance to the IBC.

If I_p > 1.0, the simplified analysis in B31.9, section 919.4.1(a) cannot be used.

Section 8
What are the Requirements for Fire Protection Sprinkler Systems?

The above identified Seismic design forces can be reduced by a factor of 1.4. Per section 1621.3.10.1, fire protection sprinkler systems designed and constructed in accordance with NFPA 13 with a capacity adequate to meet these new force levels are deemed to meet code requirements.

Section 9
Summary and Load Comparison to Past Code Requirements

In the past, the “basic” or “mapped” Seismic Acceleration factors used ranged from .05 to .4 g, except in the case of the 97 UBC where near source and soil factors could increase the maximum figure to 1.92 g. However, because the 97 UBC is design strength based, the final figure could be reduced by a further factor of 1.4 (to 1.37 g) when comparing it to the older codes. On the other hand, the maximum “mapped” short period acceleration factor with the IBC is 3 g. This yields a maximum design g force at grade of 4.8 when worst case soil and importance factors are accounted for. However, because of the design strength/design stress relationship, this needs to be reduced by a further factor of 1.4 (to 3.42 g) when comparing it to the older codes. This is still a huge increase in the code design requirement.

A direct comparison of the maximum ground accelerations figures as identified in the older and newer codes and expressed in directly comparable allowable stress design based units is as follows:

	Max Horiz Ground Accel	Max Vert Ground Accel
97 SBC, 96 BOCA	0.4 g	0.13 G (non simultaneous)
94 UBC	0.4 g	0.0 G
Calif Modified 94 UBC	0.4 g	0.13 G (simultaneous)
97 UBC (Including 1.4 factor)	1.37 g	0.46 G (simultaneous)
2000 IBC (Including 1.4 factor)	3.42 g	0.42 G (simultaneous)

The above factors are then further modified based on the equipment type, it’s location in the building, the importance of the equipment, whether or not it’s resiliently mounted and the type of anchorage used.

For mechanical equipment, these factors range as follows:

	Thru Bolt	Thru Bolt Isolator	Anchor Expansion	Anchor Isolator
97 SBC, 96 BOCA	.33 to 3.0	.33 to 6.0	.33 to 3.0	.33 to 6.0
94 UBC	.75 to 3.0	1.5 to 3.0	.75 to 3.0	1.5 to 3.0

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Calif Modified 94 UBC	.75 to 3.0	1.5 to 3.0	.75 to 3.0	1.5 to 3.0
97 UBC	.70 to 6.0	1.67 to 6.0	3.33 to 6.0	6.66 to 12.0
2000 IBC	.30 to 2.4	.60 to 4.8	.60 to 4.8	1.17 to 9.36

Thus, for equipment in a building located at this worst case site and depending on application specific factors, the design force in "g"s would range between the below listed values:

	Thru Bolt	Thru Bolt Isolator	Anchor Expansion	Anchor Isolator
97 SBC, 96 BOCA	.133 to 1.2	.133 to 2.4	.133 to 1.8	.133 to 2.4
94 UBC	.30 to 1.2	.60 to 1.2	.30 to 1.2	.60 to 1.2
Calif Modified 94 UBC	.30 to 1.2	.60 to 1.2	.30 to 1.2	.60 to 1.
97 UBC	.96 to 8.22	2.29 to 8.22	4.56 to 8.22	9.12 to 16.44
2000 IBC	1.03 to 8.20	2.05 to 16.41	2.05 to 16.41	4.00 to 32.01

Note that these are ***worst case*** and in practice, the magnitude of these values applicable to a particular project would rarely get above half of the peak magnitude listed here. It should be noted however, that the relationships when comparing these factors will remain relatively constant, without regard to seismic zone. Thus the loads to be designed for using the IBC code will be approx 10 times what they had been in the past using the 94 UBC, 96 BOCA and 97 SBC, no matter where the project is located.

To partially compensate for this, contractors, designers, architects should look strongly at moving roof mounted or other higher level equipment to lower floors where possible. This can reduce the design loads by between 2:1 and 3:1 from the peak values (depending on other factors). However, even with this, there would remain a sizable design force increase.

In addition, the designer of hospitals or other non-seismicly-excluded structures, even in relatively low seismic areas (like Chicago, Cleveland, Denver, Oklahoma City or Richmond), will be required to ensure that there is enough structural integrity in the building to both resist the loads and to properly anchor the equipment. While these factors are already addressed in places like California, the shear magnitude of these forces is likely to come as a rude awakening to people in the rest of the country.

In higher seismic areas, the use of anchor bolts will be heavily restricted, not only because of severe limitations for their use on equipment over 10 hp, but also because of factors that dictate more severe design load magnitudes when they are used. The higher loads require larger anchors and the larger anchors require greater embedment depths. If an embedment depth of under 8 bolt diameters is required due to slab thickness limitations, the design load is again doubled and the idea of using concrete anchors can be effectively eliminated. This leaves bolting through the slab as the only viable option.

Unless Housekeeping pads are monolithic to the floor slab, their added thickness cannot be included in the embedment depth. Therefore an anchor that penetrates a 6" housekeeping pad and extends 2" into the structural floor slab is considered to have an embedment depth of 2" instead of 8". Significant pre-planning is needed to ensure that the problems that can result from these situations are adequately addressed.