FM Approvals®

Member of the FM Global Group

Approval Standard for Seismic Sway Brace Components for Automatic Sprinkler Systems

Class Number 1950

February 2002

Foreword

The FM Approvals certification mark is intended to verify that the products and services described will meet FM Approvals' stated conditions of performance, safety and quality useful to the ends of property conservation. The purpose of Approval Standards is to present the criteria for FM Approval of various types of products and services, as guidance for FM Approvals personnel, manufacturers, users and authorities having jurisdiction.

Products submitted for certification by FM Approvals shall demonstrate that they meet the intent of the Approval Standard, and that quality control in manufacturing shall ensure a consistently uniform and reliable product. Approval Standards strive to be performance-oriented. They are intended to facilitate technological development.

For examining equipment, materials and services, Approval Standards:

a) must be useful to the ends of property conservation by preventing, limiting or not causing damage under the conditions stated by the Approval listing; and

b) must be readily identifiable.

Continuance of Approval and listing depends on compliance with the Approval Agreement, satisfactory performance in the field, on successful re-examinations of equipment, materials, and services as appropriate, and on periodic follow-up audits of the manufacturing facility.

FM Approvals LLC reserves the right in its sole judgment to change or revise its standards, criteria, methods, or procedures.

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1. INTRODUCTION

1.1 Purpose

1.1.1 This standard states Approval criteria for rigid seismic sway brace components for automatic sprinkler systems.

1.1.2 FM Approval criteria may include, but are not limited to, performance requirements, marking requirements, examination of manufacturing facility(ies), audit of quality assurance procedures, and a follow-up program.

1.2 Scope

1.2.1 This standard encompasses the design and performance requirements for seismic sway bracing components used in automatic sprinkler systems. The general requirements and performance requirements for seismic sway bracing components apply to the components that are attached to the structural element and the components that attach to the sprinkler piping. Although used in the testing, the component that is attached between the building attached component and the sprinkler pipe attached component is not included within the scope of this standard. In cases where metric sized pipe hanger components are to be examined for Approval, test loads comparable to the United States equivalent shall be used.

1.2.2 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 the failure of the attachment fastener. Therefore, the attachment fastener is not considered to be within the scope of this Approval Standard.

1.2.3 Seismic sway brace components are designed to attach to sprinkler pipe from 1 in. to 12 in. nominal pipe size.

1.2.4 FM Approval standards are intended to verify that the product described will meet stated conditions of performance, safety, and quality useful to the ends of property conservation.

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 Approval standard are contained in Reference 3 as listed in Section 1.8 of this standard.

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 FM Approval. Seismic sway bracing components having characteristics not anticipated by this standard may be Approved if performance equal, or superior, to that required by this standard is demonstrated, 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 Approved if other conditions that adversely affect performance exist or if the intent of this standard is not met.

1.4 Basis for FM Approval

FM Approval 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 by FM Approvals; and as far as practical,
- the durability and reliability of the product.

1.4.2 An examination of the manufacturing facilities and audit of quality control procedures shall be made to evaluate the manufacturer's ability to produce the product which was examined and tested, and the marking procedures used to identify the product. These examinations are repeated as part of the FM Approvals Product Follow-Up Program.

1.5 Basis for Continued Approval

Continued Approval is based upon:

- production or availability of the product as currently Approved;
- the continued use of acceptable quality assurance procedures;
- satisfactory field experience;
- compliance with the terms stipulated in the Approval Agreement;
- satisfactory re-examination of production samples for continued conformity to requirements; and
- satisfactory Facilities and Procedures Audits (F&PAs) conducted as part of FM Approvals' Approved Product Follow-Up Program.

Also, as a condition of retaining Approval, manufacturers may not change a product or service without prior authorization by FM Approvals.

1.6 Effective Date

The effective date of an Approval standard mandates that all products tested for Approval after the effective date shall satisfy the requirements of that standard. Products Approved under a previous edition shall comply with the new version by the effective date or forfeit Approval.

The effective date of this standard is February 1, 2002 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. 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 American National Standards Institute (ANSI)/Institute of Electrical and Electronics Engineers (IEEE)/American Society for Testing Materials (ASTM) SI 10-97, *Standard for Use of the International System of Units (SI): The Modern Metric System.*

1.8 Applicable Documents

The latest versions of the following standards, test methods, and practices are referenced in this standard:

1. ANSI/IEEE/ASTM SI 10-97, *Standard for Use of the International System of Units (SI): The Modern Metric System*.
2. FM Global Property Loss Prevention Data Sheets
3. P. K. Malhotra, Paul Senseny, Antonio Braga and Roger Allard, *Test Protocol for Sprinkler-pipe Seismic-brace Components*, Proceedings of 7th National Conference on Earthquake Engineering, Boston, MA, July 2002.

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. When the authority is FM Global, such locations are termed "FM Global Accepted." Acceptance is based upon an overall evaluation of the installation. Factors other than the use of Approved equipment impact upon the decision to accept, or not to accept. Acceptance is not a characteristic of a product. It is installation specific. A product accepted for one installation may not be acceptable elsewhere. (Contrast with Approved.)

Approval Mark

The FM Approval Mark is detailed in Appendix B. Its use is mandatory on all components of Approved seismic sway braces. These registered marks cannot be used except as authorized by FM Approvals via the granting of Approval to a specific product.

Approved

This term refers to products Approved by FM Approvals. Such products are listed in the *Approval Guide*, a publication of FM Approvals, issued annually, or one of the supplements. All products so listed have been successfully examined by FM Approvals, and their manufacturers have signed and returned an Approval Agreement to FM Approvals. This form obligates the manufacturer to allow re-examination of the product and audit of facilities and procedures at FM Approvals' discretion. It further requires the manufacturer not to deviate from the as-Approved configuration of the product without review by and agreement of FM Approvals. Approval is product specific.

Attachment Fastener

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

Corrosion Resistant

Having resistance to corrosion equal to or exceeding that of bronze alloy having a minimum copper content of 80 percent, or constructed of Series 300 Stainless Steel.

Light Wall Pipe

Pipe which has a combination of outside diameter and wall thickness not suitable for threading and not conforming to the dimensional pipe schedules for the country of intended use. Normal end connections for light wall pipe are: welded, roll grooved, and plain end. This pipe is also referred to as ‘‘Flow’’ pipe or ‘‘Schedule 7’’.

Seismic Sway Brace

An assembly consisting of three components (as described below) intended to minimize the differential movement between the sprinkler system piping and the structure to which it is attached during an earthquake. 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 at the horizontal pipe. Four-way sway bracing resists differential movement in all horizontal directions.

Seismic Sway Brace Components

The three components of a seismic sway brace include:

Building Attached Component

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

Connection Component

Usually a length of pipe, angle iron, or strut that connects the building attached component to the piping attached component.

Piping Attached Component

A component of a seismic sway brace intended to provide a means of attachment to the sprinkler piping.

2. GENERAL INFORMATION

2.1 Product Information

2.1.1 A seismic sway brace usually consists of three components combined to make a functional assembly. One part of the sway brace attaches to a structural element of the building, another part is attached to the sprinkler piping, and a third component, usually a section of pipe or angle iron, connects the building attached component to the pipe attached component. Seismic sway bracing is used to minimize the differential movement between the sprinkler system piping and the structure to which it is attached during an earthquake. 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 horizontal pipe. 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 Approval Application Requirements

To apply for an Approval examination the manufacturer, or its authorized representative, should submit a request to:

Hydraulics Group Manager
FM Approvals Hydraulics Laboratory
743A Reynolds Road
West Glocester RI 02814
U.S.A.

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

- A complete list of all models, types, sizes, and options for the products or services being submitted for Approval consideration;
- Sprinkler piping sizes, (minimum of Schedule 10 and Schedule 40);
- Structural brace types, (i.e. pipe, strut, 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;
- Brochures, sales literature, specification sheets;
- Installation, operation and maintenance procedures; and,
- The number and location of manufacturing facilities.

All documents shall be part of a controlled system 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 documents shall be provided with English translation.

2.3 Requirements for Samples for Examination

Following set-up and authorization of an Approval examination, the manufacturer shall submit samples for examination and testing. Sample requirements are to be determined by FM Approvals following review of the preliminary information. Sample requirements may vary depending on design features, results of prior testing, and/or the scope of the Approval examination. It is the manufacturer's responsibility to submit samples representative of production. Any decision to use data generated utilizing prototypes is at the discretion of FM Approvals. In the event that a component feature prevents the use of existing fixtures, the manufacturer shall supply a suitable test fixture to allow for the evaluation of the component.

3. GENERAL REQUIREMENTS

3.1 Review of Documentation

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.

3.2 Physical or Structural Features

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

Pipe Attached Components	*Building Attached Components*
Pipe Clamp	Swivel, Threaded or Non-Threaded
U-type Clamp	Rigid Brace
	Angle Brace

3.2.2 Sprinkler Pipe Attached Sway Brace Components

Sprinkler pipe attached sway brace components shall be provided with a visual means to verify that the component is adequately secured to the sprinkler pipe 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, 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. Sprinkler pipe-attached seismic sway brace components shall have adequate strength to withstand the loads for a specified number of cycles at stated test frequencies. The component shall not break or deform more than allowed limits.

3.2.3 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 loads for a specified number of cycles at stated frequencies. The component shall not break or deform more than allowed limits. Building-attached components shall be provided with a visual means (See Section 3.2.2) to verify the component is adequately secured to the building structural element (if attachment is made using set-screws, etc.) and the brace pipe or component.

3.3 Design Requirements

3.3.1 To provide adequate durability, any ferrous metal part that is 1/8 in. (3.18 mm) thick or less shall be plated with a non-ferrous material to at least 5.0×10^{-4} in. (0.0127 mm) thickness or otherwise coated to retard oxidation of the base material. Coatings shall withstand the effects of shipping, assembly and installation, weathering and corrosion.

3.3.2 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.

3.3.3 Threaded Components

To ensure adequate strength and long term durability, other threaded components used in seismic sway brace components shall have a threaded engagement length of at least the diameter of the connecting member.

3.4 Materials

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.

3.5 Markings

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

- manufacturer's name and address or marking traceable to the manufacturer;
- model or type designation;
- the maximum pipe size used with the component; and,
- FM Approval Mark, (see Appendix B).

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

3.5.3 The model or type identification shall correspond with the manufacturer's catalog designation and shall uniquely identify the product as Approved. The manufacturer shall not place this model or type identification on any other product unless covered by a separate agreement.

3.5.4 The FM Approval Mark (see Appendix B) shall be displayed visibly and permanently on the product. The manufacturer shall not use this Mark on any other product unless such product is covered by separate agreement with FM Approvals.

3.5.5 All markings shall be legible and durable.

3.6 Manufacturer's Installation and Operation Instructions

Installation and maintenance instructions, including any special dimension requirements, shall be furnished by the manufacturer. Installation instructions shall include a listing of the manufacturer's recommended fasteners for guidance in the selection of fasteners for building attached components. Installation instructions shall be provided with each shipment of seismic sway brace components.

3.7 Calibration

All examinations and tests performed in evaluation to this standard shall use calibrated measuring instruments traceable and certified to acceptable national or international standards, such as National Institute of Standards and Technology (NIST) of the United States. Copies of calibration certifications will be required at the time of testing.

4. PERFORMANCE REQUIREMENTS

The objective of these tests is to determine the maximum load a component can resist for 15 loading 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 monotonic tension, monotonic compression, and cyclic tests. The monotonic tension and monotonic compression tests shall be performed to gather data for the cyclic tests. The load rating shall be determined primarily from the results of the cyclic tests. Due to the variety of test equipment available for the cyclic tests, this standard is written to accommodate both force-control and deformation-control test equipment. The minimum requirements for force-control and deformation-control equipment have been outlined below. It is not necessary to obtain load ratings using both methods of control, as either will provide satisfactory results.

The testing for piping-attached seismic sway brace components shall be performed using an 8 inch nominal length of sprinkler pipe. The testing for building-attached seismic sway brace components shall be performed using an 18 inch maximum nominal length of brace pipe. The load frame shall be equipped with a calibrated load-cell and a deformation-measuring device. The load frame shall be capable of imparting a minimum of 3.5 inch (89 mm) deformation in monotonic tension and monotonic compression, and ±1 inch (25 mm) deformation under cyclic conditions at 3 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 FM Approvals requirements.

4.1.2 Test/Verification

A sample of each component shall be examined and compared to drawings and specifications. It shall be verified that the sample conforms to the physical and structural requirements described in Section 3, General Requirements.

4.2 Monotonic Tension Test

4.2.1 Requirement

The objective of the monotonic tension test is to gather data for the cyclic tests. Samples of each size and style of seismic sway-brace components and sub-assemblies shall be subjected to monotonic tension until either the sample fails, or the deformation exceeds 3.5 inch (89 mm). The monotonic tension test shall be performed for four orientations: $\theta = 30°, 45°, 60°$, and 90° unless it is obvious that the stress distribution in the component is independent of orientation. In the event that the seismic sway brace component can be installed in different orientations for the same installation angle (see Figure 4.2.1B), the monotonic tension test shall be conducted in multiple orientations to determine the effect on the recorded loads. Orientations that produce the lowest loads shall be evaluated in the cyclic tests.

Due to the influence that pipe wall thickness has on the load rating for a given component, the monotonic tension testing will be performed using schedule(s) 10 and 40 steel pipe as standard. At the manufacturer's option, the monotonic tension test may be performed with the schedule 10 or 40 steel pipe as either the sprinkler pipe and/or the brace pipe. Load ratings obtained using schedule 10 pipe may be used for schedule 40 pipe but not vice versa. Furthermore, data collected using Lightwall pipes in either the sprinkler pipe or brace pipe capacities, shall be limited to the specific make and model of Lightwall pipe.

Figure 4.2.1A – Seismic Sway Brace Orientations

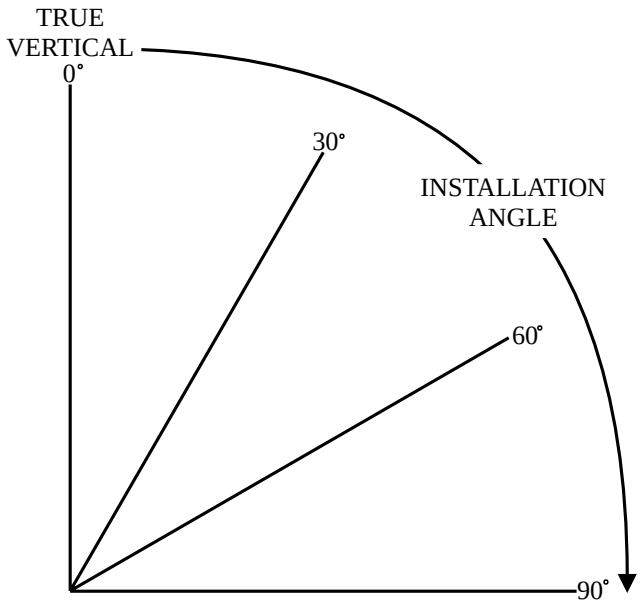
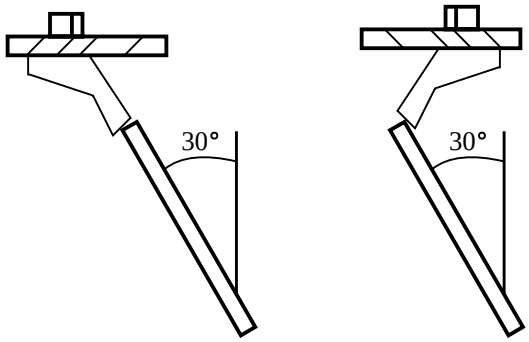


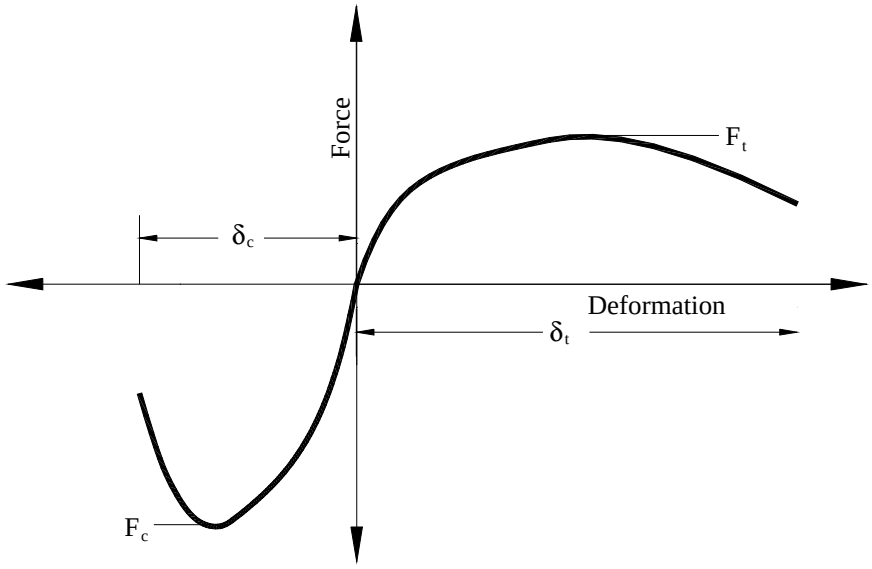
Figure 4.2.1B – Example of Different Seismic Sway Brace Orientations for Same Installation Angle



4.2.2 Test/Verification

Pre-set the test fixture to the required installation angle (θ = 30°,45°, 60°, or 90°). Assemble the seismic sway-brace component or sub-assembly in accordance with the manufacturer's specifications, and install the test assembly into the test fixture. Subject the test assembly to monotonic tension loading until either the sample fails, or the deformation exceeds 3.5 inches (89 mm). The maximum load shall be designated as F_t (see Figure 4.2.2). If the load continues to increase after 3.5 inches (89 mm) of deformation, the load at 3.5 inches (89 mm) deformation shall be regarded as F_t. The deformation at which the sample breaks (load drops to zero) shall be designated as δ_t (see Figure 4.2.2). If the sample does not break prior to 3.5 inches (89 mm) deformation, δ_t shall be assigned a value of 3.5 inches (89 mm).

Figure 4.2.2 – Monotonic Force - Deformation Sketch #1



4.3 Monotonic Compression Test

4.3.1 Requirement

The objective of the monotonic compression test is to gather data for the cyclic tests. Samples of each size and style of seismic sway-brace components shall be subjected to monotonic compression loading until either the sample fails, or the deformation exceeds 3.5 inches (89 mm). The monotonic compression test shall be performed for four orientations: θ = 30°, 45°, 60°, and 90° unless it is obvious that the stress distribution in the component is independent of orientation. In the event that the seismic sway brace component can be installed in different orientations for the same installation angle, the monotonic compression test shall be conducted in multiple orientations to determine the effect on the recorded loads. Orientations that produce the lowest loads shall be evaluated in the cyclic tests.

Due to the influence that pipe wall thickness has on the load rating for a given component, the monotonic compression testing will be performed using schedule(s) 10 and 40 steel pipe as standard. At the manufacturer's option, the monotonic compression test may be performed with the schedule 10 or 40 steel pipe as either the sprinkler pipe and/or the brace pipe. Load ratings obtained using schedule 10 pipe may be used for schedule 40 pipe but not vice versa. Furthermore, data collected using Lightwall pipes in either the sprinkler pipe or brace pipe capacities, shall be limited to the specific make and model of Lightwall pipe.

4.3.2 Test/Verification

Pre-set the test fixture to the required installation angle (θ = 30°, 45°, 60°, or 90°). Assemble the seismic sway-brace component or sub-assembly in accordance with the manufacturer's specifications, and install the test assembly into the test fixture. Subject the test assembly to monotonic compression loading until either the sample fails, or the deformation exceeds 3.5 inches (89 mm). The maximum load shall be designated as F_c (see Figure 4.2.2). If the load continues to increase after 3.5 inches (89 mm) deformation, the load at 3.5 inches (89 mm) deformation shall be regarded as F_c. The deformation at which the sample breaks (load drops to zero) shall be designated as δ_c (see Figure 4.2.2). If the sample does not break prior to 3.5 inches (89 mm) deformation, δ_c shall be assigned a value of 3.5 inches (89 mm).

4.4 Cyclic Testing (Deformation-Control)

The monotonic tension and monotonic compression tests shall be completed before conducting the cyclic tests. Based on the results of the cyclic tests, the seismic sway-brace components or sub-assemblies shall be assigned horizontal load ratings at installation angles of θ = 30°, 45°, 60°, and 90°.

The following tests shall be performed using an appropriately sized load frame with the table motion in deformation-control.

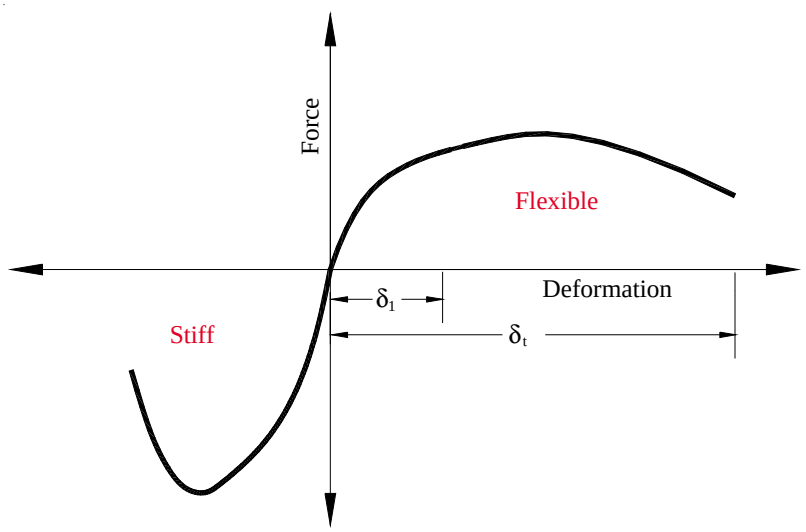
4.4.1 Requirements

The objective of these tests is to determine the maximum load a component can resist for 15 loading cycles without breaking or exceeding the deformation limits listed in Table 4.4.2.2.

4.4.2 Tests/Verification

4.4.2.1 For the selected orientation (θ = 30°, 45°, 60°, or 90°), plot the results from monotonic tension and compression tests performed in Sections 4.2 and 4.3 on an X - Y (Deformation - Force) coordinate chart. Once the data has been plotted on the Deformation - Force coordinates, the flexible loading direction shall be identified by the more gradual slope of the data curve (see Figure 4.4.2.1). Note that the flexible loading direction may be in tension or compression, depending on the component design.

Figure 4.4.2.1 – Monotonic Force - Deformation Sketch #2



4.4.2.2 From the flexible loading direction (tension or compression), estimate the test deformation δ_1 the sample can resist for 15 cycles. As an initial estimate, set δ_1 equal to the smaller of one third of the maximum deformation (δ_t or δ_c) and $\bar{\delta}$ (from Table 4.4.2.2). Once the value for the test deformation δ_1 has been found, label the Deformation - Force plot as shown in Figure 4.4.2.1.

Table 4.4.2.2 – Limiting Component Deformation Along the Brace for Different Brace Orientations

Installation Angle, θ	*Limiting Deformation, $\bar{\delta}$*
30°	0.50 inch (12 mm)
45°	0.71 inch (18 mm)
60°	0.87 inch (22 mm)
90°	1.00 inch (25 mm)

4.4.2.3 Using the Deformation – Force plot, follow along the data curve in the flexible direction to determine the force *F* that corresponds to the test deformation δ_1 (see Figure 4.4.2.3A). Record the force *F* and then follow along the stiffer loading direction curve until the value for force *F* is located (refer to Figure 4.4.2.3B). Once the value of force *F* has been found on the stiffer loading curve, determine the deformation value that corresponds to this point. This deformation point can be identified as deformation δ_2 (see Figure 4.4.2.3B).

Figure 4.4.2.3A – Monotonic Force - Deformation Sketch #3

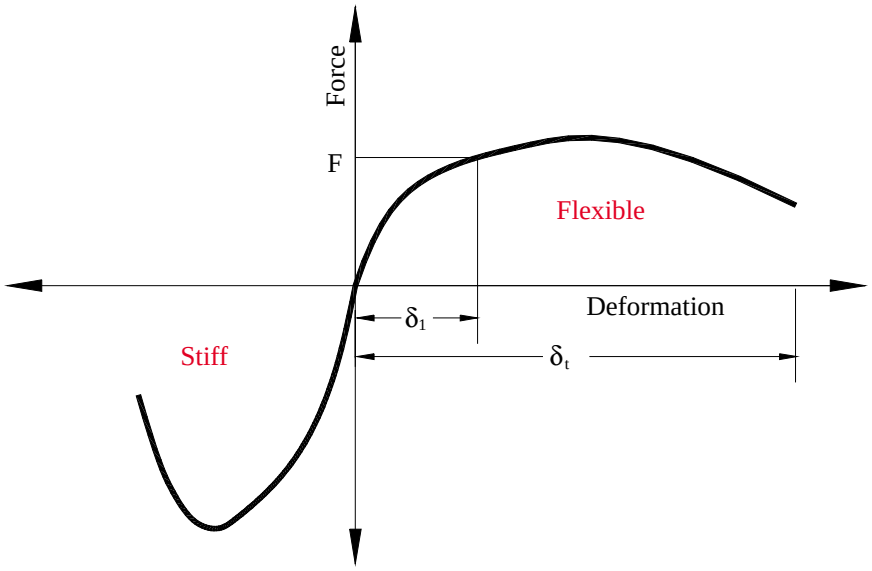
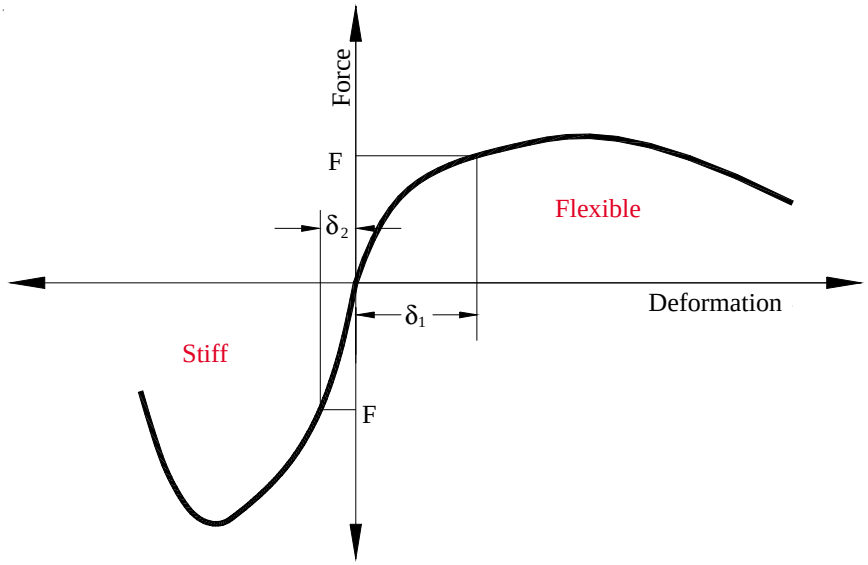
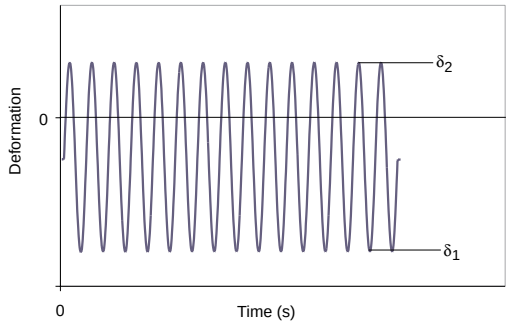


Figure 4.4.2.3B – Monotonic Force – Deformation Sketch #4



4.4.2.4 Subject a new sample to 15 cycles of un-symmetric deformation history (δ_1 on the flexible side and δ_2 on the stiff side) at 0.1 Hz (3 Hz, if the component is friction-based). See Figure 4.4.2.4.

Figure 4.4.2.4 – Applied Deformation History in Deformation-Control Test



4.4.2.5 Read the minimum force amplitude (tension or compression) during 15 cycles. If the specimen breaks before the 15 cycles are completed, lower the estimate and return to Step 3. On an X-Y chart, mark the force amplitude corresponding to the deformation δ_1 (Figure 4.4.2.5B). See Figure 4.4.2.5A.

Figure 4.4.2.5A – Measured Force-History In Deformation-Control Test

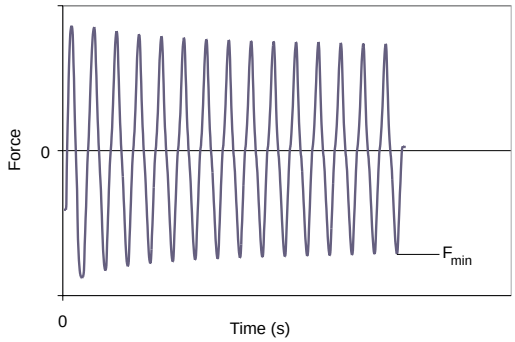
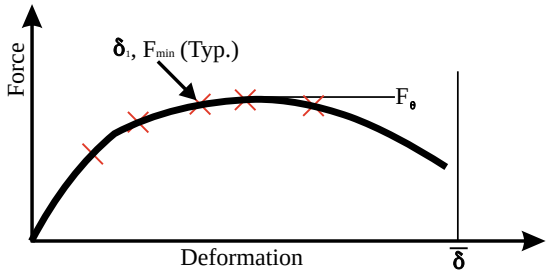
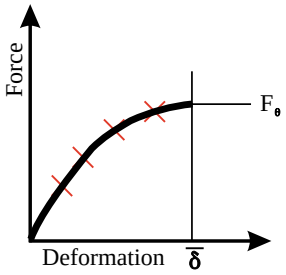


Figure 4.4.2.5B – Cyclical Force Deformation Plot



Sample Breaks Before Reaching Limiting Deformation, $\overline{\delta}$



Sample Does not Break at the Limiting Deformation, $\overline{\delta}$

4.4.2.6 If $\delta_1 < \bar{\delta}$, obtain more points on the cyclic force-deformation chart (Figure 4.4.2.5B), by increasing δ_1 by about 10 percent each time (and appropriately adjusting δ_2 to keep the force history symmetric), until the sample breaks or δ_1 approaches the limiting deformation $\bar{\delta}$. Use a new sample for each test.

4.4.2.7 Designate the highest load on the force-deformation chart (Figure 4.4.2.5B) as F_θ. Repeat the test two more times at the deformations, (δ_1 and δ_2), corresponding to F_θ and designate the lowest of three load values as F_θ. If F_θ is greater than two-thirds of the smaller of F_t and F_c, set F_θ equal to two-thirds of the smaller of F_t and F_c.

4.4.2.8. The horizontal load rating at θ orientation is $H_\theta = F_\theta \cdot \sin \theta$.

4.4.2.9 Repeat steps 1 to 8 for all four orientations. Four horizontal load ratings shall be assigned to the specimen (H_{30}, H_{45}, H_{60}, and H_{90}).

4.5 Cyclic Testing (Force-Control)

The monotonic tension and monotonic compression tests shall be completed before conducting the cyclic tests. Based on the results of cyclic tests, the seismic sway-brace components or sub-assemblies shall be assigned horizontal load ratings at installation angles of θ = 30°, 45°, 60°, and 90°.

The following tests shall be performed using an appropriately sized load frame with the table motion in force-control.

4.5.1 Requirements

The objective of these tests is to determine the maximum load a component can resist for 15 loading cycles without breaking or exceeding the deformation limits listed in Table 4.4.2.2.

4.5.2 Test/Verification

4.5.2.1 For the selected orientation (θ = 30°, 45°, 60°, or 90°), plot the results from monotonic tension and compression tests performed in Sections 4.2 and 4.3 on an X-Y (Deformation-Force) coordinate chart. Once the data has been plotted on the Deformation-Force coordinates, the flexible loading direction shall be identified by the more gradual slope of the data curve (see Figure 4.4.2.1). Note that the flexible loading direction may be in tension or compression, depending on the component design.

4.5.2.2 Estimate the maximum force F the sample can resist for 15 cycles without breaking or deforming more than the limiting deformation $\bar{\delta}$ listed in Table 4.4.2.2. As a first estimate, read force F corresponding to the deformation, which is the lesser of one third the maximum deformation on flexible side (δ_t or δ_c) and 0.9 $\bar{\delta}$. Round the force F to the nearest 100 lb (500 N, if SI units are used).

4.5.2.3 Subject a new sample to 15 load cycles of amplitude $\pm F$ at 0.1 Hz (3 Hz, if the sample is friction-based); see Figure 4.5.2.3A. Record the maximum deformation during 15 cycles (tension or compression side); see Figure 4.3.2.3B. On an X-Y chart, mark the force amplitude versus deformation (Figure 4.5.2.3C).

Figure 4.5.2.3A – Applied Force History in Force-Control Test

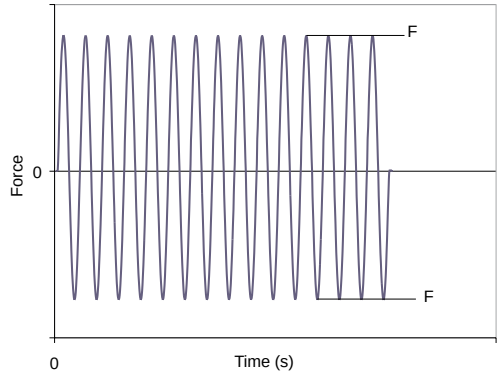


Figure 4.5.2.3B – Measured Deformation History in Force-Control Test

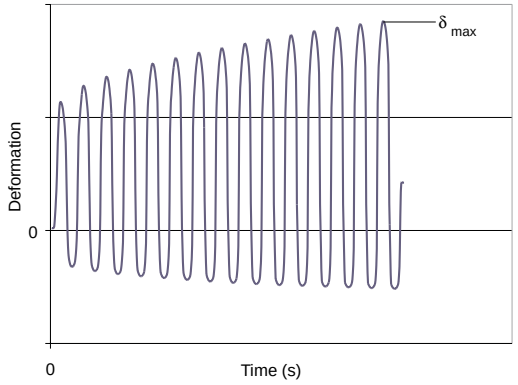
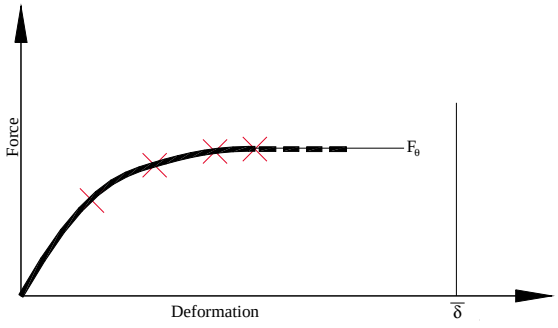
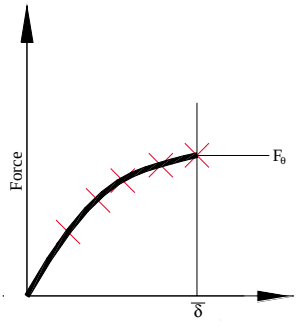


Figure 4.5.2.3C – Cyclical Force - Deformation Plot



Sample Breaks Before Reaching Limiting Deformation, $\overline{\delta}$



Sample Does not Break at the Limiting Deformation, $\overline{\delta}$

4.5.2.4 If the deformation is less than $\bar{\delta}$, repeat the test on new samples by increasing the force amplitude in steps of 100 lb (500 N, if SI units are used), until the sample breaks or the maximum deformation is greater than the limiting deformation $\bar{\delta}$ (Table 4.4.2.2). Mark force-deformation points on the X-Y chart (Figure 4.5.2.3).

4.5.2.5 From the force-deformation chart (Figure 4.5.2.3C), read the maximum force at or less than deformation $\bar{\delta}$. Repeat the test two more times on new samples with the same force amplitude. If the observed maximum deformation in these two tests is also less than the limiting deformation $\bar{\delta}$, designate the force amplitude at this orientation as F_θ. If the observed deformation in any of these two tests exceeds the limiting deformation $\bar{\delta}$ or the sample breaks, keep repeating the test on new samples by reducing the force amplitude in steps of 100 lb (500 N, if SI units are used), until a force amplitude is obtained which is resisted by three consecutive samples without exceeding the limiting deformation, $\bar{\delta}$. Designate this force amplitude as F_θ.

4.5.2.6 If F_θ is greater than two thirds of the smaller of F_t and F_c, set F_θ equal to two thirds of the smaller of F_t and F_c. The horizontal load rating at θ orientation shall be $H_\theta = F_\theta \cdot \sin \theta$.

4.5.2.7 Repeat steps 1 to 6 for all four orientations. Four horizontal load ratings shall be assigned to the specimen (H_{30}, H_{45}, H_{60}, and H_{90}).

4.6 Coating Evaluation

4.6.1 Requirements

To provide adequate durability, ferrous metal parts ⅛ in. (3.18 mm) thick or less shall be plated with a nonferrous material to a minimum 0.0005 in. (0.0127 mm) thickness or otherwise coated to retard oxidation of the base material. Coatings shall withstand the effects of shipping, assembly, and installation.

4.6.2 Test/Verification

Thickness of corrosion resistant coatings shall be measured by means of sectioning of sample components and microscopic examination of the cross-section in as many areas as judged necessary after review of each part. All corrosion-resistant coatings shall be visually inspected for continuity, adhesion, and durability.

Any discontinuous coatings shall be evaluated by subjecting three samples to a 5 percent salt spray (fog) environment as specified by ASTM B117-1990, Standard for Salt Spray (Fog) Testing for a duration of 10 days. After exposure, the samples shall be allowed to dry for a period of two to four days. At the conclusion of the test, the corrosion resistant coating shall not have lifted, or otherwise increased the exposure area of the unprotected base material of the component. The effect of coating degradation as a result of this test shall be established by subjecting the exposed components to monotonic tension testing. Results for these tests shall be compared to those from Section 4.2. Any significant reduction in observed test load will be considered a failure.

4.7 Test Procedure

Seismic sway brace component testing may be performed by an outside laboratory, or at the manufacturer's facility at the discretion of FM Approvals. FM Approvals shall specify the range of tests to be conducted, witness the testing and obtain the data, and obtain copies of the calibration certificates. In the event that testing is performed at an outside laboratory, testing may be combined with other manufacturers' products. Therefore, if a manufacturer requests to witness testing, additional time may be required.

4.8 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 FM Approvals.

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

5. OPERATIONS REQUIREMENTS

A quality control program is required to assure that subsequent seismic sway brace components produced by the manufacturer at an authorized location shall present the same quality and reliability as the specific seismic sway brace components examined. Design quality, conformance to design, and performance are the areas of primary concern. Design quality is determined during the Approval examination and tests, and is covered in the Approval Report. Conformance to design is verified by control of quality and is covered in the Facilities and Procedures Audit (F&PA). Quality of performance is determined by field performances and by periodic re-examination and testing.

5.1 Demonstrated Quality Control Program

5.1.1 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-conformance materials.

In order to assure adequate traceability of materials and products, the manufacturer shall maintain records of all quality control tests performed for a minimum period of two years from the date of manufacture.

5.1.2 Documentation/Manual

There should be an authoritative collection of procedures and policies. Such documentation shall 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.

5.1.3 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 Approval Report must be reported to, and authorized by, FM Approvals prior to implementation for production. The manufacturer shall assign an appropriate person or group to be responsible for reporting proposed changes to Approved or Listed products to FM Approvals before implementation. The manufacturer shall notify FM Approvals of changes in the product or of persons responsible for keeping FM Approvals advised by means of FM Approvals' Form 797, Approved Product Revision Report or Address/Contact Change Notice. Records of all revisions to all Approved products shall be maintained.

5.2 Facilities and Procedures Audit (F&PA)

5.2.1 An audit of the manufacturing facility is part of the Approval investigation to verify implementation of the quality control program. Its purpose is to determine that the manufacturer's equipment, procedures, and quality program are maintained to insure a consistently uniform and reliable product. Initial inspections of facilities already producing similar products may be waived at the discretion of FM Approvals.

5.2.2 Unannounced follow-up inspections shall be conducted at least annually by FM Approvals, or its designate, to determine continued compliance. More frequent audits may be required by FM Approvals.

5.2.3 The client shall manufacture the product or service only at the location(s) audited by FM Approvals and as specified in the Approval Report. Manufacture of products bearing the FM Approval mark is not permitted at any other location without prior written authorization by FM Approvals.

5.3 Manufacturer's Responsibilities

The manufacturer shall notify FM Approvals of changes in product construction, design, components, raw materials, physical characteristics, coatings, component formulation or quality assurance procedures prior to implementation of such changes.

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 used to establish the baseline test values shall be provided by the manufacturer at the time of initial plant audit, or Approval examination for those companies already subjected to annual audits. Values for load, deformation, and mode of failure (if observed) shall be measured using calibrated equipment and recorded. All tests are to be performed using the manufacturer's test procedures. The test procedures must be clearly documented, and shall identify the manufacturer's name, document number, title, date of last revision, and revision level. Production test values shall be compared to baseline values established during the initial Approval examination, and shall be generated using the manufacturer's test equipment. The allowed variation between the production test values and the baseline test values shall be ±10 percent based on one orientation angle. The number of test samples shall be in accordance with the manufacturer's Quality Control Manual, but in no case shall be less than five samples for both monotonic tension and compression loading directions.

Other methods of production testing will be evaluated by FM Approvals on a case-by-case basis.

APPENDIX A

UNITS OF MEASUREMENT

LENGTH: in. - ‘‘inches’’; (mm - ‘‘millimeters’’)
mm = in. × 25.4

ft - ‘‘feet’’; (m - ‘‘meters’’)
m = ft × 0.3048

FORCE: lb_f - ‘‘pounds force’’; (N - ‘‘Newtons’’)
lb_f = N × 4.4482

MASS: lb - ‘‘pounds’’; (kg - ‘‘kilograms’’)
lb = kg × 0.4536

APPENDIX B

APPROVAL MARKS

REPRODUCTION ART: FM Approval Marks

For use on nameplates, in literature, advertisements, packaging and other graphics.

1) The FM Approvals diamond mark is acceptable to FM Approvals as an Approval mark when used with the word ‘‘Approved.’’

2) The FM Approval logomark has no minimum size requirement, but should always be large enough to be readily identifiable.

3) Color should be black on a light background or a reverse may be used on a dark background.

For Cast-On Marks

4) Where reproduction of the mark described above is impossible because of production restrictions, a modified version of the diamond is suggested. Minimum size specifications are the same as for printed marks. Use of the word ‘‘Approved’’ with this mark is optional.

NOTE: These Approval marks are to be used only in conjunction with products or services that have been FM Approved. The FM Approval marks should never be used in any manner (including advertising, sales or promotional purposes) that could suggest or imply FM Approval or endorsement of a specific manufacturer or distributor. Nor should it be implied that Approval extends to a product or service not covered by written agreement with FM Approvals. The Approval marks signify that products or services have met certain requirements as reported by FM Approvals.

Additional reproduction art is available through

FM Approvals
P.O. Box 9102,
Norwood, Massachusetts 02062
U.S.A.

APPENDIX C

SAMPLE LISTING

Company Name, Company Address

Product Designation	*Component Description*	*Horizontal Load Rating, lb_f (N)*			*Approved for Use With*	*Remarks*
		Installation Angle (†)				
		30° - 44°	45° - 59°	60° - 90°		
XY	Angle Bracket	2000 (8895)	1500 (6670)	3000 (13 345)	– – – –	a
1-XZ	Loop Brace	1000 (4450)	1500 (6670)	2000 (8895)	XY	b
4-XZ	Loop Brace	2500 (11 120)	2000 (8895)	3000 (13 345)	XY	c

NOTE: †. Installation angle is measured from vertical direction.
a. Approved when used with 1¼ inch NPS Schedule 10 or heavier steel brace pipe.
b. Approved when used with 2 through 4 inch NPS Schedule 40 steel sprinkler pipe.
c. Approved when used with 5 through 8 inch NPS Schedule 10 and heavier steel sprinkler pipe.