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ANSI

American National Standard for Seismic Sway Braces for Pipe, Tubing and Conduit

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Foreword

This standard is intended to be used to evaluate components and performance of seismic sway brace equipment.

This American National Standard has been developed by the canvass method of standards development of the American National Standards Institute (ANSI). FM Approvals is an ANSI-accredited standards developing organization (SDO).

Approval of an American National Standard requires verification by ANSI that the principles of openness and due process have been followed and that a consensus of those directly and materially affected by the standard has been achieved. Consensus requires that all views and objections be considered, and that a concerted effort be made toward their resolution. Consensus is established when, in the judgment of the ANSI Board of Standards Review, substantial agreement has been reached.

The American National Standards Institute does not develop standards nor will it in any circumstances give an interpretation of any American National Standard. Requests for interpretations of this standard shall be addressed to FM Approvals.

ANSI regulations require that this American National Standard shall be revised, reaffirmed, or withdrawn within five years of the date of publication.

NOTE – The user's attention is called to the possibility that compliance with this standard may require use of an invention covered by patent rights. By publication of this standard, no position is taken with respect to the validity of any such claim(s) or of any patent rights in connection therewith. If a patent holder has filed a statement of willingness to grant a license under these rights on reasonable and nondiscriminatory terms and conditions to applicants desiring to obtain such a license, then details may be obtained from the standards developer.

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1. INTRODUCTION

1.1 Purpose

This standard states the examination criteria for rigid seismic sway brace components for pipe, tubing and conduit.

1.2 Scope

1.2.1 This standard encompasses the design and performance requirements for rigid seismic sway bracing components used to brace pipe, tubing and conduit.

1.2.2 For rigid seismic sway braces, the general requirements for seismic sway bracing components apply to the components that are attached to the structural element and the components that are attached to the pipe, tube or conduit. The brace member that connects the building-attached component and the piping-attached component is used in the testing, but not included within the scope of the standard. The brace member is to be designed for the tension and compression axial load applied and any eccentricity of axial force. However, the attachment nominal strength will be affected by the brace material and wall or leg thickness at the connection to the brace, which should then be part of the limitations of the load rating of the attachment.

1.2.3 The evaluation of building-attached components is based on the premise that the component would either break, or deform in excess of the allowed limits, prior to either the failure of the attachment fastener, or the deflection of the structural member (e.g. beam). Therefore, the attachment fastener and structural members are not considered to be within the scope of this Approval Standard.

1.2.4 The evaluation of piping-attached components is based on the premise that the component would break, deform in excess of allowed limits, or lose its grip on the pipe.

1.2.5 Seismic sway brace components are designed to attach to pipe, tubing or conduit from Nominal Pipe Size (NPS) 1 to 12 in (DN25 – 300) nominal pipe size.

1.3 Basis for Requirements

1.3.1 The requirements of this standard are based on experience, research and testing, and/or the standards of other organizations. The advice of manufacturers, users, trade associations, jurisdictions, and/or loss control specialists was also considered.

1.3.2 The requirements of this standard reflect tests and practices used to examine characteristics of seismic sway bracing components. Seismic sway bracing components having characteristics not anticipated by this standard may be tested if demonstrated performance is equal, or superior, to that required by this standard, or if the intent of the standard is met.

Alternatively, seismic sway bracing components that meet all of the requirements identified in this standard may not be acceptable if other conditions that adversely affect performance exist or if the intent of this standard is not met. It is the sole discretion of the testing laboratory.

1.4 Basis for ANSI Specification

1.4.1 Certification is based upon satisfactory evaluation of the product and the manufacturer. Examination and tests on production samples shall be performed to evaluate:

- The suitability of the product;
- The performance of the product as specified by the manufacturer and required by FM Approvals; and as far as practical,
- The durability and reliability of the product.

1.4.2 A satisfactory review of the manufacturer's installation instructions for the seismic sway brace components or assemblies is required. The evaluation shall be performed to ensure that the document is accurate and complete.

1.5 System of Units

Units of measurement used in this standard are United States (U.S.) customary units. These are followed by their arithmetic equivalents in International System (SI) units, enclosed in parentheses. The first value stated shall be regarded as the requirement. The converted equivalent value may be approximate. Appendix A lists the selected units and conversions to SI units for measures appearing in this standard. Conversion of U.S. customary units is in accordance with the Institute of Electrical and Electronics Engineers (IEEE)/American Society for Testing Materials (ASTM) SI 10-2002, *American National Standard for Use of the International System of Units (SI): The Modern Metric System*.

1.6 Applicable Documents

This standard is used in conjunction with the following standards, test methods, and practices.

American Iron and Steel Institute (AISI), 25 Massachusetts Avenue NW, Suite 800, Washington, DC 20001, www.steel.org
AISI S100-Feb 2010, *North American Specification for the Design of Cold Formed Steel Structural Members*

American Society of Mechanical Engineers (ASME), Three Park Avenue, New York, NY 10016, www.asme.org
ASME B36.10M-2004, *Welded and Seamless Wrought Steel Pipe*

American Society for Testing and Materials (ASTM International), 100 Bar Harbor Drive, West Conshohocken, PA, 2003, DOI: 10.1520/C0033-03A, www.astm.org
ASTM A153/A153M - 09, *Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*
ASTM B633-07, *Standard Specification for Electrodeposited Coatings of Zinc on Iron or Steel*
ASTM SI10 - 2002, *IEEE/ASTM SI 10 American National Standard for Use of the International System of Units (SI): The Modern Metric System*

FM Global, Corporate Offices, 270 Central Avenue, Johnston, RI 02919, www.fmglobal.com
P. K. Malhotra, Paul Senseny, Antonio Braga and Roger Allard, "Test protocol for sprinkler-pipe seismic-brace components," Earthquake Spectra, Volume 19, No 1, pp 87-109, February 2003.
FM Global Property Loss Prevention Data Sheets

International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland, www.iso.org
International Electrotechnical Commission (IEC), 3, rue de Varembé, P. O. Box 131, 1211 Geneva 20, Switzerland, www.iec.ch
ISO/IEC 17025-2005 (R2010), *General Requirements for the Competence of Testing and Calibration Laboratories*

Occupational Safety & Health Administration (OSHA), 200 Constitution Avenue, NW, Washington, DC 20210, www.osha.gov
OSHA Code of Federal Regulations 29 CFR part 1910, *Occupational Safety and Health Standards*
OSHA Directive Number CPL1-03 titled: NRTL Program Policies, Procedures and Guidelines

1.7 Definitions

For purposes of this standard, the following terms apply:

Accepted
This term refers to installations acceptable to the authority enforcing the applicable installation rules. Acceptance is based upon an overall evaluation of the installation. Acceptance is not a characteristic of a product. It is installation specific. A product accepted for one installation may not be acceptable elsewhere.

Allowable Strength

Used in Allowable Stress Design (ASD), the allowable strength is the horizontal nominal strength (R_{Hn}) divided by a safety factor (Ω).

Allowable Stress Design (ASD)

Allowable Stress Design (a.k.a. Allowable Strength Design) is a method of comparing the allowable strength of a component to the required strength under ASD load combinations.

Attachment Fastener

The fastener used to connect the building-attached component to the structural member.

Brace Member

This is the component between the building attached component and the piping attached component. This is usually made of: steel pipe, strip steel, angle steel, strut, etc. For the purposes of this standard, the brace member is considered rigid.

Corrosion Resistant

Having resistance to corrosion equal to or exceeding that of carbon steel coated per electro-deposit process with zinc coating thickness of a minimum of 5 µm.

Design Strength

Used in Load and Resistance Factor Design (LRFD), the design strength is the nominal strength (R_n) multiplied by a resistance factor (ϕ).

Horizontal Nominal Strenth (R_{Hn})

For the tested brace orientation (Θ), the horizontal nominal strength (R_{Hn}) is the nominal strength (R_n) multiplied by the Sin (Θ) (See Section 4.2.2.6).

Lightwall Pipe

Lightwall pipe is characterized by having a combination of outside diameter and wall thickness not suitable for cut grooving or threading. Lightwall pipe shares the same outside diameter dimensions as Schedule 40 pipe, however the wall thickness of Lightwall pipe ranges between that of Schedule 5 and 10 and can vary from manufacturer to manufacturer. The normal end connections for Lightwall pipe are: welded, roll grooved, and plain end. This pipe is also commonly referred to in industry as "Flow" pipe or "Schedule 7" pipe. There is no national or international standard for this product at this time.

Load at Failure

This term relates to the actual load at which the test sample is observed to fail either by actual mechanical fracture or by exceeding a predetermined limit for displacement.

Load and Resistance Factor Design (LRFD)

Load and Resistance Factor Design (a.k.a. strength design) is a method of comparing the design strength of a component to the required strength under LRFD load combinations.

Load Rating

This term refers to the horizontal load rating assigned to a component as the result of testing and analysis. The horizontal load rating may be expressed with factors to account for different angles of installation. The horizontal load rating may also be expressed in terms of Allowable Stress Design, or in terms of Load Resistance Factor Design.

Nominal Strength (R_n)

The nominal strength (R_n) is the lowest load at failure for the series of tests (see Section 4.2.2.5)

Pipe

For the purposes of this standard Pipe and/or Piping refers to the product being braced; that is pipe, tubing or conduit.

Resistance Factor (ϕ)

The Resistance Factor (**ϕ)** (a.k.a. Strength Reduction Factor) is used in Load and Resistance Factor Design (LRFD) Resistance Factors are less than 1.0 and load factors in LRFD load combinations are commonly greater than 1.0. Additional information related to factors used in the determination of Load and Resistance Factor Design may be found in AISI Standard S100, *North American Specification for the Design of Cold Formed Structural Steel Members.*

Rod Stiffener

This term refers to a product that is attached directly to the all-thread hanger rod in order to provide an increased measure of resistance to buckling when subjected to axial compressive loading.

Safety Factor (Ω)

Used in Allowable Stress Design (ASD), this is a factor, by which the horizontal nominal strength (R_{Hn}) is divided to account for deviations of the horizontal nominal strength from the actual strength, deviations in assumed loads, and for the manner and consequence of failure. Safety Factors are greater than 1.0 and the load factors in ASD load combinations are typically 1.0 or less. Additional information related to factors used in the determination of Allowable Stress Design may be found in AISI Standard S100, *North American Specification for the Design of Cold Formed Structural Steel Members.*

Schedule 40 Pipe

Schedule 40 pipe refers to a historically accepted combination of outside diameter and wall thickness that has been subsequently published in national standard ASME B36.10M-2004. Other national and international standards also make reference to Schedule 40 pipe but may or may not reflect the same dimensions for a given nominal pipe size. Approved end connections are threaded, welded, rolled or cut groove, or plain end.

Schedule 30 Pipe

Schedule 30 pipe refers to a historically accepted combination of outside diameter and wall thickness that has been subsequently published in national standard ASME B36.10M-2004. Other national and international standards also make reference to Schedule 30 pipe but may or may not reflect the same dimensions for a given nominal pipe size. Approved end connections are welded, rolled groove, or plain end.

Schedule 10 Pipe

Schedule 10 pipe refers to a historically accepted combination of outside diameter and wall thickness that has been subsequently published in national standard ASME B36.10M-2004. Other national and international standards also make reference to Schedule 10 pipe but may or may not reflect the same dimensions for a given nominal pipe size. Approved end connections are welded, rolled groove, or plain end.

Schedule 5 Pipe

Schedule 5 pipe refers to a historically accepted combination of outside diameter and wall thickness that has been subsequently published in national standard ASME B36.10M-2004. Other national and international standards also make reference to Schedule 5 pipe but may or may not reflect the same dimensions for a given nominal pipe size. Approved end connections are welded, roll grooved, mechanically swaged fittings.

Seismic Sway Brace – Rigid Brace Style

An assembly consisting of two components (as described below) interconnected by a rigid brace member intended to minimize the differential movement between the sprinkler system piping and the structure, to which it is attached, during an earthquake.

Building-Attached Component

A component of a seismic sway brace intended to provide a means of attachment to a structural element of a building.

Piping-Attached Component

A component of a seismic sway brace intended to provide a means of attachment to the pipe, tube or conduit.

Seismic Sway Brace – Two-Way Brace and Four-Way Brace

For risers and overhead sprinkler piping, there are two sway bracing designs: two-way and four-way. Two-way braces are designed to resist either longitudinal or lateral movement with respect to the axis of a horizontal pipe. Lateral movement is normal to longitudinal movement in the horizontal direction. Four-way sway bracing resists differential movement of a horizontal or vertical pipe in all horizontal directions at a single point or support.

2. GENERAL INFORMATION

2.1 Product Information

2.1.1 Seismic sway bracing is used to minimize the differential movement between the piping and the structure to which it is attached during an earthquake. For risers and overhead piping, there are two sway bracing designs; two-way and four-way. Two-way braces are designed to resist either longitudinal or lateral movement with respect to the axis of a horizontal pipe. Lateral movement is normal to longitudinal movement in the horizontal direction. Four-way sway bracing resists differential movement of a horizontal or vertical pipe in all horizontal directions at a single point or support.

2.1.2 In order to meet the intent of this standard, seismic sway brace components must be examined on a model-by-model, type-by-type, manufacturer-by-manufacturer, and plant-by-plant basis. This is predicated on the basis that identical designs, fabricated in identical materials by different manufacturers or, even by different plants of the same manufacturer, have been observed to perform differently in testing. Sample seismic sway brace components, selected in conformance to this criterion, shall satisfy all of the requirements of this standard.

2.2 Application Requirements

The manufacturer shall provide the following preliminary information that gives a full description of the construction of the seismic sway brace component or assembly. All documents shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level.

Test programs will be scheduled only upon receipt of all materials listed herein. All foreign language documents shall be provided with English translation.

- A complete list of all models, and sizes, for the products or services being submitted for Approval consideration;
- Products and sizes to be braced, including reference to the industry standard to which the product is to be manufactured, (minimum of Schedule 10 and Schedule 40) – For example, Schedule 10 pipe in sizes NPS 4, 6, 8 (DN100, 150, 200), or Lightwall pipe and tubing in 4 in (DN100) nominal size;
- Brace member types and thicknesses, (i.e. Schd 40 pipe, strut, angle, flats, etc.);
- General assembly drawings and one complete set of manufacturing drawings;
- Materials list(s) and material specifications (such as AISI-SAE 1020 Carbon Steel);
- Anticipated marking format;
- Specification sheets;
- Installation, operation and maintenance procedures; and;
- The number and location of manufacturing facilities.

2.3 Requirements for Samples for Examination

Sample requirements are to be determined by the testing laboratory following review of the preliminary information. Sample requirements may vary depending on design features and/or the results of any testing. It is the manufacturer's responsibility to submit samples representative of production. Any decision to use data generated utilizing prototype components or prototype systems is at the sole discretion of the testing laboratory.

3. GENERAL REQUIREMENTS

3.1 Review of Documentation

3.1.1 During the initial investigation and prior to physical testing, the manufacturer's specifications, technical data sheets, and design details shall be reviewed to assess the ease and practicality of installation and use. The product shall be capable of being used within the limits of the Approval investigation.

3.1.2 The manufacturer's dimensional specifications and/or design drawings shall fully describe the product. All critical dimensions shall be indicated with allowed upper and lower tolerance limits clearly shown.

3.2 Physical or Structural Features – Rigid Brace Assemblies

3.2.1 Some of the common types of sway bracing components encompassed by this standard are:

Piping -Attached Components	***Brace Components***	***Building-Attached Components***
Pipe Clamp U-type Clamp	Pipe Strut Structural Steel – Channel, strips	Beam Clamp Bar Joist Clamp I-Beam Attachment

3.2.2 Schematic layouts of rigid braces are shown in Figure 3.2.2A and Figure 3.2.2B for horizontal and vertical pipes respectively. The brace angle (ϴ) is defined from a line that is perpendicular to the direction of the horizontal force as shown in the figures (e.g. for horizontal pipe that is braced to the overhead structure, the brace angle corresponds to the angle from vertical). Brace angle (ϴ) must be at least 30° and may be as much as 90° (i.e. the brace resists the horizontal load directly).

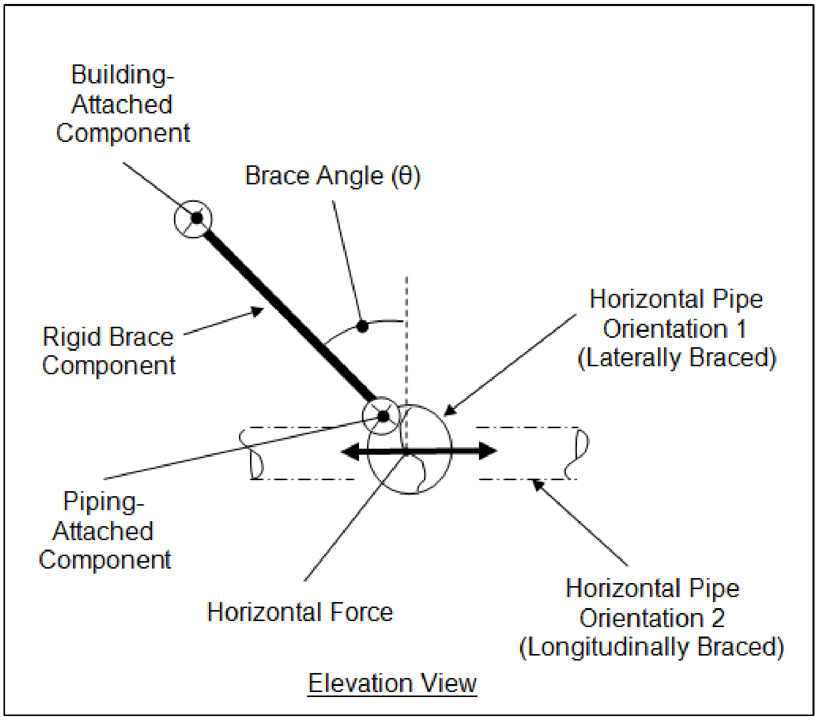

Figure 3.2.2A Typical Brace Layout, Horizontal Pipe

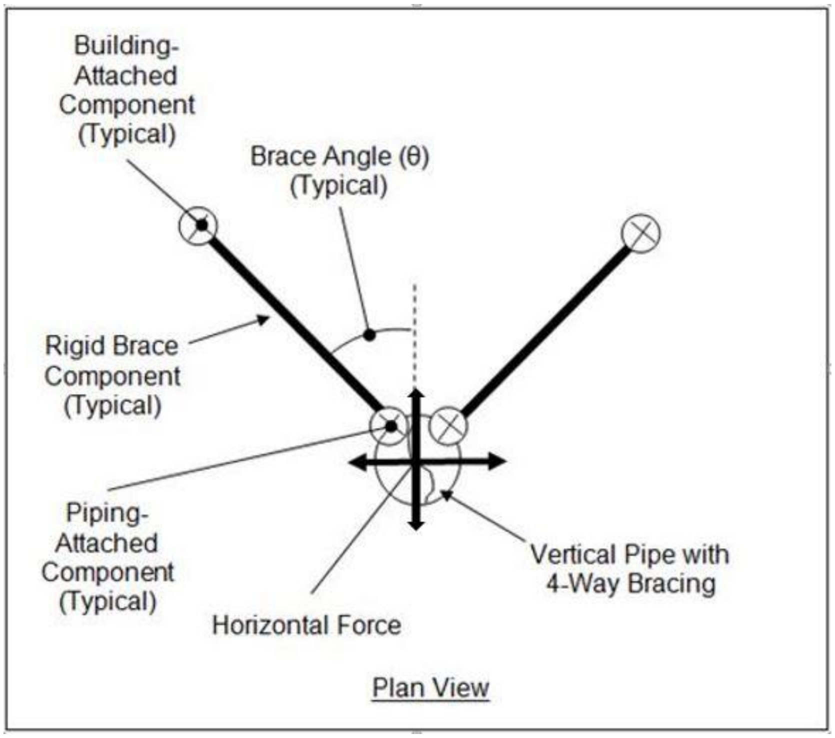

Figure 3.2.2B Typical Brace Layout, Vertical Pipe

3.2.3 Piping-Attached Sway Brace Components

Piping-attached sway brace components shall be provided with a visual means to verify that the component is adequately secured to the pipe, tube, or conduit and the bracing component. Visual verification may include but is not limited to such means as: “flat-to-flat” relative positions of components, fasteners that bottom out when properly installed, the use of “go and no go” gauges, shearing type fasteners that shear off at the proper torque, alignment fasteners which align in a specific fashion when adjusted to the proper torque. Other methods of visual verification may be acceptable and will be examined on a case by case basis. Piping-attached seismic sway brace components shall have adequate strength to withstand the cyclic loading history. The component shall not break or deform more than allowed limits.

Piping-attached sway brace components that are found to deform the run pipe during installation or testing are required to have a provision in the product literature that states that the installation of these components shall be far enough away from a pipe joint so that the deformation does not weaken the pipe joint. The local deformation of the pipe wall during testing shall be considered as contributing to the total deformation of the component.

3.2.4 Building-Attached Sway Brace Components

Building-attached components shall provide a secure connection to a building structural element and shall have adequate strength to withstand the cyclic loading history. The component shall not break or deform more than allowed limits. Building-attached components shall be provided with a visual means (See Section 3.2.3) to verify the component is adequately secured to the building structural element (if attachment is made using set-screws, etc.) and the brace member.

3.2.5 Seismic sway brace components shall be supplied with all required fasteners, pins, etc., included to make the assembly complete. The manufacturer is not required to supply the fasteners to attach building-attached components to structural members. Instructions for field installation of brace components shall also be included.

3.3 Materials

3.3.1 All materials used in these seismic sway brace components shall be suitable for the intended application. Common materials used in brace components are malleable iron, ductile iron, rolled steel, and heat treated steel. These and any other materials used in seismic sway brace components shall have physical properties necessary to render them suitable for their intended use. If unusual materials are used, special tests may be necessary to verify their suitability.

3.3.2 To provide adequate durability, any ferrous metal part less than 1/8 in (3 mm) thick shall be plated with a non-ferrous material to at least 5µm thickness as defined in ASTM B633, Service Condition SC1 (Mild), or equivalent, in order to retard oxidation of the base material. Coatings shall withstand the effects of shipping, assembly and installation, weathering and corrosion.

3.4 Markings

3.4.1 Marking on the product or, if not possible due to size, on its packaging or label, or installation instructions if accompanying the product, shall include the following information:

- Manufacturer’s name and address or marking traceable to the manufacturer;
- Model or type designation;
- Indication of strength rating, or;
- The maximum pipe size used with the component;
- Manufacturing location source code (as applicable).

3.4.2 Any other pertinent marking information required by the referenced standards or other national or international standard to which the product is manufactured shall be permanently marked on the product.

3.4.3 The model identification shall correspond with the manufacturer’s catalogue designation. The manufacturer shall not place this model identification on any other product.

3.4.4 All markings shall be legible and durable.

3.5 Manufacturer's Installation Instructions

3.5.1 Installation instructions, including any special dimension requirements, shall be furnished by the manufacturer with each shipment. Installation instructions shall include the requirements for the correct installation of both building-attached and piping-attached components.

3.5.2 Where applicable, a listing of the manufacturer’s recommended fasteners shall be included in order to assist in the proper selection of fasteners for building-attached components.

3.5.3 Installation instructions shall also include reference to the visual means (see Sections 3.2.3 and 3.2.4) to ensure that the proper installation of the components has been made. In the event that manual checking is the only means to verify installation, the instructions shall clearly indicate the criteria used to judge proper installation.

3.5.4 The installation instructions identified in Section 3.5.1 shall be available in multiple languages in support of regions where the product is intended to be sold.

3.6 Calibration

Each piece of equipment used to verify the test parameters shall be calibrated within an interval determined on the basis of stability, purpose, and usage. The certificate shall indicate that the calibration was performed against working standards whose calibration is certified as traceable to the National Institute of Standards and Technology (NIST) or traceable to other acceptable reference standards and certified by an ISO/IEC 17025, “*General Requirements for the Competence of Testing and Calibration Laboratories”*, calibration laboratory. The test equipment shall be clearly identified by label or sticker showing the last date of the calibration and the next due date.

The calibration of new equipment is also required. Documentation indicating either the date of purchase or date of shipment, equipment description, and model and serial number is required for identification. The period from the time the equipment was put into service to the date of testing must be within an interval that does not require the equipment to be calibrated as determined on the basis of the parameters mentioned above. The new test equipment shall be clearly identified by label or sticker showing the last date of the calibration and the next due date.

3.7 Test Facilities

If review of all required information indicates suitability for testing, representative samples of the seismic sway brace equipment shall be made available. The range of products, and testing orientations will be specified by the testing laboratory. If testing cannot be completed at the testing laboratory, the manufacturer shall provide facilities and all properly calibrated instrumentation required to perform these tests. Alternatively, a mutually agreeable 3rd party laboratory may be used provided that this facility has the ability to perform the tests as described herein, and can satisfy the requirements for calibration for the equipment. For testing not conducted at a testing laboratory, a representative of the testing laboratory shall witness all the tests and shall receive copies of the data collected during testing, and calibration certificates of the equipment used.

3.8 Tolerances

Tolerances on units of measure shall be as described in Appendix B, unless otherwise specified.

4. PERFORMANCE REQUIREMENTS

The objective of these tests is to determine the maximum horizontal loads (vs. brace/component orientation) a component can resist for 15 equal amplitude load cycles without breaking or exceeding the deformation limits. The testing of seismic sway brace components, whether building-attached, piping-attached, or sub-assemblies is comprised of a series of cyclic tests. The load rating shall be determined from the results of the cyclic tests. This standard is written based on the use of force-control test equipment. The minimum requirements for force-control have been outlined below.

The testing for piping-attached seismic sway brace components shall be performed using a 6 in. (150 mm) nominal length of pipe representing the service pipe and an 18 in. (460 mm) maximum nominal length of brace member. The testing for building-attached seismic sway brace components shall be performed using fixtures representing the structure and an 18 in. (460 mm) maximum nominal length of brace component. The load frame shall be equipped with a calibrated load-cell and a deformation-measuring device. The load frame shall be capable of imparting ± 1 in (25 mm) deformation under cyclic conditions at 0.1 Hz frequency.

4.1 Examination

4.1.1 Requirements

The seismic sway brace components shall conform to the manufacturer's drawings and specifications and to the physical and structural requirements outlined in Section 3, General Requirements.

4.1.2 Test/Verification

A sample of each component shall be examined and compared to the manufacturer's drawings and shall conform to the physical, material, and marking requirements described in Section 3, General Requirements.

4.2 Cyclic Testing (Component Testing)

The purpose of this testing is to determine the horizontal load ratings for the building-attached and piping-attached subassemblies of a rigid seismic sway brace. Each of these subassemblies may consist of one or more components. The testing shall incorporate the controlling case as the basis, and then other tests for comparison of results. For example, for building attached components that may be connected to structural members of different thicknesses, testing shall be performed using the minimum wall thickness structural element. Representative testing on other structural elements with heavier wall thicknesses is at the manufacturer's option. For piping attached components, due to the influence that the pipe wall thickness has on the load rating for a given component, the testing may be required using more than one pipe wall thickness. Testing will be performed using the minimum nominal pipe wall thickness as a benchmark, and representative samples of heavier wall thicknesses as deemed necessary. For example, test all sizes on Schedule 10 pipe, and representative samples using Schedule 40 steel pipe. At the manufacturer's option, the load ratings determined with the thinner wall may be used for thicker wall but not vice versa.

The total allowed displacements along the brace, given in Table 4.2.4.1, for seismic sway brace component testing correspond to a maximum horizontal displacement of 1 in. (25 mm) . Tests are carried out using fixtures that orient the components at the installation angles during the tests (see Figure 4.2). The data is then analyzed to determine the equivalent constant cycle loading in the horizontal direction.

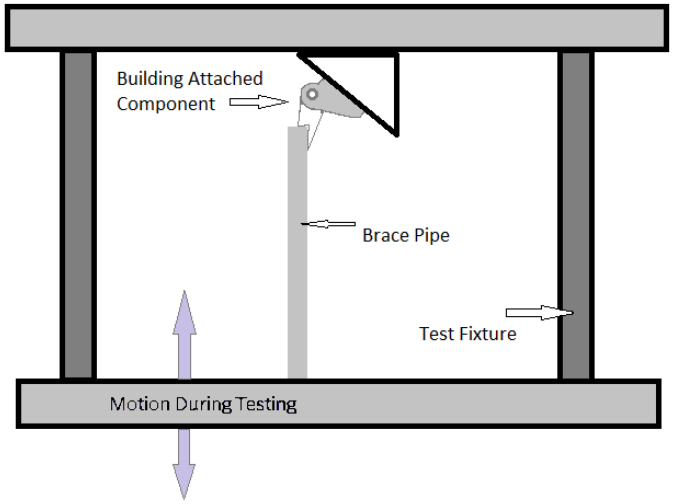

Figure 4.2 – Building Attached Subassembly, 30° Orientation

4.2.1 Requirements

The objective of these tests is to determine the maximum horizontal load a component can resist, at each orientation, for 15 equal amplitude cycles.

4.2.2 Test/Verification

4.2.2.1 Install the building/piping-attached subassembly in the test fixture and subject it to the following cyclic loading profile until either the sample breaks or exceeds the deformation limit of 1 in (25 mm) along the brace. Record the load history, displacement history, and maximum deformation while under test. The frequency shall be 0.1 Hz for the duration of the test. Deviation from 0.1 Hz as a test frequency shall be allowed only when 0.1 Hz is not possible or results in a degradation in the quality of the measurements taken. Deviation from 0.1 Hz shall not be allowed solely as a means to improve test values.

4.2.2.2 For pipe bracing components with expected load at failure in excess of 1000 pounds (4450 N), the initial loading on the sample will be 1000 pounds (4450 N). For pipe bracing components with expected load at failure less than 1000 pounds (4450 N), the initial loading on the sample will be 250 pounds (1110 N). Other starting loads may be allowed at the discretion of the test laboratory, but shall not be less than 50 percent of the expected load at failure.

4.2.2.3 With the component installed in the test fixture, and the initial load determined, subject the sample to 15 cycles alternating in direction to cause tension and compression within the sample as shown below. After the initial 15 cycles, the loading will then change to an increasing increment based on the following equation.

$$Force = X \text{ for } N \leq 15 \text{ cycles}$$

$$Force = X \times \left(\frac{15}{14}\right)^{\frac{(n-15)}{2}} \quad lb \quad for \quad n > 15$$

X = 1000 for Subassemblies with ratings expected to be greater than 1000 pounds (4450N)
X = 250 for Subassemblies with ratings expected to be less than 1000 pounds (4450N)

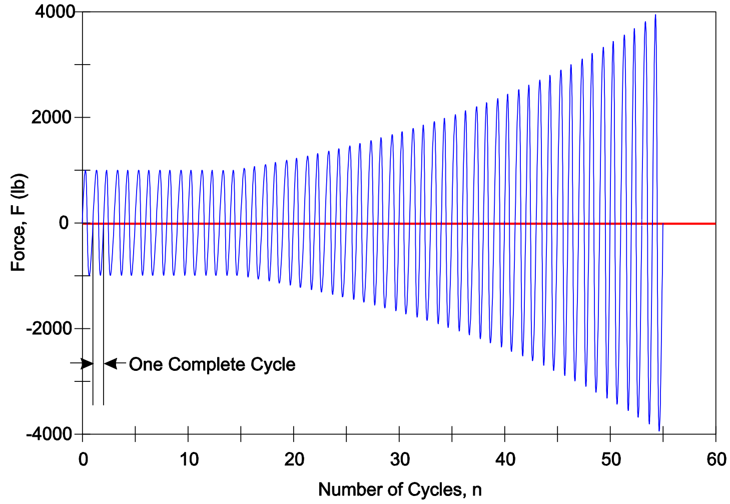

Figure 4.2.2 Force History Plot (Component Testing)

4.2.2.4 Once the sample has been observed to either break, or the deformation limit has been exceeded, the test is complete. Replace the sample with a new sample and repeat the cyclic test twice more, for a total of three tests.

4.2.2.5 The nominal strength (R_n) along the brace for the tested orientation is then found from examining the data and identifying the lowest magnitude force reading from the three samples at the point where the sample was observed to fail, or the deformation limit was exceeded. From this point, back up on the load history to the previous complete cycle and record that value.

4.2.3 Testing Orientations

The failure mode of a building-attached or piping-attached component may vary depending upon the angle at which it is loaded; therefore, it is generally not adequate to test a component at a single brace orientation angle and extrapolate the results to other angles. The number of orientations to be tested depends on several factors including:

- How the component is allowed to be installed (e.g. a building-attached component may be allowed to be connected in several different orientations, such as horizontally to an overhead concrete slab or vertically to a wall or the side of a beam as shown in Figure 4.2.3A and Figure 4.2.3B respectively.)
- How the component is allowed to be loaded per manufacturer's installation instructions (e.g. loading may be restricted to the strong side of the component as shown in the left side of Figures 4.2.3A and Figure 4.2.3B or may be allowed to be loaded also to the weak side of the component as shown on the right side of those figures.)
- The range of brace orientations that can be accommodated by the component
- Whether engineering analysis/judgment can be used to extrapolate findings from testing at certain orientations to orientations that are not tested, or to determine that additional tests are needed due to unusual features of the component.

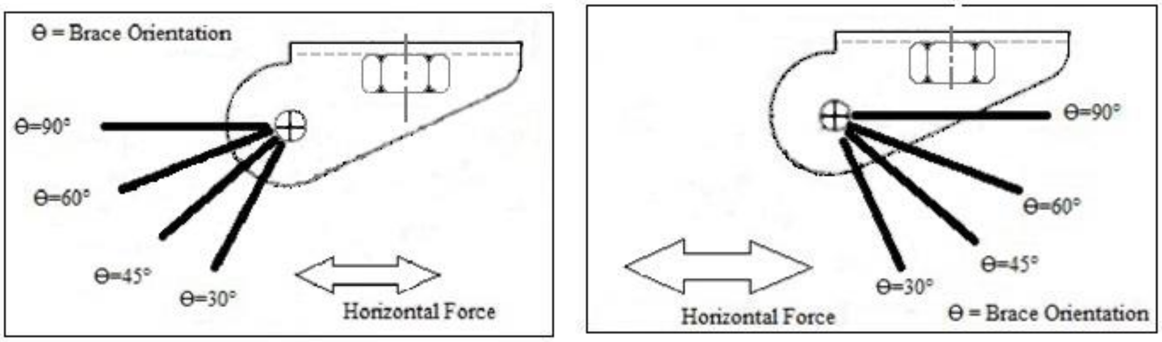

Figure 4.2.3A – Building-Attached Component with Overhead Attachment to Floor or Beam

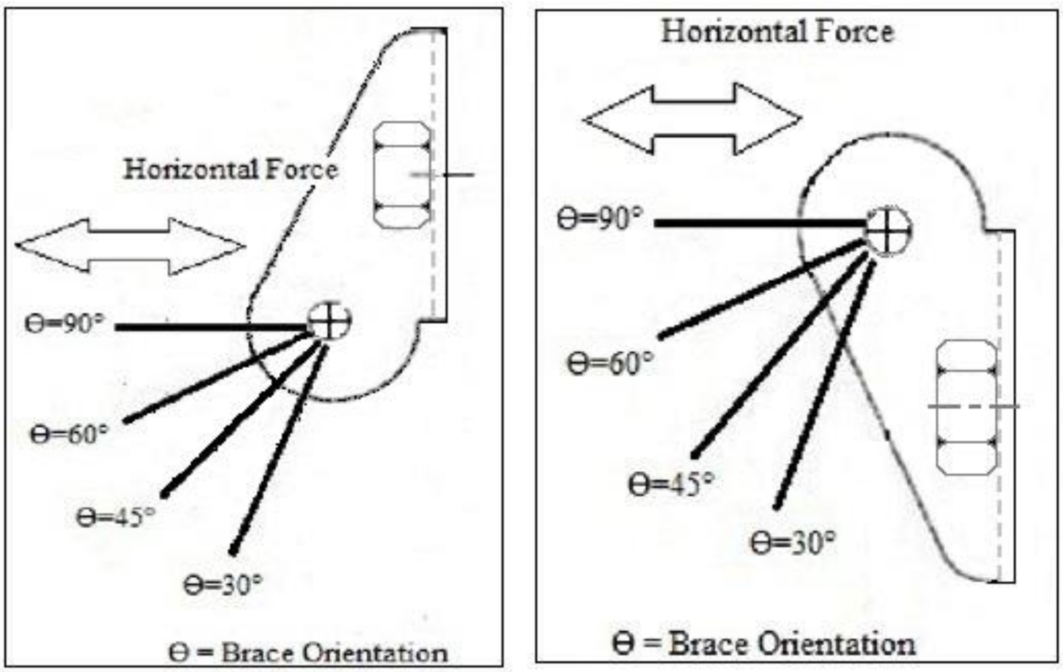

Figure 4.2.3B – Building-Attached Component with Side Attachment to Wall or Beam

Although component horizontal load ratings could be determined for each brace orientation angle from 30 ° to 90°, horizontal load ratings are commonly reported for the following ranges of brace orientation:

- 30° ≤ Θ < 45°
- 45° ≤ Θ < 60°
- 60° ≤ Θ < 90°
- Θ = 90°

In order to determine the minimum horizontal load rating applicable to each of these ranges, it is typically necessary to test the component at the endpoints of these ranges (i.e. at the brace angles (Θ) of 30°, 45°, 60° and 90°) for each installation orientation (e.g. horizontal and vertical) and each loading direction (e.g. strong side or weak side) allowed by the manufacturer.

4.2.3.1 For each allowed component installation method/orientation, determine the horizontal nominal strength (R_{Hn}) by testing according to Section 4.2.2 at brace orientation angles (ϴ) of 30°, 45°, 60°, and 90°.

4.2.3.2 Where the nominal strength can be extrapolated by engineering analysis, fewer brace orientations may be tested than required by Section 4.2.3.1. Determining nominal strengths for untested orientations solely on the basis of trigonometry rather than a rigorous engineering analysis is not allowed.

4.2.4 Determining Horizontal Load Ratings

4.2.4.1 Determine the minimum horizontal load ratings for each of the following brace orientation angle (ϴ) ranges:

- 30° ≤ ϴ < 45°
- 45° ≤ ϴ < 60°
- 60° ≤ ϴ < 90°
- ϴ = 90°

The determination of the horizontal load ratings begins with the analysis of the load history data collected in Section 4.2.2. Using the collected data, the load resisted by the sample at the actual allowed displacement is found. The actual allowed displacement is a function of installation angle, and has been shown in Table 4.2.4.1 below.

Table 4.2.4.1 – Limiting Deformation Along the Brace to Result in 1 inch Horizontal Displacement

Installation Angle (ϴ)	**Limiting Deformation, in (mm)**
30°	0.50 (12)
45°	0.71 (18)
60°	0.87 (22)
90°	1.00 (25)

The nominal strength (R_n) along the brace for the tested orientation is then found from examining the data and identifying the lowest magnitude force reading from the three samples at the point where the sample was observed to fail, or the deformation limit was exceeded. From this point, back up on the load history to the previous complete cycle and record that value. The lowest value for all of the tests conducted for a given component / orientation / installation angle combination is considered the nominal strength (R_n) for that component / orientation / installation angle combination.

4.2.4.2 For the tested brace orientation angle (ϴ), the horizontal nominal strength (R_{Hn}) is found by multiplying the nominal strength (R_n) along the brace by the Sin (ϴ).

4.2.4.3 Horizontal load ratings for Allowable Stress Design (ASD) shall be taken as the allowable strength, which is equal to the horizontal nominal strength (R_{Hn}) found per Section 4.2.2.6 divided by a safety factor (Ω). Unless otherwise allowed or required by the Authority Having Jurisdiction (AHJ), the safety factor (Ω) shall be taken as 2.2. Document the safety factor used.

4.2.4.4 Horizontal load ratings for Load and Resistance Factor Design (LRFD) shall be taken as the design strength, which is equal to the horizontal nominal strength (R_{Hn}) in the horizontal direction found per Section 4.2.2.5 multiplied by a resistance factor (ϕ). Unless otherwise allowed or required by the Authority Having Jurisdiction (AHJ), the resistance factor (ϕ) shall be taken as 0.65 . Document the resistance factor used.

4.3 Additional Tests

Additional tests may be required, depending on design features, results of any tests, material application, or to verify the integrity and reliability of the seismic sway brace components, at the discretion of the testing laboratory.

Unexplainable failures shall not be permitted. A re-test shall only be acceptable at the discretion of the testing laboratory and with adequate technical justification of the conditions and reasons for failure.

5. REPORTING REQUIREMENTS

The information outlined below represents the minimum requirements for reporting for a test program for seismic sway brace components. It is strongly encouraged that the requester and the test laboratory reach agreement on the test method to be used, the data to be recorded, and the reporting to be issued at the conclusion of the testing prior to any testing being performed.

5.1 Final Report

5.1.1 At the conclusion of a test program for seismic sway brace components the data shall be collected and organized into a final report that describes the following:

- Products tested in the evaluation
- Tests conducted for each product
- Test method and data collected for each test
- Process by which the data was analyzed to determine horizontal load ratings
- Statement of the horizontal load ratings
- Calibration of equipment
- Signature and date of review

5.1.2 Considering the amount of raw data that can be created during a project, it is envisioned that the final reporting may also include a supporting document wherein the actual raw data is kept in order to increase the usefulness of the final report. This should be agreed between the requester and the testing laboratory prior to the start of any testing.

5.2 Samples

5.2.1 Prior to the start of testing, the requester and the test laboratory shall reach an agreement on the scope of samples to be included within the test program. Changes to the samples included within the program shall only be possible via written communication between the requester and test laboratory.

5.2.2 As the tests described in Section 4.2 require that each sample be tested for a minimum of 3 runs, the manufacturer shall provide a minimum of 3 samples for each item in the test program. In most cases, at least 12 samples will be needed (4 brace orientation angles times 3 test runs each) for each installation / loading combination. It is suggested that additional samples either be provided or made available for quick delivery to the test laboratory in case of questionable results.

5.3 Test Method

5.3.1 All testing shall be performed using a documented test procedure which outlines the equipment to be used, orientation of the part under test, the data to be collected, and the level of analysis to be performed.

5.3.2 For cases where data generation and data analysis are not performed by the same group, each group shall be responsible to clearly outline their involvement with the collection of or analysis of the data.

5.3.3 It is to be expected that the variation in the data across the tests for the same combination of product / size / and installation angle will be in the approximate range of 10 – 15 percent. Data outside this range may be indicative of product variations or equipment issues with the performance of the test and should be further investigated. Any decision to disregard a test run shall be discussed in the reporting including justification for doing so.

5.4 Horizontal Load Ratings

5.4.1 The process by which the horizontal load ratings are determined from the data collected during testing shall be outlined clearly within the final report, or the supporting documentation. Any assumptions made shall be indicated.

5.4.2 The horizontal load ratings may be shown in terms of Load and Resistance and Factor Design (LRFD), or Allowable Stress Design (ASD). The final report shall also include reference to the safety or resistance factor used in the calculation of the horizontal rating, and a description of the process of converting from LRFD ratings to ASD ratings and vice versa.

5.5 Calibration of Equipment

Each piece of equipment used to verify the test parameters shall be calibrated within an interval determined on the basis of stability, purpose, and usage. A copy of the calibration certificate for each piece of test equipment shall be incorporated into the final report or supporting documents. The certificates shall indicate that the calibration was performed against working standards whose calibration is certified as traceable to the National Institute of Standards and Technology (NIST) or traceable to other acceptable reference standards and certified by an ISO/IEC 17025 accredited calibration laboratory. The test equipment shall be clearly identified by label or sticker showing the last date of the calibration and the next due date. A copy of the service accreditation certificate as an ISO/IEC 17025, “General Requirements for the Competence of Testing and Calibration Laboratories” shall be required with the measurement equipment calibration.

5.6 Review and Signatures

The review of the final report and supporting documentation shall be agreed upon between the requester and the test laboratory at the start of the program. This will outline the nature of the review and responsibilities of the signatory.

APPENDIX A: Units of Measurement

Force: lb_f - "pounds force"; (N - "Newtons")
lb_f = N x 4.4482

Frequency: Hz – hertz (Also the SI unit)

Length: in. - "inches"; (mm - "millimeters")
mm = in. x 25.4

ft - "feet"; (m - "meters")
m = ft x 0.3048

Mass: lb - "pounds"; (kg - "kilograms")
lb = kg x 0.4536

Speed: in./min - "inch per minute"; (mm/min - "millimeters per minute")
mm/min = in./min x 25.4

Torque: $ft{\cdot}lb_f$ - ''foot pound-force''; (N·m - ''Newton-meters'')
N·m = 0.7376 $ft{\cdot}lb_f$
$kg_f{\cdot}m$ = 7.233 $lb_f{\cdot}ft$

APPENDIX B: Tolerances

Unless otherwise stated, the following tolerances shall apply:

Force:	± 3 lbs of value
Length:	± 2 percent of value
Temperature:	± 5 °F (+/- 3°C)
Time:	+ 5/-0 seconds + 0.1/-0 minutes + 0.1/-0 hours + 0.25/-0 days

Unless stated otherwise, all tests shall be carried out at a room (ambient) temperature of 68 °F ± 9 °F (20 °C ± 5 °C).