Examination Standard

Seismic Sway Braces for
Pipe, Tubing and Conduit

Class Number 1950
August 2023

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Foreword

This standard is intended to verify that the products and services described will meet stated conditions of performance, safety and quality useful to the ends of property conservation. The purpose of this standard is to present the criteria for examination of various types of products and services.

Examination in accordance with this standard shall demonstrate compliance and verify that quality control in manufacturing shall ensure a consistent and reliable product.

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1 INTRODUCTION

1.1 Purpose

1.1.1 This standard states testing and certification requirements for rigid seismic sway brace components and assemblies for pipe, tubing and conduit.

1.1.2 Testing and certification criteria may include performance requirements, marking requirements, examination of manufacturing facility(ies), audit of quality assurance procedures, and a surveillance program.

1.2 Scope

1.2.1 This standard encompasses the design and performance requirements for rigid seismic sway brace components used to brace pipe, tubing and conduit (i.e. building attached components and piping attached components).

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. However, sway brace assemblies which include the brace member as a permanent, integral component of the product are 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 member, which can contribute to the limitations of the load rating of the attachment.

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 examination standard.

1.2.2 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.

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

1.2.4 In the case of rigid seismic sway brace assemblies, the general requirements and performance requirements apply to the entire assemblies.

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. The underlying details and assumptions that define the basis for the research and development of this examination standard are contained in the Earthquake Spectra article *Test protocol for sprinkler-pipe seismic-brace components*.

1.3.2 The requirements of this standard reflect tests and practices used to examine characteristics of seismic sway bracing components for the purpose of obtaining certification.

1.4 Basis for Certification

Certification is based upon satisfactory evaluation of the product and the manufacturer in the following major areas:

1.4.1 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 for certification;
- the durability and reliability of the product.

1.4.2 An examination of the manufacturing facilities and audit of quality control procedures may be made to evaluate the manufacturer's ability to consistently produce the product which is examined and tested, and the marking procedures used to identify the product. Subsequent surveillance may be required by the certification agency in accordance with the certification scheme to ensure ongoing compliance.

1.5 Basis for Continued Certification

The basis for continual certification may include, but is not limited to, the following based upon the certification scheme and requirements of the certification agency:

- production or availability of the product as currently certified;
- the continued use of acceptable quality assurance procedures;
- compliance with the terms stipulated by the certification;
- satisfactory re-examination of production samples for continued conformity to requirements; and
- satisfactory surveillance audits conducted as part of the certification agency's product surveillance program.

1.6 Effective Date

The effective date of this certification standard mandates that all products tested for certification after the effective date shall satisfy the requirements of this standard.

The effective date of this standard is eighteen (18) months after the publication date of the standard for compliance with all requirements.

1.7 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. Conversion of U.S. customary units is in accordance with ANSI/IEEE/ASTM SI 10.

1.8 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the cited edition applies.

ANSI/IEEE/ASTM SI 10, *American National Standard for Metric Practice*

ASME B36.10M, *Welded and Seamless Wrought Steel Pipe*

ASTM B633, *Standard Specification for Electrodeposited Coatings of Zinc on Iron or Steel*

1.9 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 from steel pipe, strip steel, angle steel, strut, etc. For the purposes of this standard, the brace member is considered rigid.

Conduit – For the purposes of this standard conduit refers to the product being braced; that is, pipe, tubing or conduit.

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 Strength (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 4.2.4.2)

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 4.2.4.2)

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). 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.

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. 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. Certified 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. 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. Certified 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. 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. Certified 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. 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. Certified 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 the pipe. Lateral movement is normal to longitudinal movement and is generally regarded as horizontal. Four-way sway bracing resists differential movement in all horizontal directions.

Tubing – For the purposes of this standard tubing refers to the product being braced; that is pipe, tubing or conduit.

2 GENERAL INFORMATION

2.1 Product Information

2.1.1 Seismic sway bracing is used to minimize the differential movement between the product being braced (pipe, tubing or conduit) 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 the pipe. Lateral movement is normal to longitudinal movement and is generally regarded as horizontal. Four-way sway bracing resists differential movement in all horizontal directions.

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 Certification Application Requirements

The manufacturer shall provide the following preliminary information with any request for certification consideration:

- a complete list of all models, types, sizes, and options for the products or services being submitted for certification consideration;
- products and sizes to be braced, including reference to the industry standard to which the product is to be manufactured, – For example, Schedule 10 pipe in sizes 4, 6, 8 inch NPS, or Lightwall pipe and tubing in 4 inch (DN100) nominal sizes;
- 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.
- All documents shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level. All documents shall be provided with English translation.

2.3 Requirements for Samples for Examination

Following set-up and authorization of a certification examination, the manufacturer shall submit samples for examination and testing based on the following:

- Sample requirements are to be determined by the certification agency

2.3.1 Requirements for samples may vary depending on design features, results of prior or similar testing, and results of any foregoing tests.

2.3.2 The manufacturer shall submit samples representative of production. Any decision to use data generated using prototypes is at the discretion of the certification agency.

2.3.3 It is the manufacturer's responsibility to provide any necessary test fixtures, such as those which may be required to evaluate the components.

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 certification 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.

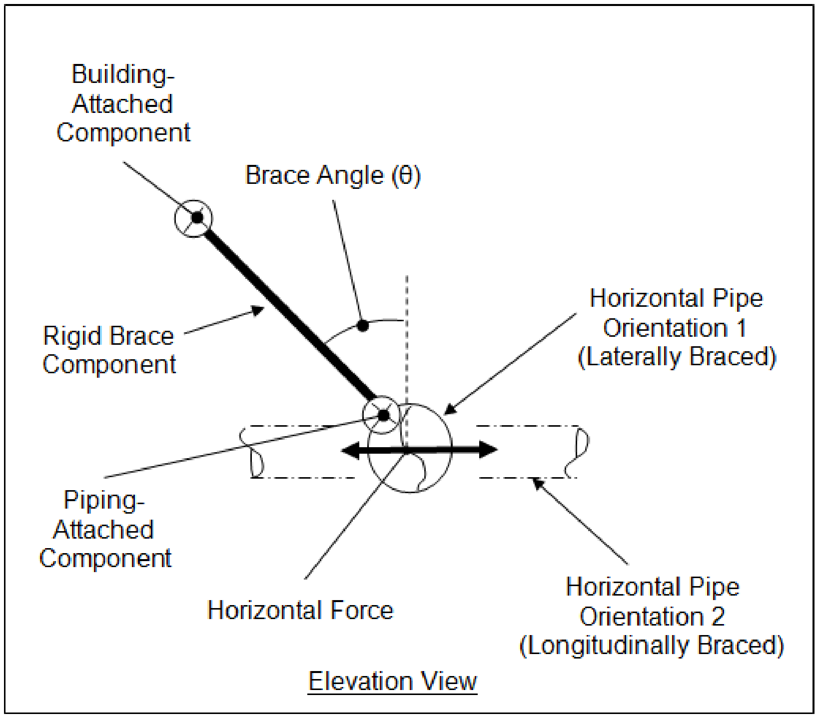
3.1.3 All documents pertaining to the product materials, dimensions, processing, and marking shall be controlled by the manufacturer's Quality Assurance procedures, and shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level. All foreign language drawings shall be provided with an English translation.

3.2 Physical or Structural Features – Rigid Brace Assemblies

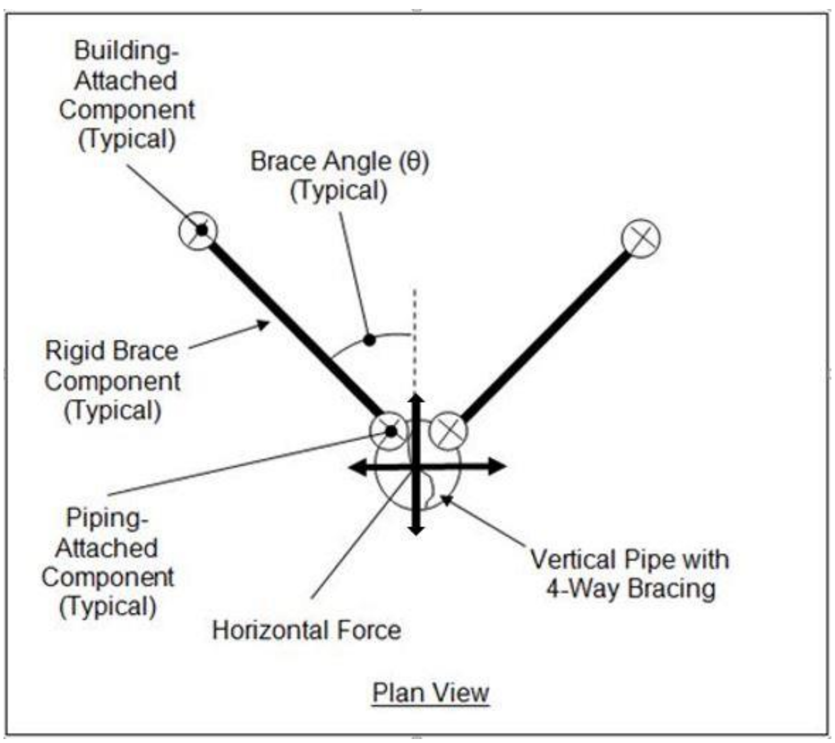
3.2.1 Some of the common types of sway bracing components encompassed by this standard are:

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



3.2.2 Figure 3.2.2A Typical Brace Layout, Horizontal Pipe



3.2.3 Figure 3.2.2B Typical Brace Layout, Vertical Pipe

3.2.4 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. Pipe-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.

3.2.5 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 3.2.4) to verify the component is adequately secured to the building structural element (if attachment is made using set-screws, etc.) and the brace member.

3.2.6 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. When 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 brace component size used with the component;

3.4.2 Seismic sway brace components that are produced at more than one location shall be identified as the product of a particular location.

3.4.3 The model or type identification shall correspond with the manufacturer's catalog designation and shall uniquely identify the certification agency's mark of conformity.

3.4.4 Markings shall be cast or forged in raised characters, etched or die stamped on the seismic sway brace component.

3.4.5 As an alternative to 3.4.4, a corrosion resistant metal nameplate or a corrosion resistant aluminum adhesive label bearing the same information as stated in Section 3.4.1 shall be considered acceptable if permanently fastened to the seismic sway brace component.

3.4.6 The certification agency's mark of conformity shall be displayed visibly and permanently on the product and/or packaging as appropriate and in accordance with the requirements of the certification agency. The manufacturer shall exercise control of this mark as specified by the certification agency and the certification scheme.

3.4.7 Each required marking listed in Section 3.4.1 shall be legible and durable and applied in any combination of the above methods.

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 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

3.6.1 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 is required. The certificate shall indicate that the calibration was performed against working standards whose calibration is certified and traceable to an acceptable reference standard 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 provider's accreditation certificate as an ISO/IEC 17025 accredited calibration laboratory should be available.

3.6.2 When the inspection equipment and/or environment is not suitable for labels or stickers, other methods such as etching of control numbers on the measuring device are allowed, provided documentation is maintained on the calibration status of thus equipment.

3.7 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 load 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. minimum length of pipe. The testing for building-attached seismic sway brace components shall be performed using an 18 in. 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 certification requirements outlined in this standard.

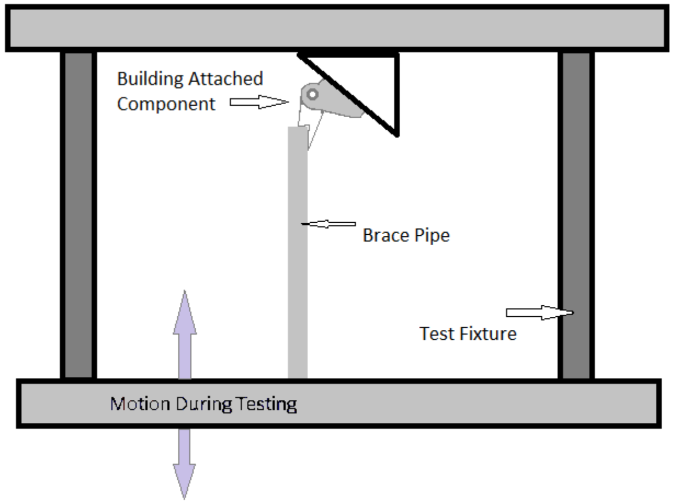
4.1.2 Test/Verification

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 and force is applied in line with the brace member during the tests (see Figure 4.2). The data is then analyzed to determine the equivalent constant cycle loading in the horizontal direction.



4.2.1 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. 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 nominal strength along the brace (R_n) in excess of 1000 pounds (4450N), the initial loading on the sample will be 1000 pounds (4450N). For pipe bracing subassemblies with expected load ratings less than 1000 pounds (4450N), the initial loading on the sample will be 250 pounds (1110N). Other starting loads may be allowed at the certification agency's sole discretion.

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.

$$Force = X \; for \; N \leq 15 \; cycles$$

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

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)

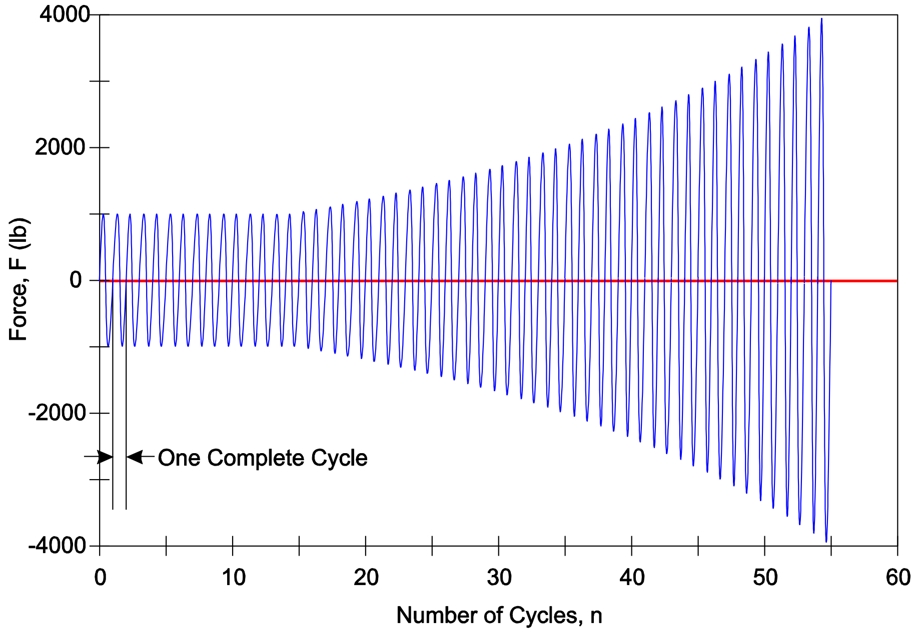


Figure 4.2 Force History Plot (Component Testing)

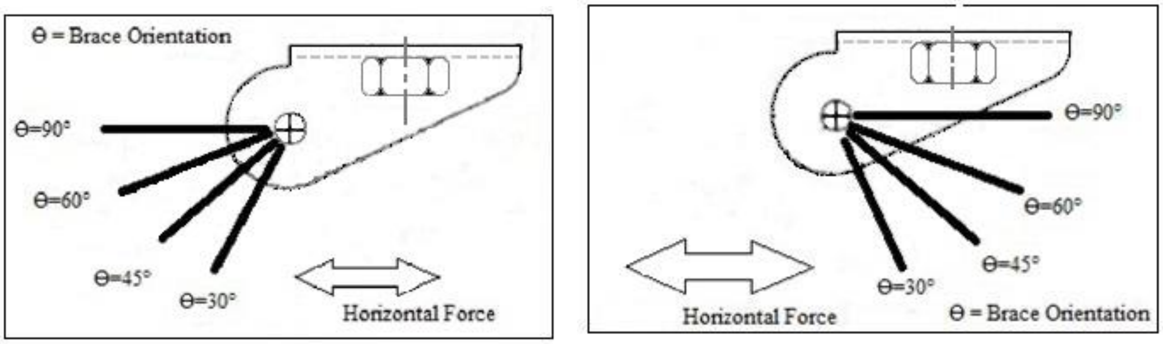
4.2.2.4 Once the sample has been observed to either break, or the deformation limit has been exceeded, the test is complete. Replace the sample with a new sample and repeat the cyclic test twice more, for a total of three tests.

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.

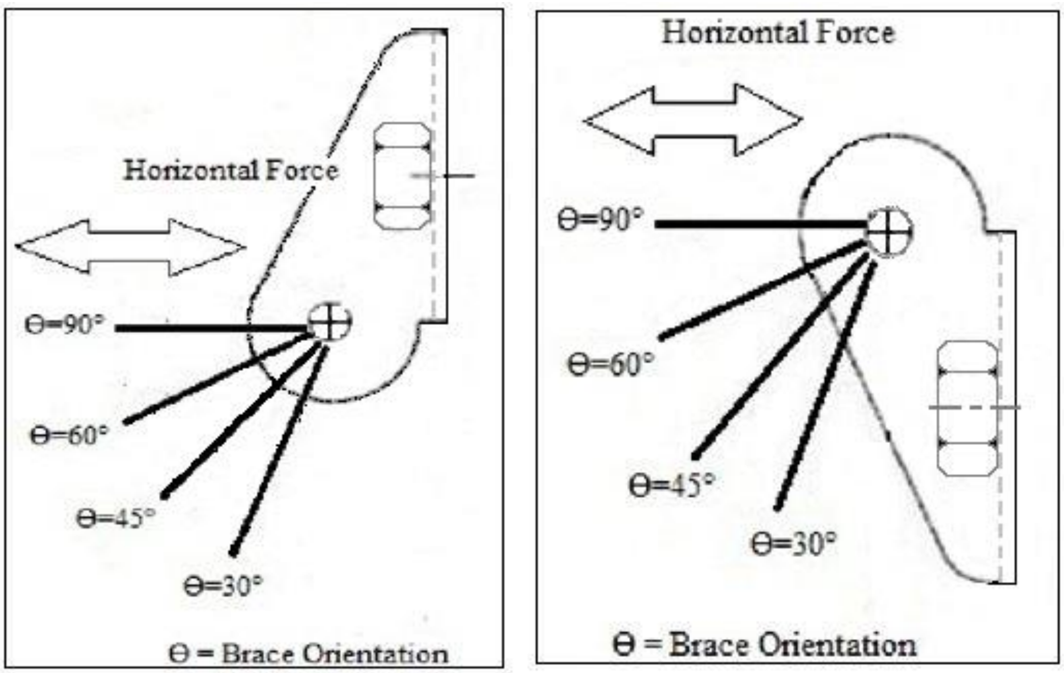
4.2.3 Testing Orientations

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.



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



4.2.3 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 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 (1" sin θ), and commonly used values 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 To determine the horizontal nominal strength (R_{Hn}) to be assigned to a range of brace angles, multiply the nominal strength (R_n) from the test at the lower end of the bracket by the sin of the lower angle and by the sin of the larger angle minus 1. Multiply the horizontal nominal strength (R_n) from the test of the upper angle by the sin of the upper angle and by the sin of the lower angle plus 1. Compare these 4 values of R_{Hn} and assign the lowest R_{Hn} to the entire bracketed range.

4.2.4.4 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 4.2.4.2 divided by a safety factor (Ω). The factor of safety used shall be 2.2

4.2.4.5 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 4.2.4.2 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. .

4.3 Cyclic Tests (Assembly Testing)

The purpose of this testing is to determine the load ratings of a complete seismic sway brace assembly. This testing method may be used for rigid style seismic sway brace assemblies as the resultant load rating will be assigned for the entire assembly. The entire assembly for this style testing is defined as using components of each of the categories shown in the table in Section 3.2.1.

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. 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 displacement for seismic sway brace assembly testing is a maximum of 2 inch (50 mm) in order to account for the allowed deformations of both the building-attached, and piping-attached components. This testing is for an entire assembly, tested as installed within the fixture at each of the installation angles individually, therefore incorporating effect of installation angle as measured from vertical. This way, the limiting deformation is always in the horizontal plane and thus has been shown in the table below as 2 inches (50 mm).

Table 4.3 Limiting Horizontal Deformation for Different Brace Orientations

Installation Angle, Θ	***Limiting Deformation***
30°	2.00 inch (50 mm)
45°	2.00 inch (50 mm)
60°	2.00 inch (50 mm)
90°	2.00 inch (50 mm)

4.3.1 Requirement

The objective of this test is to determine the load that the assembly can withstand for 15 equal amplitude load cycles. Fasteners used to install building-attached components are not included in this rating.

4.3.2 Test/Verification

4.3.2.1 Install the brace assembly in the test fixture (See Figure 4.3.2), and subject it to the following cyclic loading profile until either the sample breaks or exceeds the deformation limits shown in Table 4.3. Record the load 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.

4.3.2.2 For pipe bracing assemblies expected to exceed 2000 pounds (8900N), the initial loading on the sample will be 2000 pounds (8900N). For pipe bracing assemblies not expected to exceed 2000 pounds (8900N), the initial loading on the sample will be 500 pounds (2225N). Other starting loads may be allowed at the certification agency's sole discretion.

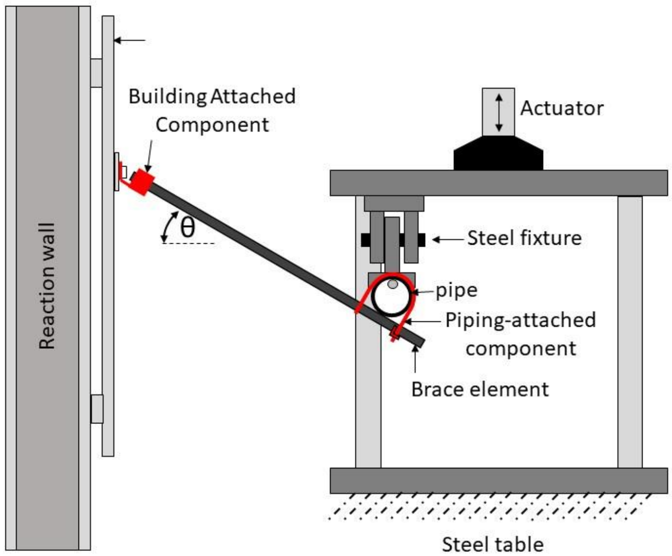


Figure 4.3.2 Test Arrangement for Assembly Testing

4.3.2.3 With the complete brace assembly installed in the test fixture, 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 = 2000 for assemblies with expected ratings greater than 2000 pounds (8900N)
X = 500 for assemblies with expected ratings less than 2000 pounds (8900N)

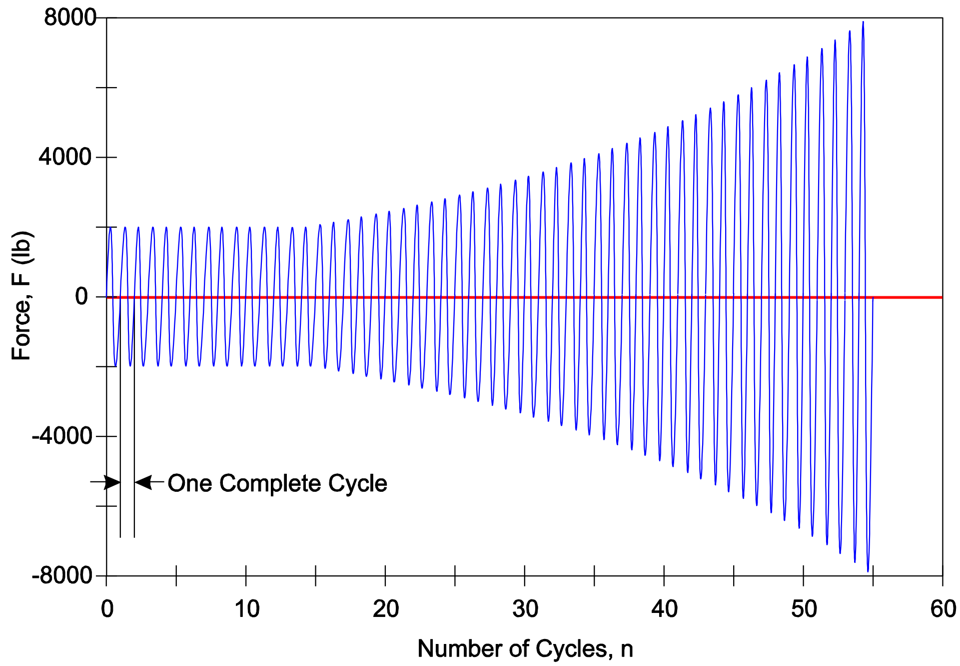


Figure 4.3.2.3 Force History Plot (Assembly Testing)

4.3.2.4 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.

4.3.2.5 The load rating is then found from examining the data and identifying the lowest magnitude load 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. Because the brace in the test is installed at an angle from the direction of the displacement equal to the installation angle, the load determined in this test is the horizontal nominal strength (R_{Hn}).

4.3.2.6 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 4.3.2.5 divided by a safety factor (Ω). The factor of safety used shall be 2.2.

4.3.2.7 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 (RHn) in the horizontal direction found per Section 4.3.2.5 multiplied by a resistance factor (ϕ). The resistance factor (ϕ) shall be 0.65 .

5 OPERATIONS REQUIREMENTS

5.1 Demonstrated Quality Control Program

5.1.1 A quality assurance program is required to assure that subsequent products produced by the manufacturer shall present the same quality and reliability as the specific products examined. Design quality, conformance to design, and performance are the areas of primary concern.

- Design quality is determined during the examination and tests and may be documented in the certification report.
- Continued conformance to this standard is verified by the certifier's surveillance program.
- Quality of performance is determined by field performance and by periodic re-examination and testing.

5.1.2 The manufacturer shall demonstrate a quality assurance program which specifies controls for at least the following areas:

- existence of corporate quality assurance guidelines;
- incoming quality assurance, including testing;
- in-process quality assurance, including testing;
- final inspection and tests;
- equipment calibration;
- drawing and change control;
- packaging and shipping; and
- handling and disposition of non-conforming materials.

5.1.3 Documentation/Manual

There should be an authoritative collection of procedures/policies. It should provide an accurate description of the quality management system while serving as a permanent reference for implementation and maintenance of that system. The system should require that sufficient records are maintained to demonstrate achievement of the required quality and verify operation of the quality system.

5.1.4 Records

To assure adequate traceability of materials and products, the manufacturer shall maintain a record of all quality assurance tests performed, for a minimum period of two years from the date of manufacture.

5.1.5 Drawing and Change Control

- The manufacturer shall establish a system of product configuration control that shall allow no unauthorized changes to the product. Changes to critical documents, identified in the certification report, may be required to be reported to, and authorized by the certification agency prior to implementation for production.
- Records of all revisions to all certified products shall be maintained.

5.2 Surveillance Audit

5.2.1 An audit of the manufacturing facility may be part of the certification agency's surveillance requirements to verify implementation of the quality assurance program. Its purpose is to determine that the manufacturer's equipment, procedures, and quality program are maintained to ensure a uniform product consistent with that which was tested and certified.

5.2.2 Certified products or services shall be produced or provided at, or provided from, location(s) disclosed as part of the certification examination. Manufacture of products bearing a certification mark is not permitted at any other location prior to disclosure to the certification agency.

5.3 Manufacturer's Responsibilities

5.3.1 The manufacturer shall notify the certification agency of changes in product construction, components, raw materials, physical characteristics, coatings, component formulation or quality assurance procedures prior to implementation.

5.4 Manufacturing and Production Tests

5.4.1 Test Requirement No. 1 - *Dimensional Check*

The manufacturer shall measure and record critical component dimensions, material thickness, markings, and threaded connections (as applicable) at the beginning of each production run. Thereafter, these measurements shall be recorded every 4 hours. The number of samples to be measured shall be based on manufacturer's Quality Control Manual, but in no case shall be less than five samples. Measurements shall be compared to the latest revision of the component drawings.

5.4.2 Test Requirement No.2 – *Monotonic Production Test*

The manufacturer shall perform and record results from monotonic tension and compression testing at the beginning of each production run. The installation angle shall be determined by the manufacturer. Values for load, deformation, and mode of failure shall be measured using calibrated equipment and recorded. All tests shall be conducted using the manufacturer's test instructions. The number of samples shall be per the manufacturer's Quality Manual, but in no case shall be less than 5 samples in the tensile and compression loading direction. Manufacturer's test instruction shall clearly identify the pass / fail criteria.

Other methods of production testing will be evaluated by the certification agency on a case by case basis.

6 BIBLIOGRAPHY

ASTM C0033, *Standard Specification for Concrete Aggregates*

ASTM A153/A153M, *Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*

ISO/IEC 17025, *General Requirements for the Competence of Testing and Calibration Laboratories*

OSHA Code of Federal Regulations 29 CFR part 1910, *Occupational Safety and Health Standards*

OSHA Directive Number CPL1, *NRTL Program Policies, Procedures and Guidelines*

APPENDIX A: Sample Listing

Seismic Sway Braces:

Seismic sway braces are used to resist the differential movement between the piping systems and the structure to which it is attached during an earthquake. For clarity, the individual listings below have been grouped under the sub-headings of: Seismic Sway Brace Components; and Seismic Sway Brace Assemblies. The reader is encouraged to read the sub-headings in order to be able to use the information within each section properly.

Seismic Sway Brace Components:

The listings contained within this section are based on testing that was conducted on the building-attached and piping-attached components individually. While included in the certification testing, the brace member used between the building-attached component and the piping-attached component was not included within the scope of certification.

Two or more listed components may be required to form a complete seismic sway brace. The specific components required depend upon the type of building construction and the pipe size.

Horizontal load ratings shown here are Allowable Stress Design (ASD) and are equal the horizontal nominal strength (R_{Hn}) found per Section 4.3.2.5 of FM 1950 divided by a safety factor (Ω) equal to 2.2.

The ratings for a component listed below may be significantly different depending on whether it is installed in the lateral or longitudinal direction. For clarity, all references to lateral and longitudinal used in the listings below are made between the piping and the brace member, and the structural element and the brace member as applicable.

Company Name, Company Address

Model	*Part Description*	*Run Pipe Nominal Size in. (mm)*	*Run Pipe Reference*	*Allowable Horizontal Capacity (F) per Installation Angle, lb (N)*				*Remarks*
				30° - 44°	*45° - 59°*	*60° - 74°*	*75° - 90°*	
A	Loop Brace	2, 2-1/2 (50, 65)	ASTM A53 Sch 40	1200 (5337)	1500 (6672)	1700 (7562)	2000 (8896)	a, d
A	Loop Brace	3, 4 (80, 100)	ASTM A53 Sch 40	1500 (6672)	1600 (7117)	1800 (8006)	2100 (9341)	a, d
B	Angle Bracket		ASTM A53 Sch 40	3000 (13344)	3000 (13344)	3100 (13789)	3500 (15568)	a, b
C	Beam Attachment Assembly	3-6 in. (80-150 mm) Beam with minimum flange 1/4 in. (6.3 mm) or smaller	ASTM A53 Sch 40	2500 (11120)	2500 (11120)	2100 (9341)	1800 (8006)	a, b, c

Notes:

a. FM Approved when installed with 1” Sch. 40 brace pipe.
b. Allowable capacity valid when installed with brace across beam or joist (Lateral bracing installation).
c. Allowable capacity valid when installed with brace along beam or joist (Longitudinal bracing installation).
d. Allowable capacity may be applied to ASTM A795 Schedule 10 pipe.

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).