CODE BASED SESIMIC DESIGN FORCES

S5.1 – Introduction:

The code based horizontal seismic force requirements for pipe and duct are either calculated by the seismic restraint manufacturer as a part of the selection and certification process, or available through a convenient and easy method provided by the manufacturer. Kinetics Noise Control provides online tools that will calculate the horizontal seismic force and make recommendations for the proper seismic restraints for the pipe or duct in question. These tools will be discussed in the next section.

This section 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 pipe or duct and the nature of the seismic forces and the factors that affect them.

S5.2 – Code Based Horizontal Seismic Design Force – ASCE/SEI 7-05 Section 13.3:

The seismic force is a mass, or weight, based force, and as such is applied to the pipe or duct at its center of gravity, which is usually at the center of the cross-section of the pipe or duct. Keep in mind that the earthquake ground motion moves the base of the building first. Then the motion of the building will accelerate the pipe or duct through the hangers. The horizontal seismic force acting on a pipe or duct will be determined in accordance with Equation 13.3-1 of ASCE/SEI 7-05.

$$F_P = \frac{0.4 a_P S_{DS} W_P}{\left(\frac{R_P}{I_P}\right)}\left(1 + 2\frac{z}{h}\right)$$

Equation S5-1

ASCE/SEI 7-05 defines and upper and lower bound for the horizontal force that is to be applied to the center of gravity of a pipe or duct. The horizontal seismic force acting on a pipe or duct is not required to be greater than;

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$F_P = 1.6 S_{DS} I_P W_P$ **Equation S5-2**

And the horizontal seismic force acting on a pipe or duct is not to be less than;

$F_P = 0.3 S_{DS} I_P W_P$ **Equation S5-3**

Where:

F_P = the design horizontal seismic force acting on a pipe or duct acting 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 is expected to be. Typically this will vary from 1.0 to 2.5, and is specified by component type in ASCE/SEI 7-05 and listed in Table S5-3.

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

W_P = the operating weight of the pipe or duct that is being restrained.

R_P = the response modification factor which usually will vary from 1.0 to 12.0. 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 values are specified by component type in ASCE 7-05 and listed in Table S5-3.

z = the structural attachment mounting height of the pipe or duct hanger 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.

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The weight of the pipe or duct being restrained will depend on the seismic restraint spacing. For the transverse seismic restraints, the weight of the pipe or duct being restrained is;

$$W_P = S_T \sum w_i$$ **Equation S5-4**

For the longitudinal seismic restraints, the weight of the pipe or duct being restrained is;

$$W_P = S_L \sum w_i$$ **Equation S5-5**

Where:

S_L = the longitudinal seismic restraint spacing.

S_T = the transverse seismic restraint spacing.

$\sum w_i$ = the sum of the weights of all of the individual pipes or ducts being restrained over a distance equal to the restraint spacing.

w_i = the weight per foot of an individual pipe or duct over the distance equal to the restraint spacing.

The $\left(1+2\frac{z}{h}\right)$ term in Equation S5-1 is recognition of the fact that all buildings and structures become more flexible as they increase in height. That is they are much stiffer 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 to the pipe and duct 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 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.

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The pipe or duct, along with its hangers, will also form a vibrating system with a natural period that depends on the mass of the pipe or duct and the stiffness of the hangers. The component amplification factor (a_P) is a measure of how closely the natural period of the pipe or duct matches the natural period of the building. For $a_P = 1.0$ the natural periods are not close, while for $a_p = 2.5$ the natural period of the pipe or duct is very close to that of the building.

The component response modification factor(R_P)is a measure of how much energy the pipe or duct along with the hanger and attachments can absorb without sustaining crippling damage. A common term used throughout the HVAC industry is fragility. As the term implies, it is concerned with how fragile a component might be. That is, how easily a component may be damaged, and to what degree it might be damaged by a specified load and loading rate. The R_P factor, then, is considered to be an indicator of how fragile a pipe or duct might be. For $R_P = 1.0$ the component is extremely fragile. For $R_P = 12.0$, on the other hand, would be a component that is very robust.

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 S5-1; S5-2, and S5-3 which represent 2000 IBC/ASCE 7-98, 2003 IBC/ASCE 7-02, and 2006/2009 IBC/ASCE 7-05 respectively.

The consensus of opinion appears to be that piping and ductwork, in general, can absorb more energy than had originally been thought. Indeed piping and ductwork that is constructed of highly deformable materials with joints made with welding or brazing can absorb a great deal of energy without sustaining enough damage to cause loss of service. These facts are reflected by the larger values for R_P which will lead to the use of fewer and smaller seismic restraints on a run or pipe or duct.

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Table S5-1; Component Amplification and Response Modification Factors for 2000 IBC (ASCE 7-98)

Component	a_P	R_P
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

Table S5-2; Component Amplification and Response Modification Factors for 2003 IBC (ASCE 7-02)

Component	a_P	R_P
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

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Table S5-3; Component Amplification and Response Modification Factors for 2006/2009 IBC (ASCE 7-05)

Component	a_P	R_P
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

S5.3 – Code Based Vertical Seismic Design Force – ASCE/SEI 7-05 Section 13.3:

ASCE/SEI 7-05 requires that a vertical seismic load be applied to the pipe or duct concurrently with the horizontal seismic load from Equation S5-1. The vertical seismic load acting on the pipe or duct will be;

$$F_V = \pm 0.2 S_{DS} W_P$$ **Equation S5-6**

This force is to be applied in the direction that causes the worst case condition. In this instance it is to be applied downward to the hanger(s) that are closest to the seismic restraint locations. This load will add to the tension load in the hanger generated by the supported weight of the pipe of duct. A check should be performed to make sure that the vertical seismic force does not overload the hanger(s).

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5.4 LRFD versus ASD – ASCE/SEI 7-05 Sections 2.3, 2.4 and 13.1.7

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 S5-1, S5-2, S5-3, and S5-6 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 S5-1 through S5-6 by multiplying the ASD values by 1.4.

S5.5 – Summary:

This section has provided an insight into the way in which the seismic design forces for pipe and duct distribution systems may be computed. It is generally not necessary for a designer to actually run the computations for the seismic design forces. Kinetics Noise Control provides web based computer tools to help the designer responsible for the seismic restraint selection determine the seismic forces that will be acting on the pipe or duct distribution system and to make the proper selection for the seismic restraints. More about the selection process and the web based tools will be said in the following sections.

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