### AGENDA
Standards Council Meeting
Hyatt Regency Boston
One Avenue deLafayette
Boston, Massachusetts 02111
617-912-1234

August 10-12, 2022

| 22-8-1 | Report of the Committee Membership Task Group (J. Quiter, Chair). |
| 22-8-1-a | Act on pending applications for Committee Members. No Attachment. |
| 22-8-1-b | Consider the request AFSA for reconsideration of applicants to the Technical Committee on Electronic Computer Systems (ELT-AAA). No Attachment. |
| 22-8-1-c | Consider the request of Lilla Rodriguez for reconsideration of non-reappointment to the Technical Committee on Record Protection (REA-AAA) No Attachment. |
| 22-8-1-d | Review of Multi-Representative policy and status on NFPA committees. No Attachment |
| 22-8-1-e | Discuss organization instructed vote classifications. No Attachment |
| 22-8-2 | Report of the Policy and Procedures Task Group (J. Foisel, Chair). No Attachment |
| 22-8-3 | Report of the April 2022 Minutes. No Attachment |

### ISSUANCE OF STANDARDS
(Including Approvals and Amendments)

| 22-8-4 | Act on the issuance of NFPA 25, Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems, with an issuance date of August 12, 2022, and an effective date of September 1, 2022, as acted on at the NFPA Technical Meeting, with five amendments and no appeals. |
| 22-8-4-a | **CAM 25-3:** Accept an Identifiable Part of Committee Comment No. 3. CAM 25-3 passed vote of the participating Membership during the NFPA Technical Meeting. **PASSED** TC Ballot – 44 voting members/35 agree/4 disagree/0 abstained/5 ballots not returned. See Attachment 22-8-4-a |
| 22-8-4-b | **CAM 25-10:** Reject Second Revision No. 4. **No Ballot Necessary per NFPA Regulations** See Attachment 22-8-4-b |
| 22-8-4-c | **CAM 25-16:** Reject Second Revision No. 2. **No Ballot Necessary per NFPA Regulations** See Attachment 22-8-4-c |
| 22-8-4-c-1 | **Follow-Up Motion to CAM 25-16:** Reject an Identifiable Part of Second Revision No. 13 (Table 5.1.1.2. Under “inspection”, line 22 which states: ‘Sprinklers (concealed) frequency every five years’ and referenced paragraph 5.2.1.1.1).  **No Ballot Necessary per NFPA Regulations**  
See Attachment 22-8-4-c-1 |
| 22-8-4-d | **CAM 25-17:** Reject an Identifiable Part of Second Revision No. 13.  **No Ballot Necessary per NFPA Regulations**  
See Attachment 22-8-4-d |
| **22-8-5** | **NFPA 70** | Act on the issuance of NFPA 70®, National Electrical Code®, with an issuance date of August 12, 2022, and an effective date of September 1, 2022, as acted on at the NFPA Technical Meeting, with eighteen amendments and fourteen appeals. |
| 22-8-5-a | **CAM 70-48:** Reject Second Correlating Revision No. 110. CAM 70-48 passed vote of the participating Membership during the NFPA Technical Meeting. **PASSED** panel Ballot – 20 voting members/20 agree/0 disagree/0 abstained/0 ballots not returned. **PASSED** CC Ballot – 12 voting members/11 agree/1 disagree/0 abstained/0 ballots not returned.  
See Attachment 22-8-5-a |
| 22-8-5-b | **CAM 70-49:** Reject an Identifiable Part of Second Correlating Revision No. 160. CAM 70-49 passed vote of the participating Membership during these NFPA Technical Meeting. **PASSED** panel Ballot – 20 voting members/19 agree/1 disagree/0 abstained/0 ballots not returned. **PASSED** CC Ballot – 12 voting members/11 agree/1 disagree/0 abstained/0 ballots not returned.  
See Attachment 22-8-5-b |
| 22-8-5-c | **CAM 70-51:** Reject an Identifiable part of Second Correlating Revision No. 126. CAM 70-51 passed vote of the participating Membership during the NFPA Technical Meeting. **PASSED** panel Ballot – 20 voting members/20 agree/0 disagree/0 abstained/0 ballots not returned. **PASSED** CC Ballot – 12 voting members/11 agree/1 disagree/0 abstained/0 ballots not returned.  
See Attachment 22-8-5-c |
| 22-8-5-d | **CAM 70-53:** Reject an Identifiable Part of Second Revision No. 8466. CAM 70-53 passed vote of the participating Membership during the NFPA Technical Meeting. **FAILED** panel Ballot – 20 voting members/10 agree/10 disagree/0 abstained/0 ballots not returned. **PASSED** CC Ballot – 12 voting members/11 agree/1 disagree/0 abstained/0 ballots not returned.  
See Attachment 22-8-5-d |
| 22-8-5-d-1 | Consider a comment received from George Zimmerman and members of Code-Making Panel 3 related to CAM 70-53.  
See Attachment 22-8-5-d-1 |
| 22-8-5-d-2 | Consider a comment received from Ernest Gallo related to CAM 70-53.  
See Attachment 22-8-5-d-2 |
| 22-8-5-e | **CAM 70-55:** Reject an Identifiable Part of Second Revision No. 109. CAM 70-55 passed vote of the participating Membership during the NFPA Technical Meeting. **PASSED** panel Ballot – 20 voting members/18 agree/0 disagree/0 abstained/2 ballots not returned. **PASSED** CC Ballot – 12 voting members/11 agree/1 disagree/0 abstained/0 ballots not returned.  
See Attachment 22-8-5-e |
<table>
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<tr>
<td>22-8-5-f</td>
<td><strong>CAM 70-56</strong>: Reject an Identifiable Part of Second Correlating Revision No. 136. CAM 70-56 passed vote of the participating Membership during the NFPA Technical Meeting. <strong>PASSED</strong> panel Ballot – 20 voting members/20 agree/0 disagree/0 abstained/0 ballots not returned. <strong>PASSED</strong> CC Ballot – 12 voting members/11 agree/1 disagree/0 abstained/0 ballots not returned.</td>
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<td>22-8-5-g</td>
<td><strong>CAM 70-57</strong>: Reject Second Correlating Revision No. 135. CAM 70-57 passed vote of the participating Membership during the NFPA Technical Meeting. <strong>PASSED</strong> panel Ballot – 20 voting members/20 agree/0 disagree/0 abstained/0 ballots not returned. <strong>PASSED</strong> CC Ballot – 12 voting members/11 agree/1 disagree/0 abstained/0 ballots not returned.</td>
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<tr>
<td>22-8-5-h</td>
<td><strong>CAM 70-58</strong>: Reject Second Correlating Revision No. 111. CAM 70-58 passed vote of the participating Membership during the NFPA Technical Meeting. <strong>PASSED</strong> panel Ballot – 20 voting members/20 agree/0 disagree/0 abstained/0 ballots not returned. <strong>PASSED</strong> CC Ballot – 12 voting members/11 agree/1 disagree/0 abstained/0 ballots not returned.</td>
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<td>22-8-5-i</td>
<td><strong>CAM 70-60</strong>: Consider the Appeal of Peter Graser, Copperweld Bimetals, as related to the Appeal filed on CAM-70-126. CAM 70-60 was not pursued at the NFPA Technical Meeting. See related Items 22-8-5-y through 22-8-5-mm</td>
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<td>22-8-5-j</td>
<td><strong>CAM 70-61</strong>: Consider the Appeal of Peter Graser, Copperweld Bimetals, requesting the Standards Council overturn the results of CAM-70-61 and Accept Public Comment No. 490. This CAM failed to achieve simple majority support of the voting Association Members during the NFPA Technical Meeting.扥朸i</td>
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<tr>
<td>22-8-5-j-1</td>
<td>Comment received from Scott Harding, Chair, CMP 5, regarding the appeal of CAM 70-61.</td>
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<tr>
<td>22-8-5-j-2</td>
<td>Comment received from Trevor Bowmer, Bunya Telecom Consulting, LLC, regarding the appeal of CAM 70-61.</td>
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<tr>
<td>22-8-5-k</td>
<td><strong>CAM 70-63</strong>: Accept Public Comment No. 2028. CAM 70-63 passed vote of the participating Membership during the NFPA Technical Meeting. <strong>FAILED</strong> panel Ballot – 14 voting members/7 agree/6 disagree/1 abstained/0 ballots not returned. <strong>PASSED</strong> CC Ballot – 12 voting members/10 agree/2 disagree/0 abstained/0 ballots not returned.</td>
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<tr>
<td>22-8-5-k-1</td>
<td><strong>CAM 70-63</strong>: Consider the appeal of Joseph Andre, requesting the Standards Council overturn the ballot results of Code-Making Panel 6 on CAM 70-63. CAM 70-63 failed panel ballot but passed the correlating committee ballot. This CAM achieved simple majority support of the membership during the NFPA Technical Session</td>
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<td>22-8-5-k-2</td>
<td>Comment received from Christel Hunter, Cerrowire, regarding the appeal of CAM 70-63. See Attachment 22-8-5-k-3.</td>
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<tr>
<td>22-8-5-k-3</td>
<td>Comment received from Tim Earl, GBH International, regarding the appeal of CAM 70-63. See Attachment 22-8-5-k-4.</td>
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<td>22-8-5-l</td>
<td><strong>CAM 70-82:</strong> Reject Second Correlating Revision No. 46. CAM 70-82 passed vote of the participating Membership during the NFPA Technical Meeting. <strong>PASSED</strong> Panel 3 Ballot – 20 voting members/16 agree/3 disagree/1 abstained/0 ballots not returned. <strong>PASSED</strong> Panel 14 Ballot – 19 voting members/16 agree/0 disagree/0 abstained/3 ballots not returned. <strong>PASSED</strong> CC Ballot – 12 voting members/10 agree/2 disagree/0 abstained/0 ballots not returned. (*Note: CMP 3 and CMP 14 both balloted as each had text affected by the Correlating Revision) See Attachment 22-8-5-l</td>
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<td>22-8-5-m</td>
<td><strong>CAM 70-83:</strong> Reject Second Revision No. 8298 and any related portions of First Revisions and First Correlating Revisions. <strong>No Ballot Necessary per NFPA Regulations</strong> See Attachment 22-8-5-m</td>
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<tr>
<td>22-8-5-n</td>
<td><strong>CAM 70-85:</strong> Reject Second Revision No. 8133 and any related portions of First Revisions and First Correlating Revisions. <strong>No Ballot Necessary per NFPA Regulations</strong> See Attachment 22-8-5-n</td>
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<td>22-8-5-o</td>
<td><strong>APPEAL</strong> <strong>CAM 70-88:</strong> Consider the Appeal of James Moellmann, Maxivolt, requesting the Standards Council overturn the results of CAM 70-88 and Accept Public Comment No. 583. This CAM failed to achieve simple majority support of the voting Association Members during the NFPA Technical Meeting. See Attachment 22-8-5-o</td>
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<tr>
<td>22-8-5-o-1</td>
<td>Comment received from Nathan Philips, Chair, CMP 10, regarding the appeal of CAM 70-88. See Attachment 22-8-5-o-1.</td>
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<tr>
<td>22-8-5-o-2</td>
<td>Comment received from Keith Waters, Schneider Electric, regarding the appeal of CAMs 70-88. See Attachment 22-8-5-o-2.</td>
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<tr>
<td>22-8-5-p</td>
<td><strong>APPEAL</strong> <strong>CAM 70-89/CAM 70-109:</strong> Consider the Appeal of James Moellmann, Maxivolt, requesting the Standards Council overturn the results of CAM 70-89 and CAM 79-109 and Accept Public Comment No. 582 and Accept an Identifiable Part of Public Comment No. 1918. These CAMs each failed to achieve simple majority support of the voting Association Members during the NFPA Technical Meeting. See Attachment 22-8-5-p</td>
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<td>22-8-5-p-1</td>
<td>Comment received from Nathan Philips, Chair, CMP 10, regarding the appeal of CAMs 70-89/70-109. See Attachment 22-8-5-p-1.</td>
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<tr>
<td>22-8-5-p-2</td>
<td>Comment received from Keith Waters, Schneider Electric, regarding the appeal of CAMs 70-89/70-109. See Attachment 22-8-5-p-2.</td>
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| 22-8-5-q | **APPEAL** | CAM 70-90: Consider the Appeal of James Moellmann, Maxivolt, requesting the Standards Council overturn the results of CAM 70-90 and Accept Public Comment No. 522. This CAM failed to achieve simple majority support of the voting Association Members during the NFPA Technical Meeting.  
See Attachment 22-8-5-q |
| 22-8-5-q-1 | Comment received from Nathan Philips, Chair, CMP 10, regarding the appeal of CAM 70-90.  
See Attachment 22-8-5-q-1 |
| 22-8-5-q-2 | Comment received from Keith Waters, Schneider Electric, regarding the appeal of CAMs 70-90.  
See Attachment 22-8-5-q-2 |
| 22-8-5-r | **APPEAL** | CAM 70-94: Consider the Appeal of Greg Woyczynski, Association of Home Appliance Manufacturers (AHAM) requesting that the NFPA Standards Council overturn the results of CAM 70-94 and Reject Second Revision No. 7956. This CAM failed to achieve simple majority support of the voting Association Members during the NFPA Technical Meeting.  
See Attachment 22-8-5-r |
| 22-8-5-r-1 | Comment received from David Humphrey, Chair, CMP 2, regarding the appeal of CAM 70-94.  
See Attachment 22-8-5-r-1 |
| 22-8-5-s | **APPEAL** | CAM 70-95: Consider the Appeal of Greg Woyczynski, Association of Home Appliance Manufacturers (AHAM) requesting that the NFPA Standards Council overturn the results of the CAM 70-95 and Reject an Identifiable Part of Second Revision No. 7966. This CAM failed to achieve simple majority support of the voting Association Members during the NFPA Technical Meeting.  
See Attachment 22-8-5-s |
| 22-8-5-s-1 | Comment received from David Humphrey, Chair, CMP 2, regarding the appeal of CAM 70-95.  
See Attachment 22-8-5-s-1 |
| 22-8-5-t | **CAM 70-105:** Accept Committee Comment No. 8204. CAM 70-105 passed vote of the participating Membership during the NFPA Technical Meeting. **FAILED** panel Ballot – 16 voting members/8 agree/8 disagree/0 abstained/0 ballots not returned. **PASSED** CC Ballot – 12 voting members/11 agree/1 disagree/0 abstained/0 ballots not returned.  
See Attachment 22-8-5-t |
| 22-8-5-u | **CAM 70-107:** Reject Second Revision No. 8036. CAM 70-107 passed vote of the participating Membership during the NFPA Technical Meeting. **PASSED** panel Ballot – 24 voting members/14 agree/7 disagree/0 abstained/3 ballots not returned. **PASSED** CC Ballot – 12 voting members/11 agree/1 disagree/0 abstained/0 ballots not returned.  
See Attachment 22-8-5-u |
| 22-8-5-v | **CAM 70-115:** Accept an Identifiable Part of Public Comment No. 1824. CAM 70-115 passed vote of the participating Membership during the NFPA Technical Meeting. **PASSED** panel Ballot – 14 voting members/13 agree/0 disagree/0 abstained/1 ballot not returned. **PASSED** CC Ballot – 12 voting members/11 agree/1 disagree/0 abstained/0 ballots not returned.  
See Attachment 22-8-5-v |
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| 22-8-5-w | CAM 70-117 | **APPEAL**
CAM 70-117: Consider the appeal of Frederic Hartwell, Hartwell Electrical Services, requesting the Standards Council overturn the results of the panel ballot and Accept Public Comment No. 2058. This CAM achieved simple majority support of the voting Association Members during the NFPA Technical Session but failed panel Ballot.

See Attachment 22-8-5-w-1 |
| 22-8-5-x | CAM 70-120 | **APPEAL**
CAM 70-120: Consider the Appeal of Peter Graser, Copperweld Bimetals, as related to the Appeal filed on CAM-126. CAM 70-127 was not pursued at the NFPA Technical Meeting. See related Items 22-8-5-i; 22-8-5-y through 22-8-5-aa-1. |
| 22-8-5-y | CAM 70-126 | **APPEAL**
CAM 70-126: Consider the appeal of Peter Graser, Copperweld Bimetals, requesting the Standards Council overturn the results of the voting Association Members during the NFPA Technical Session and Accept an Identifiable Part of Committee Comment (FR No. 8371 that failed re-balloting at Second Draft stage). This CAM failed to achieve simple majority support of the membership during the NFPA Technical Session. See related Items 22-8-5-i; 22-8-5-y through 22-8-5-aa-1. |
| 22-8-5-aa | CAM 70-128 | **APPEAL**
CAM 70-128: Accept an Identifiable part of Committee Comment (FR No. 8427 that failed reballoting at Second Draft stage). CAM 70-128 passed vote of the participating Membership during the NFPA Technical Meeting. **FAILED** panel Ballot – 14 voting members/8 agree/5 disagree/1 abstained/0 ballots not returned. **PASSED** CC Ballot – 12 voting members/10 agree/2 disagree/0 abstained/0 ballots not returned. |

See Attachment 22-8-5-aa |
| 22-8-5-aa-1 | **APPEAL** | **CAM 70-128** Consider the Appeal of Peter Graser, Copperweld Bimetallics, as related to the Appeal filed on CAM-126. CAM 70-128 achieved simple majority support of the membership during the NFPA Technical Session. See related Items 22-8-5-i; 22-8-5-y through 22-8-5-aa. See Attachment 22-8-5-aa-1 |
| 22-8-5-aa-2 |  | Comment received from Brian Deacy, Atkore, regarding the appeal of CAM 70-128. See Attachment 22-8-5-aa-2 |
| 22-8-5-bb | **APPEAL** | **CAM 70-129** Consider the Appeal of Peter Graser, Copperweld Bimetallics, as related to the Appeal filed on CAM-126. This CAM was not pursued at the NFPA Technical Meeting. See related Items 22-8-5-i; 22-8-5-y through 22-8-5-aa-1. See Attachment 22-8-5-bb |
| 22-8-6 | **NFPA 86** | Act on the issuance of NFPA 86, *Standard for Ovens and Furnaces*, with an issuance date of August 12, 2022, and an effective date of September 1, 2022, as acted on at the NFPA Technical Meeting, with no amendments (CAM Failed) and one appeal. |
| 22-8-6-1 | **APPEAL** | **CAM 86-6:** Consider the Appeal of Michael Grande, Wisconsin Oven Corporation, requesting the Standards Council overturn the results of CAM 86-6 and Reject Second Revision No. 7. This CAM failed to achieve simple majority support of the voting Association Membership during the NFPA Technical Session. See Attachment 22-8-6-1 |
| 22-8-6-1-a |  | Comment received from William Norge, 3M, regarding the appeal of CAM 86-6. See Attachment 22-8-6-1-a |
| 22-8-6-1-b |  | Comment received from Ted Jablkowski, Fives North American Combustion, Inc., regarding the appeal of CAM 86-6. See Attachment 22-8-6-1-b |
| 22-8-6-1-c |  | Comment received from Franklin Switzer, TC Chair., regarding the appeal of CAM 86-6. See Attachment 22-86-1-c |
| 22-8-7 | **NFPA 130** | Act on the issuance of NFPA 130, *Standard for Fixed Guideway Transit and Passenger Rail Systems*, with an issuance date of August 12, 2022, and an effective date of September 1, 2022, as acted on at the NFPA Technical Meeting, with no amendments (CAMs Failed) and no appeals. No Attachment. |
| 22-8-8 | **NFPA 285** | Act on the issuance of NFPA 285, *Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Wall Assemblies Containing Combustible Components*, with an issuance date of August 12, 2022, and an effective date of September 1, 2022, as acted on at the NFPA Technical Meeting, with no amendments and no appeals. No Attachment. |
| 22-8-9 | **NFPA 502** | Act on the issuance of NFPA 502, *Standard for Road Tunnels, Bridges, and Other Limited Access Highways*, with an issuance date of August 12, 2022, and an effective date of September 1, 2022, as acted on at the NFPA Technical Meeting, with five amendments and no appeals. |
| 22-8-9-a | CAM 502-2: Accept Public Comment No. 12. CAM 502-2 passed vote of the participating Membership during the NFPA Technical Meeting. **PASSED** TC Ballot – 28 voting members/22 agree/0 disagree/0 abstained/6 ballots not returned.  
See Attachment 22-8-9-a |
| 22-8-9-b | CAM 502-4: Accept an Identifiable Part of Public Comment No. 13. CAM 502-4 passed vote of the participating Membership during the NFPA Technical Meeting. **PASSED** TC Ballot – 28 voting members/21 agree/0 disagree/1 abstained/6 ballots not returned.  
See Attachment 22-8-9-b |
| 22-8-9-c | CAM 502-5: Accept Public Comment No. 17. CAM 502-5 passed vote of the participating Membership during the NFPA Technical Meeting. **PASSED** TC Ballot – 28 voting members/19 agree/4 disagree/0 abstained/5 ballots not returned.  
See Attachment 22-8-9-c |
| 22-8-9-d | CAM 502-7: Accept Public Comment No. 18. CAM 502-7 passed vote of the participating Membership during the NFPA Technical Meeting. **PASSED** TC Ballot – 28 voting members/17 agree/6 disagree/0 abstained/5 ballots not returned.  
See Attachment 22-8-9-d |
| 22-8-9-e | CAM 502-9: Accept an Identifiable Part of Public Comment No. 13. CAM 502-9 passed vote of the participating Membership during the NFPA Technical Meeting. **PASSED** TC Ballot – 28 voting members/21 agree/0 disagree/0 abstained/7 ballots not returned.  
See Attachment 22-8-9-e |
| 22-8-10 NFPA 855 | Act on the issuance of NFPA 855, *Standard for the Installation of Stationary Energy Storage Systems*, with an issuance date of August 12, 2022, and an effective date of September 1, 2022, as acted on at the NFPA Technical Meeting, with no amendments (CAMs Failed) and no appeals.  
No Attachment. |
| 22-8-11 NFPA 13 | Act on the issuance of proposed Tentative Interim Amendment No. 1633 to replace current Figure 25.8.2.4(b) of the 2019 edition of NFPA 13, *Standard for the Installation of Sprinkler Systems*.  
| 22-8-11-a | Text of proposed TIA No. 1633.  
See Attachment 22-8-11-a |
| 22-8-11-b | Ballot results of TIA No. 1633. **PASSED** TC ballot on technical merit and emergency nature – 35 voting members/30 agree on technical merit/0 disagree/0 abstained/5 ballots not returned/29 agree on emergency nature/1 disagree/0 abstained/5 ballots not returned. **PASSED** CC ballot on correlation – 22 voting members/20 agree on correlation/0 disagrees/0 abstained/2 ballots not returned.  
See Attachment 22-8-11-b |
| 22-8-11-c | No comments were received. No Attachment. |
| 22-8-12-a | Text of proposed TIA No. 1641.  
See Attachment 22-8-12-a |
| 22-8-12-b | Ballot results of TIA No. 1641. **PASSED** TC ballot on technical merit and emergency nature– 37 voting members/26 agree on technical merit/3 disagree/0 abstained/8 ballots not returned/23 agree on emergency nature/5 disagree/1 abstained/8 ballots not returned. **PASSED** CC ballot on correlation– 22 voting members/20 agree on correlation/0 disagrees/0 abstained/2 ballots not returned.  
See Attachment 22-8-12-b |
| 22-8-12-c | Two comments were received.  
See Attachment 22-8-12-c |
| 22-8-13-30B | Act on the issuance of proposed Tentative Interim Amendment No. 1652 to Revise 4.3.1 item (2) of the proposed 2023 edition of NFPA 30B, *Code for the Manufacture and Storage of Aerosol Products*. |
| 22-8-13-a | Text of proposed TIA No. 1652.  
See Attachment 22-8-13-a |
| 22-8-13-b | Ballot results of TIA No. 1652. **PASSED** TC ballot on technical merit and emergency nature –29 voting members/21 agree on technical merit/3 disagree/0 abstained/5 ballots not returned/21 agree on emergency nature/3 disagree/0 abstained/5 ballots not returned.  
See Attachment 22-8-13-b |
| 22-8-13-c | No comments were received.  
No Attachment. |
| 22-8-14-70 | Act on the issuance of proposed Tentative Interim Amendment No. 1632 to add a new item “e” to paragraph 700.10(B)(5) of the 2017 and 2020 editions of NFPA 70®, *National Electrical Code®*. |
| 22-8-14-a | Text of proposed TIA No. 1632.  
See Attachment 22-8-14-a |
| 22-8-14-b | Ballot results of TIA No. 1632. **PASSED** Panel ballot on both technical merit and emergency nature – 24 voting members/21 agree on technical merit/0 disagree/0 abstained/3 ballots not returned/18 agree on emergency nature/1 disagree/2 abstained/3 ballots not returned. **PASSED** CC ballot on correlation -12 voting members/9 agree on correlation/0 disagree/1 abstained/2 ballots not returned.  
See Attachment 22-8-14-b |
| 22-8-14-c | Three comments were received.  
See Attachment 22-8-14-c |
| 22-8-15-70 | Act on the issuance of proposed Tentative Interim Amendment No. 1649 to revise paragraph 314.29(A) of the proposed 2023 edition of NFPA 70®, *National Electrical Code®*. |
| 22-8-15-a | Text of proposed TIA No. 1649.  
See Attachment 22-8-15-a |
Ballot results of TIA No. 1649. **FAILED** Panel ballot on both technical merit and emergency nature – 14 voting members/6 agree on technical merit/7 disagree/0 abstained/1 ballot not returned/7 agree on emergency nature/6 disagree/0 abstained/1 ballot not returned. **PASSED** CC ballot on correlation -12 voting members/11 agree on correlation/1 disagree/0 abstained/0 ballots not returned.

See Attachment 22-8-15-b

Seventy-nine comments were received.

See Attachment 22-8-15-c

**22-8-16**

**NFPA 70**

Act on the issuance of proposed Tentative Interim Amendment No. 1653 to revise paragraph 2108(F) of the 2020 edition of NFPA 70®, *National Electrical Code®*.

Text of proposed TIA No. 1653.

See Attachment 22-8-16-a

Ballot results of TIA No. 1653. **FAILED** Panel ballot on technical merit but **PASSED** on emergency nature -16 voting members/11 agree on technical merit/5 disagree/0 abstained/0 ballots not returned/12 agree on emergency nature/4 disagree/0 abstained/0 ballots not returned. **PASSED** CC ballot on correlation- 12 voting members/10 agree on correlation/0 disagree/1 abstained/1 ballot not returned.

See Attachment 22-8-16-b

Five comments were received.

See Attachment 22-8-16-c

**22-8-16-d**

**APPEAL**

Consider the Appeal of William Koffel, Leading Builders of American, to (1) issue TIA Nos. 1653 and 1654 as recommended and submitted (by the Task Group established at the request of Council) and (2) not issue TIA Nos. 1656 and 1657. See related Item 22-8-16-e, 22-8-16-f, 22-8-17-d, 22-8-19-d, 22-8-20-d

See Attachment 22-8-16-d

**22-8-16-e**

**APPEAL**

Consider the Appeal of Mary Koban, Air-Conditioning, Heating, and Refrigeration Institute to (1) issue TIA Nos. 1653 and 1654 as recommended and submitted (by the Task Group established at the request of Council) and (2) not issue TIA Nos. 1656 and 1657. See related item 22-8-16-d, 22-8-16-f, 22-8-17-d, 22-8-19-d, 22-8-20-d

See Attachment 22-8-16-e

**22-8-16-f**

**APPEAL**

Consider the Appeal of David Bixby, Air Conditioning Contractors of America (ACCA), to (1) issue TIA Nos. 1653 and 1654 as recommended and submitted (by the Task Group established at the request of Council) and (2) not issue TIA Nos. 1656 and 1657. See related Item 22-8-16-d, 22-8-16-f, 22-8-17-f, 22-8-19-e, 22-8-20-e

See Attachment 22-8-16-f

**22-8-17**

**NFPA 70**

Act on the issuance of proposed Tentative Interim Amendment No. 1654 to revise paragraph 210.8(F) of the proposed 2023 edition of NFPA 70, *National Electrical Code®*.

Text of proposed TIA No. 1654.

See Attachment 22-8-17-a
| 22-8-17-b | Ballot results of TIA No. 1654. **FAILED** Panel ballot on technical merit but **PASSED** on emergency nature – 16 voting members/11 agree on technical merit/4 disagree/0 abstained/0 ballots not returned/12 agree on emergency nature/4 disagree/0 abstained/0 ballots not returned. **PASSED** CC ballot on correlation -12 voting members/10 agree on correlation/0 disagree/1 abstained/1 ballot not returned.  
See Attachment 22-8-17-b |
| 22-8-17-c | Seven comments were received.  
See Attachment 22-8-17-c |
| 22-8-17-d | Consider the Appeal of William Koffel, Leading Builders of American, to (1) issue TIA Nos. 1653 and 1654 as recommended and submitted (by the Task Group established at the request of Council) and (2) not issue TIA Nos. 1656 and 1657. See related Item 22-8-16-d, 22-8-19-d, 22-8-20-d  
See Attachment 22-8-17-d |
| 22-8-17-e | Consider the Appeal of Mary Koban, Air-Conditioning, Heating, and Refrigeration Institute to (1) issue TIA Nos. 1653 and 1654 as recommended and submitted (by the Task Group established at the request of Council) and (2) not issue TIA Nos. 1656 and 1657. See related item 22-8-16-d, 22-8-16-f, 22-8-17-d, 22-8-17-f, 22-8-19-d, 22-8-19-d, 22-8-19-e, 22-8-20-d, 22-8-20-e  
See Attachment 22-8-17-e |
| 22-8-17-f | Consider the Appeal of David Bixby, Air Conditioning Contractors of America (ACCA), to (1) issue TIA Nos. 1653 and 1654 as recommended and submitted (by the Task Group established at the request of Council) and (2) not issue TIA Nos. 1656 and 1657. See related Item 22-8-16-d, 22-8-16-e, 22-8-17-d, 22-8-17-e, 22-8-19-d, 22-8-20-d  
See Attachment 22-8-17-f |
| 22-8-18-a | Text of proposed TIA No. 1655.  
See Attachment 22-8-18-a |
| 22-8-18-b | Ballot results of TIA No. 1655. **PASSED** Panel ballot on both technical merit and emergency nature – 15 voting members/10 agree on technical merit/1 disagree/0 abstained/4 ballots not returned/10 agree on emergency nature/1 disagree/0 abstained/4 ballots not returned. **PASSED** CC ballot on correlation -12 voting members/9 agree on correlation/0 disagree/1 abstained/2 ballot not returned.  
See Attachment 22-8-18-b |
| 22-8-18-c | One comment was received.  
See Attachment 22-8-18-c |
| 22-8-19 | Act on the issuance of proposed Tentative Interim Amendment No. 1656 to revise paragraph 210.8(F) of the 2020 edition of NFPA 70, *National Electrical Code*®. |
| 22-8-19-a | Text of proposed TIA No. 1656.  
See Attachment 22-8-19-a |
| 22-8-19-b | Ballot results of TIA No. 1656. **PASSED** Panel ballot on both technical merit and emergency nature – 16 voting members/12 agree on technical merit/4 disagree/0 abstained/0 ballots not returned/14 agree on technical merit/14 disagree/0 abstained/0 ballots not returned.  
See Attachment 22-8-19-b |
<table>
<thead>
<tr>
<th>Section</th>
<th>Text</th>
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<tbody>
<tr>
<td>22-8-19-c</td>
<td>Four comments were received. See Attachment 22-8-19-c</td>
</tr>
<tr>
<td>22-8-19-d</td>
<td>Consider the Appeal of William Koffel, Leading Builders of American, to (1) issue TIA Nos. 1653 and 1654 as recommended and submitted (by the Task Group established at the request of Council) and (2) not issue TIA Nos. 1656 and 1657. See related items 22-8-16-d, 22-8-17-d, 22-8-19-d. See Attachment 22-8-19-d</td>
</tr>
<tr>
<td>22-8-19-e</td>
<td>Consider the Appeal of David Bixby, Air Conditioning Contractors of America (ACCA), to (1) issue TIA Nos. 1653 and 1654 as recommended and submitted (by the Task Group established at the request of Council) and (2) not issue TIA Nos. 1656 and 1657. See related items 22-8-17-f, 22-8-19-e, 22-8-20-e. See Attachment 22-8-19-e</td>
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<tr>
<td>22-8-20</td>
<td>Act on the issuance of proposed Tentative Interim Amendment No. 1657 to revise paragraph 210.8(F) of the proposed 2023 edition of NFPA 70, <em>National Electrical Code®</em>.</td>
</tr>
<tr>
<td>22-8-20-a</td>
<td>Text of proposed TIA No. 1657. See Attachment 22-8-20-a</td>
</tr>
<tr>
<td>22-8-20-b</td>
<td>Ballot results of TIA No. 1657. <strong>PASSED</strong> Panel ballot on both technical merit and emergency nature – 16 voting members/12 agree on technical merit/4 disagree/0 abstained/0 ballots not returned/14 agree on emergency nature/2 disagree/0 abstained/0 ballots not returned. <strong>PASSED</strong> CC ballot on correlation -12 voting members/10 agree on correlation/1 disagree/1 abstained/0 ballots not returned. See Attachment 22-8-20-b</td>
</tr>
<tr>
<td>22-8-20-c</td>
<td>Five comments were received. See Attachment 22-8-20-c</td>
</tr>
<tr>
<td>22-8-20-d</td>
<td>Consider the Appeal of William Koffel, Leading Builders of American, to (1) issue TIA Nos. 1653 and 1654 as recommended and submitted (by the Task Group established at the request of Council) and (2) not issue TIA Nos. 1656 and 1657. See related items 22-8-16-d, 22-8-17-d, 22-8-19-d. See Attachment 22-8-20-d</td>
</tr>
<tr>
<td>22-8-20-e</td>
<td>Consider the Appeal of David Bixby, Air Conditioning Contractors of America (ACCA), to (1) issue TIA Nos. 1653 and 1654 as recommended and submitted (by the Task Group established at the request of Council) and (2) not issue TIA Nos. 1656 and 1657. See related items 22-8-16-f, 22-8-17-f, 22-8-19-e. See Attachment 22-8-20-e</td>
</tr>
<tr>
<td>22-8-21</td>
<td>Act on the issuance of proposed Tentative Interim Amendment No. 1658 to revise paragraph 555.13 of the proposed 2023 edition of NFPA 70, <em>National Electrical Code®</em>.</td>
</tr>
<tr>
<td>22-8-21-a</td>
<td>Text of proposed TIA No. 1658.</td>
</tr>
<tr>
<td>Date</td>
<td>Text</td>
</tr>
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<td>------------</td>
<td>---------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>22-8-21-b</td>
<td>Ballot results of TIA No. 1658. <strong>FAILED</strong> Panel ballot on technical merit but <strong>PASSED</strong> on emergency nature – 19 voting members/12 agree on technical merit/5 disagree/0 abstained/2 ballots not returned/15 agree on emergency nature/2 disagree/0 abstained/2 ballots not returned. <strong>PASSED</strong> CC ballot on correlation -12 voting members/10 agree on correlation/1 disagree/1 abstained/0 ballot not returned. See Attachment 22-8-21-b</td>
</tr>
<tr>
<td>22-8-21-c</td>
<td>Fourteen comments were received. See Attachment 22-8-21-c</td>
</tr>
<tr>
<td>22-8-22</td>
<td>Act on the issuance of proposed Tentative Interim Amendment No. 1659 to revise paragraph 555.30 of the proposed 2023 edition of NFPA 70, National Electrical Code®.</td>
</tr>
<tr>
<td>22-8-22-a</td>
<td>Text of proposed TIA No. 1659. See Attachment 22-8-22-a</td>
</tr>
<tr>
<td>22-8-22-b</td>
<td>Ballot results of TIA No. 1659. <strong>PASSED</strong> Panel ballot on both technical merit and emergency nature – 19 voting members/15 agree on technical merit/1 disagree/1 abstained/2 ballots not returned/15 agree on emergency nature/1 disagree/1 abstained/2 ballots not returned. <strong>PASSED</strong> CC ballot on correlation -12 voting members/9 agree on correlation/0 disagree/1 abstained/2 ballot not returned. See Attachment 22-8-22-b</td>
</tr>
<tr>
<td>22-8-22-c</td>
<td>Nine comments were received. See Attachment 22-8-22-c</td>
</tr>
<tr>
<td>22-8-23</td>
<td>Act on the issuance of proposed Tentative Interim Amendment No. 1660 to revise paragraph 555.35 of the proposed 2023 edition of NFPA 70, National Electrical Code®.</td>
</tr>
<tr>
<td>22-8-23-a</td>
<td>Text of proposed TIA No. 1660. See Attachment 22-8-23-a</td>
</tr>
<tr>
<td>22-8-23-b</td>
<td>Ballot results of TIA No. 1660. <strong>PASSED</strong> Panel ballot on both technical merit and emergency nature – 19 voting members/16 agree on technical merit/1 disagree/0 abstained/2 ballots not returned/15 agree on emergency nature/2 disagree/0 abstained/2 ballots not returned. <strong>PASSED</strong> CC ballot on correlation -12 voting members/9 agree on correlation/0 disagree/1 abstained/2 ballot not returned. See Attachment 22-8-23-b</td>
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<tr>
<td>22-8-23-c</td>
<td>Eight comments were received. See Attachment 22-8-23-c</td>
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<tr>
<td>22-8-24</td>
<td>Act on the issuance of proposed Tentative Interim Amendment No. 1661 to revise paragraph 680.26(B)(2)(b) of the 2020 and proposed 2023 edition of NFPA 70, National Electrical Code®.</td>
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<tr>
<td>22-8-24-a</td>
<td>Text of proposed TIA No. 1661. See Attachment 22-8-24-a</td>
</tr>
<tr>
<td>22-8-24-b</td>
<td>Ballot results of TIA No. 1661. <strong>FAILED</strong> Panel ballot on both technical merit and emergency nature – 15 voting members/4 agree on technical merit/10 disagree/1 abstained/0 ballots not returned/5 agree on</td>
</tr>
<tr>
<td>Date</td>
<td>Summary</td>
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<td>---------------------------------------------------------------------------------------------------</td>
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<tr>
<td>22-8-24</td>
<td>Emergency nature/9 disagree/1 abstained/0 ballots not returned. <strong>PASSED</strong> CC ballot on correlation -12 voting members/9 agree on correlation/2 disagree/1 abstained/0 ballot not returned.</td>
</tr>
<tr>
<td></td>
<td><strong>APPEAL</strong></td>
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<tr>
<td>22-8-25</td>
<td><strong>NFPA 70</strong> Act on the issuance of proposed Tentative Interim Amendment No. 1668 to revise Section 210.70, 210.70 Informational Note(new) and 210.7(D)(new) of the proposed 2023 edition of NFPA 70, <em>National Electrical Code®</em>.</td>
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<tr>
<td>22-8-26</td>
<td><strong>NFPA 72</strong> Act on the issuance of proposed Tentative Interim Amendment No. 1643 to revise 29.11.3.4 item (4)(a), (4)(b), (5)(a) and (5)(b) of the 2022 edition of NFPA 72, <em>National Fire Alarm Signaling Code®</em>.</td>
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<tr>
<td>Date</td>
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<td>22-8-27</td>
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<td>22-8-29</td>
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<td><strong>22-8-30</strong></td>
<td><strong>NFPA 1851</strong></td>
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</table>
| | **22-8-30-a** | Text of proposed TIA No. 1663.  
See Attachment 22-8-30-a |
| | **22-8-30-b** | Ballot results of TIA No. 1663. **FAILED** TC ballot on both technical merit and emergency nature – 36 voting members/18 agree on technical merit/8 disagree/2 abstained/8 ballots not returned/18 agree on emergency nature/8 disagree/2 abstained/8 ballots not returned. **FAILED** CC ballot on correlation – 27 voting members/13 agree on correlation/6 disagree/4 abstained/4 ballot not returned.  
See Attachment 22-8-30-b |
| | **22-8-30-c** | One comment was received.  
See Attachment 22-8-30-c |

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<th><strong>22-8-31</strong></th>
<th><strong>NFPA 1851</strong></th>
<th>Act on the issuance of proposed Tentative Interim Amendment No. 1664 to add a new item (8) to paragraph 7.3.13.2 of the 2020 edition of NFPA 1851, <em>Standard on Selection, Care, and Maintenance of Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting.</em></th>
</tr>
</thead>
</table>
| | **22-8-31-a** | Text of proposed TIA No. 1664.  
See Attachment 22-8-31-a |
| | **22-8-31-b** | Ballot results of TIA No. 1664. **PASSED** TC ballot on both technical merit and emergency nature – 36 voting members/20 agree on technical merit/6 disagree/2 abstained/8 ballots not returned/20 agree on emergency nature/6 disagree/2 abstained/8 ballots not returned. **FAILED** CC ballot on correlation – 27 voting members/12 agree on correlation/7 disagree/4 abstained/4 ballot not returned.  
See Attachment 22-8-31-b |
| | **22-8-31-c** | One comment was received.  
See Attachment 22-8-31-c |

| --- | --- | --- |
| | **22-8-32-a** | Text of proposed TIA No. 1669.  
See Attachment 22-8-32-a |
| | **22-8-32-b** | Ballot results of TIA No. 1669. **PASSED** TC ballot on both technical merit and emergency nature – 23 voting members/20 agree on technical merit/0 disagree/0 abstained/3 ballots not returned/20 agree on emergency nature/0 disagree/0 abstained/3 ballots not returned. **PASSED** CC ballot on correlation – 27 voting members/22 agree on correlation/0 disagree/0 abstained/5 ballots not returned.  
See Attachment 22-8-32-b |
| | **22-8-32-c** | No comments were received.  
No Attachment. |
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<th>22-8-33</th>
<th>NFPA 1990</th>
<th>Act on the issuance of proposed Tentative Interim Amendment No. 1628 to revise Section 1.3.1.5, Table 5.2.3.1.2(a), Table 5.3.3.2(a), Table 5.4.3.2(a), 7.1.8.2 and Table 7.1.8.2 of the 2022 edition of NFPA 1990, Standards for Protective Ensembles for Hazardous Materials and Emergency Medial Operations.</th>
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<tr>
<td>22-8-33-a</td>
<td>Text of proposed TIA No. 1628. See Attachment 22-8-33-a</td>
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<td>22-8-33-b</td>
<td>Ballot results of TIA No. 1628. <strong>FAILED</strong> TC ballot on both technical merit and emergency nature – 33 voting members/7 agree on technical merit/14 disagree/6 abstained/6 ballots not returned/8 agree on emergency nature/15 disagree/4 abstained/6 ballots not returned. <strong>FAILED</strong> CC ballot on correlation –27 voting members/6 agree on correlation/10 disagree/6 abstained/5 ballots not returned. See Attachment 22-8-33-b</td>
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<td>22-8-33-c</td>
<td>No comments were received. No Attachment.</td>
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<tr>
<th>22-8-34</th>
<th>NFPA 1990</th>
<th>Act on the issuance of proposed Tentative Interim Amendment No. 1650 to revise Section 1.3.1.5, Table 5.2.3.1.2(a), Table 5.3.3.2(a), Table 5.4.3.2(a), 7.1.8.2 and Table 7.1.8.2 of the 2022 edition of NFPA 1990, Standards for Protective Ensembles for Hazardous Materials and Emergency Medial Operations.</th>
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<tr>
<td>22-8-34-a</td>
<td>Text of proposed TIA No. 1650. See Attachment 22-8-34-a</td>
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<tr>
<td>22-8-34-b</td>
<td>Ballot results of TIA No. 1650. <strong>PASSED</strong> TC ballot on both technical merit and emergency nature – 33 voting members/24 agree on technical merit/0 disagree/0 abstained/9 ballots not returned/24 agree on emergency nature/0 disagree/0 abstained/9 ballots not returned. <strong>PASSED</strong> CC ballot on correlation –27 voting members/18 agree on correlation/0 disagree/0 abstained/9 ballots not returned. See Attachment 22-8-34-b</td>
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<td>22-8-34-c</td>
<td>No comments were received. No Attachment.</td>
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<td>Text of proposed TIA No. 1651. See Attachment 22-8-35-a</td>
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<tr>
<td>22-8-35-b</td>
<td>Ballot results of TIA No. 1651. <strong>PASSED</strong> TC ballot on both technical merit and emergency nature – 33 voting members/23 agree on technical merit/0 disagree/0 abstained/10 ballots not returned/23 agree on emergency nature/0 disagree/0 abstained/10 ballots not returned. <strong>PASSED</strong> CC ballot on correlation –27 voting members/18 agree on correlation/0 disagree/0 abstained/9 ballots not returned. See Attachment 22-8-35-b</td>
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<tr>
<td>22-8-35-c</td>
<td>No comments were received. No Attachment.</td>
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</table>
GENERAL BUSINESS

22-8-36  At the April 2020 meeting the Standards Council approved the request of the Correlating Committee on Combustible Dusts to combine NFPA standards 61, 91, 484, 652, 654, 655, and 664 into new draft standard NFPA 660, *Standard for Combustible Dusts*. The Correlating Committee is now requesting that NFPA 91 remain a separate standard as it applies to non-dust materials, including vapors, gases, and mists. The Correlating Committee also requests that NFPA 91 be opened for Public Input with a closing date of June 1, 2023. See related item 22-8-38
See Attachment 22-8-36

REVISION CYCLES

22-8-37  Consider requests to change the respective revision schedules as follows:

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<tbody>
<tr>
<td>NFPA 409</td>
<td>2022</td>
<td>PI Closing: January 4, 2024</td>
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<tr>
<td>NFPA 415</td>
<td>2022</td>
<td>PI Closing: January 4, 2024</td>
</tr>
<tr>
<td>NFPA 423</td>
<td>2022</td>
<td>PI Closing: January 4, 2024</td>
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<tr>
<td>NFPA 1082</td>
<td>2023</td>
<td>PI Closing: January 4, 2024</td>
</tr>
<tr>
<td>NFPA 1850</td>
<td>New</td>
<td>PI Closing: June 1, 2023</td>
</tr>
</tbody>
</table>

See Attachment 22-8-37

NEW PROJECTS

22-8-38  Consider the request of the Correlating Committee on Combustible Dusts to approve the preliminary draft of NFPA 660, *Standard for Combustible Dusts*. The Correlating Committee also requests the standard be entered into its initial revision cycle, with a Public Input closing date of January 5, 2023.

Five Technical Committees voted to request NFPA 660 enter its initial revision cycle:

*TC on Agricultural Dusts:* 33 voting members/26 agree/3 disagree/0 abstained/4 ballots not returned.

*TC on Combustible Metals and Metal Dusts:* 35 voting members/28 agree/0 disagree/0 abstained/7 ballots not returned.

*TC on Fundamentals of Combustible Dusts:* 37 voting members/30 agree/2 disagree/0 abstained/5 ballots not returned.

*TC on Handling and Conveying of Dusts, Vapors, and Gases:* 33 voting members/27 agree/1 disagree/0 abstained/5 ballots not returned.

*TC on Wood and Cellulosic Materials Processing:* 29 voting members/22 agree/3 disagree/0 abstained/4 ballots not returned.

See related item 22-8-36
See Attachment 22-8-38

22-8-39  Consider the request of the Technical Committee on Hanging and Bracing for Fire Suppression Systems to approve the proposed draft standard NFPA 200, *Standard for Hanging and Bracing of Fire*
**Suppression Systems.** The Technical Committee also requests the standard be entered into its initial revision cycle, with a Public Input closing date of June 1, 2023.
See Attachment 22-8-39

| 22-8-40 | Consider the request of the Technical Committee on Spaceports to approve the proposed draft standard NFPA 461, *Standard for Fire Protection and Life Safety at Spaceport and Support Facilities*. The Technical Committee also requests the standard be entered into its initial revision cycle, with a Public Input closing date of June 1, 2023.
See Attachment 22-8-40 |

### GENERAL ITEMS

| 22-8-41 | Presentation of Annual 2025, Fall 2025, Annual 2026, and Fall 2026 revision cycle schedules.
See Attachment 22-8-41 |

<table>
<thead>
<tr>
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<th>Dates of upcoming Council meetings:</th>
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<tr>
<td></td>
<td>December 7-8, 2022</td>
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<tr>
<td></td>
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<td>March 29-30, 2023</td>
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<td>August 2023</td>
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<td>Dates and location to be determined</td>
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</table>

| 22-8-42 | Updates from the Council Secretary
No Attachment. |
M E M O R A N D U M

TO: Standards Council
FROM: Chad Duffy, NFPA 200 Staff Liaison
DATE: May 9, 2022
SUBJECT: Request for approval to release Draft NFPA 200 for Public Input

According to Section 4.3.2.1(b) of the NFPA Regulations Governing the Development of NFPA Standards prior to entering into a Revision Cycle and approved for public review a Ballot of the Committee is required by at least a simple majority. The results of the ballot to release the NFPA 200 Preliminary Draft, Standard for Hanging and Bracing of Fire Suppression Systems, was finalized on May 6, 2022. The ballot received the necessary affirmative votes to pass.

Based upon the ballot results, the recommendation to the Standards Council is that NFPA 200 enter the Annual 2025 revision cycle, with a Public Input closing date of June 1, 2023. At the completion of the Annual 2025 revision cycle the document would then move to the Annual 2029 revision cycle so that it is one year ahead of NFPA 13, allowing Chapters 5 and 6 to be extracted as Chapters 17 and 18 of NFPA 13. From the Annual 2029 revision cycle forward NFPA 200 would remain in a 3-year revision cycle.

Enclosures: NFPA 200 Draft
             NFPA 200 Preliminary Release Final Ballot Results
MEMORANDUM

TO: Technical Committee on Hanging and Bracing for Fire Suppression Systems

FROM: Elena Liolin, Sr. Committee Administrator

DATE: May 6, 2022

SUBJECT: Ballot to Release NFPA 200 Preliminary Draft - Final Results

According to the final ballot results, the ballot did receive the necessary affirmative votes to pass ballot. The Technical Committee recommends NFPA 200 to enter the A2025 cycle. Please see the attached report for results and any comments received.

33 Eligible to Vote
0 Not Returned

The criteria necessary to pass ballot is a simple majority of the Technical Committee and Correlating Committee, if any. See Section 4.3.2.1(b) of the Regulations Governing the Development of NFPA Standards.
NFPA 200 Preliminary Draft Release Ballot - FINAL

TRUE
Per section 4.3.2.1(b) of the Regs, prior to entering a future Revision Cycle and approval for public review, a Ballot of the Committee is required to pass by at least, a simple majority. Note: This ballot is for formally voting on whether or not you are in agreement with the release of the NFPA 200 draft.

Eligible to Vote: 33
Not Returned : 0

<table>
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<tr>
<th>Vote Selection</th>
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<th>Comments</th>
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<td>Affirmative</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Affirmative with Comment</td>
<td>1</td>
<td>Agree</td>
</tr>
<tr>
<td>Zac Brown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Prasad S. Naik</td>
<td></td>
<td>The reference of ASCE 19 standard in section 2.3.3 and A.6.5.4.2 need to be reviewed before sending this draft for the public comments. Several issues has been identified in the development of ASCE 19 - 2016 Appendix E that show a violation of the ASCE’s rules for standards development and ANSI’s consensus standards development process. An appeal has been filed to the ASCE’s codes and standards development committee and the subject is currently under investigation. ASCE has also put a hold on the current development of this standard until the appeal is filed.</td>
</tr>
<tr>
<td>Abstain</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Total Voted : 33

For Simple majority, the affirmative votes needed are 17
5.1.2 (2) The points of support shall be able to support the system.  Chap?

5.2.1.3 Where the pitch of the branch line is 6 in 12 or greater?

Table 5.2.1.5.1 What is up with the 5” and 6” pipe size related to the Bent Eye mm?

8.9.2 (2) Spacing of “0”?

9.3.2 The agent storage container shall be restrained so as to prevent movement during discharge for the conditions identified 0, 0 and 0?

9.4.4 The bracing system shall include two or more braces located at one-third and two-thirds the height of the container.  I do not think this is right, for example Inergen cylinders only have one cradle just over half way up.

C.1.2.7 FSSA Publications, There is a much newer edition of the Pipe Design Handbook than 2003.


The third edition of the handbook was published in August 2019
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Standard for Hanging and Bracing of Fire Suppression Systems

Preliminary Draft
Chapter 1 Administration

1.1 Scope.

1.1.1 This standard shall provide the minimum requirements for the hanging, bracing, support, and anchorage of components and devices for fire suppression systems covered within this standard.

1.1.2 Performance-based design of hanging, bracing, support, and anchorage of components and devices for fire suppression systems shall be permitted.

1.1.3 This standard shall not cover the following system components:

    (1) Releasing service control panels and associated devices
    (2) Devices or appurtenances not associated with the life safety function of the system

1.2 Purpose.

The purpose of this standard shall be to provide a base level of protection for life and property from fire and seismic events through standardization of design and installation for hanging, bracing, support, and anchorage of fire suppression systems, based on sound engineering principles, test data, and field experience.

1.3 Application.

1.3.1 The requirements of this standard apply to the fire suppression systems listed in Table 1.3.1.

Table 1.3.1 Fire Suppression Systems and Applicable Standards

<table>
<thead>
<tr>
<th>Fire Suppression System Type</th>
<th>NFPA Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-, medium-, and high-expansion foam systems</td>
<td>NFPA 11</td>
</tr>
<tr>
<td>Carbon dioxide systems</td>
<td>NFPA 12</td>
</tr>
<tr>
<td>Halon 1301 systems</td>
<td>NFPA 12A</td>
</tr>
<tr>
<td>Sprinkler systems</td>
<td>NFPA 13</td>
</tr>
<tr>
<td>Residential sprinkler systems</td>
<td>NFPA 13R</td>
</tr>
<tr>
<td>Standpipe systems</td>
<td>NFPA 14</td>
</tr>
</tbody>
</table>
1.3.2

This standard shall also apply to “combined service mains” used to carry water for both fire service and other uses as well as to mains for fire service use only.

1.4 Retroactivity.

The provisions of this standard shall reflect a consensus of what is necessary to provide an acceptable degree of protection from the hazards addressed in this standard at the time the standard was issued.

1.4.1

Unless otherwise specified, the provisions of this standard shall not apply to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the standard.

1.4.2

Where specified, the provisions of this standard shall be retroactive.

1.4.3

In those cases where the authority having jurisdiction determines that the existing situation presents an unacceptable degree of risk, the authority having jurisdiction shall be permitted to apply retroactively any portions of this standard.

1.4.4

The retroactive requirements of this standard shall be permitted to be modified if, in the judgment of the authority having jurisdiction, their application would be impractical or it is evident that a reasonable degree of safety is provided.
1.5 Equivalency.

Nothing in this standard shall be intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard.

1.5.1

Technical documentation shall be submitted to the authority having jurisdiction to demonstrate equivalency.

1.5.2

The system, method, or device shall be approved for the intended purpose by the authority having jurisdiction.

1.6 New Technology.

1.6.1

Nothing in this standard shall be intended to restrict new technologies or alternate arrangements, provided the level of safety prescribed by this standard is not lowered.

1.6.2

Materials or devices not specifically designated by this standard shall be utilized in complete accord with all conditions, requirements, and limitations of their listings.

1.7 Units and Formulas.

1.7.1

Metric units of measurement in this standard shall be in accordance with the modernized metric system known as the International System of Units (SI).

1.7.2

Liter and bar units, which are outside of but recognized by SI and commonly used in international fire protection, shall be included in this standard, as needed.

1.7.3

Units with conversion factors shall be used as listed in Table 1.7.3.

Table 1.7.3 Conversion Factors
<table>
<thead>
<tr>
<th>Name of Unit</th>
<th>Unit Symbol</th>
<th>Conversion Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Millimeter</td>
<td>mm</td>
<td>1 in. = 25 mm</td>
</tr>
<tr>
<td>Meter</td>
<td>m</td>
<td>1 ft = 0.3048 m</td>
</tr>
<tr>
<td>Area</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Square millimeters</td>
<td>mm²</td>
<td>1 in.² = 645.2 mm²</td>
</tr>
<tr>
<td>Square meter</td>
<td>m²</td>
<td>1 ft² = 0.0929 m²</td>
</tr>
<tr>
<td>Volume</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cubic millimeter</td>
<td>mm³</td>
<td>1 in.³ = 163.9 mm³</td>
</tr>
<tr>
<td>Cubic meter</td>
<td>m³</td>
<td>1 ft³ = 0.02832 m³</td>
</tr>
<tr>
<td>Fluid capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liter</td>
<td>L</td>
<td>1 fl oz = 0.02957 L</td>
</tr>
<tr>
<td>Liter per minute</td>
<td>L/min</td>
<td>1 gpm = 3.7848 L/min</td>
</tr>
<tr>
<td>Pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bar</td>
<td>bar</td>
<td>1 psi = 0.0689 bar</td>
</tr>
<tr>
<td>Discharge density</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Millimeter/minute</td>
<td>mm/min</td>
<td>1 gpm/ft² = 40.746 mm/min</td>
</tr>
<tr>
<td>Liter/minute/m²</td>
<td>(L/min)/m²</td>
<td>1 gpm/ft² = 40.746 (L/min)/m²</td>
</tr>
<tr>
<td>k-factor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>k-factor</td>
<td>L/min/(bar)²</td>
<td>1 gpm/(psi)² = 14.285 L/min/(bar)²</td>
</tr>
<tr>
<td>Weight</td>
<td>Kilogram</td>
<td>1 lb = 0.4536 kg</td>
</tr>
<tr>
<td>Density</td>
<td>Kilogram/cubic meter</td>
<td>1 lb/ft³ = 16.02 kg/m³</td>
</tr>
<tr>
<td>Temperature</td>
<td>Fahrenheit</td>
<td>°F = 9/5 × C° + 32</td>
</tr>
<tr>
<td>Celcius</td>
<td>°C</td>
<td>C° = 5/9 (F° − 32)</td>
</tr>
<tr>
<td>Velocity</td>
<td>Kilometers per hour</td>
<td>1 mph = 1.609 km/h</td>
</tr>
<tr>
<td>Pound force</td>
<td>Newtons</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 lb force = 4.44822 N</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Millimeter</td>
<td>mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12 gauge = 2.8 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14 gauge = 1.98 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16 gauge = 1.57 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22 gauge = 0.78 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24 gauge = 0.63 mm</td>
</tr>
</tbody>
</table>

Note: For additional conversions and information, see ASTM SI 10, IEEE/ASTM SI 10 American National Standard for Metric Practice.
1.7.4*
If a value for measurement as given in this standard is followed by an equivalent value in other units, the first stated shall be regarded as the requirement.
Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.

2.2 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.


2.3 Other Publications.

2.3.1 ACI Publications.

American Concrete Institute, 38800 Country Club Drive, Farmington Hills, MI 48331-3439.

ACI 318, Building Code Requirements for Structural Concrete and Commentary, 2019.


ACI 355.2, Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary.


2.3.2 AISC Publications.

American Institute of Steel Construction, 130 East Randolph, Suite 2000, Chicago, IL 60601.


2.3.3 ASCE Publications.

American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, VA 20191-4400.

ASCE 19, Structural Applications of Steel Cables for Buildings, 2016.


2.3.4 ASME Publications.

ASME International, Two Park Avenue, New York, NY 10016-5990.

ASME B31, Codes for Pressure Piping, 2010.


2.3.5 ASTM Publications.
ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM A36/A36M, Standard Specification for Carbon Structural Steel, 2019


ASTM E580/E580M, Standard Practice for Installation of Ceiling Suspension Systems for Acoustical Tile and Lay-in Panels in Areas Subject to Earthquake Ground Motions, 2020


2.3.6 AWWA Publications.

American Water Works Association, 6666 West Quincy Avenue, Denver, CO 80235.


AWWA D107, Composite Elevated Tanks for Water Storage, 2016.

AWWA D110, Wire-And Strand-Wound, Circular, Prestressed Concrete Water Tanks, 2013(R18).


2.3.7 **FM Publications.**

FM Global, 270 Central Avenue, P.O. Box 7500, Johnston, RI 02919-4923.


2.3.8 **ICC Publications.**

International Code Council, 500 New Jersey Avenue, NW, 6th Floor, Washington, DC 20001.


2.3.9 **MSS Publications.**

Manufacturers Standardization Society of the Valve and Fittings Industry, 127 Park Street, NE, Vienna, VA 22180-4602.


2.3.10 **UL Publications.**

Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.


2.3.11 **Other Publications.**


2.4 **References for Extracts in Mandatory Sections.**


Chapter 3 Definitions

3.1 General.

3.1.1
The definitions contained in this chapter shall apply to the terms used in this standard.

3.1.2
Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used.

3.1.3
Merriam-Webster’s Collegiate Dictionary, current edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved.
Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ).
An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.3 Labeled.
Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with
3.2.4* Listed.

Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.5 Shall.

Indicates a mandatory requirement.

3.2.6 Should.

Indicates a recommendation or that which is advised but not required.

3.2.7 Standard.

An NFPA standard, the main text of which contains only mandatory provisions using the word “shall” to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA manuals of style. When used in a generic sense, such as in the phrase “standards development process” or “standards development activities,” the term “standards” includes all NFPA standards, including codes, standards, recommended practices, and guides.

3.3 General Definitions.

3.3.1 Brace.

A component or assembly capable of supporting the seismic loads enacted on a piping system during an earthquake.

3.3.2 Branch Line.
The pipe supplying sprinklers, either directly or through sprigs, drops, return bends, or arm-overs. [13, 2022]

### 3.3.3 Component Manufacturer.

Manufacturer of hangers, supports, restraints, braces, or other components not listed as a component of the listed system.

### 3.3.4 Feed Main.

The pipes supplying cross mains, either directly or through risers. [13, 2022]

### 3.3.5 Fire Department.

An organization providing rescue, fire suppression, and related activities, including any public, governmental, private, industrial, or military organization engaging in this type of activity. [1002, 2017]

### 3.3.6 Foam Generators.

#### 3.3.6.1 Foam Generators — Aspirator Type.

Foam generators, fixed or portable, in which jet streams of foam solution aspirate sufficient amounts of air that is then entrained on the screens to produce foam, and which usually produce foam with expansion ratios of not more than 250:1. [11, 2021]

#### 3.3.6.2* Foam Generators — Blower Type.

Foam generators, fixed or portable, in which the foam solution is discharged as a spray onto screens through which an airstream developed by a fan or blower is passing. [11, 2021]

### 3.3.7* Four-Way Bracing.

Adjacent sway braces or a sway brace assembly intended to resist differential movement of the system piping in all horizontal directions. [13, 2022]

### 3.3.8 Hanger.

A device or assembly used to support the gravity load of the system piping. [13, 2022]
3.3.9 Horizontal Force, \( F_{pw} \).

The horizontal force due to seismic load acting on a brace at working stress levels. [13, 2022]

3.3.10 Lateral Brace.

A sway brace intended to resist differential movement perpendicular to the axis of the system piping. [13, 2022]

3.3.11 Longitudinal Brace.

A sway brace intended to resist differential movement parallel to the axis of the system piping. [13, 2022]

3.3.12 Net Vertical Force.

The vertical reaction due to the angle of installation of sway braces on system piping resulting from earthquake motion. [13, 2022]

3.3.13* Post-Installed Anchors.

A device used for fastening pipe to the building structure, installed in hardened concrete. [13, 2022]

3.3.14* Prying Factor.

A factor based on fitting geometry and brace angle from vertical that results in an increase in tension load due to the effects of prying between the upper seismic brace attachment fitting and the structure. [13, 2022]

3.3.15 Restraint.

A component or assembly capable of supporting thrust loads enacted on a piping system during system discharge.

3.3.16 Riser Nipple.

A vertical pipe between the cross main and branch line. [13, 2022]

3.3.17 Seismic Coefficient, \( C_p \).

### 3.3.18* Seismic Separation Assembly.

An assembly of fittings, pipe, flexible pipe, and/or couplings that permits movement in all directions to accommodate seismic differential movement across building seismic separation joints. [13, 2022]

### 3.3.19 Short Period Spectral Response Acceleration Parameter, $S_s$.

The maximum considered earthquake ground motion for 0.2-second spectral response acceleration (5 percent of critical damping), site Class B for a specific site. [13, 2022]

### 3.3.20 Support.

A component or assembly, typically connected to the structure below the piping system, capable of supporting the gravitational load of a piping system.

### 3.3.21 Sway Brace.

An assembly intended to be attached to the system piping to resist horizontal earthquake loads in two directions. [13, 2022]
Chapter 4 General Requirements
4.1 General.

The requirements of this chapter shall apply to all new systems designed per the requirements of the following standards:

1. NFPA 11
2. NFPA 12
3. NFPA 12A
4. NFPA 13
5. NFPA 13R
6. NFPA 14
7. NFPA 15
8. NFPA 17
9. NFPA 20
10. NFPA 22
11. NFPA 24
12. NFPA 750
13. NFPA 2001

4.2 Goals and Objectives.

This chapter shall provide the minimum requirements for the design, installation, and acceptance of pipe hangers, supports, and restraints used in fire protection systems.

4.3 Additional Requirements.

The authority having jurisdiction shall be permitted to require the selection and application of pipe hangers and supports to conform to additional codes and standards, including, but not limited to, the following:
4.4 Compliance Options.

4.4.1

Compliance with the goals and objectives of Section 4.2 shall be provided in accordance with either of the following:

(1) The prescriptive-based provisions per 4.4.2
(2) The performance-based provisions per 4.4.3

4.4.2 Prescriptive-Based Option.

4.4.2.1

A prescriptive-based option shall be in accordance with Chapter 5 through Chapter 21 of this standard.

4.4.2.2

The requirements of this chapter shall apply to all fire protection systems unless modified by specific rules in Chapter 5 through Chapter 21 of this standard.

4.4.3 Performance-Based Option.

4.4.3.1

Hangers, supports, and restraints as follows, certified by a registered design professional working within their area of expertise, shall be an acceptable performance-based option:

(1) Hangers and supports in tension or bending shall be designed to the lower of the following values:
   (a) A minimum tensile strength at service temperature of 29 percent
   (b) A minimum yield strength at service temperature of 67 percent
(2) Hangers and supports in shear shall be designed based on the value obtained in 4.4.3.1(1) as follows:
(a) The value obtained in 4.4.3.1(1) shall be multiplied by a factor of 0.8.
(b) The points of support shall be able to support the system design loads.
(c) The spacing between hangers, supports, and restraints shall not exceed the value given for the type of pipe as indicated in Table UKN of ANSI/MSS SP-58, *Pipe Hangers and Supports — Materials, Design, Manufacture, Selection, Application, and Installation*.
(d) Seismic system performance shall be at least equal to that of the building structure under expected seismic forces.
(e) Detailed calculations shall be submitted where required by the reviewing authority, showing stresses developed in hangers, piping, and fittings, and safety factors allowed.

### 4.4.3.2

Prescriptive requirements shall be permitted to be used as part of the performance approach, if they, in conjunction with the performance features, meet the overall goals and objectives of this standard.

### 4.5 Materials.

#### 4.5.1

Components used in hangers, supports, and restraints shall be ferrous as indicated in Table 4.6.1(a) and Table 4.6.1(b) of ANSI/MSS SP-58, *Pipe Hangers and Supports — Materials, Design, Manufacture, Selection, Application, and Installation*.

#### 4.5.2

Other metallic or nonmetallic materials that have been proven by fire tests for the hazard application, which are listed for this purpose, and support the gravity load of the system during a fire or during prolonged thermal exposure shall be permitted.

#### 4.5.3

Material in contact with the pipe shall be compatible with the piping material so that neither has a deteriorating action on the other.

#### 4.5.4

Materials subject to corrosion or galvanic action shall be protected using either a factory-applied or field-applied protective coating.
4.5.4.1

Field-applied protective coatings shall be performed in accordance with the coating manufacturer's recommendations.

4.5.4.2

Repair of protective coatings shall be performed in accordance with the coating manufacturer's recommendations.

4.6 Basis of Design.

Allowable stresses, load ratings, and temperatures for hangers, supports, and restraints shall be in accordance with the following:

1) ANSI/MSS SP-58, *Pipe Hangers and Supports — Materials, Design, Manufacture, Selection, Application, and Installation*

2) MSS SP-127, *Bracing for Piping Systems*

4.7 System Piping.

4.7.1

The maximum spacing for hangers, supports, and restraints shall be as indicated in Table 4.7.1 of ANSI/MSS SP-58, *Pipe Hangers and Supports — Materials, Design, Manufacture, Selection, Application, and Installation*.

4.7.2

The minimum rod diameters for hangers, supports, and restraints shall be as indicated in Table 4.7.2 of ANSI/MSS SP-58, *Pipe Hangers and Supports — Materials, Design, Manufacture, Selection, Application, and Installation*.

4.8 Installation. (Reserved)

4.9 System Acceptance.

4.9.1

Hangers, supports, and restraint assemblies shall be verified to ensure that all components have been installed and positioned according to this standard and manufacturers’ specifications.
4.9.2
Where present, threaded components of each hanger, support, or restraint shall be checked for thread engagement.

4.9.3
RestRAINT control devices shall be checked to ensure that pipe movement is limited.

4.9.4
Piping systems shall be inspected to verify that no interference exists between the pipe and the building structure or equipment.

4.9.5
Piping systems shall be inspected to verify that the pipe is elevated in accordance with the installation plans.

Chapter 5 Installation Requirements for Hanging and Support of Sprinkler System Piping

5.1* General.

5.1.1
Unless the requirements of 5.1.2 are met, types of hangers shall be in accordance with the requirements of Chapter 5. [13:17.1.1]

5.1.2
Hangers certified by a registered professional engineer to include all of the following shall be an acceptable alternative to the requirements of Chapter 5:

(1) Hangers shall be designed to support five times the weight of the water-filled pipe, plus 250 lb (115 kg) at each point of piping support.

(2) The points of support shall be able to support the system.

(3) The spacing between hangers shall not exceed the value given for the type of pipe as indicated in Table 5.4.2.1(a) or Table 5.4.2.1(b).
(4) Hanger components shall be ferrous, unless the provision of 5.1.2(5) is met.

(5) Nonferrous components that have been proven by fire tests for the hazard application, that are listed for this purpose, and that are in compliance with the other requirements of 5.1.2 shall be acceptable.

(6) Detailed calculations shall be submitted, where required by the reviewing authority, showing stresses developed in hangers, piping, and fittings, and safety factors allowed.

5.1.3 Support of Non-System Components. [13:17.1.3]

5.1.3.1* Sprinkler piping or hangers shall not be used to support nonsystem components. [13:17.1.3.1]

5.1.3.2 Sprinkler piping shall be permitted to utilize shared support assemblies in accordance with 5.1.4. [13:17.1.3.2]

5.1.4

Shared support assemblies shall be certified by a registered professional engineer in accordance with 5.1.2 and 5.1.4. [13:17.1.4]

5.1.4.1* The design of a shared support assembly shall be based on either 5.1.4.1.1 or 5.1.4.1.2. [13:17.1.4.1]

5.1.4.1.1 Sprinkler pipe and other distribution systems shall be permitted to be supported from a shared support assembly designed to support five times the weight of water-filled sprinkler pipe and other supported distribution systems plus 250 lb (115 kg), based on the allowable ultimate stress. [13:17.1.4.1.1]

5.1.4.1.2 Sprinkler pipe and other distribution systems shall be permitted to be supported from a shared support assembly designed to support five times the weight of the water-filled sprinkler pipe plus 250 lb (115 kg), and one and one-half times the weight of all other supported distribution systems. [13:17.1.4.1.2]
5.1.4.1.3

The building structure shall not be considered a shared support assembly. [13:17.1.4.1.3]

5.1.4.1.4*

The requirements of 5.1.4.1 shall not apply to 5.4.1.3.3. [13:17.1.4.1.4]

5.1.4.1.5

Systems that are incompatible with the fire sprinkler systems based on vibration, thermal expansion and contraction, or other factors shall not share support assemblies. [13:17.1.4.1.5]

5.1.5

Where water-based fire protection systems are required to be protected against damage from earthquakes, hangers shall also meet the requirements of Section 6.7. [13:17.1.5]

5.1.6 Listing.

5.1.6.1*

Unless permitted by 5.1.6.2 or 5.1.6.3, the components of hanger assemblies that directly attach to the pipe, building structure, or racking structure shall be listed. [13:17.1.6.1]

5.1.6.2*

Mild steel hanger rods and hangers formed from mild steel rods shall be permitted to be not listed. [13:17.1.6.2]

5.1.6.3*

Fasteners as specified in 5.2.2, 5.2.3, and 5.2.4 shall be permitted to be not listed. [13:17.1.6.3]

5.1.6.4

Other fasteners shall be permitted as part of a hanger assembly that has been tested, listed, and installed in accordance with the listing requirements. [13:17.1.6.4]

5.1.7 Component Material.

5.1.7.1

Unless permitted by 5.1.7.2 or 5.1.7.3, hangers and their components shall be ferrous metal. [13:17.1.7.1]
5.1.7.2

Nonferrous components that have been proven by fire tests to be adequate for the hazard application, that are listed for this purpose, and that are in compliance with the other requirements of this section shall be acceptable. [13:17.1.7.2]

5.1.7.3

Holes through solid structural members shall be permitted to serve as hangers for the support of system piping, provided such holes are permitted by applicable building codes and the spacing and support provisions for hangers of this standard are satisfied. [13:17.1.7.3]

5.2 Hanger Components.

5.2.1 Hanger Rods.

5.2.1.1

Unless the requirements of 5.2.1.2 are met, hanger rod size shall be the same as that approved for use with the hanger assembly, and the size of rods shall not be less than that given in Table 5.2.1.1. [13:17.2.1.1]

Table 5.2.1.1 Hanger Rod Sizes

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>Diameter of Rod</th>
</tr>
</thead>
<tbody>
<tr>
<td>in.</td>
<td>mm</td>
</tr>
<tr>
<td>Up to and including 4</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>125</td>
</tr>
<tr>
<td>6</td>
<td>150</td>
</tr>
<tr>
<td>8</td>
<td>200</td>
</tr>
<tr>
<td>10</td>
<td>250</td>
</tr>
<tr>
<td>12</td>
<td>300</td>
</tr>
</tbody>
</table>
### Table 5.2.1.1

<table>
<thead>
<tr>
<th>Pipe Size (in.)</th>
<th>Diameter of Rod (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>350</td>
</tr>
<tr>
<td>16</td>
<td>400</td>
</tr>
<tr>
<td>18</td>
<td>450</td>
</tr>
<tr>
<td>20</td>
<td>500</td>
</tr>
<tr>
<td>24</td>
<td>600</td>
</tr>
<tr>
<td>20</td>
<td>500</td>
</tr>
<tr>
<td>1 ¼</td>
<td>32</td>
</tr>
</tbody>
</table>

### 5.2.1.2

Rods of smaller diameters than indicated in Table 5.2.1.1 shall be permitted where the hanger assembly has been tested and listed by a testing laboratory and installed within the limits of pipe sizes expressed in individual listings. [13:17.2.1.2]

### 5.2.1.3

Where the pitch of the branch line is 6 in 12 or greater, a reduction in the lateral loading on branch line hanger rods shall be done by one of the following:

1. *Second hanger installed in addition to the required main hangers*
2. Lateral sway brace assemblies on the mains
3. Branch line hanger utilizing an articulating structural attachment
4. Equivalent means providing support to the branch line hanger rods

[13:17.2.1.3]

### 5.2.1.4 U-Hooks.

The size of the rod material of U-hooks shall not be less than that given in Table 5.2.1.4. [13:17.2.1.4]
Table 5.2.1.4 U-Hook Rod Sizes

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>Hook Material Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in. mm</td>
</tr>
<tr>
<td>Up to and including 2</td>
<td>50 5/16 8</td>
</tr>
<tr>
<td>2 1/2 to 6</td>
<td>65 to 150 3/8 10</td>
</tr>
<tr>
<td>8</td>
<td>200 1/2 13</td>
</tr>
<tr>
<td>10 to 12</td>
<td>250 to 300 3/4 20</td>
</tr>
<tr>
<td>14 to 18</td>
<td>350 to 450 1 25</td>
</tr>
<tr>
<td>20 to 24</td>
<td>500 to 600 1 1/4 32</td>
</tr>
</tbody>
</table>

5.2.1.5 Eye Rods.

5.2.1.5.1

The size of the rod material for eye rods shall not be less than specified in Table 5.2.1.5.1. [13:17.2.1.5.1]

Table 5.2.1.5.1 Eye Rod Sizes

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>Diameter of Rod</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With Bent Eye</td>
</tr>
<tr>
<td></td>
<td>in. mm</td>
</tr>
<tr>
<td>Up to and including 4</td>
<td>100 3/8 10</td>
</tr>
<tr>
<td>5</td>
<td>125 1/2 13</td>
</tr>
<tr>
<td>6</td>
<td>150 1/2 12</td>
</tr>
</tbody>
</table>
### Diameter of Rod

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>With Bent Eye</th>
<th>With Welded Eye</th>
</tr>
</thead>
<tbody>
<tr>
<td>in.</td>
<td>mm</td>
<td>in.</td>
</tr>
<tr>
<td>8</td>
<td>200</td>
<td>3/4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1/2</td>
</tr>
<tr>
<td>10 to 12</td>
<td>250 to 300</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3/4</td>
</tr>
<tr>
<td>14 to 18</td>
<td>250 to 300</td>
<td>1 1/4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7/8</td>
</tr>
<tr>
<td>20 to 24</td>
<td>500 to 600</td>
<td>1 3/4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 1/8</td>
</tr>
</tbody>
</table>

**5.2.1.5.2**

Eye rods shall be secured with lock washers to prevent lateral motion. [13:17.2.1.5.2]

**5.2.1.5.3**

Where eye rods are fastened to wood structural members, the eye rod shall be backed with a large flat washer bearing directly against the structural member, in addition to the lock washer. [13:17.2.1.5.3]

**5.2.1.6 Threaded Sections of Rods.**

Threaded sections of rods shall not be formed or bent. [13:17.2.1.6]

**5.2.2* Fasteners in Concrete.**

**5.2.2.1**

Unless prohibited by 5.2.2.2 or 5.2.2.3, the use of listed inserts set in concrete and listed post-installed anchors to support hangers shall be permitted for mains and branch lines. [13:17.2.2.1]

**5.2.2.1.1**

The use of post-installed concrete anchors in overhead applications shall be prequalified for cracked concrete applications in accordance with ACI 355.2, *Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary*. 
5.2.2.1.2

Post-installed concrete anchors shall be installed in accordance with the manufacturer’s instructions.

5.2.2.2

Post-installed anchors shall not be used in cinder concrete, except for branch lines where the post-installed anchors are alternated with through-bolts or hangers attached to beams. [13:17.2.2.2]

5.2.2.3

Post-installed anchors shall not be used in ceilings of gypsum or other similar soft material. [13:17.2.2.3]

5.2.2.4

Unless the requirements of 5.2.2.5 are met, post-installed anchors shall be installed in a horizontal position in the sides of concrete beams. [13:17.2.2.4]

5.2.2.5

Post-installed anchors shall be permitted to be installed in the vertical position under any of the following conditions:

(1) When used in concrete having gravel or crushed stone aggregate to support pipes 4 in. (100 mm) or less in diameter
(2) When post-installed anchors are alternated with hangers connected directly to the structural members, such as trusses and girders, or to the sides of concrete beams [to support pipe 5 in. (125 mm) or larger]
(3) When post-installed anchors are spaced not over 10 ft (3 m) apart [to support pipe 4 in. (100 mm) or larger]

[13:17.2.2.5]

5.2.2.6

Holes for post-installed anchors in the side of beams shall be above the centerline of the beam or above the bottom reinforcement steel rods. [13:17.2.2.6]

5.2.2.7
Holes for post-installed anchors used in the vertical position shall be drilled to provide uniform contact with the shield over its entire circumference. [13:17.2.2.7]

5.2.2.8

The depth of the post-installed anchor hole shall be in accordance with the anchor manufacturers' installation instructions.

5.2.2.9 Powder-Driven Studs.

5.2.2.9.1

Powder-driven studs, welding studs, and the tools used for installing these devices shall be listed. [13:17.2.2.9.1]

5.2.2.9.2

Pipe size, installation position, and construction material into which they are installed shall be in accordance with individual listings. [13:17.2.2.9.2]

5.2.2.9.3*

Where test records indicating the strength of the concrete into which studs are being driven are not available, representative samples of the concrete shall be tested to determine that the studs will hold a minimum load of 750 lb (340 kg) for 2 in. (50 mm) or smaller pipe; 1000 lb (454 kg) for 2 1/2 in., 3 in., or 3 1/2 in. (65 mm, 80 mm, or 90 mm) pipe; and 1200 lb (544 kg) for 4 in. or 5 in. (100 mm or 125 mm) pipe. [13:17.2.2.9.3]

5.2.2.9.4

Increaser couplings shall be attached directly to the powder-driven studs. [13:17.2.2.9.4]

5.2.2.10 Minimum Bolt or Rod Size for Concrete.

5.2.2.10.1

The size of a bolt or rod used with a hanger and installed through concrete shall not be less than specified in Table 5.2.2.10.1. [13:17.2.2.10.1]

Table 5.2.2.10.1 Minimum Bolt or Rod Size for Concrete
<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>Size of Bolt or Rod</th>
</tr>
</thead>
<tbody>
<tr>
<td>in.</td>
<td>mm</td>
</tr>
<tr>
<td>Up to and including 4</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>125</td>
</tr>
<tr>
<td>6</td>
<td>150</td>
</tr>
<tr>
<td>8</td>
<td>200</td>
</tr>
<tr>
<td>10</td>
<td>250</td>
</tr>
<tr>
<td>12</td>
<td>300</td>
</tr>
<tr>
<td>14</td>
<td>350</td>
</tr>
<tr>
<td>16</td>
<td>400</td>
</tr>
<tr>
<td>18</td>
<td>450</td>
</tr>
<tr>
<td>20</td>
<td>500</td>
</tr>
<tr>
<td>24</td>
<td>600</td>
</tr>
</tbody>
</table>

5.2.2.10.2

Holes for bolts or rods shall not exceed 1/16 in. (1.6 mm) greater than the diameter of the bolt or rod. [13:17.2.2.10.2]

5.2.2.10.3

Bolts and rods shall be provided with flat washers and nuts. [13:17.2.2.10.3]

5.2.3 Fasteners in Steel.

5.2.3.1*
Powder-driven studs, welding studs, and the tools used for installing these devices shall be listed. \[13:17.2.3.1\]

5.2.3.2

Pipe size, installation position, and construction material into which they are installed shall be in accordance with individual listings. \[13:17.2.3.2\]

5.2.3.3

Increaser couplings shall be attached directly to the powder-driven studs or welding studs. \[13:17.2.3.3\]

5.2.3.4

Where approved by a registered engineer, structural-grade bolts shall be allowed to be welded directly to steel structural members to support, hang, or brace piping.

5.2.3.4.1

Bolts shall be grade A307 or greater.

5.2.3.4.2

Welding shall be performed by qualified welders with an American Welding Society D10.9 level AR-3 or higher certification.

5.2.3.4.3

The use of a listed weld stud tool shall deem to meet the requirements of 5.2.3.4.2.

5.2.3.4.4

Structural steel members to which bolts are welded shall be 12 gauge or greater.

5.2.3.5 Minimum Bolt or Rod Size for Steel.

5.2.3.5.1

The size of a bolt or rod used with a hanger and installed through steel shall not be less than specified in Table 5.2.3.5.1. \[13:17.2.3.5.1\]

Table 5.2.3.5.1 Minimum Bolt or Rod Size for Steel
<table>
<thead>
<tr>
<th>Pipe Size (in.)</th>
<th>Size of Bolt or Rod (in.)</th>
<th>Size of Bolt or Rod (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to and including 4</td>
<td>100</td>
<td>3/8</td>
</tr>
<tr>
<td>5</td>
<td>125</td>
<td>1/2</td>
</tr>
<tr>
<td>6</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>250</td>
<td>5/8</td>
</tr>
<tr>
<td>12</td>
<td>300</td>
<td>3/4</td>
</tr>
<tr>
<td>14</td>
<td>350</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>450</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>500</td>
<td>1 1/4</td>
</tr>
<tr>
<td>24</td>
<td>600</td>
<td></td>
</tr>
</tbody>
</table>

5.2.3.5.2

Holes for bolts or rods shall not exceed 1/16 in. (1.6 mm) greater than the diameter of the bolt or rod. [13:17.2.3.5.2]

5.2.3.5.3

Bolts and rods shall be provided with flat washers and nuts. [13:17.2.3.5.3]

5.2.4 Fasteners in Wood.

5.2.4.1 Drive Screws.
5.2.4.1.1

Drive screws shall be used only in a horizontal position as in the side of a beam and only for 2 in. (50 mm) or smaller pipe. [13:17.2.4.1.1]

5.2.4.1.2

Drive screws shall only be used in conjunction with hangers that require two points of attachments. [13:17.2.4.1.2]

5.2.4.2 Ceiling Flanges and U-Hooks with Screws.

5.2.4.2.1

Unless the requirements of 5.2.4.2.2 or 5.2.4.2.3 are met, for ceiling flanges and U-hooks, screw dimensions shall not be less than those given in Table 5.2.4.2.1. [13:17.2.4.2.1]

Table 5.2.4.2.1 Screw Dimensions for Ceiling Flanges and U-Hooks

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>Two-Screw Ceiling Flanges</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>in.</td>
<td>mm</td>
</tr>
<tr>
<td>Up to and including 2</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>or</td>
</tr>
<tr>
<td></td>
<td>Lag screw 5/16 in. × 1 1/2 in.</td>
</tr>
<tr>
<td></td>
<td>Three-Screw Ceiling Flanges</td>
</tr>
<tr>
<td>Up to and including 2</td>
<td>50</td>
</tr>
<tr>
<td>2 1/2</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>(10 mm × 50 mm)</td>
</tr>
</tbody>
</table>
## Pipe Size

<table>
<thead>
<tr>
<th>in.</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>80</td>
</tr>
<tr>
<td>3 ½</td>
<td>90</td>
</tr>
</tbody>
</table>

### Two-Screw Ceiling Flanges

<table>
<thead>
<tr>
<th></th>
<th>Lag screw 1/2 in. × 2 in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>(13 mm × 50 mm)</td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

### Four-Screw Ceiling Flanges

<table>
<thead>
<tr>
<th></th>
<th>Lag screw 5/8 in. × 2 in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>(16 mm × 50 mm)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Wood screw No. 18 × 1 1/2 in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 ½</td>
<td>Lag screw 3/8 in. × 1 1/2 in.</td>
</tr>
<tr>
<td></td>
<td>(10 mm × 40 mm)</td>
</tr>
<tr>
<td>3</td>
<td>80</td>
</tr>
<tr>
<td>3 ½</td>
<td>90</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Lag screw 1/2 in. × 2 in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>(13 mm × 50 mm)</td>
</tr>
<tr>
<td>Pipe Size</td>
<td><strong>Two-Screw Ceiling Flanges</strong></td>
</tr>
<tr>
<td>-----------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td><strong>in.</strong></td>
<td><strong>mm</strong></td>
</tr>
<tr>
<td>5</td>
<td>125</td>
</tr>
<tr>
<td>6</td>
<td>150</td>
</tr>
<tr>
<td>8</td>
<td>Lag screw 5/8 in. × 2 in.</td>
</tr>
<tr>
<td></td>
<td>(16 mm × 50 mm)</td>
</tr>
<tr>
<td>U-Hooks</td>
<td></td>
</tr>
<tr>
<td>Up to and including 2</td>
<td>50</td>
</tr>
<tr>
<td>Drive screw No. 16 × 2 in.</td>
<td></td>
</tr>
<tr>
<td>Or</td>
<td>Wood screw No. 18 x 1 1/2 in.</td>
</tr>
<tr>
<td>Or</td>
<td>Lag screw 5/16 in. × 1 1/2 in.</td>
</tr>
<tr>
<td>2 1/2</td>
<td>Lag screw 3/8 in. × 2 1/2 in.</td>
</tr>
<tr>
<td></td>
<td>(10 mm × 65 mm)</td>
</tr>
<tr>
<td>3</td>
<td>80</td>
</tr>
<tr>
<td>3 1/2</td>
<td>90</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>125</td>
</tr>
</tbody>
</table>

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Pipe Size | Two-Screw Ceiling Flanges
--- | ---
in. | mm
6 | 150
8 | 200

Lag screw 5⁄8 in. × 3 in.
(16 mm × 75 mm)

5.2.4.2.2
When the thickness of planking and thickness of flange do not permit the use of screws 2 in. (50 mm) long, screws 1 3⁄4 in. (45 mm) long shall be permitted with hangers spaced not over 10 ft (3 m) apart. [13:17.2.4.2.2]

5.2.4.2.3
When the thickness of beams or joists does not permit the use of screws 2 1⁄2 in. (65 mm) long, screws 2 in. (50 mm) long shall be permitted with hangers spaced not over 10 ft (3 m) apart. [13:17.2.4.2.3]

5.2.4.2.4
Pipe larger than 8 in. (200 mm) shall not be hung using ceiling flanges unless approved by a registered professional engineer.

5.2.4.3 Bolts, Rods, or Lag Screws.

5.2.4.3.1
Unless the requirements of 5.2.4.3.2 are met, the size of bolt, rod, or lag screw used with a hanger and installed on the side of the beam shall not be less than specified in Table 5.2.4.3.1. [13:17.2.4.3.1]

Table 5.2.4.3.1 Minimum Bolt, Rod, or Lag Screw Sizes for Side of Beam Installation [13:17.2.4.3.1]
<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>Size of Bolt, Rod or Lag Screw</th>
<th>Length of Lag Screw Used with Wood Beams</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in.</td>
<td>mm</td>
</tr>
<tr>
<td>Up to and including 2</td>
<td>50</td>
<td>3/8</td>
</tr>
<tr>
<td>21/2 to 6 (inclusive)</td>
<td>65 to 150</td>
<td>1/2</td>
</tr>
<tr>
<td>8</td>
<td>200</td>
<td>5/8</td>
</tr>
</tbody>
</table>

[13:Table 17.2.4.3.1]

5.2.4.3.2

Where the thickness of beams or joists does not permit the use of screws 2 1/2 in. (65 mm) long, screws 2 in. (50 mm) long shall be permitted with hangers spaced not over 10 ft (3 m) apart. [13:17.2.4.3.2]

5.2.4.3.3

All holes for lag screws shall be predrilled 1/8 in. (3 mm) less in diameter than the maximum root diameter of the lag screw thread. [13:17.2.4.3.3]

5.2.4.3.4

Holes for bolts or rods shall not exceed 1/16 in. (1.6 mm) greater than the diameter of the bolt or rod. [13:17.2.4.3.4]

5.2.4.3.5

Bolts and rods shall be provided with flat washers and nuts. [13:17.2.4.3.5]

5.2.4.4 Wood Screws.

Wood screws shall be installed with a manually turned or power-driven screwdriver.

5.2.4.5 Nails.

Nails shall not be acceptable for fastening hangers. [13:17.2.4.5]

5.2.4.6 Screws Inside of Timber or Joists.

5.2.4.6.1
Screws in the side of a timber or joist shall be not less than 2 1/2 in. (65 mm) from the lower edge where supporting pipe is up to and including nominal 2 1/2 in. (65 mm) and not less than 3 in. (75 mm) where supporting pipe is greater than nominal 2 1/2 in. (65 mm). [13:17.2.4.6.1]

5.2.4.6.2

The requirements of 5.2.4.6.1 shall not apply to 2 in. (50 mm) or thicker nailing strips resting on top of steel beams. [13:17.2.4.6.2]

5.2.4.7 Coach Screw Rods.

5.2.4.7.1 Minimum Coach Screw Rod Size.

The size of coach screw rods shall not be less than the requirements of Table 5.2.4.7.1. [13:17.2.4.7.1]

Table 5.2.4.7.1 Minimum Coach Screw Rod Size [13:17.2.4.7.1]

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>Diameter of Rod</th>
<th>Minimum Penetration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in.</td>
<td>mm</td>
</tr>
<tr>
<td>Up to and including 4</td>
<td>100</td>
<td>3/8</td>
</tr>
<tr>
<td>Larger than 4</td>
<td>100</td>
<td>NP</td>
</tr>
</tbody>
</table>

NP: Not permitted.

[13:Table 17.2.4.7.1]

5.2.4.7.2

The minimum plank thickness and the minimum width of the lower face of beams or joists in which coach screw rods are used shall be not less than that specified in Table 5.2.4.7.2 and shown in Figure 5.2.4.7.2. [13:17.2.4.7.2]

Table 5.2.4.7.2 Minimum Plank Thicknesses and Beam or Joist Widths [13:17.2.4.7.2]

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>Nominal Plank Thickness</th>
<th>Nominal Width of Beam or Joist Face</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in.</td>
<td>mm</td>
</tr>
<tr>
<td>Up to and including 2</td>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>2 1/2</td>
<td>65</td>
<td>4</td>
</tr>
</tbody>
</table>
### Table 17.2.4.7.2

**Dimensions for Structural Members with Coach Screw Rods.**

<table>
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<tr>
<th>Pipe Size</th>
<th>Nominal Plank Thickness</th>
<th>Nominal Width of Beam or Joist Face</th>
</tr>
</thead>
<tbody>
<tr>
<td>in.</td>
<td>mm</td>
<td>in.</td>
</tr>
<tr>
<td>3</td>
<td>80</td>
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</tr>
<tr>
<td>3½</td>
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<tr>
<td>4</td>
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</tr>
</tbody>
</table>

[13:Table 17.2.4.7.2]

**Figure 5.2.4.7.2**

5.2.4.7.3
Coach screw rods shall not be used for support of pipes larger than 4 in. (100 mm) in diameter. [13:17.2.4.7.3]

5.2.4.7.4

All holes for coach screw rods shall be predrilled 1/8 in. (3 mm) less in diameter than the maximum root diameter of the wood screw thread. [13:17.2.4.7.4]

5.3* Trapeze Hangers.

5.3.1

For trapeze hangers, the minimum size of steel angle or pipe span between structural members shall be such that the section modulus required in Table 5.3.1(a) or Table 5.3.1(b) does not exceed the available section modulus of the trapeze member in Table 5.3.1(c) or Table 5.3.1(d). [13:17.3.1]

Table 5.3.1(a) Section Modulus Required for Trapeze Members (in.³) [13:17.3.1(a)]

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<td>0.22</td>
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<td>Span (ft)</td>
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### Span (ft) Nominal Diameter of Pipe Being Supported — Schedule 10 Steel

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Note: The table is based on a maximum bending stress of 15 ksi and a midspan concentrated load from 15 ft of water-filled pipe, plus 250 lb.

[13:Table 17.3.1(a)]

### Table 5.3.1(b) Section Modulus Required for Trapeze Members (mm³) [13:17.3.1(b)]

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<td>8.50</td>
<td>(3\times \frac{1}{2} \times 2\times \frac{1}{4})</td>
<td>0.75</td>
</tr>
</tbody>
</table>

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### Table 5.3.1(d) Available Section Modulus of Common Trapeze Hangers (cm³)

<table>
<thead>
<tr>
<th>Pipe (in.)</th>
<th>Modulus (in.³)</th>
<th>Angles (in.)</th>
<th>Modulus (in.³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 × 4 × 3/8</td>
<td>1.52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 × 3¹/₂ × 5/₁₆</td>
<td>1.94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 × 4 × 1/₂</td>
<td>1.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 × 4 × 5/₈</td>
<td>2.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 × 4 × 3/₄</td>
<td>2.81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 × 4 × 3/₈</td>
<td>3.32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 × 4 × 1/₂</td>
<td>4.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 × 4 × 3/₄</td>
<td>6.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 × 6 × 1</td>
<td>8.57</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[13:Table 17.3.1(c)]

**Table 5.3.1(d) Available Section Modulus of Common Trapeze Hangers (cm³)**

<table>
<thead>
<tr>
<th>Pipe (mm)</th>
<th>Modulus (mm³)</th>
<th>Angles (mm)</th>
<th>Modulus (mm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schedule 10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>19.7</td>
<td>40 × 40 × 5</td>
<td>1640</td>
</tr>
<tr>
<td>32</td>
<td>31.1</td>
<td>50 × 50 × 3</td>
<td>2130</td>
</tr>
<tr>
<td>40</td>
<td>42.6</td>
<td>50 × 40 × 5</td>
<td>2950</td>
</tr>
<tr>
<td>50</td>
<td>68.8</td>
<td>50 × 50 × 5</td>
<td>3110</td>
</tr>
<tr>
<td>65</td>
<td>113</td>
<td>50 × 50 × 6</td>
<td>4100</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Pipe (mm)</th>
<th>Modulus (mm³)</th>
<th>Angles (mm)</th>
<th>Modulus (mm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>170</td>
<td>65 × 40 × 5</td>
<td>4590</td>
</tr>
<tr>
<td>90</td>
<td>226</td>
<td>65 × 50 × 5</td>
<td>4750</td>
</tr>
<tr>
<td>100</td>
<td>288</td>
<td>50 × 50 × 8</td>
<td>4920</td>
</tr>
<tr>
<td>125</td>
<td>497</td>
<td>65 × 65 × 5</td>
<td>4920</td>
</tr>
<tr>
<td>150</td>
<td>713</td>
<td>50 × 50 × 10</td>
<td>5740</td>
</tr>
<tr>
<td></td>
<td></td>
<td>65 × 65 × 6</td>
<td>6390</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80 × 50 × 5</td>
<td>6720</td>
</tr>
</tbody>
</table>

**Schedule 40**

<table>
<thead>
<tr>
<th>Pipe (mm)</th>
<th>Modulus (mm³)</th>
<th>Angles (mm)</th>
<th>Modulus (mm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>21.0</td>
<td>80 × 65 × 10</td>
<td>7050</td>
</tr>
<tr>
<td>32</td>
<td>38.0</td>
<td>80 × 80 × 5</td>
<td>7210</td>
</tr>
<tr>
<td>40</td>
<td>54.0</td>
<td>65 × 65 × 8</td>
<td>7870</td>
</tr>
<tr>
<td>50</td>
<td>92.0</td>
<td>80 × 50 × 6</td>
<td>8850</td>
</tr>
<tr>
<td>65</td>
<td>174.0</td>
<td>65 × 50 × 10</td>
<td>9010</td>
</tr>
<tr>
<td>80</td>
<td>282.0</td>
<td>65 × 65 × 10</td>
<td>9340</td>
</tr>
<tr>
<td>90</td>
<td>392.0</td>
<td>80 × 80 × 6</td>
<td>9500</td>
</tr>
<tr>
<td>100</td>
<td>526.0</td>
<td>80 × 80 × 8</td>
<td>11,600</td>
</tr>
<tr>
<td>125</td>
<td>893.0</td>
<td>65 × 65 × 15</td>
<td>11,800</td>
</tr>
<tr>
<td>150</td>
<td>1393.0</td>
<td>90 × 65 × 6</td>
<td>12,300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80 × 65 × 10</td>
<td>13,300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80 × 80 × 10</td>
<td>13,600</td>
</tr>
</tbody>
</table>
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5.3.3
All angles shall be installed with the longer leg vertical. [13:17.3.3]

5.3.4
The trapeze member shall be secured to prevent slippage. [13:17.3.4]

5.3.5*
All components of each hanger assembly that attach to a trapeze member shall conform to 5.1.6 and be sized to support the suspended sprinkler pipe. [13:17.3.5]

5.3.6
The ring, strap, or clevis installed on a pipe trapeze shall be manufactured to fit the pipe size of the trapeze member. [13:17.3.6]

5.3.7
Holes for bolts or rods shall not exceed 1/16 in. (1.6 mm) greater than the diameter of the bolt or rod. [13:17.3.7]

5.3.8
Bolts and rods shall be provided with flat washers and nuts. [13:17.3.8]

5.3.9
Where angles are used for trapeze hangers and slotted holes are used, the slotted holes shall meet all of the following:

(1) The length of each slotted hole shall not exceed 3 in. (75 mm).
(2) The width of the slotted hole shall not exceed 1/16 in. (1.6 mm) greater than the bolt or rod diameter.
(3) The minimum distance between slotted holes shall be 3 in. (75 mm) edge to edge.
(4) The minimum distance from the end of the angle to the edge of the slotted hole shall be 3 in. (75 mm).
(5) The number of slots shall be limited to three per section of angle.
(6) The washer(s) required by 5.3.8 shall have a minimum thickness of one-half the thickness of the angle.
(7) Washers and nuts required by 5.3.8 shall be provided on both the top and bottom of the angle.
5.4* Installation of Pipe Hangers.

5.4.1 General.

5.4.1.1 Ceiling Sheathing.

5.4.1.1.1*

Unless the requirements of 5.4.1.1.2 are met, sprinkler piping shall be supported independently of the ceiling sheathing. [13:17.4.1.1.1]

5.4.1.1.2

Toggle hangers shall be permitted only for the support of pipe 1 1/2 in. (40 mm) or smaller in size under ceilings of hollow tile or metal lath and plaster. [13:17.4.1.1.2]

5.4.1.2 Storage Racks.

Where sprinkler piping is installed in storage racks, piping shall be supported from the storage rack structure or building in accordance with all applicable provisions of Section 5.4 and Chapter 6. [13:17.4.1.2]

5.4.1.3* Building Structure.

5.4.1.3.1

Sprinkler piping shall be substantially supported from the building structure, which must support the added load of the water-filled pipe plus 250 lb (115 kg) applied at the point of hanging, except where permitted by 5.4.1.1.2, 5.4.1.3.3, and 5.4.1.4.1. [13:17.4.1.3.1]

5.4.1.3.2

Trapeze hangers shall be used where necessary to transfer loads to appropriate structural members. [13:17.4.1.3.2]

5.4.1.3.3* Flexible Sprinkler Hose Fittings.

5.4.1.3.3.1

Listed flexible sprinkler hose fittings and their anchoring components intended for use in installations connecting the sprinkler system piping to sprinklers shall be installed in accordance with the requirements of the listing, including any installation instructions. [13:17.4.1.3.3.1]
5.4.1.3.3.2

When installed and supported by suspended ceilings, the ceiling shall meet ASTM C635/C635M, Standard Specification for Manufacture, Performance, and Testing of Metal Suspension Systems for Acoustical Tile and Lay-In Panel Ceilings, and shall be installed in accordance with ASTM C636/C636M, Standard Practice for Installation of Metal Ceiling Suspension Systems for Acoustical Tile and Lay-In Panels. [13:17.4.1.3.3.2]

5.4.1.3.3*

Where flexible sprinkler hose fittings exceed 6 ft (1.8 m) in length and are supported by a suspended ceiling in accordance with 5.4.1.3.3.2, a hanger(s) attached to the structure shall be required to ensure that the maximum unsupported length does not exceed 6 ft (1.8 m). [13:17.4.1.3.3.3]

5.4.1.3.4*

Where flexible sprinkler hose fittings are used to connect sprinklers to branch lines in suspended ceilings, a label limiting relocation of the sprinkler shall be provided on the anchoring component. [13:17.4.1.3.3.4]

5.4.1.4 Metal Deck.

5.4.1.4.1*

Branch line hangers attached to metal deck shall be permitted only for the support of pipe 1 in. (25 mm) or smaller in size, by drilling or punching the vertical portion of the metal deck and using through bolts. [13:17.4.1.4.1]

5.4.1.4.2

The distance from the bottom of the bolt hole to the bottom of the vertical member shall be not less than 3/8 in. (10 mm). [13:17.4.1.4.2]

5.4.1.5

Where sprinkler piping is installed below ductwork, piping shall be supported from the building structure or from the ductwork supports, provided such supports are capable of handling both the load of the ductwork and the load specified in 5.4.1.3.1. [13:17.4.1.5]

5.4.2* Maximum Distance Between Hangers.

5.4.2.1
The maximum distance between hangers shall not exceed that specified in Table 5.4.2.1(a) or Table 5.4.2.1(b), except where the provisions of 5.4.4 apply. [13:17.4.2.1]

### Table 5.4.2.1(a) Maximum Distance Between Hangers (ft-in.)

<table>
<thead>
<tr>
<th>Nominal Pipe Size (in.)</th>
<th>3/4</th>
<th>1</th>
<th>11/4</th>
<th>11/2</th>
<th>2</th>
<th>21/2</th>
<th>3</th>
<th>31/2</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>≥8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel pipe except threaded lightwall</td>
<td>NA</td>
<td>12-0</td>
<td>12-0</td>
<td>15-0</td>
<td>15-0</td>
<td>15-0</td>
<td>15-0</td>
<td>15-0</td>
<td>15-0</td>
<td>15-0</td>
<td>15-0</td>
<td>15-0</td>
</tr>
<tr>
<td>Threaded lightwall steel pipe</td>
<td>NA</td>
<td>12-0</td>
<td>12-0</td>
<td>12-0</td>
<td>12-0</td>
<td>12-0</td>
<td>12-0</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Copper tube</td>
<td>8-0</td>
<td>8-0</td>
<td>10-0</td>
<td>10-0</td>
<td>12-0</td>
<td>12-0</td>
<td>12-0</td>
<td>12-0</td>
<td>15-0</td>
<td>15-0</td>
<td>15-0</td>
<td>15-0</td>
</tr>
<tr>
<td>CPVC</td>
<td>5-6</td>
<td>6-0</td>
<td>6-6</td>
<td>7-0</td>
<td>8-0</td>
<td>9-0</td>
<td>10-0</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Ductile-iron pipe</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>15-0</td>
<td>NA</td>
<td>15-0</td>
<td>15-0</td>
<td>15-0</td>
<td>15-0</td>
</tr>
</tbody>
</table>

NA: Not applicable.

### Table 5.4.2.1(b) Maximum Distance Between Hangers (m)

<table>
<thead>
<tr>
<th>Nominal Pipe Size (mm)</th>
<th>20</th>
<th>25</th>
<th>32</th>
<th>40</th>
<th>50</th>
<th>65</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>125</th>
<th>150</th>
<th>≥200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel pipe except threaded lightwall</td>
<td>NA</td>
<td>3.7</td>
<td>3.7</td>
<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
</tr>
<tr>
<td>Threaded lightwall steel pipe</td>
<td>NA</td>
<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Copper tube</td>
<td>2.4</td>
<td>2.4</td>
<td>3.0</td>
<td>3.0</td>
<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
</tr>
<tr>
<td>CPVC</td>
<td>1.7</td>
<td>1.8</td>
<td>2.0</td>
<td>2.1</td>
<td>2.4</td>
<td>2.7</td>
<td>3.0</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>
Nominal Pipe Size (mm)

<table>
<thead>
<tr>
<th></th>
<th>20</th>
<th>25</th>
<th>32</th>
<th>40</th>
<th>50</th>
<th>65</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>125</th>
<th>150</th>
<th>≥200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ductile-iron pipe</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>4.6</td>
<td>4.6</td>
<td>NA</td>
<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
</tr>
</tbody>
</table>

NA: Not applicable.

5.4.2.2

The maximum distance between hangers for listed nonmetallic pipe shall be modified as specified in the individual product listings. [13:17.4.2.2]

5.4.3 Location of Hangers on Branch Lines.

5.4.3.1

Subsection 5.4.3 shall apply to the support of steel pipe or copper tube as specified in 7.3.1 of NFPA 13 and subject to the provisions of 5.4.2. [13:17.4.3.1]

5.4.3.2* Minimum Number of Hangers.

5.4.3.2.1

Unless the requirements of 5.4.3.2.2 through 5.4.3.2.5 are met, there shall be not less than one hanger for each section of pipe. [13:17.4.3.2.1]

5.4.3.2.2*

Unless the requirements of 5.4.3.2.3 are met, where sprinklers are spaced less than 6 ft (1.8 m) apart, hangers spaced up to a maximum of 12 ft (3.7 m) shall be permitted. [13:17.4.3.2.2]

5.4.3.2.3

For welded or mechanical outlets on a continuous section of pipe, hanger spacing shall be according to Table 5.4.2.1(a) or Table 5.4.2.1(b). [13:17.4.3.2.3]

5.4.3.2.4*

Starter lengths less than 6 ft (1.8 m) shall not require a hanger, unless on the end line of a sidefeed system or where an intermediate cross main hanger has been omitted. [13:17.4.3.2.4]

5.4.3.2.5*
A single section of pipe shall not require a hanger when the cumulative distance between
hangers on the branch line does not exceed the spacing required by Table 5.4.2.1(a) and Table
5.4.2.1(b). [13:17.4.3.2.5]

5.4.3.3 Clearance to Hangers.
The distance between a hanger and the centerline of an upright sprinkler shall not be less than
3 in. (75 mm). [13:17.4.3.3]

5.4.3.4* Unsupported Lengths.

5.4.3.4.1
For steel pipe, the unsupported horizontal length between the end sprinkler and the last hanger
on the line shall not be greater than 36 in. (900 mm) for 1 in. (25 mm) pipe, 48 in. (1200 mm) for
1 1/4 in. (32 mm) pipe, and 60 in. (1500 mm) for 1 1/2 in. (40 mm) or larger pipe. [13:17.4.3.4.1]

5.4.3.4.2
For copper tube, the unsupported horizontal length between the end sprinkler and the last
hanger on the line shall not be greater than 18 in. (450 mm) for 1 in. (25 mm) pipe, 24 in.
(600 mm) for 1 1/4 in. (32 mm) pipe, and 30 in. (750 mm) for 1 1/2 in. (40 mm) or larger pipe.
[13:17.4.3.4.2]

5.4.3.4.3
Where the limits of 5.4.3.4.1 and 5.4.3.4.2 are exceeded, the pipe shall be extended beyond the
end sprinkler and shall be supported by an additional hanger. [13:17.4.3.4.3]

5.4.3.4.4* Unsupported Length with Maximum Pressure Exceeding 100 psi (6.9 bar) and
Branch Line Above Ceiling Supplying Sprinklers in Pendent Position Below Ceiling.
[13:17.4.3.4.4]

5.4.3.4.4.1
Where the maximum static or flowing pressure, whichever is greater at the sprinkler, applied
other than through the fire department connection, exceeds 100 psi (6.9 bar) and a branch line
above a ceiling supplies sprinklers in a pendent position below the ceiling, the hanger assembly
supporting the pipe supplying an end sprinkler in a pendent position shall be of a type that
restrains upward movement of the pipe. [13:17.4.3.4.4.1]

5.4.3.4.4.2
The unsupported length between the end sprinkler in a pendent position or drop nipple and the last hanger on the branch line shall not be greater than 12 in. (300 mm) for steel pipe or 6 in. (150 mm) for copper pipe. [13:17.4.3.4.4.2]

5.4.3.4.4.3

When the limit of 5.4.3.4.4.2 is exceeded, the pipe shall be extended beyond the end sprinkler and supported by an additional hanger. [13:17.4.3.4.4.3]

5.4.3.4.4.4

Unless flexible hose fittings in accordance with 5.4.1.3.3.1 and ceilings in accordance with 5.4.1.3.3.2 are used, the hanger closest to the sprinkler shall be of a type that restrains the pipe from upward movement. [13:17.4.3.4.4.4]

5.4.3.5* Unsupported Armover Length.

5.4.3.5.1

The cumulative horizontal length of an unsupported armover to a sprinkler, sprinkler drop, or sprig shall not exceed 24 in. (600 mm) for steel pipe or 12 in. (300 mm) for copper tube. [13:17.4.3.5.1]

5.4.3.5.2* Unsupported Armover Length with Maximum Pressure Exceeding 100 psi (6.9 bar) and Branch Line Above Ceiling Supplying Sprinklers in Pendent Position Below Ceiling. [13:17.4.3.5.2]

5.4.3.5.2.1

Where the maximum static or flowing pressure, whichever is greater at the sprinkler, applied other than through the fire department connection, exceeds 100 psi (6.9 bar) and a branch line above a ceiling supplies sprinklers in a pendent position below the ceiling, the cumulative horizontal length of an unsupported armover to a sprinkler or sprinkler drop shall not exceed 12 in. (300 mm) for steel pipe and 6 in. (150 mm) for copper tube. [13:17.4.3.5.2.1]

5.4.3.5.2.2

Unless flexible sprinkler hose fittings in accordance with 5.4.1.3.3.1 are used, the hanger closest to the sprinkler shall be of a type that restrains upward movement of the pipe. [13:17.4.3.5.2.2]

5.4.3.5.2.3
Where the armover exceeds the maximum unsupported length of 5.4.3.5.2.1, a hanger shall be installed so that the distance from the end sprinkler or drop nipple to the hanger is not greater than 12 in. (300 mm) for steel or 6 in. (150 mm) for copper, or the pipe shall be extended beyond the end sprinkler and shall be supported by an additional hanger. [13:17.4.3.5.2.3]

5.4.3.6*

Wall-mounted sidewall sprinklers shall be restrained to prevent movement. [13:17.4.3.6]

5.4.3.7 Sprigs.

Sprigs 4 ft (1.2 m) or longer shall be restrained against lateral movement. [13:17.4.3.7]

5.4.4 Location of Hangers on Mains.

5.4.4.1

Unless any of the requirements of 5.4.4.2 through 5.4.4.7 are met, hangers for mains shall be in accordance with 5.4.2, between each branch line, or on each section of pipe, whichever is the lesser dimension. [13:17.4.4.1]

5.4.4.2

For welded or mechanical outlets on a continuous section of pipe, hanger spacing shall be according to Table 5.4.2.1(a) or Table 5.4.2.1(b). [13:17.4.4.2]

5.4.4.3

For cross mains in steel pipe systems in bays having two branch lines, the intermediate hanger shall be permitted to be omitted, provided that a hanger attached to a purlin is installed on each branch line located as near to the cross main as the location of the purlin permits. [13:17.4.4.3]

5.4.4.3.1

The remaining branch line hangers shall be installed in accordance with 5.4.3. [13:17.4.4.3.1]

5.4.4.4

For cross mains in steel pipe systems only in bays having three branch lines, either side or center feed, one (only) intermediate hanger shall be permitted to be omitted, provided that a hanger attached to a purlin is installed on each branch line located as near to the cross main as the location of the purlin permits. [13:17.4.4.4]

5.4.4.4.1
The remaining branch line hangers shall be installed in accordance with 5.4.3. [13:17.4.4.4.1]

5.4.4.5

For cross mains in steel pipe systems only in bays having four or more branch lines, either side or center feed, two intermediate hangers shall be permitted to be omitted, provided the maximum distance between hangers does not exceed the distances specified in 5.4.2 and a hanger attached to a purlin on each branch line is located as near to the cross main as the purlin permits. [13:17.4.4.5]

5.4.4.6

The unsupported length of the end of a main shall be no greater than one half the maximum allowable hanger spacing per Table 5.4.2.1(a) and Table 5.4.2.1(b). [13:17.4.4.6]

5.4.4.7

At the end of the main, intermediate trapeze hangers shall be installed unless the main is extended to the next framing member with a hanger installed at this point, in which event an intermediate hanger shall be permitted to be omitted in accordance with 5.4.4.3, 5.4.4.4, and 5.4.4.5. [13:17.4.4.7]

5.4.4.8*

A single section of pipe shall not require a hanger when the cumulative distance between hangers on the main does not exceed the spacing required by Table 5.4.2.1(a) and Table 5.4.2.1(b). [13:17.4.4.8]

5.4.5 Support of Risers.

5.4.5.1

Risers shall be supported by riser clamps or by hangers located on the horizontal connections within 24 in. (600 mm) of the centerline of the riser. [13:17.4.5.1]

5.4.5.2

Riser clamps supporting risers by means of set screws shall not be used. [13:17.4.5.2]

5.4.5.3*

Riser clamps anchored to walls using hanger rods in the horizontal position shall not be permitted to vertically support risers. [13:17.4.5.3]
5.4.5.4 Multistory Buildings.

5.4.5.4.1

In multistory buildings, riser supports shall be provided at the lowest level, at each alternate level above, above and below offsets, and at the top of the riser. [13:17.4.5.4.1]

5.4.5.4.2*

Supports above the lowest level shall also restrain the pipe to prevent movement by an upward thrust where flexible fittings are used. [13:17.4.5.4.2]

5.4.5.4.3

Where risers are supported from the ground, the ground support shall constitute the first level of riser support. [13:17.4.5.4.3]

5.4.5.4.4

Where risers are offset or do not rise from the ground, the first ceiling level above the offset shall constitute the first level of riser support. [13:17.4.5.4.4]

5.4.5.5

Distance between supports for risers shall not exceed 25 ft (7.6 m). [13:17.4.5.5]

5.5* Pipe Stands.

5.5.1 General.

5.5.1.1

Where pipe stands are used to support system piping, the requirements of Section 5.5 shall apply unless the requirements of 5.5.1.2 are met. [13:17.5.1.1]

5.5.1.2

Pipe stands certified by a registered professional engineer to include all of the following shall be an acceptable alternative to the requirements of Section 5.5:

(1) Pipe stands shall be designed to support five times the weight of water-filled pipe plus 250 lb (115 kg) at each point of piping support.

(2) These points of support shall be adequate to support the system.
(3) The spacing between pipe stands shall not exceed the value given for the type of pipe as indicated in Table 5.4.2.1(a) or Table 5.4.2.1(b).

(4) Pipe stand components shall be ferrous.

(5) Detailed calculations shall be submitted, when required by the reviewing authority, showing stresses developed in the pipe stand, the system piping and fittings, and safety factors allowed.

[13:17.5.1.2]

5.5.1.3

Where water-based fire protection systems are required to be protected against damage from earthquakes, pipe stands shall also meet the requirements of Section 6.8. [13:17.5.1.3]

5.5.2 Component Material.

5.5.2.1

Pipe stands and their components shall be ferrous unless permitted by 5.5.2.2. [13:17.5.2.1]

5.5.2.2

Nonferrous components that have been proven by fire tests to be adequate for the hazard application and that are in compliance with the other requirements of this section shall be acceptable. [13:17.5.2.2]

5.5.3 Sizing.

5.5.3.1*

The maximum heights for pipe stands shall be in accordance with Table 5.5.3.1(a) or Table 5.5.3.1(b) unless the requirements of 5.5.3.2 are met. [13:17.5.3.1]

Table 5.5.3.1(a) Maximum Pipe Stand Heights(ft) [13:17.5.3.1(a)]

<table>
<thead>
<tr>
<th>System Pipe Diameter (in.)†</th>
<th>Pipe Stand Diameter (in.)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11/2</td>
</tr>
<tr>
<td>11/2</td>
<td>6.6</td>
</tr>
<tr>
<td>2</td>
<td>4.4</td>
</tr>
<tr>
<td>11/2</td>
<td>—</td>
</tr>
</tbody>
</table>
**System Pipe Diameter (in.)†** | **Pipe Stand Diameter (in.)***
---|---
3 |   |
   | 5.2 11.3 13.8 18.0 26.8 |
4 up to and including 8 |   |
   |   |   |   | 14.7 26.8 |

*Pipe stands are Schedule 40 pipe.
†System piping is assumed to be Schedule 40 (8 in. is Schedule 30).

**Table 5.5.3.1(b) Maximum Pipe Stand Heights (m) [13:17.5.3.1(b)]**

<table>
<thead>
<tr>
<th>System Pipe Diameter (mm)†</th>
<th>Pipe Stand Diameter (mm)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40 50 65 80 100 150</td>
</tr>
<tr>
<td>40</td>
<td>2 2.9 3.4 4.2 5.5 8.2</td>
</tr>
<tr>
<td>50</td>
<td>1.3 2.9 3.4 4.2 5.5 8.2</td>
</tr>
<tr>
<td>65</td>
<td>2.5 3.4 4.2 5.5 8.2</td>
</tr>
<tr>
<td>80</td>
<td>1.6 3.4 4.2 5.5 8.2</td>
</tr>
<tr>
<td>100 up to and including 200</td>
<td></td>
</tr>
</tbody>
</table>

*Pipe stands are Schedule 40 pipe.
†System piping is assumed to be Schedule 40 (200 mm is Schedule 30).

**5.5.3.2**

Pipe diameters up to and including 10 in. (250 mm) Schedule 40 are permitted to be supported by 2 in. (50 mm) Schedule 40 diameter pipe stands when all of the following conditions are met:

1. The maximum height shall be 4 ft (1.2 m), as measured from the base of the pipe stand to the centerline of the pipe being supported.
2. The pipe stand shall be axially loaded.

**5.5.3.3**
The distance between pipe stands shall not exceed the values in Table 5.4.2.1(a) or Table 5.4.2.1(b). [13:17.5.3.3]

5.5.4 Pipe Stand Base.

5.5.4.1
The pipe stand base shall be secured by an approved method. [13:17.5.4.1]

5.5.4.2*
Pipe stand base plates shall be threaded malleable iron flanges or welded steel flanges in accordance with Table 7.4.1 of NFPA 13. [13:17.5.4.2]

5.5.4.2.1
Pipes stands installed in accordance with 5.5.3.2 shall be permitted to use a welded steel plate. [13:17.5.4.2.1]

5.5.4.3*
Pipe stands shall be fastened to a concrete floor or footing using listed concrete anchors or other approved means. [13:17.5.4.3]

5.5.4.4
A minimum of four anchors shall be used to attach the base plate to the floor. [13:17.5.4.4]

5.5.4.4.1
Pipe stands installed in accordance with 5.5.3.2 shall be permitted to use a minimum of two anchors to attach the base plate to the floor. [13:17.5.4.4.1]

5.5.4.5
The minimum diameter for the anchors shall be 1/2 in. (15 mm) for pipe stand diameters up to and including 3 in. (80 mm) and 5/8 in. (16 mm) for pipe stands 4 in. (100 mm) diameter and larger. [13:17.5.4.5]

5.5.4.5.1
Where the pipe stand complies with 5.5.3.2, 3/8 in. (10 mm) anchors shall be permitted. [13:17.5.4.5.1]

5.5.5 Attaching to System Piping.
5.5.5.1
Piping shall be attached to the pipe stand with U-bolts or equivalent attachment, unless the requirements of 5.5.5.2 are met.

5.5.5.2
Where a saddle-type pipe stand is utilized and the pipe is not subject to a net vertical upward force, a through-bolt or equivalent attachment shall not be required.

5.5.5.3*
Where a horizontal bracket is used to attach the system piping to the pipe stand, it shall not be more than 1 ft (0.3 m) as measured horizontally from the centerline of the pipe stand to the centerline of the supported pipe. [13:17.5.5.3]

5.5.5.4
Horizontal support brackets shall be sized such that the section modulus required in Table 5.5.5.4 does not exceed the available section modulus from Table 5.3.1(c). [13:17.5.5.4]

Table 5.5.5.4 Required Section Modulus for Pipe Stand Horizontal Support Arms (in.³) [13:Table 17.5.5.4]

<table>
<thead>
<tr>
<th>Nominal Diameter of Pipe Being Supported (in.)</th>
<th>1</th>
<th>1 1/4</th>
<th>1 1/2</th>
<th>2</th>
<th>2 1/2</th>
<th>3</th>
<th>3 1/2</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section Modulus – Schedule 10 Steel</td>
<td>0.22</td>
<td>0.23</td>
<td>0.24</td>
<td>0.25</td>
<td>0.30</td>
<td>0.36</td>
<td>0.42</td>
<td>0.49</td>
<td>0.66</td>
<td>0.85</td>
<td>1.40</td>
</tr>
<tr>
<td>Section Modulus – Schedule 40 Steel</td>
<td>0.22</td>
<td>0.24</td>
<td>0.24</td>
<td>0.27</td>
<td>0.36</td>
<td>0.45</td>
<td>0.54</td>
<td>0.63</td>
<td>0.86</td>
<td>1.13</td>
<td>1.64</td>
</tr>
</tbody>
</table>

For SI units, 1 in. = 25.4 mm.

Note: The table is based on the controlling section modulus determined for a concentrated load at a 1 ft (0.3 m) cantilever using: a) a maximum bending stress of 15 ksi (103 MPa) and a concentrated load equal to the weight of 15 ft (4.6 m) of water-filled pipe plus 250 lb (115 kg), or b) a maximum bending stress of 28 ksi (193 MPa) and a concentrated load equal to five times the weight of 15 ft (4.6 m) of water-filled pipe plus 250 lb (115 kg).

5.5.6 Thrust.
5.5.6.1*

System piping shall be supported and restrained to restrict movement due to sprinkler/nozzle reaction and water surges. [13:17.5.6.1]

5.5.6.2*

Where thrust forces are anticipated to be high, a pipe ring or clamp shall secure the system piping to the pipe stand. [13:17.5.6.2]

5.5.7 Exterior Applications.

5.5.7.1

Where required, pipe stands used in exterior applications shall be made of galvanized steel or other suitable corrosion-resistant materials. [13:17.5.7.1]

5.5.7.2

A welded, threaded, grooved, or other approved cap shall be securely attached to the top of the pipe stand. [13:17.5.7.2]
Chapter 6 Installation Requirements for Seismic Protection of Sprinkler System Piping

6.1* Protection of Piping Against Damage Where Subject to Earthquakes.

6.1.1

Where water-based fire protection systems are required to be protected against damage from earthquakes, the requirements of Chapter 6 shall apply, unless the requirements of 6.1.2 are met. [13:18.1.1]

6.1.1.1

Where sway bracing is required, a combination of lateral sway bracing, longitudinal sway bracing, and sprinkler system line restraint shall control all pipe from moving differently than the building structure that it is attached to unless specific omission is allowed.

6.1.1.2

The control shall be accomplished by providing bracing or restraint in two directions perpendicular to each other.

6.1.2

Alternative methods of providing earthquake protection of sprinkler systems based on a seismic analysis certified by a registered professional engineer such that system performance will be at least equal to that of the building structure under expected seismic forces shall be permitted. [13:18.1.2]

6.1.3 Obstructions to Sprinklers.

Braces and restraints shall not obstruct sprinklers and shall comply with the obstruction rules of NFPA 13 Chapters 10 through 14. [13:18.1.3]

6.2* Flexible Couplings.

6.2.1

Flexible couplings joining grooved end pipe shall be provided as flexure joints to allow individual sections of piping 2 1/2 in. (65 mm) or larger to move differentially with the individual sections of the building to which it is attached. [13:18.2.1]

6.2.2
Flexible couplings shall be arranged to coincide with structural separations within a building. [13:18.2.2]

6.2.3

Systems having more flexible couplings than required by this section shall be provided with additional sway bracing as required in 6.5.5.9. [13:18.2.3]

6.2.3.1

The flexible couplings shall be installed as follows:

(1) *Within 24 in. (600 mm) of the top and bottom of all risers, unless the following provisions are met:
   (a) In risers less than 3 ft (900 mm) in length, flexible couplings shall be permitted to be omitted.
   (b) In risers 3 ft to 7 ft (900 mm to 2100 mm) in length, one flexible coupling shall be adequate.

(2) Within 12 in. (300 mm) above and within 24 in. (600 mm) below the floor in multistory buildings, unless the following provision is met:
   (c) *In risers up to 7 ft (2.1 m) in length terminating above the roof assembly or top landing, the flexible coupling shall not be required above the landing or roof assembly.

(3) On both sides of concrete or masonry walls within 1 ft (300 mm) of the wall surface, unless clearance is provided in accordance with Section 6.4

(4) *Within 24 in. (600 mm) of building expansion joints

(5) Within 24 in. (600 mm) of the top of drops exceeding 15 ft (4.6 m) in length to portions of systems supplying more than one sprinkler, regardless of pipe size

(6) Within 24 in. (600 mm) above and 24 in. (600 mm) below any intermediate points of support for a riser or other vertical pipe

[13:18.2.3.1]

6.2.3.2

When the flexible coupling below the floor is above the tie-in main to the main supplying that floor, a flexible coupling shall be provided in accordance with one of the following:

(1) *On the horizontal portion within 24 in. (600 mm) of the tie-in where the tie-in is horizontal

(2) *On the vertical portion of the tie-in where the tie-in incorporates a riser
6.2.4* Flexible Couplings for Drops.

Flexible couplings for drops to hose lines, rack sprinklers, mezzanines, and free-standing structures shall be installed regardless of pipe sizes as follows:

1. Within 24 in. (600 mm) of the top of the drop
2. Within 24 in. (600 mm) above the uppermost drop support attachment, where drop supports are provided to the structure or mezzanine
3. Within 24 in. (600 mm) above the bottom of the drop where no additional drop support is provided
4. Within 24 in. (600 mm) of the top of the drop to rack sprinklers, where there is an assembly of flexible couplings, flexible fittings, or flexible piping with flexibility to allow movement of the top of the drop equal to or greater than 5 percent of the distance from the floor to the top of the drop

6.3* Seismic Separation Assembly.

6.3.1

An approved seismic separation assembly shall be installed where sprinkler piping, regardless of size, crosses building seismic separation joints at ground level and above. [13:18.3.1]

6.3.2

Seismic separation assemblies shall consist of flexible fittings or flexible piping so as to allow movement sufficient to accommodate closing of the separation, opening of the separation to twice its normal size, and movement relative to the separation in the other two dimensions in an amount equal to the separation distance. [13:18.3.2]

6.3.3*

The seismic separation assembly shall include a four-way brace on the piping upstream and downstream within 6 ft (1.8 m) of the seismic separation assembly.

6.3.4

Bracing shall not be attached to the seismic separation assembly. [13:18.3.4]

6.3.5*
The seismic separation assembly shall include a hanger on the piping both upstream and downstream within 6 ft (1.8 m) of the seismic separation assembly.

6.3.6

Where the cumulative horizontal length of the piping and the seismic separation assembly exceeds the maximum allowable spacing between hangers, then additional hanger(s) shall be added to the seismic separation assembly.

6.3.6.1

If additional hangers are installed on a seismic separation assembly, the hangers shall be in accordance with the seismic separation assembly manufacturer’s guidelines.

6.3.6.2

Where there are no manufacturers’ guidelines for hangers on a seismic separation assembly, the hangers on the assembly shall not adversely affect the assemblies intended movement during a seismic event.

6.4* Clearance.

6.4.1*

Clearance shall be provided around all piping extending through walls, floors, platforms, and foundations, including drains, fire department connections, and other auxiliary piping. [13:A.18.4.1]

6.4.2

Unless any of the requirements of 6.4.3 through 6.4.7 or 6.4.10 are met, where pipe passes through holes in platforms, foundations, walls, or floors, the holes shall be sized such that the diameter of the holes is nominally 2 in. (50 mm) larger than the pipe for pipe 1 in. (25 mm) nominal to 3 1/2 in. (90 mm) nominal and 4 in. (100 mm) larger than the pipe for pipe 4 in. (100 mm) nominal and larger. [13:18.4.2]

6.4.3

Where clearance is provided by a pipe sleeve, a nominal diameter 2 in. (50 mm) larger than the nominal diameter of the pipe shall be acceptable for pipe sizes 1 in. (25 mm) through 3 1/2 in. (90 mm), and the clearance provided by a pipe sleeve of nominal diameter 4 in. (100 mm) larger
than the nominal diameter of the pipe shall be acceptable for pipe sizes 4 in. (100 mm) and larger. [13:18.4.3]

6.4.4

No clearance shall be required for piping passing through gypsum board or equally frangible construction. [13:18.4.4]

6.4.5

No clearance shall be required if flexible couplings are located within 1 ft (300 mm) of each side of a wall or if the requirements of 6.2.3.1(2) are met. [13:18.4.5]

6.4.6

No clearance shall be required where horizontal piping passes perpendicularly through successive studs or joists that form a wall or floor/ceiling assembly. [13:18.4.6]

6.4.7

No clearance shall be required where nonmetallic pipe has been demonstrated to have inherent flexibility equal to or greater than the minimum provided by flexible couplings located within 1 ft (300 mm) of each side of a wall, floor, platform, or foundation. [13:18.4.7]

6.4.8

Where required, the clearance shall be filled with a flexible material that is compatible with the piping material. [13:18.4.8]

6.4.9

The installed horizontal and upward vertical clearance between horizontal sprinkler piping and structural members not penetrated or used, collectively or independently, to support the piping shall be at least 2 in. (50 mm). [13:18.4.9]

6.4.10*

No clearance shall be required where piping is supported by holes through structural members as permitted by 5.1.7.3. [13:18.4.10]

6.4.11*

The installed clearance between a sprinkler and structural elements not used collectively or independently to support the sprinklers shall be at least 3 in. (75 mm). [13:18.4.11]
6.4.11.1

Where sprinklers are installed using flexible sprinkler hose, clearance for the sprinkler shall not be required. [13:18.4.11.1]

6.4.12

Clearance shall not be required for piping that is vertically supported by the bottom edge of holes through structural members as permitted by 5.1.7.3. [13:18.4.12]

6.4.13

No horizontal clearance (tight fit) shall be provided for piping that is laterally supported by the side edges of holes through structural members. [13:18.4.13]

6.4.13.1

Clearance shall be permitted where piping is secured to the structural member with an approved hanger or restraint. [13:18.4.13.1]

6.5* Sway Bracing.

6.5.1 General.

6.5.1.1

The system piping shall be braced to resist both lateral and longitudinal horizontal seismic loads and to prevent vertical motion resulting from seismic loads. [13:18.5.1.1]

6.5.1.2

The structural components to which bracing is attached shall be determined to be capable of resisting the added applied seismic loads. [13:18.5.1.2]

6.5.1.3*

Horizontal loads on system piping shall be determined in accordance with 6.5.9. [13:18.5.1.3]

6.5.1.4*

A shared support assembly shall be permitted to support both the gravity loads addressed in 5.1.4.1 and the seismic loads addressed in 6.5.9. [13:18.5.1.4]

6.5.1.4.1
When a shared support assembly is used to support gravity and seismic loads, the structure shall be designed to support these loads for all pipe and distribution systems on the structure using either 6.5.9.3 or 6.5.9.4 with an importance factor, $I_p$, of 1.5 being applied to all of the distribution systems. [13:18.5.1.4.1]

6.5.1.5*

If a shared support assembly is used to support sprinkler pipe and other distribution systems per 5.1.4.1 and that assembly does not provide seismic resistance as required in 6.5.1.4, the following shall be met:

1. The sprinkler pipe shall be braced using the method in 6.5.6 with the zone of influence including the water-filled sprinkler pipe and all other distribution systems that are not independently equipped with seismic protection and attached to the shared support assembly.

2. The sprinkler sway bracing attachment shall be connected to the same building or structure as the shared support assembly.

[13:18.5.1.5]

6.5.1.6

Bracing requirements of Section 6.5 shall not apply to drain piping downstream of the drain valve. [13:18.5.1.6]

6.5.2 Listing.

6.5.2.1

Sway bracing assemblies shall be listed for a maximum load rating, unless the requirements of 6.5.2.2 are met. [13:18.5.2.1]

6.5.2.2

Where sway bracing utilizing pipe, angles, flats, or rods as shown in Table 6.5.11.8(a) through Table 6.5.11.8(f) is used, the components shall not require listing. [13:18.5.2.2]

6.5.2.2.1

Bracing fittings and connections used with those specific materials shall be listed. [13:18.5.2.2.1]

6.5.2.3*
The listed load rating shall be reduced as shown in Table 6.5.2.3 to determine the allowable load for installations where the brace is less than 90 degrees from vertical. [13:18.5.2.3]

**Table 6.5.2.3 Listed Horizontal Load Adjustment**

<table>
<thead>
<tr>
<th>Brace Angle Degrees from Vertical</th>
<th>Allowable Horizontal Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 to 44</td>
<td>Listed load rating divided by 2.000</td>
</tr>
<tr>
<td>45 to 59</td>
<td>Listed load rating divided by 1.414</td>
</tr>
<tr>
<td>60 to 89</td>
<td>Listed load rating divided by 1.155</td>
</tr>
<tr>
<td>90</td>
<td>Listed load rating</td>
</tr>
</tbody>
</table>

[13:Table A.18.5.2.3]

**6.5.2.3.1**

Maximum allowable horizontal loads shall be determined by testing at angles of 30, 45, 60, and 90 degrees from vertical and confirmed to be equal to or greater than those calculated using 6.5.2.3. [13:18.5.2.3.1]

**6.5.2.3.2**

For attachments to structures, additional tests shall be performed at 0 degrees. [13:18.5.2.3.2]

**6.5.2.4**

All sway brace fittings shall have a minimum load rating as specified in Table 6.5.2.4.

**Table 6.5.2.4 Minimum Rated Load**

<table>
<thead>
<tr>
<th>Sprinkler system pipe size, NPS</th>
<th>Minimum rated load</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 and smaller</td>
<td>680 (3,025)</td>
</tr>
</tbody>
</table>
6.5.3 Component Material.

6.5.3.1 Unless permitted by 6.5.3.2, components of sway brace assemblies shall be ferrous. [13:18.5.3.1]

6.5.3.2 Nonferrous components that have been proven by fire tests to be adequate for the hazard application, that are listed for this purpose, and that are in compliance with the other requirements of this section shall be acceptable. [13:18.5.3.2]

6.5.4 Sway Bracing Design.

6.5.4.1 Sway braces shall be designed to withstand forces in tension and compression, unless the requirements of 6.5.4.2 are met. [13:18.5.4.1]

6.5.4.2* Tension-only bracing systems shall be permitted for use where listed for this service and where installed in accordance with their listing limitations, including installation instructions. [13:18.5.4.2]

6.5.4.3
For all braces, whether or not listed, the maximum allowable load shall be based on the weakest component of the brace with safety factors. [13:18.5.4.3]

6.5.5 Lateral Sway Bracing.

6.5.5.1* Lateral sway bracing shall be provided on all sprinkler system feed and cross mains regardless of size and all sprinkler system branch lines and all other piping with a diameter of 2 1/2 in. (65 mm) and larger.

6.5.5.1.1 Where sprinkler system branch lines are not provided with lateral sway bracing, they shall be provided with restraint in accordance with Section 6.6.

6.5.5.2* The spacing between lateral sway braces shall be in accordance with either Table 6.5.5.2(a) through Table 6.5.5.2(n) or 6.5.5.3, based on the piping material used.

Table 6.5.5.2(a) Maximum Load ($F_{pw}$) in Zone of Influence (lb), ($F_y = 30$ ksi) Schedule 10 Steel Pipe

<table>
<thead>
<tr>
<th>Diameter of Pipe (in.) Being Braced</th>
<th>Lateral Sway Brace Spacing (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
</tr>
<tr>
<td>1</td>
<td>111</td>
</tr>
<tr>
<td>1 1/4</td>
<td>176</td>
</tr>
<tr>
<td>1 1/2</td>
<td>241</td>
</tr>
<tr>
<td>2</td>
<td>390</td>
</tr>
<tr>
<td>2 1/2</td>
<td>641</td>
</tr>
<tr>
<td>3</td>
<td>966</td>
</tr>
</tbody>
</table>
### Table 6.5.5.2(a) Maximum Load ($F_{pw}$) in Zone of Influence (kg), ($F_y = 207$ N/mm$^2$) Schedule 10 Steel Pipe

<table>
<thead>
<tr>
<th>Diameter of Pipe (mm) Being Braced</th>
<th>Lateral Sway Brace Spacing (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1</td>
<td>50</td>
</tr>
<tr>
<td>7.6</td>
<td>80</td>
</tr>
<tr>
<td>9.1</td>
<td>109</td>
</tr>
<tr>
<td>11</td>
<td>177</td>
</tr>
<tr>
<td>12</td>
<td>291</td>
</tr>
</tbody>
</table>

Note: ASTM A106 Grade B or ASTM A53 Grade B has an $F_y = 35$ ksi. An $F_y = 30$ ksi was used as a conservative value to account for differences in material properties as well as other operational stresses.

*Larger diameter pipe can be used when justified by engineering analysis.

[13:Table 18.5.5.2(a)]
### Table 6.5.5.2(c) Maximum Load ($F_{pw}$) in Zone of Influence (lb), ($F_y = 30$ ksi) Schedule 40 Steel Pipe

<table>
<thead>
<tr>
<th>Diameter of Pipe (in.) Being Braced</th>
<th>Lateral Sway Brace Spacing (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
</tr>
<tr>
<td>1</td>
<td>121</td>
</tr>
<tr>
<td>1 1/4</td>
<td>214</td>
</tr>
<tr>
<td>1 1/2</td>
<td>306</td>
</tr>
<tr>
<td>2</td>
<td>520</td>
</tr>
<tr>
<td>2 1/2</td>
<td>984</td>
</tr>
<tr>
<td>3</td>
<td>1597</td>
</tr>
</tbody>
</table>

**Note:** ASTM A106 Grade B or ASTM A53 Grade B has an $F_y = 241$ N/mm². An $F_y = 207$ N/mm² was used also as a conservative value to account for differences in material properties as well as other operational stresses.

*Larger diameter pipe can be used when justified by engineering analysis.*

[13:Table 18.5.5.2(b)]
### Diameter of Pipe (in.) Being Braced

<table>
<thead>
<tr>
<th>Diameter of Pipe (in.) Being Braced</th>
<th>Lateral Sway Brace Spacing (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 1/2</td>
<td>20: 2219 25: 1775 30: 1455 35: 1247 40: 1044</td>
</tr>
<tr>
<td>5</td>
<td>20: 5061 25: 4049 30: 3317 35: 2843 40: 2381</td>
</tr>
<tr>
<td>6 and larger*</td>
<td>20: 7893 25: 6314 30: 5173 35: 4434 40: 3713</td>
</tr>
</tbody>
</table>

Note: ASTM A106 Grade B or ASTM A53 Grade B has an $F_y = 35$ ksi. An $F_y = 30$ ksi was used as a conservative value to account for differences in material properties as well as other operational stresses.

*Larger diameter pipe can be used when justified by engineering analysis.

[13:Table 18.5.5.2(c)]

### Table 6.5.5.2(d) Maximum Load ($F_{pw}$) in Zone of Influence (kg), ($F_y = 207$ N/mm$^2$) Schedule 40 Steel Pipe

<table>
<thead>
<tr>
<th>Diameter of Pipe (mm) Being Braced</th>
<th>Lateral Sway Brace Spacing (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.1 7.6 9.1 11 12</td>
</tr>
<tr>
<td>25</td>
<td>55 44 36 31 26</td>
</tr>
<tr>
<td>32</td>
<td>97 78 63 54 45</td>
</tr>
<tr>
<td>40</td>
<td>139 111 91 78 65</td>
</tr>
<tr>
<td>50</td>
<td>236 189 155 132 111</td>
</tr>
<tr>
<td>65</td>
<td>446 357 293 251 210</td>
</tr>
<tr>
<td>80</td>
<td>724 580 475 407 341</td>
</tr>
</tbody>
</table>

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### Diameter of Pipe (mm) Being Braced vs. Lateral Sway Brace Spacing (m)

<table>
<thead>
<tr>
<th>Diameter of Pipe (mm)</th>
<th>6.1 (m)</th>
<th>7.6 (m)</th>
<th>9.1 (m)</th>
<th>11 (m)</th>
<th>12 (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>1007</td>
<td>805</td>
<td>660</td>
<td>566</td>
<td>474</td>
</tr>
<tr>
<td>100</td>
<td>1352</td>
<td>1082</td>
<td>886</td>
<td>760</td>
<td>636</td>
</tr>
<tr>
<td>125</td>
<td>2296</td>
<td>1837</td>
<td>1505</td>
<td>1290</td>
<td>1080</td>
</tr>
<tr>
<td>150*</td>
<td>3580</td>
<td>2864</td>
<td>2346</td>
<td>2011</td>
<td>1684</td>
</tr>
</tbody>
</table>

**Note:** ASTM A106 Grade B or ASTM A53 Grade B has an $F_y = 241$ N/mm$^2$. An $F_y = 207$ N/mm$^2$ was used also as a conservative value to account for differences in material properties as well as other operational stresses.

*Larger diameter pipe can be used when justified by engineering analysis.*

[13:Table 18.5.5.2(d)]

### Table 6.5.5.2(e) Maximum Load ($F_{pw}$) in Zone of Influence (lb), ($F_y = 30$ ksi) Schedule 5 Steel Pipe

<table>
<thead>
<tr>
<th>Diameter of Pipe (in.)</th>
<th>Lateral Sway Brace Spacing (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
</tr>
<tr>
<td>1</td>
<td>71</td>
</tr>
<tr>
<td>1 1/4</td>
<td>116</td>
</tr>
<tr>
<td>1 1/2</td>
<td>154</td>
</tr>
<tr>
<td>2</td>
<td>246</td>
</tr>
<tr>
<td>2 1/2</td>
<td>459</td>
</tr>
<tr>
<td>3</td>
<td>691</td>
</tr>
</tbody>
</table>

*Attachment 22-8-39*
### Diameter of Pipe (in.) Being Braced

<table>
<thead>
<tr>
<th>Lateral Sway Brace Spacing (ft)</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 1/2</td>
<td>910</td>
<td>728</td>
<td>597</td>
<td>511</td>
<td>428</td>
</tr>
<tr>
<td>4*</td>
<td>1160</td>
<td>928</td>
<td>760</td>
<td>652</td>
<td>546</td>
</tr>
</tbody>
</table>

Note: ASTM A106 Grade B or ASTM A53 Grade B has an $F_y = 35$ ksi. An $F_y = 30$ ksi was used as a conservative value to account for differences in material properties as well as other operational stresses.

*Larger diameter pipe can be used when justified by engineering analysis.

[13:Table 18.5.5.2(e)]

**Table 6.5.5.2(f) Maximum Load ($F_{pw}$) in Zone of Influence (kg), ($F_y = 207$ N/mm$^2$) Schedule 5 Steel Pipe**

<table>
<thead>
<tr>
<th>Diameter of Pipe (mm) Being Braced</th>
<th>Lateral Sway Brace Spacing (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.1</td>
</tr>
<tr>
<td>25</td>
<td>32</td>
</tr>
<tr>
<td>32</td>
<td>53</td>
</tr>
<tr>
<td>40</td>
<td>70</td>
</tr>
<tr>
<td>50</td>
<td>112</td>
</tr>
<tr>
<td>65</td>
<td>208</td>
</tr>
<tr>
<td>80</td>
<td>313</td>
</tr>
<tr>
<td>90</td>
<td>413</td>
</tr>
<tr>
<td>100*</td>
<td>526</td>
</tr>
</tbody>
</table>
Note: ASTM A106 Grade B or ASTM A53 Grade B has an $F_y = 241 \text{ N/mm}^2$. An $F_y = 207 \text{ N/mm}^2$ was used also as a conservative value to account for differences in material properties as well as other operational stresses.

*Larger diameter pipe can be used when justified by engineering analysis.

[13:Table 18.5.5.2(f)]

Table 6.5.5.2(g) Maximum Load ($F_{pw}$) in Zone of Influence (lb), ($F_y = 8 \text{ ksi}$) CPVC Pipe

<table>
<thead>
<tr>
<th>Diameter of Pipe (in.) Being Braced</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4</td>
<td>15</td>
<td>12</td>
<td>10</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>1</td>
<td>28</td>
<td>22</td>
<td>18</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>1 1/4</td>
<td>56</td>
<td>45</td>
<td>37</td>
<td>30</td>
<td>26</td>
</tr>
<tr>
<td>1 1/2</td>
<td>83</td>
<td>67</td>
<td>55</td>
<td>45</td>
<td>39</td>
</tr>
<tr>
<td>2</td>
<td>161</td>
<td>129</td>
<td>105</td>
<td>87</td>
<td>76</td>
</tr>
<tr>
<td>2 1/2</td>
<td>286</td>
<td>229</td>
<td>188</td>
<td>154</td>
<td>135</td>
</tr>
<tr>
<td>3</td>
<td>516</td>
<td>413</td>
<td>338</td>
<td>278</td>
<td>243</td>
</tr>
</tbody>
</table>

[13:Table 18.5.5.2(g)]

Table 6.5.5.2(h) Maximum Load ($F_{pw}$) in Zone of Influence (kg), ($F_y = 55 \text{ N/mm}^2$) CPVC Pipe

<table>
<thead>
<tr>
<th>Diameter of Pipe (mm) Being Braced</th>
<th>6.1</th>
<th>7.6</th>
<th>9.1</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Diameter of Pipe (mm) Being Braced</td>
<td>Lateral Sway Brace Spacing (m)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>--------------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.1</td>
<td>7.6</td>
<td>9.1</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>25</td>
<td>13</td>
<td>10</td>
<td>8</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>32</td>
<td>25</td>
<td>20</td>
<td>17</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>40</td>
<td>38</td>
<td>30</td>
<td>25</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>50</td>
<td>73</td>
<td>59</td>
<td>48</td>
<td>39</td>
<td>34</td>
</tr>
<tr>
<td>65</td>
<td>130</td>
<td>104</td>
<td>85</td>
<td>70</td>
<td>61</td>
</tr>
<tr>
<td>80</td>
<td>234</td>
<td>187</td>
<td>153</td>
<td>126</td>
<td>110</td>
</tr>
</tbody>
</table>

[13:Table 18.5.5.2(h)]

Table 6.5.5.2(i) Maximum Load ($F_{pw}$) in Zone of Influence (lb), ($F_y = 30$ ksi) Type M Copper Tube (with Soldered Joints)

<table>
<thead>
<tr>
<th>Diameter of Pipe (in.) Being Braced</th>
<th>Lateral Sway Brace Spacing (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
</tr>
<tr>
<td>3/4</td>
<td>16</td>
</tr>
<tr>
<td>1</td>
<td>29</td>
</tr>
<tr>
<td>1 1/4</td>
<td>53</td>
</tr>
<tr>
<td>1 1/2</td>
<td>86</td>
</tr>
<tr>
<td>2*</td>
<td>180</td>
</tr>
</tbody>
</table>

*Larger diameter pipe can be used when justified by engineering analysis.

[13:Table 18.5.5.2(i)]
Table 6.5.5.2(j) Maximum Load ($F_{pw}$) in Zone of Influence (kg), ($F_y = 3207$ N/mm$^2$) Type M Copper Tube (with Soldered Joints)

<table>
<thead>
<tr>
<th>Diameter of Pipe (mm) Being Braced</th>
<th>Lateral Sway Brace Spacing (m)</th>
<th>6.1</th>
<th>7.6</th>
<th>9.1</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td></td>
<td>7.3</td>
<td>5.9</td>
<td>5</td>
<td>4.1</td>
<td>3.6</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td>13.2</td>
<td>10.9</td>
<td>8.6</td>
<td>7.3</td>
<td>6.4</td>
</tr>
<tr>
<td>32</td>
<td></td>
<td>24</td>
<td>19.1</td>
<td>15.9</td>
<td>12.7</td>
<td>11.3</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>39</td>
<td>31.3</td>
<td>25.4</td>
<td>20.9</td>
<td>18.6</td>
</tr>
<tr>
<td>50*</td>
<td></td>
<td>81.6</td>
<td>65.3</td>
<td>53</td>
<td>44</td>
<td>38.6</td>
</tr>
</tbody>
</table>

*Larger diameter pipe can be used when justified by engineering analysis.

[13:Table 18.5.5.2(j)]

Table 6.5.5.2(k) Maximum Load ($F_{pw}$) in Zone of Influence (lb), ($F_y = 9$ ksi) Type M Copper Tube (with Brazed Joints)

<table>
<thead>
<tr>
<th>Diameter of Pipe (in.) Being Braced</th>
<th>Lateral Sway Spacing (ft)</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4</td>
<td></td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>11</td>
<td>9</td>
<td>7</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>1 1/4</td>
<td></td>
<td>20</td>
<td>16</td>
<td>13</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>1 1/2</td>
<td></td>
<td>33</td>
<td>27</td>
<td>22</td>
<td>19</td>
<td>16</td>
</tr>
<tr>
<td>2*</td>
<td></td>
<td>70</td>
<td>56</td>
<td>46</td>
<td>39</td>
<td>33</td>
</tr>
</tbody>
</table>

*Larger diameter pipe can be used when justified by engineering analysis.
### Table 6.5.5.2(k) Maximum Load ($F_{pw}$) in Zone of Influence (kg), ($F_y = 62$ N/mm$^2$) Type M Copper Tube (with Brazed Joints)

<table>
<thead>
<tr>
<th>Diameter of Pipe (mm) Being Braced</th>
<th>Lateral Sway Spacing (m)</th>
<th>6.1</th>
<th>7.6</th>
<th>9.1</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td></td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>32</td>
<td></td>
<td>9</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>15</td>
<td>12</td>
<td>10</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>50*</td>
<td></td>
<td>32</td>
<td>25</td>
<td>21</td>
<td>18</td>
<td>15</td>
</tr>
</tbody>
</table>

*Larger diameter pipe can be used when justified by engineering analysis.*

### Table 6.5.5.2(l) Maximum Load ($F_{pw}$) in Zone of Influence (lb), ($F_y = 9$ ksi) Red Brass Pipe (with Brazed Joints)

<table>
<thead>
<tr>
<th>Diameter of Pipe (in.) Being Braced</th>
<th>Lateral Sway Spacing (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
</tr>
<tr>
<td>3/4</td>
<td>34</td>
</tr>
<tr>
<td>1</td>
<td>61</td>
</tr>
<tr>
<td>1 1/4</td>
<td>116</td>
</tr>
<tr>
<td>1 1/2</td>
<td>161</td>
</tr>
<tr>
<td>2*</td>
<td>272</td>
</tr>
</tbody>
</table>

*Larger diameter pipe can be used when justified by engineering analysis.*
Table 6.5.5.2(n) Maximum Load \( (F_{pw}) \) in Zone of Influence (lb), \( (F_y = 62 \text{ N/mm}^2) \) Red Brass Pipe (with Brazed Joints)

<table>
<thead>
<tr>
<th>Diameter of Pipe (mm) Being Braced</th>
<th>Lateral Sway Spacing (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.1</td>
</tr>
<tr>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>25</td>
<td>28</td>
</tr>
<tr>
<td>32</td>
<td>53</td>
</tr>
<tr>
<td>40</td>
<td>73</td>
</tr>
<tr>
<td>50*</td>
<td>124</td>
</tr>
</tbody>
</table>

*Larger diameter pipe can be used when justified by engineering analysis.

[13:Table 18.5.5.2(n)]

6.5.5.2.1

Specially listed nonstandard pipe shall be permitted using the values in Table 6.5.5.2(e) and Table 6.5.5.2(f) or with values provided by the manufacturer. [13:18.5.5.2.1]

6.5.5.2.2

Spacing shall not exceed a maximum interval of 40 ft (12 m) on center. [13:18.5.5.2.2]

6.5.5.2.3

The maximum permissible load in the zone of influence of a sway brace shall not exceed the values given in Table 6.5.5.2(a) through Table 6.5.5.2(l) or the values calculated in accordance with 6.5.5.3. [13:18.5.5.2.3]

6.5.5.2.4

When determining permissible loads in accordance with 6.5.5.2 or 6.5.5.2.1 on a main with varying sizes, the allowable load shall be based on the smallest pipe size within the zone of influence. [13:18.5.5.2.4]

6.5.5.3

The maximum load \( (F_{pw}) \) in the zone of influence for specially listed pipe shall be calculated. (See Annex E.) [13:18.5.5.3]

6.5.5.4
The requirements of 6.5.5.1 shall not apply to 2 1/2 in. (65 mm) starter pieces that do not exceed 12 ft (3.7 m) in length provided that the additional length of the line beyond the starter pieces is provided with the required bracing or restraint.

6.5.5.5

The distance between the last brace and the end of the pipe shall not exceed 6 ft (1.8 m). [13:18.5.5.5]

6.5.5.6

Where there is a change in direction of the piping, the cumulative distance between consecutive lateral sway braces shall not exceed the maximum permitted distance in accordance with 6.5.5.2.2. [13:18.5.5.6]

6.5.5.7

The last length of pipe at the end of a feed or cross main shall be provided with a lateral brace. [13:18.5.5.7]

6.5.5.8

Lateral braces shall be allowed to act as longitudinal braces if they are within 24 in. (600 mm) of the centerline of the piping braced longitudinally and the lateral brace is on a pipe of equal or greater size than the pipe being braced longitudinally. [13:18.5.5.8]

6.5.5.9

Where flexible couplings are installed on mains other than as required in Section 6.2, a lateral brace shall be provided within 24 in. (600 mm) of every other coupling, including flexible couplings at grooved fittings, but not more than 40 ft (12 m) on center. [13:18.5.5.9]

6.5.5.10*

The lateral sway bracing required by 6.5.5 shall be deemed to be met where 6.5.5.10.1 for sprinkler system branch lines or 6.5.5.10.2 for mains is met.

6.5.5.10.1

Sprinkler system branch lines shall be deemed to meet the requirement to be laterally braced by complying with all of the following:
(1) *The branch lines shall be individually supported within 6 in. (150 mm) of the structure, measured between the top of the pipe and the point of attachment to the building structure.

(2) At least 75 percent of all the hangers on the branch line shall meet the requirements of 6.5.5.10.1(1).

(3) Consecutive hangers on the branch line shall not be permitted to exceed the limitation in 6.5.5.10.1(1).

6.5.5.10.2

Mains shall comply with all the following:

(1) *The sprinkler system main piping and all other piping shall be deemed to meet the requirements for lateral bracing by being individually supported within 6 in. (150 mm) of the structure, measured between the top of the pipe and the point of attachment to the building structure.

(2) At least 75 percent of all the hangers on the main shall meet the requirements of 6.5.5.10.2(1).

(3) Consecutive hangers on the main shall not be permitted to exceed the limitation in 6.5.5.10.2(1)

(4) The seismic coefficient ($C_p$) shall not exceed 0.5.

(5) The nominal pipe diameter shall not exceed 6 in. (150 mm) for feed mains and 4 in. (100 mm) for cross mains.

(6) Hangers shall not be omitted in accordance with 5.4.4.3, 5.4.4.4, or 5.4.4.5.

6.5.5.10.3

Sprinkler system branch lines that are laterally restrained or braced as per 6.5.5.10.1 shall not be omitted from load calculations for the mains serving them in 6.5.9.6.

6.5.5.10.4

Where piping is supported by or suspended from trapeze hangers, sway bracing shall be provided.
6.5.5.11*

The lateral sway bracing required by 6.5.5 shall be deemed to be accomplished when 6.5.5.11.1 for branch lines or 6.5.5.11.2 for mains is met.

6.5.5.11.1

Sprinkler system branch lines shall comply with the following:

1) The branch lines shall be individually supported by wraparound u-hooks or u-hooks arranged to keep pipe tight to the structural element provided the legs are bent out at least 30 degrees from the vertical and the maximum length of each leg and the rod size satisfies the conditions of Table 6.5.11.8(a) through Table 6.5.11.8(f).

2) If the rod size does not satisfy the conditions of Table 6.5.11.8(a) through Table 6.5.11.8(f), the length of the rod shall be calculated.

3) At least 75 percent of all the hangers on the branch line shall meet the requirements of 6.5.5.11.1(1).

4) Consecutive hangers on the branch line shall not be permitted to exceed the limitation in 6.5.5.11.1(1).

6.5.5.11.2

Mains shall comply with all the following:

1) The main piping shall be individually supported by wraparound u-hooks or u-hooks arranged to keep pipe tight to the structural element provided the legs are bent out at least 30 degrees from the vertical and the maximum length of each leg and rod size satisfies the conditions of Tables 6.5.11.8(a) through 6.5.11.8(f).

2) At least 75 percent of all the hangers on the main shall meet the requirements of 6.5.5.11.2(1).

3) Consecutive hangers on the main shall not be permitted to exceed the limitation in 6.5.5.11.2(1).

4) The seismic coefficient ($C_p$) shall not exceed 0.5.

5) The nominal pipe diameter shall not exceed 6 in. (150 mm) for feed mains and 4 in. (100 mm) for cross mains.
(6) Hangers shall not be omitted in accordance with 5.4.4.3, 5.4.4.4, or 5.4.4.5. [13:18.5.5.11.2]

6.5.5.11.3

Where piping is supported by or suspended from trapeze hangers, sway bracing shall be provided.

6.5.6* Longitudinal Sway Bracing.

6.5.6.1

Longitudinal sway bracing spaced at a maximum of 80 ft (24 m) on center shall be provided for feed and cross mains. [13:18.5.6.1]

6.5.6.12

Unless the requirements of 6.5.9.6 are met, longitudinal sway bracing shall be provided on branch lines at a maximum spacing of 80 ft (24m) on center. [13:18.5.6.2]

6.5.6.3

Longitudinal braces shall be allowed to act as lateral braces if they are within 24 in. (600 mm) of the centerline of the piping braced laterally. [13:18.5.6.3]

6.5.6.4

The distance between the last brace and the end of the pipe or a change in direction shall not exceed 40 ft (12 m). [13:18.5.6.4]

6.5.7 Pipe with Change(s) in Direction.

6.5.7.1

Each run of pipe between changes in direction shall be provided with both lateral and longitudinal bracing, unless the requirements of 6.5.7.2 are met. [13:18.5.7.1]

6.5.7.2* 

Pipe runs less than 12 ft (3.7 m) in length shall be permitted to be supported by the braces on adjacent runs of pipe. [13:18.5.7.2]

6.5.8 Sway Bracing of Risers.
6.5.8.1*
Tops of risers exceeding 36 in. (900 mm) in length shall be provided with a four-way brace located on the topmost section of vertical piping, but not more than 24 in. (600 mm) below the top coupling. [13:18.5.8.1]

6.5.8.1.1*
The four-way brace shall not be required for risers up to 7 ft (2.1 m) in length that terminate above the roof assembly or top landing. [13:18.5.8.1.1]

6.5.8.2
Riser nipples shall be permitted to omit the four-way brace required by 6.5.8.1. [13:18.5.8.2]

6.5.8.3
When a four-way brace at the top of a riser is attached on the horizontal piping, it shall be within 24 in. (600 mm) of the centerline of the riser and the loads for that brace shall include both the vertical and horizontal pipe. [13:18.5.8.3]

6.5.8.4
Distance between four-way braces for risers shall not exceed 25 ft (7.6 m). [13:18.5.8.4]

6.5.8.5
Four-way bracing shall not be required where risers penetrate intermediate floors in multistory buildings where the clearance does not exceed the limits of Section 6.4. [13:18.5.8.5]

6.5.9* Horizontal Seismic Loads.

6.5.9.1*
The horizontal seismic load for the braces shall be as determined in 6.5.9.6 or 6.5.9.7, or as required by the authority having jurisdiction. [13:18.5.9.1]

6.5.9.2
The weight of the system being braced (Wp) shall be taken as 1.15 times the weight of the water-filled piping. (See A.6.5.9.1.) [13:18.5.9.2]

6.5.9.3
For high or limited deformability piping joined by threading, bonding, compression couplings or grooved couplings in Site Class A-D, the horizontal force, $F_{pw}$, acting on the brace shall be taken as $F_{pw} = C_p W_p$, where $C_p$ is the seismic coefficient selected in Table 6.5.9.3 utilizing the short period response parameter, $S_s$. (See Figure E.3.)

**Table 6.5.9.3 Seismic Coefficient Table**

<table>
<thead>
<tr>
<th>$S_s$</th>
<th>Default $C_p$</th>
<th>Site Class-Specific $C_p$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>0.33 or less</td>
<td>0.24</td>
<td>0.13</td>
</tr>
<tr>
<td>0.4</td>
<td>0.28</td>
<td>0.15</td>
</tr>
<tr>
<td>0.5</td>
<td>0.33</td>
<td>0.19</td>
</tr>
<tr>
<td>0.6</td>
<td>0.37</td>
<td>0.23</td>
</tr>
<tr>
<td>0.7</td>
<td>0.41</td>
<td>0.27</td>
</tr>
<tr>
<td>0.8</td>
<td>0.45</td>
<td>0.30</td>
</tr>
<tr>
<td>0.9</td>
<td>0.51</td>
<td>0.34</td>
</tr>
<tr>
<td>1.0</td>
<td>0.56</td>
<td>0.38</td>
</tr>
<tr>
<td>1.1</td>
<td>0.62</td>
<td>0.42</td>
</tr>
<tr>
<td>1.2</td>
<td>0.68</td>
<td>0.45</td>
</tr>
<tr>
<td>1.3</td>
<td>0.73</td>
<td>0.49</td>
</tr>
<tr>
<td>1.4</td>
<td>0.79</td>
<td>0.53</td>
</tr>
<tr>
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<td>0.84</td>
<td>0.56</td>
</tr>
<tr>
<td>1.6</td>
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<td>0.64</td>
</tr>
<tr>
<td>1.8</td>
<td>1.01</td>
<td>0.68</td>
</tr>
<tr>
<td>$S_s$</td>
<td>Default $C_p$</td>
<td>Site Class–Specific $C_p$</td>
</tr>
<tr>
<td>-------</td>
<td>--------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>1.9</td>
<td>1.07</td>
<td>0.71</td>
</tr>
<tr>
<td>2.0</td>
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<td>0.83</td>
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<tr>
<td>2.3</td>
<td>1.29</td>
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<td>2.4</td>
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<td>0.90</td>
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<td>1.40</td>
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<td>1.68</td>
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</tr>
<tr>
<td>3.8</td>
<td>2.13</td>
<td>1.42</td>
</tr>
</tbody>
</table>
### 6.5.9.3.1

The value of $S_s$ from Table 6.5.9.3 shall be obtained from the authority having jurisdiction or from seismic hazard maps. \[13:18.5.9.3.1\]

### 6.5.9.3.2

The default value of $C_p$ from Table 6.5.9.3 shall be used unless 6.5.9.3.2.1 is met. \[13:18.5.9.3.2\]

#### 6.5.9.3.2.1*

The use of a site class–specific $C_p$, obtained from the authority having jurisdiction, from Table 18.5.9.3 shall be permitted. \[13:18.5.9.3.2.1\]

#### 6.5.9.3.2.2*

Where site class E or F is applicable, the authority having jurisdiction shall confirm whether it is acceptable to use the method outlined in 6.5.9.3 and 6.5.9.4, or an alternative method in accordance with 6.1.2, to determine $F_{pw}$. \[13:18.5.9.3.2.2\]

### 6.5.9.3.3*

Linear interpolation shall be permitted to be used for intermediate values of $S_s$. \[13:18.5.9.3.3\]

### 6.5.9.3.4*

Where the height of the component attachment to the structure is between 51 percent and 75 percent of the average roof height, the $C_p$ value shall be permitted to be multiplied by a factor of 0.875. \[13:18.5.9.3.4\]

## Table 18.5.9.3

<table>
<thead>
<tr>
<th>$S_s$</th>
<th>Default $C_p$</th>
<th>Site Class–Specific $C_p$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>3.9</td>
<td>2.19</td>
<td>1.46</td>
</tr>
<tr>
<td>4.0</td>
<td>2.24</td>
<td>1.50</td>
</tr>
</tbody>
</table>

\[13:Table 18.5.9.3\]
Where the height of the component attachment to the structure is less than 50 percent of the average roof height, the \( C_P \) value shall be permitted to be multiplied by a factor of 0.75. *(See Figure A.18.5.9.3.4.)* [13:18.5.9.3.5]

### 6.5.9.3.5.1

For components other than high- or limited-deformability piping joined by threading, bonding, compression couplings, or grooved couplings in Site Class A-D, the horizontal force, \( F_{pw} \), acting on the brace or for anchorage shall be taken as \( F_{pw} \), which is calculated as described in 6.5.9.4.

### 6.5.9.4*

The horizontal force, \( F_{pw} \), acting on the brace shall be permitted to be determined in accordance with 13.3.1 of ASCE/SEI 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, multiplied by 0.7 to convert to allowable stress design (ASD). [13:18.5.9.4]

### 6.5.9.5*

Where data for determining \( C_P \) are not available, the horizontal seismic force acting on the braces shall be determined as specified in 6.5.9.3 with \( C_P = 0.5 \). [13:18.5.9.5]

### 6.5.9.6*

The zone of influence for lateral braces shall include all branch lines, drops, sprigs, and mains tributary to the brace, except branch lines that are provided with longitudinal bracing. [13:18.5.9.6]

### 6.5.9.6.1*

When riser nipples are provided in systems requiring seismic protection, they shall satisfy the requirements of 6.5.9.6.2 unless the following requirements are met:

1. Where riser nipples are 4 ft (1.2 m) or less in length and \( C_P \) is 0.50 or less
2. Where riser nipples are 3 ft (900 mm) or less in length and \( C_P \) is less than 0.67
3. Where riser nipples are 2 ft (600 mm) or less in length and \( C_P \) is less than 1.0 [13:18.5.9.6.1]

### 6.5.9.6.2

If the calculated value as determined by the following equation is equal to or greater than the allowable yield strength of the riser nipple, \( F_y \), the longitudinal seismic load of each line shall be
evaluated individually, and branch lines shall be provided with longitudinal sway bracing in accordance with 6.5.6. \[13:18.5.9.6.2\]

\[
\frac{(H_r \cdot W_p \cdot C_p)}{S} \geq F_y \quad [6.5.9.6.2] 
\]

where:

- $H_r$ = length of riser nipple piping (in.)
- $W_p$ = tributary weight (lb) for the branch line or portion of branch line within the zone of influence including the riser nipple
- $C_p$ = seismic coefficient
- $S$ = sectional modulus of the riser nipple pipe
- $F_y$ = allowable yield strength of 30,000 psi (2070 bar) for steel, 30,000 psi for copper (soldered), and 8000 psi (550 bar) for CPVC

\[13:18.5.9.6.2\]

6.5.9.7

The zone of influence for longitudinal braces shall include all mains tributary to the brace. \[13:18.5.9.7\]

6.5.10 Net Vertical Forces.

Braced or anchored components shall be designed to resist a vertical seismic force of $0.2 \cdot S_{DS} \cdot W_p$, concurrent with the vertical reaction to the horizontal seismic force, in both upward and downward directions, unless any of the following conditions apply:

1. The seismic coefficient used is less than or equal to $0.308 \cdot C_p$ and the brace angle is equal to or greater than 30 degrees from vertical.
2. The seismic coefficient used is less than or equal to $0.497 \cdot C_p$ and the brace angle is equal to or greater than 45 degrees from vertical.
3. The seismic coefficient used is less than or equal to $0.770 \cdot C_p$ and the brace angle is equal to or greater than 60 degrees from vertical.
6.5.10.1

The net upward vertical force for braced components shall be resisted by one of the following:

1. A second rigid sway brace installed vertically or at an angle, acting in concert with the first rigid sway brace, and limited in length and compression strength by \( l/r \) not exceeding 300.
2. A hanger that resists upward movement, is located within 6 in. of a sway brace, and with the hanger rod stiffened, where required, to meet the length and compression strength limits by \( l/r \) not exceeding 300.

6.5.10.2

The net downward vertical force for braced components shall be resisted by the hanger nearest the brace.

6.5.10.3

The net vertical force in the upward and downward direction shall be calculated using the following formulas:

1. Single hanger piping net upward vertical force = \( \frac{F_{pw}}{\text{Tangent brace angle from vertical}} + (0.2SDS \times W_p) - 0.6W_p \)
2. Single hanger piping net downward vertical force = \( \frac{F_{pw}}{\text{Tangent brace angle from vertical}} + (0.2SDS \times W_p) + 1.0W_p \) tributary to one hanger

6.5.11* Sway Brace Installation.

6.5.11.1*

Bracing shall be attached directly to the system pipe. [13:18.5.11.1]

6.5.11.2

Sway bracing shall be tight. [13:18.5.11.2]

6.5.11.3

For individual braces, the slenderness ratio \( (l/r) \) shall not exceed 300, where \( l \) is the length of the brace and \( r \) is the least radius of gyration. [13:18.5.11.3]

6.5.11.4
Where threaded pipe is used as part of a sway brace assembly, it shall not be less than Schedule 30. \[13:18.5.11.4\]

**6.5.11.5**

All parts and fittings of a brace shall lie in a straight line to avoid eccentric loadings on fittings and fasteners. \[13:18.5.11.5\]

**6.5.11.5.1**

Sway brace fittings that are listed but do not lie in a straight line shall be installed in accordance with the manufacturers’ guidelines.

**6.5.11.6**

For longitudinal braces only, the brace shall be permitted to be connected to a tab welded to the pipe in conformance to 7.5.2 of NFPA 13. \[13:18.5.11.6\]

**6.5.11.7**

For tension-only braces, two tension-only brace components opposing each other must be installed at each lateral or longitudinal brace location. \[13:18.5.11.7\]

**6.5.11.8**

The loads determined in 6.5.9 shall not exceed the lesser of the maximum allowable loads provided in Table 6.5.11.8(a) through Table 6.5.11.8(f), and the manufacturer’s certified maximum allowable horizontal loads for brace angles of 30 to 44 degrees, 45 to 59 degrees, 60 to 89 degrees, or 90 degrees. \[13:18.5.11.8\]

**Table 6.5.11.8(a) Maximum Horizontal Loads for Sway Braces with l/r = 100 for Steel Braces with \(F_y = 36 \text{ ksi}\)**
<table>
<thead>
<tr>
<th>Brace Shape and Size (in.)</th>
<th>Area (in.²)</th>
<th>Least Radius of Gyration (r) (in.)</th>
<th>Maximum Length for $l/r = 100$</th>
<th>Maximum Horizontal Load (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>ft</td>
<td>in.</td>
</tr>
<tr>
<td>Pipe Schedule 40</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.494</td>
<td>0.421</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>1 1/4</td>
<td>0.669</td>
<td>0.540</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>1 1/2</td>
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<td>0.623</td>
<td>5</td>
<td>2</td>
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<tr>
<td>2</td>
<td>1.07</td>
<td>0.787</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Angles</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1 1/2 × 1 1/2 × 1 1/4</td>
<td>0.688</td>
<td>0.292</td>
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<td>5</td>
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<tr>
<td>2 × 2 × 1 1/4</td>
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<td>0.391</td>
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<td>3</td>
</tr>
<tr>
<td>2 1/2 × 2 × 1 1/4</td>
<td>1.06</td>
<td>0.424</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>2 1/2 × 1/2 × 1/4</td>
<td>1.19</td>
<td>0.491</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Brace Shape and Size (in.)</td>
<td>Area (in.$^2$)</td>
<td>Least Radius of Gyration ($r$) (in.)</td>
<td>Maximum Length for $l/r = 100$</td>
<td>Maximum Horizontal Load (lb)</td>
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<td>---------------------------</td>
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<td>----------------------------------</td>
<td>-------------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ft</td>
<td>30° to 44° Angle from Vertical</td>
</tr>
<tr>
<td>3 × 2</td>
<td>1.31</td>
<td>0.528</td>
<td>4</td>
<td>8,354</td>
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<tr>
<td>1/2 × 1/4</td>
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<tr>
<td>1/4</td>
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<tr>
<td>Rods (all thread)</td>
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<td>446</td>
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<td>Rods (threaded at ends only)</td>
<td>3/8</td>
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</tr>
<tr>
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<td>1/2</td>
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</tr>
<tr>
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<td>7/8</td>
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<td>1</td>
<td>3,833</td>
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</table>
### Area (in.²)

<table>
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<th>Least Radius of Gyration (r) (in.)</th>
<th>Maximum Length for l/r = 100</th>
<th>Maximum Horizontal Load (lb)</th>
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<tbody>
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<td>ft</td>
<td>in.</td>
</tr>
<tr>
<td>Flats</td>
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<td>7</td>
</tr>
<tr>
<td>1 1/2 × 1/4</td>
<td>0.375</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>2 × 1/4</td>
<td>0.5</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>2 × 3/8</td>
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<td>10</td>
</tr>
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[13: Table 18.5.11.8(a)]

Table 6.5.11.8(b) Maximum Horizontal Loads for Sway Braces with l/r = 200 for Steel Braces with $F_y = 36$ ksi

<table>
<thead>
<tr>
<th>Brace Shape and Size (in.)</th>
<th>Least Radius of Gyration (r) (in.)</th>
<th>Maximum Length for l/r = 200</th>
<th>Maximum Horizontal Load (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ft</td>
<td>in.</td>
</tr>
<tr>
<td>Pipe Schedule 40</td>
<td></td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>1 1/4</td>
<td>0.494</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>1 1/2</td>
<td>0.669</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>1 1/2</td>
<td>0.799</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Brace Shape and Size (in.)</td>
<td>Area (in.²)</td>
<td>Least Radius of Gyration (r) (in.)</td>
<td>Maximum Length for $l/r = 200$ (ft, in.)</td>
</tr>
<tr>
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<td>-------------</td>
<td>----------------------------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30° to 44° Angle from Vertical</td>
</tr>
<tr>
<td>2</td>
<td>1.07</td>
<td>0.787</td>
<td>13, 1</td>
</tr>
<tr>
<td>Angles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 1/2 × 1/2 × 1/4</td>
<td>0.688</td>
<td>0.292</td>
<td>4, 10</td>
</tr>
<tr>
<td>2 × 2 × 1/4</td>
<td>0.938</td>
<td>0.391</td>
<td>6, 6</td>
</tr>
<tr>
<td>2 1/2 × 2 × 1/4</td>
<td>1.06</td>
<td>0.424</td>
<td>7, 0</td>
</tr>
<tr>
<td>2 1/2 × 2 × 1/2 × 1/4</td>
<td>1.19</td>
<td>0.491</td>
<td>8, 2</td>
</tr>
<tr>
<td>3 × 2 × 1/4</td>
<td>1.31</td>
<td>0.528</td>
<td>8, 9</td>
</tr>
<tr>
<td>3 × 3 × 1/4</td>
<td>1.44</td>
<td>0.592</td>
<td>9, 10</td>
</tr>
<tr>
<td>Brace Shape and Size (in.)</td>
<td>Area (in.²)</td>
<td>Least Radius of Gyration (r) (in.)</td>
<td>Maximum Length for l/r = 200 (ft in.)</td>
</tr>
<tr>
<td>----------------------------</td>
<td>-------------</td>
<td>-----------------------------------</td>
<td>-----------------------------------------</td>
</tr>
<tr>
<td><strong>Rods (all thread)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>0.07</td>
<td>0.075</td>
<td>1 2</td>
</tr>
<tr>
<td>1/2</td>
<td>0.129</td>
<td>0.101</td>
<td>1 8</td>
</tr>
<tr>
<td>56</td>
<td>0.207</td>
<td>0.128</td>
<td>2 1</td>
</tr>
<tr>
<td>34</td>
<td>0.309</td>
<td>0.157</td>
<td>2 7</td>
</tr>
<tr>
<td>78</td>
<td>0.429</td>
<td>0.185</td>
<td>3 0</td>
</tr>
<tr>
<td><strong>Rods (threaded at ends only)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>0.11</td>
<td>0.094</td>
<td>1 6</td>
</tr>
<tr>
<td>1/2</td>
<td>0.196</td>
<td>0.125</td>
<td>2 0</td>
</tr>
<tr>
<td>56</td>
<td>0.307</td>
<td>0.156</td>
<td>2 7</td>
</tr>
<tr>
<td>34</td>
<td>0.442</td>
<td>0.188</td>
<td>3 1</td>
</tr>
<tr>
<td>78</td>
<td>0.601</td>
<td>0.219</td>
<td>3 7</td>
</tr>
<tr>
<td><strong>Flats</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 1/2 × 1/4</td>
<td>0.375</td>
<td>0.0722</td>
<td>1 2</td>
</tr>
<tr>
<td>2 × 1/4</td>
<td>0.5</td>
<td>0.0722</td>
<td>1 2</td>
</tr>
</tbody>
</table>
### Maximum Horizontal Loads for Sway Braces with $l/r = 300$ for Steel Braces with $F_y = 36$ ksi

<table>
<thead>
<tr>
<th>Brace Shape and Size (in.)</th>
<th>Least Radius of Gyration ($r$) (in.)</th>
<th>Maximum Length for $l/r = 300$</th>
<th>Maximum Horizontal Load (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (in.²)</td>
<td>ft in.</td>
<td>30° to 44° Angle from Vertical</td>
</tr>
<tr>
<td>2 × 3⁄8</td>
<td>0.75</td>
<td>1 9</td>
<td>1406</td>
</tr>
</tbody>
</table>

[13:Table 18.5.11.8(b)]
<table>
<thead>
<tr>
<th>Brace Shape and Size (in.)</th>
<th>Area (in.²)</th>
<th>Least Radius of Gyration (r) (in.)</th>
<th>Maximum Length for l/r = 300</th>
<th>Maximum Horizontal Load (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>ft</td>
<td>in.</td>
</tr>
<tr>
<td>1/2 x 1/4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 x 2 x 1/4</td>
<td>0.938</td>
<td>0.391</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>2 1/2 x 2 x 1/4</td>
<td>1.06</td>
<td>0.424</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>2 1/2 x 1/2 x 1/4</td>
<td>1.19</td>
<td>0.491</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>3 x 2 x 1/2 x 1/4</td>
<td>1.31</td>
<td>0.528</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>3 x 3 x 1/4</td>
<td>1.44</td>
<td>0.592</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>Rods (all thread)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/8</td>
<td>0.07</td>
<td>0.075</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>1/2</td>
<td>0.129</td>
<td>0.101</td>
<td>2</td>
<td>6</td>
</tr>
</tbody>
</table>
### Table 6.5.11.8(d) Maximum Horizontal Loads for Sway Braces with \( l/r = 100 \) for Steel Braces with \( F_y = 248 \text{ N/mm}^2 \)

<table>
<thead>
<tr>
<th>Brace Shape and Size (in.)</th>
<th>Area (in.(^2))</th>
<th>Least Radius of Gyration ((r)) (in.)</th>
<th>Maximum Length for ( l/r = 300 )</th>
<th>Maximum Horizontal Load (lb)</th>
<th>Brace Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>ft</td>
<td>in.</td>
<td>30° to 44° Angle from Vertical</td>
</tr>
<tr>
<td>Rods (threaded at ends only)</td>
<td>3/8</td>
<td>0.11</td>
<td>2</td>
<td>4</td>
<td>92</td>
</tr>
<tr>
<td></td>
<td>1/2</td>
<td>0.196</td>
<td>3</td>
<td>1</td>
<td>163</td>
</tr>
<tr>
<td></td>
<td>5/6</td>
<td>0.307</td>
<td>3</td>
<td>10</td>
<td>256</td>
</tr>
<tr>
<td></td>
<td>3/4</td>
<td>0.442</td>
<td>4</td>
<td>8</td>
<td>368</td>
</tr>
<tr>
<td></td>
<td>7/8</td>
<td>0.601</td>
<td>5</td>
<td>5</td>
<td>501</td>
</tr>
<tr>
<td>Flats</td>
<td>1 1/2 (\times) 1/4</td>
<td>0.375</td>
<td>1</td>
<td>9</td>
<td>313</td>
</tr>
<tr>
<td></td>
<td>2 (\times) 1/4</td>
<td>0.5</td>
<td>1</td>
<td>9</td>
<td>417</td>
</tr>
<tr>
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<td>2 (\times) 3/8</td>
<td>0.75</td>
<td>2</td>
<td>8</td>
<td>625</td>
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</table>

[13:Table 18.5.11.8(c)]
<table>
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<th>Brace Shape and Size (mm)</th>
<th>Area (mm²)</th>
<th>Least Radius of Gyration (r) (mm)</th>
<th>Maximum Length for l/r = 100</th>
<th>Maximum Horizontal Load (kg)</th>
<th>Brace Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>meters</td>
<td>mm</td>
<td>mm</td>
</tr>
<tr>
<td>Pipe Schedule 40</td>
<td>25</td>
<td>318.7</td>
<td>1.0</td>
<td>150</td>
<td>1,429</td>
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</tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>32</td>
<td>431.6</td>
<td>1.2</td>
<td>150</td>
<td>1,935</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>515.5</td>
<td>1.5</td>
<td>50</td>
<td>2,311</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>690.3</td>
<td>1.8</td>
<td>150</td>
<td>3,095</td>
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<td>Angles</td>
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<td></td>
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<tr>
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<td></td>
<td>x 6</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>65</td>
<td>683.9</td>
<td>1.0</td>
<td>150</td>
<td>3,066</td>
</tr>
<tr>
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<td>x 50</td>
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<td>x 6</td>
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<td>767.7</td>
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<td>25</td>
<td>3,442</td>
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<td></td>
<td>x 50</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>x 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brace Shape and Size (mm)</td>
<td>Area (mm$^2$)</td>
<td>Least Radius of Gyration (r) (mm)</td>
<td>Maximum Length for $l/r = 100$ (meters)</td>
<td>Maximum Horizontal Load (kg)</td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>--------------</td>
<td>----------------------------------</td>
<td>-----------------------------------------</td>
<td>-----------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>mm</td>
<td>30° to 44° Angle from Vertical</td>
<td>45° to 59° Angle from Vertical</td>
</tr>
<tr>
<td>65 x 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>80 x 6</td>
<td>845.2</td>
<td>13</td>
<td>1.2</td>
<td>3,789</td>
<td>5,359</td>
</tr>
<tr>
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<td>929.0</td>
<td>15</td>
<td>1.2</td>
<td>4,165</td>
<td>5,891</td>
</tr>
<tr>
<td>Rods (all thread)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>45.2</td>
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<td>0.0</td>
<td>202</td>
<td>286</td>
</tr>
<tr>
<td>15</td>
<td>83.2</td>
<td>3</td>
<td>0.0</td>
<td>373</td>
<td>528</td>
</tr>
<tr>
<td>16</td>
<td>133.5</td>
<td>3</td>
<td>0.3</td>
<td>0</td>
<td>847</td>
</tr>
<tr>
<td>20</td>
<td>199.4</td>
<td>4</td>
<td>0.3</td>
<td>75</td>
<td>894</td>
</tr>
<tr>
<td>22</td>
<td>276.8</td>
<td>5</td>
<td>0.3</td>
<td>150</td>
<td>1,241</td>
</tr>
<tr>
<td>Rods (threaded at ends only)</td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>10</td>
<td>71.0</td>
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<td>318</td>
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<td>126.5</td>
<td>3</td>
<td>0.3</td>
<td>0</td>
<td>567</td>
</tr>
</tbody>
</table>

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### Table 18.5.11.8(d)

Table 6.5.11.8(e) Maximum Horizontal Loads for Sway Braces with $l/r = 200$ for Steel Braces with $F_y = 248$ N/mm²

<table>
<thead>
<tr>
<th>Brace Shape and Size (mm)</th>
<th>Area (mm²)</th>
<th>Least Radius of Gyration ($r$) (mm)</th>
<th>Maximum Length for $l/r = 100$</th>
<th>Maximum Horizontal Load (kg)</th>
<th>Brace Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>meters</td>
<td>mm</td>
<td>30° to 44° Angle from Vertical</td>
</tr>
<tr>
<td>16</td>
<td>198.1</td>
<td>4</td>
<td>0.3</td>
<td>75</td>
<td>888</td>
</tr>
<tr>
<td>20</td>
<td>285.2</td>
<td>5</td>
<td>0.3</td>
<td>150</td>
<td>1,279</td>
</tr>
<tr>
<td>22</td>
<td>387.7</td>
<td>5</td>
<td>0.3</td>
<td>225</td>
<td>1,739</td>
</tr>
<tr>
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<td></td>
<td>0.0</td>
<td>175</td>
<td>1,085</td>
</tr>
<tr>
<td>40 × 6</td>
<td>241.9</td>
<td>2</td>
<td>0.0</td>
<td>175</td>
<td>1,447</td>
</tr>
<tr>
<td>50 × 6</td>
<td>322.6</td>
<td>2</td>
<td>0.0</td>
<td>175</td>
<td>1,447</td>
</tr>
<tr>
<td>50 × 10</td>
<td>483.9</td>
<td>3</td>
<td>0.0</td>
<td>250</td>
<td>2,170</td>
</tr>
</tbody>
</table>

[13:Table 18.5.11.8(d)]
<table>
<thead>
<tr>
<th>Brace Shape and Size (mm)</th>
<th>Area (mm²)</th>
<th>Least Radius of Gyration (r) (mm)</th>
<th>Maximum Length for (l/r = 200) (meters)</th>
<th>Maximum Horizontal Load (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30° to 44° Angle from Vertical</td>
</tr>
<tr>
<td>Pipe Schedule 40</td>
<td>25</td>
<td>318.7</td>
<td>2.1</td>
<td>420</td>
</tr>
<tr>
<td></td>
<td>32</td>
<td>431.6</td>
<td>2.7</td>
<td>569</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>515.5</td>
<td>3</td>
<td>679</td>
</tr>
<tr>
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<td>585</td>
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<td>605.2</td>
<td>1.8</td>
<td>798</td>
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<td>65 (\times) 50 (\times) 6</td>
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<td>2.1</td>
<td>902</td>
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<td></td>
<td>65 (\times) 767.7</td>
<td>12</td>
<td>2.4</td>
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<td>Area (mm²)</td>
<td>Least Radius of Gyration (r) (mm)</td>
<td>Maximum Length for ( l/r = 200 )</td>
<td>Maximum Horizontal Load (kg)</td>
</tr>
<tr>
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<td>----------------------------------</td>
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<td>200</td>
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<td>276.8</td>
<td>0.9</td>
<td>0</td>
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<td>0.6</td>
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## Table 6.5.11.8(f) Maximum Horizontal Loads for Sway Braces with \( l/r = 300 \) for Steel Braces with \( F_y = 248 \text{ N/mm}^2 \)

<table>
<thead>
<tr>
<th>Brace Shape and Size (mm)</th>
<th>Area (( \text{mm}^2 ))</th>
<th>Least Radius of Gyration (( r )) (mm)</th>
<th>Maximum Length for ( l/r = 200 )</th>
<th>Maximum Horizontal Load (kg)</th>
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</thead>
<tbody>
<tr>
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<td>mm</td>
</tr>
<tr>
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<td>198.1</td>
<td>4</td>
<td>0.6</td>
<td>175</td>
</tr>
<tr>
<td>20</td>
<td>285.2</td>
<td>5</td>
<td>0.9</td>
<td>25</td>
</tr>
<tr>
<td>22</td>
<td>387.7</td>
<td>5</td>
<td>0.9</td>
<td>175</td>
</tr>
<tr>
<td>Flats 40 × 6</td>
<td>241.9</td>
<td>2</td>
<td>0.3</td>
<td>50</td>
</tr>
<tr>
<td>Flats 50 × 6</td>
<td>322.6</td>
<td>2</td>
<td>0.3</td>
<td>50</td>
</tr>
<tr>
<td>Flats 50 × 10</td>
<td>483.9</td>
<td>3</td>
<td>0.3</td>
<td>225</td>
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</tbody>
</table>

[13:Table 18.5.11.8(e)]

Table 6.5.11.8(f) Maximum HorizontalLoads for Sway Braces with \( l/r = 300 \) for Steel Braces with \( F_y = 248 \text{ N/mm}^2 \)
<table>
<thead>
<tr>
<th>Brace Shape and Size (mm)</th>
<th>Area (mm²)</th>
<th>Least Radius of Gyration (r) (mm)</th>
<th>Maximum Length for $l/r = 300$</th>
<th>Maximum Horizontal Load (kg)</th>
</tr>
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<td>19.7</td>
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<td>Angles</td>
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<tr>
<td>65 × 50 × 6</td>
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<td>3</td>
<td>175</td>
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<tr>
<td>65 ×</td>
<td>767.7</td>
<td>12.3</td>
<td>3.7</td>
<td>75</td>
</tr>
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<td>Brace Shape and Size (mm)</td>
<td>Area (mm²)</td>
<td>Least Radius of Gyration (r) (mm)</td>
<td>Maximum Length for $l/r = 300$</td>
<td>Maximum Horizontal Load (kg)</td>
</tr>
<tr>
<td>---------------------------</td>
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<tr>
<td></td>
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<td>mm</td>
<td></td>
<td>Brace Angle</td>
</tr>
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<td></td>
<td></td>
<td>30° to 44° Angle from Vertical</td>
<td>45° to 59° Angle from Vertical</td>
</tr>
<tr>
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<td>845.2</td>
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<tr>
<td>80 x 65 x 6</td>
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<td>1.9</td>
<td>0.3</td>
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<tr>
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<td>15</td>
<td>83.2</td>
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<tr>
<td></td>
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<td>133.5</td>
<td>3.2</td>
<td>0.9</td>
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<td>199.4</td>
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<td>276.8</td>
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<td>1.2</td>
</tr>
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<td>Rods (threaded at ends only)</td>
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</table>
### Brace Shape and Size (mm)

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<th>Area (mm²)</th>
<th>Least Radius of Gyration (r) (mm)</th>
<th>Maximum Length for ( l/r = 300 )</th>
<th>Maximum Horizontal Load (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>mm</td>
<td>30° to 44° Angle from Vertical</td>
<td>45° to 59° Angle from Vertical</td>
</tr>
<tr>
<td>16</td>
<td>198.1</td>
<td>3.9</td>
<td>0.9</td>
<td>250</td>
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<tr>
<td>20</td>
<td>285.2</td>
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<td>1.2</td>
<td>200</td>
</tr>
<tr>
<td>22</td>
<td>387.7</td>
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<td>1.5</td>
<td>125</td>
</tr>
<tr>
<td>Flats</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>40 × 6</td>
<td>241.9</td>
<td>1.8</td>
<td>0.3</td>
<td>225</td>
</tr>
<tr>
<td>50 × 6</td>
<td>322.6</td>
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</tr>
<tr>
<td>50 × 10</td>
<td>483.9</td>
<td>2.7</td>
<td>0.6</td>
<td>200</td>
</tr>
</tbody>
</table>

[13:Table 18.5.11.8(f)]

#### 6.5.11.9*

Other pipe schedules and materials not specifically included in Table 6.5.11.8(a) through Table 6.5.11.8(f) shall be permitted to be used if certified by a registered professional engineer to support the loads determined in accordance with the criteria in the tables. [13:18.5.11.9]

#### 6.5.11.9.1

Calculations shall be submitted where required by the authority having jurisdiction. [13:18.5.11.9.1]

#### 6.5.11.10
C-type clamps including beam and large flange clamps, with or without restraining straps, shall not be used to attach braces to the building structure unless specifically listed for this purpose.

6.5.11.11

Powder-driven fasteners shall not be used to attach braces to the building structure, unless they are specifically listed for service in resisting lateral loads in areas subject to earthquakes. [13:18.5.11.11]

6.5.12* Fasteners.

6.5.12.1

The designated angle category for the fastener(s) used in the sway brace installation shall be determined in accordance with Figure 6.5.12.1. [13:18.5.12.1]

Figure 6.5.12.1 Designation of Angle Category Based on Angle of Sway Brace and Fastener Orientation. [13:Figure 18.5.12.1]
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**Load Perpendicular to Structural Member**

- **Angle A, B, or C**
  - Angle A = 30° to 44°
  - Angle B = 45° to 59°
  - Angle C = 60° to 90°

- **Fastener orientation**
  - Angle D, E, or F
  - Angle D = 30° to 44°
  - Angle E = 45° to 59°
  - Angle F = 60° to 90°

- **Minimum 1/2 depth of beam but not <3 in. (75 mm) for wood beams**

---

**Load Parallel to Structural Member**

- **Angle G, H, or I**
  - Angle G = 30° to 44°
  - Angle H = 45° to 59°
  - Angle I = 60° to 90°

- **Minimum four fastener diameters but not <1/3 beam depth and not <3 in. (75 mm) for wood beams**
6.5.12.2*

For individual fasteners, unless alternative allowable loads are determined and certified by a registered professional engineer, the loads determined in 6.5.9 shall not exceed the allowable loads provided in Table 6.5.12.2(a) through Table 6.5.12.2(m) or 6.5.12.7. [13:18.5.12.2]

Table 6.5.12.2(a) Maximum Load for Wedge Anchors in 3000 psi (207 bar) Lightweight Cracked Concrete on Metal Deck

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<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
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<td>2.375</td>
<td>6.25</td>
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<td>123</td>
<td>183</td>
<td>233</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>1⁄2</td>
<td>3.750</td>
<td>6.25</td>
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<td>147</td>
<td>231</td>
<td>310</td>
<td>---</td>
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<td></td>
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<tr>
<td>5⁄8</td>
<td>3.875</td>
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<td>387</td>
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### Wedge Anchors in 3000 psi Sand Lightweight Cracked Concrete on 4 1/2 in. Flute Width Metal Deck (lb)

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</table>

**Pr**: Prying factor range (see A.6.5.12.2 for additional information).

[13: Table 18.5.12.2(a)]

**Table 6.5.12.2(b) Maximum Load for Wedge Anchors in 3000 psi (207 bar) Lightweight Cracked Concrete**
| Diameter (in.) | Min. Nom. Embedment (in.) | Min. Slab Thickness (in.) | Min. Edge Distance (in.) | A | B | C | D | E | F | G | H | I |
|---------------|--------------------------|--------------------------|--------------------------|---|---|---|---|---|---|---|---|---|---|
| 3/8           | 2.375                    | 5                        | 4                        | 142 | 216 | 280 | 162 | 216 | 256 | 139 | 208 | 244 |
| 1/2           | 3.750                    | 6                        | 6                        | 200 | 314 | 419 | 243 | 314 | 362 | 209 | 312 | 365 |
| 5/8           | 3.875                    | 6                        | 6                        | 259 | 394 | 512 | 297 | 394 | 467 | 255 | 380 | 446 |
| 3/4           | 4.500                    | 7                        | 8                        | 356 | 552 | 731 | 424 | 552 | 641 | 365 | 544 | 636 |
| 3/8           | 2.375                    | 5                        | 4                        | 89  | 154 | 229 | 133 | 154 | 157 | 117 | 170 | 204 |
| 1/2           | 3.750                    | 6                        | 6                        | 119 | 218 | 335 | 195 | 218 | 209 | 172 | 250 | 299 |
| 5/8           | 3.875                    | 6                        | 6                        | 163 | 281 | 418 | 244 | 281 | 286 | 215 | 311 | 373 |
| 3/4           | 4.500                    | 7                        | 8                        | 214 | 386 | 588 | 343 | 386 | 376 | 303 | 438 | 525 |
| 3/8           | 2.375                    | 5                        | 4                        | 62  | 119 | 194 | 113 | 119 | 108 | 101 | 144 | 175 |
| 1/2           | 3.750                    | 6                        | 6                        | 83  | 167 | 279 | 163 | 167 | 144 | 147 | 208 | 254 |
| 5/8           | 3.875                    | 6                        | 6                        | 113 | 218 | 354 | 207 | 218 | 197 | 186 | 263 | 320 |
| 3/4           | 4.500                    | 7                        | 8                        | 150 | 297 | 492 | 288 | 297 | 259 | 259 | 367 | 447 |

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### Wedge Anchors in 3000 psi Lightweight Cracked Concrete (lb)

| Diameter (in.) | Min. Nom. Embedment (in.) | Min. Slab Thickness (in.) | Min. Edge Distance (in.) | A | B | C | D | E | F | G | H | I |
|----------------|---------------------------|---------------------------|--------------------------|---|---|---|---|---|---|---|---|---|---|
| 3/8            | 2.375                     | 5                         | 4                        | 47 | 97 | 168 | 98 | 82 | 89 | 125 | 154 | |
| 1/2            | 3.750                     | 6                         | 6                        | 63 | 130 | 239 | 140 | 109 | 128 | 178 | 220 | |
| 5/8            | 3.875                     | 6                         | 6                        | 87 | 178 | 306 | 179 | 150 | 163 | 228 | 281 | |
| 3/4            | 4.500                     | 7                         | 8                        | 115 | 234 | 422 | 248 | 234 | 197 | 226 | 315 | 389 | |

Pr: Prying factor range (see A.6.5.12.2 for additional information).

[13:Table 18.5.12.2(b)]

### Table 6.5.12.2(c) Maximum Load for Wedge Anchors in 3000 psi (207 bar) Normal Weight Cracked Concrete

| Diameter (in.) | Min. Nom. Embedment (in.) | Min. Slab Thickness (in.) | Min. Edge Distance (in.) | A | B | C | D | E | F | G | H | I |
|----------------|---------------------------|---------------------------|--------------------------|---|---|---|---|---|---|---|---|---|---|
| 3/8            | 2.375                     | 5                         | 4                        | 189 | 274 | 342 | 197 | 274 | 340 | 170 | 251 | 297 | |
| 1/2            | 3.750                     | 6                         | 6                        | 272 | 423 | 563 | 326 | 423 | 490 | 281 | 419 | 490 | |
| 5/8            | 3.875                     | 6                         | 6                        | 407 | 623 | 814 | 472 | 623 | 733 | 406 | 605 | 709 | |
| 3/4            | 4.500                     | 7                         | 8                        | 613 | 940 | 1232 | 715 | 940 | 1104 | 615 | 916 | 1073 | |

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### Wedge Anchors in 3000 psi Normal Weight Cracked Concrete (lb)

| Diameter (in.) | Min. Nom. Embedment (in.) | Min. Slab Thickness (in.) | Min. Edge Distance (in.) | A  | B  | C  | D  | E  | F  | G  | H  | I  |
|----------------|---------------------------|--------------------------|--------------------------|----|----|----|----|----|----|----|----|----|----|
| 3/4            | 2.375                     | 5                        | 4                        | 125| 203| 288| 167| 203| 219| 147| 212| 256|
| 1/2            | 3.750                     | 6                        | 6                        | 162| 295| 451| 263| 295| 285| 233| 337| 403|
| 5/8            | 3.875                     | 6                        | 6                        | 252| 441| 662| 386| 441| 442| 341| 492| 590|
| 3/4            | 4.500                     | 7                        | 8                        | 378| 665| 999| 583| 665| 662| 515| 744| 892|
| 3/8            | 2.375                     | 5                        | 4                        | 92 | 162| 249| 145| 162| 159| 130| 184| 225|
| 1/2            | 3.750                     | 6                        | 6                        | 113| 226| 377| 220| 226| 196| 199| 281| 342|
| 5/8            | 3.875                     | 6                        | 6                        | 176| 341| 557| 326| 341| 293| 415| 506|
| 3/4            | 4.500                     | 7                        | 8                        | 264| 514| 841| 493| 514| 456| 443| 627| 763|
| 3/8            | 2.375                     | 5                        | 4                        | 70 | 134| 220| 128| 134| 121| 116| 162| 200|
| 1/2            | 3.750                     | 6                        | 6                        | 87 | 178| 323| 190| 178| 149| 173| 241| 298|

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### Wedge Anchors in 3000 psi Normal Weight Cracked Concrete (lb)

<table>
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<tr>
<th>Diameter (in.)</th>
<th>Min. Nom. Embedment (in.)</th>
<th>Min. Slab Thickness (in.)</th>
<th>Min. Edge Distance (in.)</th>
<th>A = Pr ≤ 2.0</th>
<th>B = Pr ≤ 1.1</th>
<th>C = Pr ≤ 0.7</th>
<th>D = Pr ≤ 1.2</th>
<th>E = Pr ≤ 1.1</th>
<th>F = Pr ≤ 1.4</th>
<th>G = Pr ≤ 0.9</th>
<th>H = Pr ≤ 0.8</th>
<th>I = Pr ≤ 0.8</th>
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<tbody>
<tr>
<td>5/8</td>
<td>3.875</td>
<td>6</td>
<td>6</td>
<td>135</td>
<td>276</td>
<td>481</td>
<td>283</td>
<td>276</td>
<td>232</td>
<td>258</td>
<td>359</td>
<td>442</td>
</tr>
<tr>
<td>3/4</td>
<td>4.500</td>
<td>7</td>
<td>8</td>
<td>203</td>
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<td>426</td>
<td>413</td>
<td>348</td>
<td>389</td>
<td>541</td>
<td>667</td>
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</table>

Pr: Prying factor range (see A.6.5.12.2 for additional information).

[13:Table 18.5.12.2(c)]

**Table 6.5.12.2(d) Maximum Load for Wedge Anchors in 4000 psi (276 bar) Normal Weight Cracked Concrete**

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<th>Diameter (in.)</th>
<th>Min. Nom. Embedment (in.)</th>
<th>Min. Slab Thickness (in.)</th>
<th>Min. Edge Distance (in.)</th>
<th>A = Pr ≤ 2.0</th>
<th>B = Pr ≤ 1.1</th>
<th>C = Pr ≤ 0.7</th>
<th>D = Pr ≤ 1.2</th>
<th>E = Pr ≤ 1.1</th>
<th>F = Pr ≤ 1.4</th>
<th>G = Pr ≤ 0.9</th>
<th>H = Pr ≤ 0.8</th>
<th>I = Pr ≤ 0.8</th>
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<tbody>
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<td>293</td>
<td>360</td>
<td>208</td>
<td>293</td>
<td>370</td>
<td>179</td>
<td>264</td>
<td>313</td>
</tr>
<tr>
<td>1/2</td>
<td>3.750</td>
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<td>6</td>
<td>304</td>
<td>466</td>
<td>610</td>
<td>353</td>
<td>466</td>
<td>548</td>
<td>304</td>
<td>453</td>
<td>531</td>
</tr>
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<td>5/8</td>
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<td>469</td>
<td>716</td>
<td>935</td>
<td>542</td>
<td>716</td>
<td>844</td>
<td>467</td>
<td>694</td>
<td>814</td>
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<tr>
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<td>657</td>
<td>997</td>
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<td>750</td>
<td>997</td>
<td>1182</td>
<td>646</td>
<td>959</td>
<td>1125</td>
</tr>
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</table>

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## Wedge Anchors in 4000 psi Normal Weight Cracked Concrete (lb)

| Diameter (in.) | Min. Nom. Embedment (in.) | Min. Slab Thickness (in.) | Min. Edge Distance (in.) | A | B | C | D | E | F | G | H | I |
|----------------|--------------------------|--------------------------|--------------------------|---|---|---|---|---|---|---|---|---|---|
|                |                          |                          |                          | Pr ≤ 2.0 | Pr ≤ 1.1 | Pr ≤ 0.7 | Pr ≤ 1.2 | Pr ≤ 1.1 | Pr ≤ 1.4 | Pr ≤ 0.9 | Pr ≤ 0.8 |
| 5/8            | 3.875                    | 6                        | 6                        | 291   | 508   | 761   | 444   | 508   | 511   | 392   | 566   | 678   |
| 3/4            | 4.500                    | 7                        | 8                        | 414   | 711   | 1057  | 617   | 711   | 725   | 544   | 786   | 942   |
|                |                          |                          |                          | A | B | C | D | E | F | G | H | I |
|                |                          |                          |                          | Pr ≤ 5.0 | Pr ≤ 2.5 | Pr ≤ 1.3 | Pr ≤ 2.2 | Pr ≤ 2.5 | Pr ≤ 2.9 | Pr ≤ 1.7 | Pr ≤ 1.4 |
| 3/8            | 2.375                    | 5                        | 4                        | 103   | 177   | 268   | 156   | 177   | 179   | 139   | 197   | 241   |
| 1/2            | 3.750                    | 6                        | 6                        | 131   | 255   | 417   | 244   | 255   | 227   | 219   | 310   | 378   |
| 5/8            | 3.875                    | 6                        | 6                        | 203   | 393   | 641   | 375   | 393   | 352   | 337   | 477   | 582   |
| 3/4            | 4.500                    | 7                        | 8                        | 289   | 553   | 894   | 524   | 553   | 500   | 470   | 665   | 810   |
|                |                          |                          |                          | A | B | C | D | E | F | G | H | I |
|                |                          |                          |                          | Pr ≤ 6.5 | Pr ≤ 3.2 | Pr ≤ 1.6 | Pr ≤ 2.7 | Pr ≤ 3.2 | Pr ≤ 3.8 | Pr ≤ 2.1 | Pr ≤ 1.7 |
| 3/8            | 2.375                    | 5                        | 4                        | 80    | 148   | 237   | 139   | 148   | 138   | 125   | 175   | 216   |
| 1/2            | 3.750                    | 6                        | 6                        | 100   | 205   | 360   | 211   | 205   | 173   | 192   | 268   | 330   |
| 5/8            | 3.875                    | 6                        | 6                        | 156   | 319   | 554   | 325   | 319   | 268   | 296   | 413   | 509   |
| 3/4            | 4.500                    | 7                        | 8                        | 222   | 452   | 774   | 455   | 452   | 381   | 414   | 577   | 711   |

Pr: Prying factor range (see A.6.5.12.2 for additional information).

[13:Table 18.5.12.2(d)]
Table 6.5.12.2(e) Maximum Load for Wedge Anchors in 6000 psi (414 bar) Normal Weight Cracked Concrete

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<th>Min. Nom. Embedment (in.)</th>
<th>Min. Slab Thickness (in.)</th>
<th>Min. Edge Distance (in.)</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
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<td>4</td>
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<td>219</td>
<td>313</td>
<td>402</td>
<td>189</td>
<td>277</td>
<td>329</td>
</tr>
<tr>
<td>1/2</td>
<td>3.750</td>
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<td>354</td>
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<td>529</td>
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<td>337</td>
<td>500</td>
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<td>6</td>
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<td>601</td>
<td>812</td>
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<td>766</td>
<td>902</td>
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<td>4.500</td>
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<td>8</td>
<td>763</td>
<td>1127</td>
<td>1429</td>
<td>829</td>
<td>1127</td>
<td>1370</td>
<td>714</td>
<td>1055</td>
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<tr>
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<th>Min. Nom. Embedment (in.)</th>
<th>Min. Slab Thickness (in.)</th>
<th>Min. Edge Distance (in.)</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
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</thead>
<tbody>
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<td>7</td>
<td>8</td>
<td>763</td>
<td>1127</td>
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<td>1127</td>
<td>1370</td>
<td>714</td>
<td>1055</td>
<td>1243</td>
</tr>
</tbody>
</table>

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### Wedge Anchors in 6000 psi Normal Weight Cracked Concrete (lb)

| Diameter (in.) | Min. Nom. Embedment (in.) | Min. Slab Thickness (in.) | Min. Edge Distance (in.) | A | B | C | D | E | F | G | H | I |
|----------------|--------------------------|--------------------------|--------------------------|---|---|---|---|---|---|---|---|---|---|
| 3/4            | 4.500                    | 7                        | 8                        | 354 | 647 | 1019 | 596 | 647 | 612 | 534 | 756 | 921 |

### Table 6.5.12.2(f) Maximum Load for Metal Deck Inserts in 3000 psi (207 bar) Lightweight Cracked Concrete on Metal Deck

| Diameter (in.) | Min. Effect. Embedment (in.) | Min. Slab Thickness (in.) | Max. Flute Center Offset (in.) | A | B | C | D | E | F | G | H | I |
|----------------|-----------------------------|--------------------------|--------------------------------|---|---|---|---|---|---|---|---|---|---|
| 3/4            | 1.750                       | 6.25                     | 1                              | 135 | 192 | 236 | —   | —   | —   | —   | —   | —   |
| 1/2            | 1.750                       | 6.25                     | 1                              | 138 | 199 | 247 | —   | —   | —   | —   | —   | —   |
| 5/8            | 1.750                       | 6.25                     | 1                              | 138 | 199 | 247 | —   | —   | —   | —   | —   | —   |

Pr: Prying factor range (see A.6.5.12.2 for additional information).

[13:Table 18.5.12.2(e)]

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## Metal Deck Inserts in 3000 psi Sand Lightweight Cracked Concrete on 4\(\frac{1}{2}\) in. Flute Width Metal Deck (lb)

<table>
<thead>
<tr>
<th>Diameter (in.)</th>
<th>Min. Effect. Embedment (in.)</th>
<th>Min. Slab Thickness (in.)</th>
<th>Min. Slab Thickness (in.)</th>
<th>Max. Flute Center Offset (in.)</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
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<tr>
<td>1/2</td>
<td>1.750</td>
<td>6.25</td>
<td>1</td>
<td>90</td>
<td>144</td>
<td>201</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>5/8</td>
<td>1.750</td>
<td>6.25</td>
<td>1</td>
<td>91</td>
<td>148</td>
<td>209</td>
<td>—</td>
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<tr>
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<td>1</td>
<td>97</td>
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<td>275</td>
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<td>67</td>
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<td>181</td>
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<td>1</td>
<td>67</td>
<td>136</td>
<td>229</td>
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<td>—</td>
<td>—</td>
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### Metal Deck Inserts in 3000 psi Sand Lightweight Cracked Concrete on 4\(\frac{1}{2}\) in. Flute Width Metal Deck (lb)

| Diameter (in.) | Min. Effect. Embedment (in.) | Min. Slab Thickness (in.) | Max. Flute Center Offset (in.) | A | B | C | D | E | F | G | H | I |
|---------------|------------------------------|--------------------------|--------------------------------|---|---|---|---|---|---|---|---|---|---|---|
| 3/8           | 1.750                        | 6.25                     | 1                              | 52| 96| 165|--|--|--|--|--|--|   |
| 1/2           | 1.750                        | 6.25                     | 1                              | 52| 98| 160|--|--|--|--|--|--|   |
| 5/8           | 1.750                        | 6.25                     | 1                              | 52| 98| 160|--|--|--|--|--|--|   |
| 3/4           | 1.750                        | 6.25                     | 1                              | 52| 106|196|--|--|--|--|--|--|   |

*Pr*: Prying factor range *(see A.6.5.12.2 for additional information).*

**[13:Table 18.5.12.2(f)]**

### Table 6.5.12.2(g) Maximum Load for Wood Form Inserts in 3000 psi (207 bar) Lightweight Cracked Concrete

| Diameter (in.) | Min. Effect. Embedment (in.) | Min. Slab Thickness (in.) | Min. Edge Distance (in.) | A | B | C | D | E | F | G | H | I |
|---------------|------------------------------|--------------------------|--------------------------|---|---|---|---|---|---|---|---|---|---|
| 3/8           | 1.100                        | 4                        | 6                        | 224|316|387|223|316|401|193|283|336|   |
| 1/2           | 1.690                        | 4                        | 6                        | 252|376|480|278|376|454|239|355|418|   |
| 5/8           | 1.750                        | 4                        | 8                        | 252|376|480|278|376|454|239|355|418|   |
| 3/4           | 1.750                        | 4                        | 8                        | 252|376|480|278|376|454|239|355|418|   |

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### Wood Form Inserts in 3000 psi Lightweight Cracked Concrete (lb)

| Diameter (in.) | Min. Effect. Embedment (in.) | Min. Slab Thickness (in.) | Min. Edge Distance (in.) | A   | B   | C   | D   | E   | F   | G   | H   | I   |
|----------------|-----------------------------|--------------------------|--------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 3/8            | 1.100                       | 4                        | 6                        | 150 | 239 | 331 | 192 | 239 | 264 | 169 | 243 | 293 |
| 1/2            | 1.690                       | 4                        | 6                        | 163 | 272 | 398 | 231 | 272 | 286 | 204 | 294 | 354 |
| 5/8            | 1.750                       | 4                        | 8                        | 163 | 272 | 398 | 231 | 272 | 286 | 204 | 294 | 354 |
| 3/4            | 1.750                       | 4                        | 8                        | 163 | 272 | 398 | 231 | 272 | 286 | 204 | 294 | 354 |

| Diameter (in.) | Min. Effect. Embedment (in.) | Min. Slab Thickness (in.) | Min. Edge Distance (in.) | A   | B   | C   | D   | E   | F   | G   | H   | I   |
|----------------|-----------------------------|--------------------------|--------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 3/8            | 1.100                       | 4                        | 6                        | 113 | 193 | 290 | 169 | 193 | 196 | 150 | 213 | 260 |
| 1/2            | 1.690                       | 4                        | 6                        | 115 | 213 | 339 | 198 | 213 | 199 | 178 | 251 | 307 |
| 5/8            | 1.750                       | 4                        | 8                        | 115 | 213 | 339 | 198 | 213 | 199 | 178 | 251 | 307 |
| 3/4            | 1.750                       | 4                        | 8                        | 115 | 213 | 339 | 198 | 213 | 199 | 178 | 251 | 307 |

| Diameter (in.) | Min. Effect. Embedment (in.) | Min. Slab Thickness (in.) | Min. Edge Distance (in.) | A   | B   | C   | D   | E   | F   | G   | H   | I   |
|----------------|-----------------------------|--------------------------|--------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 3/8            | 1.100                       | 4                        | 6                        | 88  | 161 | 257 | 150 | 161 | 152 | 135 | 190 | 234 |
| 1/2            | 1.690                       | 4                        | 6                        | 88  | 175 | 296 | 173 | 175 | 152 | 157 | 219 | 271 |
| 5/8            | 1.750                       | 4                        | 8                        | 88  | 175 | 296 | 173 | 175 | 152 | 157 | 219 | 271 |
| 3/4            | 1.750                       | 4                        | 8                        | 88  | 175 | 296 | 173 | 175 | 152 | 157 | 219 | 271 |

Pr: Prying factor range (see A.6.5.12.2 for additional information).
### Table 6.5.12.2(h) Maximum Load for Wood Form Inserts in 3000 psi (207 bar) Normal Weight Cracked Concrete

| Diameter (in.) | Min. Effect. Embedment (in.) | Min. Slab Thickness (in.) | Min. Edge Distance (in.) | A       | B       | C       | D       | E       | F       | G       | H       | I       |
|----------------|-----------------------------|--------------------------|--------------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 3/8            | 1.100                       | 4                        | 6                        | 248     | 342     | 411     | 237     | 342     | 444     | 205     | 300     | 357     |
| 1/2            | 1.690                       | 4                        | 6                        | 297     | 443     | 565     | 327     | 443     | 535     | 282     | 418     | 492     |
| 5/8            | 1.750                       | 4                        | 8                        | 297     | 443     | 565     | 327     | 443     | 535     | 282     | 418     | 492     |
| 3/4            | 1.750                       | 4                        | 8                        | 297     | 443     | 565     | 327     | 443     | 535     | 282     | 418     | 492     |

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<th>Min. Effect. Embedment (in.)</th>
<th>Min. Slab Thickness (in.)</th>
<th>Min. Edge Distance (in.)</th>
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<th>1.1 &lt; Pr ≤ 1.8</th>
<th>0.7 &lt; Pr ≤ 1.0</th>
<th>1.2 &lt; Pr ≤ 1.7</th>
<th>1.1 &lt; Pr ≤ 1.8</th>
<th>1.4 &lt; Pr ≤ 2.0</th>
<th>0.9 &lt; Pr ≤ 1.3</th>
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<td>272</td>
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<td>347</td>
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<td>1.750</td>
<td>4</td>
<td>8</td>
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<td>468</td>
<td>272</td>
<td>321</td>
<td>336</td>
<td>240</td>
<td>347</td>
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<tr>
<td>3/4</td>
<td>1.750</td>
<td>4</td>
<td>8</td>
<td>192</td>
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<td>272</td>
<td>321</td>
<td>336</td>
<td>240</td>
<td>347</td>
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<tr>
<th>Diameter (in.)</th>
<th>Min. Effect. Embedment (in.)</th>
<th>Min. Slab Thickness (in.)</th>
<th>Min. Edge Distance (in.)</th>
<th>3.5 &lt; Pr ≤ 5.0</th>
<th>1.8 &lt; Pr ≤ 2.5</th>
<th>1.0 &lt; Pr ≤ 1.3</th>
<th>1.7 &lt; Pr ≤ 2.2</th>
<th>1.8 &lt; Pr ≤ 2.5</th>
<th>2.0 &lt; Pr ≤ 2.9</th>
<th>1.9 &lt; Pr ≤ 2.4</th>
<th>1.3 &lt; Pr ≤ 1.7</th>
<th>1.1 &lt; Pr ≤ 1.4</th>
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<td>282</td>
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<tr>
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<td>1.690</td>
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<td>6</td>
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<td>399</td>
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<td>251</td>
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### Wood Form Inserts in 3000 psi Normal Weight Cracked Concrete (lb)

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<th>Min. Slab Thickness (in.)</th>
<th>Min. Edge Distance (in.)</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
</tr>
</thead>
<tbody>
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<td>8</td>
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<td>251</td>
<td>399</td>
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<td>251</td>
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<td>296</td>
<td>361</td>
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<tr>
<td>3/4</td>
<td>1.750</td>
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**Pr:** Prying factor range (see A.6.5.12.2 for additional information).

[13: Table 18.5.12.2(h)]

### Table 6.5.12.2(i) Maximum Load for Wood Form Inserts in 4000 psi (276 bar) Normal Weight Cracked Concrete

<table>
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<tr>
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<th>Min. Slab Thickness (in.)</th>
<th>Min. Edge Distance (in.)</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
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**Pr:** Prying factor range (see A.6.5.12.2 for additional information).
### Wood Form Inserts in 4000 psi Normal Weight Cracked Concrete (lb)

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<th>Min. Slab Thickness (in.)</th>
<th>Min. Edge Distance (in.)</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
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<td>8</td>
<td>344</td>
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<td>653</td>
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<td>326</td>
<td>482</td>
<td>568</td>
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<td>Diameter (in.)</td>
<td>Min. Effect. Embedment (in.)</td>
<td>Min. Slab Thickness (in.)</td>
<td>Min. Edge Distance (in.)</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td>G</td>
<td>H</td>
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<td>6</td>
<td>218</td>
<td>361</td>
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</tr>
<tr>
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<td>1.750</td>
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<td>8</td>
<td>222</td>
<td>371</td>
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<td>481</td>
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<td>1.750</td>
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<td>8</td>
<td>222</td>
<td>371</td>
<td>541</td>
<td>315</td>
<td>371</td>
<td>389</td>
<td>278</td>
<td>400</td>
<td>481</td>
</tr>
<tr>
<td>Diameter (in.)</td>
<td>Min. Effect. Embedment (in.)</td>
<td>Min. Slab Thickness (in.)</td>
<td>Min. Edge Distance (in.)</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td>G</td>
<td>H</td>
<td>I</td>
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<td>236</td>
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<td>290</td>
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<td>461</td>
<td>270</td>
<td>290</td>
<td>271</td>
<td>242</td>
<td>342</td>
<td>417</td>
</tr>
</tbody>
</table>

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## Wood Form Inserts in 4000 psi Normal Weight Cracked Concrete (lb)

<table>
<thead>
<tr>
<th>Diameter (in.)</th>
<th>Min. Effect. Embedment (in.)</th>
<th>Min. Slab Thickness (in.)</th>
<th>Min. Edge Distance (in.)</th>
<th>A Pr ≤ 2.0</th>
<th>B Pr ≤ 1.1</th>
<th>C Pr ≤ 0.7</th>
<th>D Pr ≤ 1.2</th>
<th>E Pr ≤ 1.1</th>
<th>F Pr ≤ 1.4</th>
<th>G Pr ≤ 0.9</th>
<th>H Pr ≤ 0.8</th>
<th>I Pr ≤ 1.7</th>
</tr>
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<td>305</td>
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<td>202</td>
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<td>275</td>
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<td>1.690</td>
<td>4</td>
<td>6</td>
<td>120</td>
<td>234</td>
<td>390</td>
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<td>234</td>
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<td>207</td>
<td>290</td>
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</tr>
<tr>
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<td>8</td>
<td>120</td>
<td>239</td>
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<td>207</td>
<td>214</td>
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<td>236</td>
<td>239</td>
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*Pr: Prying factor range (see A.6.5.12.2 for additional information).*

[13:Table 18.5.12.2(i)]

### Table 6.5.12.2(j) Maximum Load for Wood Form Inserts in 6000 psi (414 bar) Normal Weight Cracked Concrete

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<th>Min. Edge Distance (in.)</th>
<th>A Pr ≤ 2.0</th>
<th>B Pr ≤ 1.1</th>
<th>C Pr ≤ 0.7</th>
<th>D Pr ≤ 1.2</th>
<th>E Pr ≤ 1.1</th>
<th>F Pr ≤ 1.4</th>
<th>G Pr ≤ 0.9</th>
<th>H Pr ≤ 0.8</th>
<th>I Pr ≤ 1.7</th>
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<td>8</td>
<td>421</td>
<td>627</td>
<td>800</td>
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<td>627</td>
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<td>399</td>
<td>591</td>
<td>696</td>
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</table>

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### Wood Form Inserts in 6000 psi Normal Weight Cracked Concrete (lb)

| Diameter (in.) | Min. Effect. Embedment (in.) | Min. Slab Thickness (in.) | Min. Edge Distance (in.) | A | B | C | D | E | F | G | H | I |
|----------------|-----------------------------|--------------------------|--------------------------|---|---|---|---|---|---|---|---|---|---|
| 3/8            | 1.100                       | 4                        | 6                        | 216 | 319 | 409 | 237 | 319 | 379 | 207 | 297 | 360 |
| 1/2            | 1.690                       | 4                        | 6                        | 256 | 413 | 578 | 336 | 413 | 449 | 296 | 426 | 512 |
| 5/8            | 1.750                       | 4                        | 8                        | 272 | 454 | 662 | 386 | 454 | 476 | 340 | 491 | 589 |
| 3/4            | 1.750                       | 4                        | 8                        | 272 | 454 | 662 | 386 | 454 | 476 | 340 | 491 | 589 |

### Diameter (in.) | Min. Effect. Embedment (in.) | Min. Slab Thickness (in.) | Min. Edge Distance (in.) | A | B | C | D | E | F | G | H | I |
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<td>332</td>
<td>296</td>
<td>419</td>
<td>511</td>
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</tr>
</tbody>
</table>

### Diameter (in.) | Min. Effect. Embedment (in.) | Min. Slab Thickness (in.) | Min. Edge Distance (in.) | A | B | C | D | E | F | G | H | I |
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</table>
### Wood Form Inserts in 6000 psi Normal Weight Cracked Concrete (lb)

| Diameter (in.) | Min. Effect. Embedment (in.) | Min. Slab Thickness (in.) | Min. Edge Distance (in.) | A | B | C | D | E | F | G | H | I |
|----------------|-------------------------------|---------------------------|--------------------------|---|---|---|---|---|---|---|---|---|---|
| \( \frac{3}{4} \) | 1.750 | 4 | 8 | 147 | 293 | 493 | 289 | 293 | 253 | 263 | 366 | 451 |

*Pr: Prying factor range (see A.6.5.12.2 for additional information).*

[13:Table 18.5.12.2(j)]

### Table 6.5.12.2(k) Maximum Load for Connections to Steel Using Unfinished Steel Bolts

#### Connections to Steel (Values Assume Bolt Perpendicular to Mounting Surface)

<table>
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<th>B</th>
<th>C</th>
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<table>
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<th>B</th>
<th>C</th>
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</tbody>
</table>

[13:Table 18.5.12.2(l)]

### Table 6.5.12.2(l) Maximum Load for Through-Bolts in Sawn Lumber or Glue-Laminated Timbers

#### Through-Bolts in Sawn Lumber or Glue-Laminated Timbers (Load Perpendicular to Grain)

<table>
<thead>
<tr>
<th>Bolt Diameter (in.)</th>
</tr>
</thead>
</table>

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### Table 13: Through-Bolts in Sawn Lumber or Glue-Laminated Timbers (Load Perpendicular to Grain)

<table>
<thead>
<tr>
<th>Length of Bolt in Timber (in.)</th>
<th>1/2</th>
<th>5/8</th>
<th>3/4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/2</td>
<td>11</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>2 1/2</td>
<td>14</td>
<td>22</td>
<td>39</td>
</tr>
<tr>
<td>3 1/2</td>
<td>17</td>
<td>20</td>
<td>27</td>
</tr>
<tr>
<td>5 1/2</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Note: Wood fastener maximum capacity values are based on the 2001 National Design Specifications (NDS) for wood with a specific gravity of 0.35. Values for other types of wood can be obtained by multiplying the above values by the factors in Table 6.12.2(n).

### Table 6.5.12.2(m) Maximum Load for Lag Screws and Lag Bolts in Wood

#### Lag Screws and Lag Bolts in Wood (Load Perpendicular to Grain — Holes Predrilled Using Good Practice)

<table>
<thead>
<tr>
<th>Length of Bolt in Timber (in.)</th>
<th>3/8</th>
<th>1/2</th>
<th>5/8</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 1/2</td>
<td>16</td>
<td>17</td>
<td>—</td>
</tr>
<tr>
<td>4 1/2</td>
<td>18</td>
<td>17</td>
<td>—</td>
</tr>
<tr>
<td>5 1/2</td>
<td>19</td>
<td>17</td>
<td>—</td>
</tr>
<tr>
<td>6 1/2</td>
<td>19</td>
<td>17</td>
<td>—</td>
</tr>
</tbody>
</table>

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Note: Wood fastener maximum capacity values are based on the 2001 National Design Specifications (NDS) for wood with a specific gravity of 0.35. Values for other types of wood can be obtained by multiplying the above values by the factors in Table 6.5.12.2(n).

[13:Table 18.5.12.2(m)]

Table 6.5.12.2(n) Factors for Wood Based on Specific Gravity

<table>
<thead>
<tr>
<th>Specific Gravity of Wood</th>
<th>Multiplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.36 thru 0.49</td>
<td>1.17</td>
</tr>
<tr>
<td>0.50 thru 0.65</td>
<td>1.25</td>
</tr>
<tr>
<td>0.66 thru 0.73</td>
<td>1.50</td>
</tr>
</tbody>
</table>

[13:Table 18.5.12.2(n)]

6.5.12.3*

The type of fasteners used to secure the bracing assembly to the structure shall be limited to those shown in Table 6.5.12.2(a) through Table 6.5.12.2(m) or to listed devices. [13:18.5.12.3]

6.5.12.4*

For connections to wood, through-bolts with washers on each end shall be used, unless the requirements of 6.5.12.5 are met. [13:18.5.12.4]

6.5.12.5

Where it is not practical to install through-bolts due to the thickness of the wood member in excess of 12 in. (300 mm) or inaccessibility, lag screws shall be permitted and holes shall be predrilled 1/8 in. (3 mm) smaller than the maximum root diameter of the lag screw. [13:18.5.12.5]

6.5.12.6

Holes for through-bolts and similar listed attachments shall be 1/16 in. (1.6 mm) greater than the diameter of the bolt. [13:18.5.12.6]

6.5.12.6.1
The requirements of 6.5.12 shall not apply to other fastening methods, which shall be acceptable for use if certified by a registered professional engineer to support the loads determined in accordance with the criteria in 6.5.9. [13:18.5.12.6.1]

6.5.12.6.2

Calculations shall be submitted where required by the authority having jurisdiction. [13:18.5.12.6.2]

6.5.12.7* Concrete Anchors.

6.5.12.7.1*

Post-installed concrete anchors shall be prequalified for seismic applications in accordance with ACI 355.2, Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary, and installed in accordance with the manufacturer's instructions. [13:18.5.12.7.1]

6.5.12.7.2

Unless the requirements of 6.5.12.7.3 are met, concrete anchors shall be based on concrete strength, anchor type, designated angle category A through I, prying factor \((Pr)\) range, and allowable maximum load. [13:18.5.12.7.2]

6.5.12.7.2.1

Sway brace manufacturers shall provide prying factors \((Pr)\) based on the geometry of the structure attachment fitting and the designated angle category A through I as shown in Figure 6.5.12.1. [13:18.5.12.7.2.1]

6.5.12.7.2.2

Where the prying factor \((Pr)\) for the fitting is unknown, the largest \(Pr\) range in Table 6.5.12.2(a) through Table 6.5.12.2(j) for the concrete strength and designated angle category A through I shall be used. [13:18.5.12.7.2.2]

6.5.12.7.3

The allowable maximum load shall be permitted to be calculated. [13:18.5.12.7.3]

6.5.12.7.3.1

Allowable concrete anchor loads shall be permitted to be determined using approved software that considers the effects of prying for concrete anchors. [13:18.5.12.7.3.1]
6.5.12.7.3.2

Anchors shall be seismically prequalified per 6.5.12.7.1. [13:18.5.12.7.3.2]

6.5.12.7.3

Allowable maximum loads shall be based on anchor capacities given in approved evaluation service reports, where the calculation of allowable stress design (ASD) allowable shear and tension values are determined in accordance with Chapter 17 of ACI 318, Building Code Requirements for Structural Concrete and Commentary, and include the effects of prying, the brace angle, and the over strength factor ($\Omega=2.0$). [13:18.5.12.7.3.3]

6.5.12.7.3.4*

The shear and tension values determined in 6.5.12.7.3.3 shall be multiplied by 0.43. [13:18.5.12.7.3.4]

6.5.12.7.4

Concrete anchors shall be acceptable for use where designed in accordance with the requirements of the applicable building code and certified by a registered professional engineer. [13:18.5.12.7.4]

6.5.12.7.5*

Headed cast-in specialty inserts (i.e., concrete inserts) as prescribed in Table 6.5.12.2(a) through Table 6.5.12.2(j) shall be prequalified for seismic applications in accordance with ICC-ES AC446, Acceptance Criteria for Headed Cast-in Specialty Inserts in Concrete, and installed in accordance with the manufacturer’s instructions. [13:18.5.12.7.5]

6.5.13 Braces to Buildings with Differential Movement.

A length of pipe shall not be braced to sections of the building that will move differentially. [13:18.5.13]

6.6 Restraint of Branch Lines.

6.6.1*

Restraint is considered a lesser degree of resisting loads than bracing and shall be provided by use of one of the following:

(1) Listed sway brace assembly
(2) Wraparound U-hook satisfying the requirements of 6.5.5.11
(3) No. 12, 440 lb (200 kg) wire installed at least 45 degrees from the vertical plane and anchored on both sides of the pipe
(4) CPVC hangers listed to provide restraint
(5) *Hanger not less than 45 degrees from vertical installed within 6 in. (150 mm) of the vertical hanger arranged for restraint against upward movement, provided it is utilized such that $l/r$ does not exceed 400, where the rod extends to the pipe or a surge clip has been installed
(6) Other approved means

[13:18.6.1]

6.6.2 Wire Restraint.

6.6.2.1

Wire used for restraint shall be located within 2 ft (600 mm) of a hanger. [13:18.6.2.1]

6.6.2.2

The hanger closest to a wire restraint shall be of a type that resists upward movement of a branch line. [13:18.6.2.2]

6.6.3

The end sprinkler on a branch line shall be restrained. [13:18.6.3]

6.6.3.1

The location of the restraint from end of the line shall not be greater than 36 in. (900 mm) for 1 in. (25 mm) pipe, 48 in. (1200 mm) for 1 1/4 in. (32 mm) pipe, and 60 in. (1.5 m) for 1 1/2 in. (40 mm) or larger pipe. [13:18.6.3.1]

6.6.4*

Branch lines shall be laterally restrained at intervals not exceeding those specified in Table 6.6.4(a) or Table 6.6.4(b) based on branch line diameter and the value of $C_p$. [13:18.6.4]

Table 6.6.4(a) Maximum Spacing [ft (m)] of Steel Pipe Restraints
### Table 6.6.4(b) Maximum Spacing [ft (m)] of CPVC, Copper, and Red Brass Pipe Restraints

<table>
<thead>
<tr>
<th>Pipe [in. (mm)]</th>
<th>Seismic Coefficient, $C_p$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$C_p \leq 0.50$</td>
</tr>
<tr>
<td>$\frac{1}{2}$ (15)</td>
<td>34 (10.3)</td>
</tr>
<tr>
<td>$\frac{3}{4}$ (20)</td>
<td>38 (11.6)</td>
</tr>
<tr>
<td>1 (25)</td>
<td>43 (13.1)</td>
</tr>
<tr>
<td>$\frac{1}{2}$ (32)</td>
<td>46 (14.0)</td>
</tr>
<tr>
<td>$\frac{1}{2}$ (40)</td>
<td>49 (14.9)</td>
</tr>
<tr>
<td>2 (50)</td>
<td>53 (16.1)</td>
</tr>
</tbody>
</table>

[13:Table 18.6.4(a)]

6.6.5

Where the branch lines are supported by rods less than 6 in. (150 mm) long measured between the top of the pipe and the point of attachment to the building structure, the requirements of 6.6.1 through 6.6.4 shall not apply and additional restraint shall not be required for the branch lines. [13:18.6.5]
6.6.6*
Sprigs 4 ft (1.2 m) or longer shall be restrained against lateral movement. [13:18.6.6]

6.6.7
Drops and armovers shall not require restraint. [13:18.6.7]

6.7 Hangers and Fasteners Subject to Earthquakes.

6.7.1
Where seismic protection is provided, C-type clamps (including beam and large flange clamps) used to attach hangers to the building structure shall be equipped with a restraining strap unless the provisions of 6.7.1.1 are satisfied. [13:18.7.1]

6.7.1.1
As an alternative to the installation of a required restraining strap, a device investigated and specifically listed to restrain the clamp to the structure is permitted where the intent of the device is to resist the worst-case expected horizontal load. [13:18.7.1.1]

6.7.2
The restraining strap shall be listed for use with a C-type clamp or shall be a steel strap of not less than 16 gauge (1.57 mm) thickness and not less than 1 in. (25 mm) wide for pipe diameters 8 in. (200 mm) or less and 14 gauge (1.98 mm) thickness and not less than 1 1/4 in. (32 mm) wide for pipe diameters greater than 8 in. (200 mm). [13:18.7.2]

6.7.3
The restraining strap shall wrap around the beam flange not less than 1 in. (25 mm). [13:18.7.3]

6.7.4
A lock nut on a C-type clamp shall not be used as a method of restraint. [13:18.7.4]

6.7.5
A lip on a “C” or “Z” purlin shall not be used as a method of restraint. [13:18.7.5]

6.7.6
Where purlins or beams do not provide a secure lip to a restraining strap, the strap shall be through-bolted or secured by a self-tapping screw. [13:18.7.6]
6.7.7

In areas where the horizontal force factor exceeds 0.50 $W_p$, powder-driven studs shall be permitted to attach hangers to the building structure where they are specifically listed for use in areas subject to earthquakes. [13:18.7.7]

6.7.8*

Where seismic protection is provided, concrete anchors used to secure hangers to the building structure shall be in accordance with ACI 355.2, Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary, and installed in accordance with manufacturer's instructions. [13:18.7.8]

6.7.9

Where seismic protection is provided, cast-in-place anchors used to secure hangers to the building structure shall be in accordance with ICC-ES AC446, Acceptance Criteria for Headed Cast-in Specialty Inserts in Concrete, and installed in accordance with manufacturer's instructions. [13:18.7.9]

6.8* Pipe Stands Subject to Earthquakes.

6.8.1

In areas where the horizontal force factor exceeds 0.5 $W_p$, pipe stands over 4 ft (1.2 m) in height shall be certified by a registered professional engineer to be adequate for the seismic forces. [13:18.8.1]

6.8.2

Where seismic protection is provided, concrete anchors used to secure pipe stands to their bases shall be in accordance with ACI 355.2, Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary, and shall be installed in accordance with manufacturer's instructions. [13:18.8.2]

6.9 Sway Brace Calculations.

6.9.1*

Sway brace calculations shall show those items from 6.9.1.1 through 6.9.1.10 that pertain to the design of the brace.

6.9.1.1
Project Information shall include the following:

(1) Project name
(2) Project address
(3) Date
(4) Relevant contact information
(5) Edition of NFPA 200
(6) Edition of building code
(7) Edition of ASCE 7

6.9.1.2 Brace Information.

Brace information shall include the following:

(1) Brace name or identifier
(2) Listing agency
(3) Brace type (e.g., lateral, longitudinal, riser, and so forth)

6.9.1.3 Structure Information.

Structure information shall include the following:

(1) Description of structure (e.g., concrete, wood, steel, composite, and so forth)
(2) Dimensional and structural properties

6.9.1.4 Brace Member Information.

Brace member information shall include the following:

(1) Brace member description
(2) Brace member max length
(3) Brace member installation angle range
(4) Brace member least radius of gyration
(5) Brace member $l/r$ max
(6) Brace member max horizontal load capacity

6.9.1.5 Seismic Brace Components.

Seismic brace component information shall include the following:

(1) Component manufacturer
(2) Component model or figure
(3) Component size
(4) Component load rating at intended installation angle range
(5) Component prying factors at intended installation angle range

6.9.1.6 Seismic Brace Component Assembly Schematic Diagram.
Seismic brace component assembly schematic diagram information shall include the following:

(1) Installation details
(2) Location of attachment to structure
(3) Brace angle from vertical
(4) Component identification

6.9.1.7 Fastener Information.
Fastener information shall include the following:

(1) Source of fastener load capacity, generic NFPA 200 or manufacturer specific
(2) Fastener name or identifier
(3) Fastener installation orientations (A–I)
(4) Fastener diameter
(5) Fastener embedments (e.g., nominal, effective, and so forth)
(6) Minimum edge distances (e.g., 1, 2, 3, 4)
(7) Fastener max horizontal load capacity

6.9.1.8 Cp Calculations.
$C_p$ calculation information shall include the following:

(1) Calculation method
(2) $S_i$ value
(3) $C_p$ value
(4) Values of variables differing from the assumed values in Annex E

6.9.1.9 Pipe within the Zone of Influence (ZOI).
Pipe within the ZOI information shall include the following:

(1) Braced service pipe sizes
(2) Braced service pipe schedule or engineered/listed pipe description
(3) Braced service pipe weight per unit length (lb/ft)
(4) Braced service allowable horizontal load capacity at span
(5) Tributary pipe information (branchline), which shall include the following:
   (a) Pipe size, type, length, weight per unit length for each pipe within the tributary
   (b) Riser nipple compliance with 6.5.9.6.1

6.9.1.10 $F_{pw}$ Calcs.

$F_{pw}$ calcs information shall include the following:

   (1) Total pipe weight within the ZOI
   (2) $W_p$ (pipe weight times 1.15)
   (3) $F_{pw}$ ($C_p \times W_p$)

6.9.1.11 Net Vertical Reaction Forces Information per 6.5.9.6.1.

If net vertical forces need to be specially addressed per 6.5.10, the method of meeting the requirements shall comply with 6.5.10.

Chapter 7 Installation Requirements for Hanging, Support, and Anchorage of Water-Spray Fixed Systems

7.1 General.

This chapter shall provide minimum requirements for the support and restraint of piping systems designed per the requirements in NFPA 15.

7.1.1 Pipe Support.

7.1.1.1

System piping shall be supported to maintain its integrity under fire conditions. [15:6.3.2.1]

7.1.1.2

Piping shall be supported from steel or concrete structural members or pipe stands. [15:6.3.2.2]

7.1.1.2.1

Where a horizontal bracket is used to attach the system piping to the pipe stand, it shall not be more than 18 in. (457.2 mm) as measured horizontally from the centerline of the pipe stand to the centerline of the support pipe. [15:6.3.2.2.1]

7.1.1.2.2*
Pipe stands used to support piping shall be in accordance with Table 7.1.1.2.2(a), Table 7.1.1.2.2(b), and Table 7.1.1.2.2(c) to determine maximum heights for pipe stands supporting various diameters of looped piping. [15:6.3.2.2.2]

### Table 7.1.1.2.2(a) Maximum Pipe Stand Heights for Axially Loaded Pipe Stands

<table>
<thead>
<tr>
<th>System Pipe Diameter</th>
<th>Pipe Stand Diameter</th>
<th>1½ in.</th>
<th>2 in.</th>
<th>2½ in.</th>
<th>3 in.</th>
<th>4 in.</th>
<th>6 in.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ft</td>
<td>m</td>
<td>ft</td>
<td>m</td>
<td>ft</td>
<td>m</td>
<td>ft</td>
</tr>
<tr>
<td>1½ in.</td>
<td>10</td>
<td>3.05</td>
<td>14</td>
<td>4.27</td>
<td>18</td>
<td>5.49</td>
<td>28</td>
</tr>
<tr>
<td>2 in.</td>
<td>8</td>
<td>2.44</td>
<td>12</td>
<td>3.66</td>
<td>16</td>
<td>4.88</td>
<td>26</td>
</tr>
<tr>
<td>2½ in.</td>
<td>6</td>
<td>1.83</td>
<td>10</td>
<td>3.05</td>
<td>14</td>
<td>4.27</td>
<td>24</td>
</tr>
<tr>
<td>4 in.</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>6 in.</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>8 in.</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

[15:Table 6.3.2.2.2(a)]

### Table 7.1.1.2.2(b) Maximum Pipe Stand Heights with Support Arms Up to 1 ft 0 in. (0.305 m) in Length

<table>
<thead>
<tr>
<th>System Pipe Diameter</th>
<th>Pipe Stand Diameter</th>
<th>1½ in.</th>
<th>2 in.</th>
<th>2½ in.</th>
<th>3 in.</th>
<th>4 in.</th>
<th>6 in.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ft</td>
<td>m</td>
<td>ft</td>
<td>m</td>
<td>ft</td>
<td>m</td>
<td>ft</td>
</tr>
<tr>
<td>1½ in.</td>
<td>9</td>
<td>2.74</td>
<td>14</td>
<td>4.27</td>
<td>18</td>
<td>5.49</td>
<td>28</td>
</tr>
<tr>
<td>2½ in.</td>
<td>—</td>
<td>—</td>
<td>8</td>
<td>2.44</td>
<td>14</td>
<td>4.27</td>
<td>24</td>
</tr>
<tr>
<td>4 in.</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>
Table 7.1.1.2.2(c) Maximum Pipe Stand Heights with Support Arms Up to 1 ft 6 in. (0.46 m) in Length

<table>
<thead>
<tr>
<th>System Pipe Diameter</th>
<th>Pipe Stand Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1½ in.</td>
</tr>
<tr>
<td></td>
<td>ft</td>
</tr>
<tr>
<td>6 in.</td>
<td>—</td>
</tr>
<tr>
<td>8 in.</td>
<td>—</td>
</tr>
</tbody>
</table>

(15:Table 6.3.2.2.2(b))

Where a cantilevered support arm is used to support system piping, the minimum size of the support arm shall be such that the section modulus required in Table 7.1.1.2.3(a) and Table 7.1.1.2.3(b) does not exceed the section modulus of the support arm. (15:6.3.2.2.3)

Table 7.1.1.2.3(a) Required Section Modulus for Pipe Stand Horizontal Support Arms 1 ft 0 in. (305 m) in Length

<table>
<thead>
<tr>
<th>System Pipe Diameter</th>
<th>Pipe Stand Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1½ in.</td>
</tr>
<tr>
<td></td>
<td>ft</td>
</tr>
<tr>
<td>4 in.</td>
<td>—</td>
</tr>
<tr>
<td>6 in.</td>
<td>—</td>
</tr>
<tr>
<td>8 in.</td>
<td>—</td>
</tr>
</tbody>
</table>
Nominal Diameter of Pipe Being Supported — Schedule 10 Steel

<table>
<thead>
<tr>
<th>Nominal Diameter of Pipe Being Supported — Schedule 10 Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 in.</td>
</tr>
<tr>
<td>0.15</td>
</tr>
</tbody>
</table>

Nominal Diameter of Pipe Being Supported — Schedule 40 Steel

<table>
<thead>
<tr>
<th>Nominal Diameter of Pipe Being Supported — Schedule 40 Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 in.</td>
</tr>
<tr>
<td>0.16</td>
</tr>
</tbody>
</table>

For SI units, 1 in. = 25.4 mm; 1 ft = 0.305 m.

[15:Table 6.3.2.2.3(a)]

Table 7.1.1.2.3(b) Required Section Modulus for Pipe Stand Horizontal Support Arms 1 ft 6 in. (0.46 m) in Length (in.3)

<table>
<thead>
<tr>
<th>Nominal Diameter of Pipe Being Supported — Schedule 10 Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 in.</td>
</tr>
<tr>
<td>0.23</td>
</tr>
</tbody>
</table>

Nominal Diameter of Pipe Being Supported — Schedule 40 Steel

<table>
<thead>
<tr>
<th>Nominal Diameter of Pipe Being Supported — Schedule 40 Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 in.</td>
</tr>
<tr>
<td>0.24</td>
</tr>
</tbody>
</table>

For SI units, 1 in. = 25.4 mm; 1 ft = 0.305 m.

[15:Table 6.3.2.2.3(b)]

7.1.1.2.4

Where pipe stands are used to support straight runs of piping or other configurations that are not looped or are not rigidly supported at the top of the pipe stand in a manner that will resist movement in all directions, the pipe stands shall be designed in accordance with the requirements of Chapter 5. [15:6.3.2.2.4]

7.1.1.2.5*
Distance between pipe stands exceeding those in Table 7.1.1.2.5 shall be permitted where a 45-degree diagonal is attached between the pipe stand and the loop piping. (See Figure A.7.1.1.2.5.) For piping of other than Schedule 40, pipe stand shall be spaced in accordance with the hanger references of Chapter 5. [15:6.3.2.2.5]

**Table 7.1.1.2.5 Pipe Stand Distance**

<table>
<thead>
<tr>
<th>Loop Size</th>
<th>Distance Between Pipe Stands</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in.</td>
</tr>
<tr>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>1½</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>2½</td>
<td>65–200</td>
</tr>
</tbody>
</table>

[15:Table 6.3.2.2.5]

**7.1.1.2.6**

Pipe stands shall be constructed of Schedule 40 threaded pipe, malleable iron flange base, and shall have a threaded, grooved, or welded cap top. [15:6.3.2.2.6]

**7.1.1.2.7***

Pipe stands shall be anchored to a concrete pier or footing with either expansion shields, bolts for concrete, or cast-in-place J hooks. [15:6.3.2.2.7]

**7.1.1.2.8***

Piping shall be attached to the pipe stand with U-bolts or equivalent attachment. [15:6.3.2.2.8]

**7.1.1.3**

Piping support shall be permitted to be attached directly to vessels or other equipment, provided the equipment is capable of supporting the system and the design is certified by a registered professional engineer. [15:6.3.2.3]

**7.1.1.4**

Tapping and drilling of load-bearing structural elements shall be permitted only where the design of the structural members takes the drilling or tapping into account, where the design
includes the additional loads created by the water spray system, and where the design is certified by a registered professional engineer. [15:6.3.2.4]

7.1.1.5

Where welding of supports directly to vessels or equipment is necessary, it shall be done in a safe manner in conformance with the provisions of all safety, structural, and fire codes and standards. [15:6.3.2.5]

7.1.1.6*

Hangers shall be installed and located in accordance with Chapter 5. [15:6.3.2.6]

7.1.1.7*

Where the pipe support methods outlined in this standard cannot be used, water spray system piping shall be supported in a manner equivalent to the performance requirements of this standard and the design certified by a registered professional engineer. [15:6.3.2.7]

7.1.1.8

Piping shall be supported and braced to restrict movement due to nozzle reaction and water surges so that system performance and integrity is maintained. [15:6.3.2.8]

Chapter 8 Installation Requirements for Hanging, Support, and Anchorage of Gaseous Systems

8.1 General.

8.1.1

This chapter shall provide minimum requirements for the support and restraint of piping systems designed per the requirements of NFPA 12, NFPA 12A, NFPA 17, and NFPA 2001.

8.1.2

Piping shall be supported from the building structure, which must support the vertical and horizontal system design loads.

8.1.3 *
Hangers and supports shall be capable of supporting the fluid- or media-filled gravity weight of the piping system.

8.1.4

Installation of hangers, supports, and restraints shall be in accordance with the component manufacturer’s installation manual or the system manufacturer’s listed installation manual.

8.1.5

Hangers, supports, restraints, pipes, and fittings shall not be used to support nonsystem components.

8.1.5.1*

Hangers or supports for system piping shall be permitted to support other system components.

8.1.5.2

Piping shall be permitted to utilize shared support structures.

8.1.6

Hangers, supports, restraints, pipes, and fittings shall not obstruct discharge devices.

8.2 Hanger and Support Requirements.

8.2.1

Unless the requirements of 8.2.2 are met, types of hangers and supports shall be in accordance with the requirements of Chapter 8.

8.2.2 *

Hangers and supports certified by a registered professional engineer to include all of the following shall be an acceptable alternative to the requirements of Chapter 8:

(1) Hangers and supports shall be designed to support 3.5 times the weight of fluid- or media-filled pipe at each point of piping support or a minimum of 150 lb (68 kg).
(2) The point of attachment to the building structure shall be able to support the system design loads.
(3) Hanger and support components shall be ferrous unless the material has been evaluated to ensure the component is able to support the gravity load of the system during a fire or during prolonged thermal exposure.
(4) Detailed calculations shall be submitted, where required by the reviewing authority, showing stresses developed in the hangers, supports, piping, fittings, and safety factors allowed.

8.2.3
Minimum rod diameters for the hanging of horizontal pipes shall be 3/8 in. (M10) for up to 4 in. (100 mm) pipe and ½ in. (M12) for up to 8 in. (200 mm) pipe.

8.2.4
Minimum fastener diameters for the hanging of horizontal pipes shall be 3/8 in. (M10) for up to 4 in. (100 mm) pipe and ½ in. (M12) for up to 8 in. (200 mm) pipe.

8.2.5*
Hangers and supports designed as both a hanger and a restraint shall be permitted as long as the requirements of Sections 8.2 and 8.4 are met.

8.2.6*
Beam clamps shall be positively engaged to a beam without the use of a set screw or friction.

8.3 Thermal Expansion and Contraction.

8.3.1
Thermal expansion and contraction of the piping system relative to the building structure shall be considered.

8.3.2
Hangers, supports, and restraints shall be permitted to be installed to accommodate thermal expansion and contraction.

8.3.3
Expansion loops or flexible piping shall be permitted to be installed to accommodate thermal expansion and contraction.

8.3.4
Where used, all hangers, supports, and restraints shall be able to support any additional load from the expansion loops and flexible piping.

8.4 Restraint Requirements.

8.4.1
The piping system shall be restrained during system discharge.

8.4.2
Unless the requirements of 8.4.3 are met, types of restraints shall be in accordance with requirements of Chapter 8.
8.4.3*

Restraints certified by a registered professional engineer to include all of the following shall be an acceptable alternative to the requirements of Chapter 8:

(1) Restraints shall be designed to restrain 3.5 times the design force applied by pressure thrust loads, fluid thrust loads, thermal expansion, wind loads, or any other dynamic force applied to the system at the point of piping restraint or a minimum of 100 lbf (667 N).

(2) The point of attachment to the building structure shall be able to support the system design loads.

(3) Restraint components shall be ferrous unless the material has been evaluated to ensure the component is able to restrain the thrust load of the system during system discharge or during prolonged thermal exposure.

(4) Detailed calculations shall be submitted, where required by the reviewing authority, showing stresses developed in the restraints, piping, fittings, and safety factors allowed.

8.4.4

Minimum fastener diameters for the restraint of pipes are 3/8 in. (M10) for up to 4 in. (100 mm) pipe and ½ in. (M12) for up to 8 in. (200 mm) pipe.

8.4.5

Restraints shall be per the system manufacturer’s listed installation instructions.

8.4.5.1*

Where information referenced in 8.4.5 does not exist, restraints shall be designed to support a minimum horizontal force per Table 8.4.5(a) or Table 8.4.5(b).

<table>
<thead>
<tr>
<th>Table 8.4.5(a) Restraint Minimum Design Load (lbf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Pipe or Tube Size (in.)</td>
</tr>
<tr>
<td>≤1</td>
</tr>
<tr>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 8.4.5(b) Restraint Minimum Design Load (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Pipe or Tube Size (mm)</td>
</tr>
<tr>
<td>445</td>
</tr>
</tbody>
</table>

8.5 Installation of Hangers and Supports—Horizontal Piping.

8.5.1
The maximum distance between hangers and supports shall be per the system manufacturer’s listed installation instructions.

8.5.1.1

Where information referenced in 8.5.1 does not exist, the maximum distance between hangers and supports shall not exceed that specified in Table 8.5.1.1(a) or Table 8.5.1.1(b).

Table 8.5.1.1(a) Maximum Distance Between Hangers and Supports (ft)

<table>
<thead>
<tr>
<th>Nominal Pipe or Tube Size (in.)</th>
<th>¼</th>
<th>½</th>
<th>¾</th>
<th>1</th>
<th>1¼</th>
<th>1½</th>
<th>2</th>
<th>2½</th>
<th>3</th>
<th>3½</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel Pipe</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>16</td>
<td>17</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Stainless Pipe</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>16</td>
<td>17</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Copper Tube</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>16</td>
</tr>
</tbody>
</table>

Table 8.5.1.1(b) Maximum Distance Between Hangers and Supports (m)

<table>
<thead>
<tr>
<th>Nominal Pipe or Tube Size (mm)</th>
<th>8</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>32</th>
<th>40</th>
<th>50</th>
<th>65</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>125</th>
<th>150</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel Pipe</td>
<td>2.1</td>
<td>2.1</td>
<td>2.1</td>
<td>2.1</td>
<td>2.7</td>
<td>3.0</td>
<td>3.4</td>
<td>3.7</td>
<td>4.0</td>
<td>4.3</td>
<td>4.9</td>
<td>5.2</td>
<td>5.8</td>
<td></td>
</tr>
<tr>
<td>Stainless Pipe</td>
<td>2.1</td>
<td>2.1</td>
<td>2.1</td>
<td>2.1</td>
<td>2.7</td>
<td>3.0</td>
<td>3.4</td>
<td>3.7</td>
<td>4.0</td>
<td>4.3</td>
<td>4.9</td>
<td>5.2</td>
<td>5.8</td>
<td></td>
</tr>
<tr>
<td>Copper Tube</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.8</td>
<td>2.1</td>
<td>2.4</td>
<td>2.4</td>
<td>2.7</td>
<td>3.0</td>
<td>3.4</td>
<td>3.7</td>
<td>4.0</td>
<td>4.3</td>
<td>4.9</td>
</tr>
</tbody>
</table>

8.5.2

A hanger or support shall be installed within 2 ft (0.9 m) of a change in direction unless the requirements of 8.5.3 are met.

8.5.3

The hanger or support per 8.5.2 shall not be required if the length of pipe between fittings is 2 ft (0.6 m) or less.

8.5.4*

Maximum rod or fastener span for a trapeze of channel and angle iron shall be per Table 8.5.4(a) or Table 8.5.4(b).

Table 8.5.4(a) Maximum Rod or Anchor Span for Trapeze Hangers (ft)

<table>
<thead>
<tr>
<th>Nominal Pipe or Tube Size (in.)</th>
<th>≤1½</th>
<th>2</th>
<th>2½</th>
<th>3</th>
<th>3½</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>3⅛ x 1⅛ x 12 ga Channel</td>
<td>16</td>
<td>14</td>
<td>12</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>4.5</td>
<td>3</td>
<td>1.5</td>
</tr>
</tbody>
</table>
### Table 8.5.4(b) Maximum Rod or Anchor Span for Trapeze Hangers (m)

<table>
<thead>
<tr>
<th>Nominal Pipe or Tube Size (mm)</th>
<th>≤40</th>
<th>50</th>
<th>65</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>125</th>
<th>150</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>83 x 41 x 12 ga Channel</td>
<td>4.9</td>
<td>4.3</td>
<td>3.7</td>
<td>3</td>
<td>2.7</td>
<td>2.4</td>
<td>1.4</td>
<td>0.9</td>
<td>0.5</td>
</tr>
<tr>
<td>83 x 41 x 12 ga Welded Channel</td>
<td>6.1</td>
<td>6.1</td>
<td>6.1</td>
<td>5.5</td>
<td>4.9</td>
<td>4.6</td>
<td>3.7</td>
<td>3</td>
<td>1.7</td>
</tr>
<tr>
<td>41 x 41 x 12 ga Channel</td>
<td>2.7</td>
<td>2.1</td>
<td>2</td>
<td>1.4</td>
<td>0.9</td>
<td>0.8</td>
<td>0.5</td>
<td>0.3</td>
<td>-</td>
</tr>
<tr>
<td>41 x 41 x 12 ga Welded Channel</td>
<td>4.6</td>
<td>3.7</td>
<td>3</td>
<td>3</td>
<td>2.7</td>
<td>2.1</td>
<td>1.4</td>
<td>0.9</td>
<td>0.5</td>
</tr>
<tr>
<td>21 x 41 x 12 ga Channel</td>
<td>1.4</td>
<td>1.1</td>
<td>0.6</td>
<td>0.5</td>
<td>0.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>21 x 41 x 12 ga Welded Channel</td>
<td>2.1</td>
<td>2.1</td>
<td>1.8</td>
<td>1.2</td>
<td>0.9</td>
<td>0.6</td>
<td>0.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>38 x 38 x 6.4 Angle</td>
<td>2.1</td>
<td>2.1</td>
<td>1.8</td>
<td>1.4</td>
<td>0.9</td>
<td>0.8</td>
<td>0.5</td>
<td>0.3</td>
<td>-</td>
</tr>
<tr>
<td>51 x 51 x 6.4 Angle</td>
<td>3.0</td>
<td>3.0</td>
<td>2.4</td>
<td>2.1</td>
<td>1.8</td>
<td>1.4</td>
<td>0.8</td>
<td>0.6</td>
<td>0.3</td>
</tr>
<tr>
<td>51 x 51 x 9.5 Angle</td>
<td>2.9</td>
<td>2.9</td>
<td>2.7</td>
<td>2.4</td>
<td>2.1</td>
<td>2.0</td>
<td>1.2</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>64 x 64 x 9.5 Angle</td>
<td>3.8</td>
<td>3.8</td>
<td>3.7</td>
<td>3.0</td>
<td>2.7</td>
<td>2.4</td>
<td>2.0</td>
<td>1.4</td>
<td>0.8</td>
</tr>
<tr>
<td>76 x 76 x 9.5 Angle</td>
<td>4.6</td>
<td>4.6</td>
<td>4.3</td>
<td>3.7</td>
<td>3.0</td>
<td>3.0</td>
<td>2.7</td>
<td>2.0</td>
<td>1.1</td>
</tr>
<tr>
<td>76 x 76 x 12.7 Angle</td>
<td>4.4</td>
<td>4.4</td>
<td>4.4</td>
<td>4.3</td>
<td>3.7</td>
<td>3.0</td>
<td>2.7</td>
<td>2.4</td>
<td>1.4</td>
</tr>
</tbody>
</table>

8.6 Installation of Hangers and Supports—Vertical Piping.

8.6.1
Supports shall be placed at a maximum spacing of 20 ft (6.1 m).

8.6.2

Pipe segments longer than 2 ft (0.6 m) shall have a hanger or support.

8.6.3

A hanger or support within 2 ft (0.6 m) of the top or bottom of a riser shall be permitted to act as riser support.

8.7 Installation of Restraints.

8.7.1

Restraints shall be installed per the restraint manufacturer’s installation instructions or per the system manufacturer’s listed installation instructions.

8.7.2

A restraint shall be placed at every change of direction within the piping system to restrict movement in the direction of thrust during system discharge unless the requirements of 8.7.3 are met.

8.7.3*

A restraint is not required if the length of pipe in the changed direction between the fittings is 4 ft (1.2 m) or less.

8.7.4*

Restraints shall be permitted to be attached to trapeze hangers installed per Table 8.5.3(a) or Table 8.5.3(b) as long as all hangers and supports within the load path are designed to accommodate the calculated thrust loads and gravity loads.

8.7.5*

Restraints shall comply with both of the following:

(1) Be installed within 2 ft (0.6 m) of a nozzle
(2) Restrain movement horizontally and vertically unless the requirements of 8.7.6(2) are met

8.7.6*

Vertical restraints shall not be required on a vertical drop or upright of 4 ft (1.2 m) or less if a vertical thrust restraint is installed within 2 ft (0.6 m) of the change of direction.

8.8 Expansion Loops.

Hangers, supports, restraints, and braces shall not restrict the designed movement of an expansion loop.
8.9 Seismic Bracing Requirements.

8.9.1

Where fire protection piping systems are required to be protected against damage from earthquakes, sway bracing shall be provided unless the requirements in 8.9.2 are met.

8.9.2

Seismic bracing shall be permitted to be excluded if one of the following is satisfied:

(1) Where the piping system is supported within 12 in. (305 mm) of the building structure and where an individual hanger rod or hanger fastener load does not exceed 50 lb (22.7 kg)

(2) Where the piping system is restrained per Section 0 with thrust restraints spaced at a maximum span of 20 ft (6.1 m) or two times the max horizontal hanger spacing per 0, whichever is greater

(3) Where the requirements of ASCE/SEI 7, Minimum Design Loads and Associated Criteria for Buildings and Other Structures, are met.

8.9.3

Where additional seismic braces are required, braces shall be designed and installed per the requirements of Chapter 6 or MSS SP-127, Bracing for Piping Systems: Seismic – Wind – Dynamic Design, Selection, and Application.

8.9.4

Alternative methods of providing earthquake protection of gaseous systems based on a seismic analysis certified by a registered professional engineer such that system performance will be at least equal to that of the building structure under expected seismic forces shall be permitted.

8.9.5

Lateral sway braces on horizontal pipes shall be spaced at a maximum span of 40 ft (12.2 m).

8.9.6

Longitudinal sway braces on horizontal pipes shall be spaced at a maximum span of 80 ft (24.4 m).

8.9.7

Seismic braces on riser pipes shall be installed at a maximum span of 25 ft (7.6 m).

8.9.8

The pipe shall be able to withstand the flexural stresses developed by the lateral seismic design loads.

8.9.9
Chapter 9 Installation Requirements for Hanging, Support, Restraint, and Seismic Bracing of Gaseous Fire Suppression Agent Storage Containers

9.1 General.
This chapter shall provide minimum requirements for the support and restraint of agent storage containers designed per the requirements of NFPA 12, NFPA 12A, NFPA 17, and NFPA 2001.

9.2 Support.

9.2.1 Agent storage containers, propellant containers, manual actuation stations, and fixed agent delivery systems (e.g., skids) shall be installed and supported according to the system manufacturer's listed installation instructions.

9.2.2 All methods of support shall be permitted where tested, listed, and installed in accordance with the listing requirements or with the system manufacturer's listed installation instructions.

9.2.3 Agent storage containers shall be supported by a building structure, rack, or similar assembly designed for such use.

9.2.4 The structure shall be able to support the system design load.

9.3 Restraint.

9.3.1 Agent storage containers shall be restrained according to the system manufacturer's listed installation instructions.
The agent storage container shall be restrained so as to prevent movement during discharge for the conditions identified 0, 0, and 0.

9.3.2.1
The agent storage container shall be in place while piping is connected.

9.3.2.2
The agent storage container shall be in place while piping is disconnected and a safety cap is in place.

9.3.2.3
The agent storage container shall be in place while piping is disconnected, a safety cap is not in place, and the cylinder valve fails or unexpectedly opens.

9.3.3
The structure shall be able to withstand design thrust force.

9.4 Bracing.

9.4.1
Bracing components shall be ferrous unless the material has been evaluated to ensure the component is able to brace the seismic load of the agent storage container during system discharge or during prolonged thermal exposure.

9.4.2
All methods of seismic protection shall be permitted where tested, listed, and installed in accordance with the listing requirements or with the system manufacturer’s listed installation instructions.

9.4.3
Agent storage containers shall be braced to a building structure, rack, or a similar assembly designed for such use, so as to prevent movement during a seismic event.

9.4.4*
The bracing system shall include two or more braces located at one-third and two-thirds the height of the container.
Chapter 10 Installation Requirements for Hanging, Support, and Anchorage of Water Mist Systems

10.1 Supports.

10.1.1

All references to hangers shall include supports. [750:6.5.1]

10.1.2

Hangers used on low-pressure water mist systems shall be permitted to be designed and installed in accordance with Chapter 5. [750:6.5.2]

10.2 Special Designed Hangers.

Plastic inserts shall be permitted in tube clamps to avoid dissimilar metal reactions or dampen vibrations.

10.3 Listed Inserts.

The use of listed inserts set in concrete to support hangers shall be permitted.

10.4 Piping Support.

10.4.1 Tube hangers shall be spaced in accordance with Table 10.4.1.

Table 10.4.1 Tube Hanger Maximum Spacing.

<table>
<thead>
<tr>
<th>Tube O.D.</th>
<th>Maximum Distance Between Hangers</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>in.</td>
</tr>
<tr>
<td>6–14</td>
<td>1/4, 3/8, 1/2</td>
</tr>
<tr>
<td>15–22</td>
<td>3/4–7/8</td>
</tr>
<tr>
<td>23–28</td>
<td>1</td>
</tr>
<tr>
<td>30–38</td>
<td>1 1/4–1 1/2</td>
</tr>
<tr>
<td>40–49</td>
<td></td>
</tr>
</tbody>
</table>
10.4.2 Location of Hangers and Supports.

10.4.2.1

Hangers and supports shall be located in accordance with the requirements contained within the system’s design manual.

10.4.2.2

For low-pressure and intermediate systems, steel pipe and copper tubing shall be supported in accordance with Chapter 5.

10.5* Protection of System Components Against Damage Where Subject to Earthquakes.

Where subject to earthquakes, water mist systems shall be protected to prevent pipe breakage in accordance with the seismic requirements of NFPA 13.

10.6 Manifolded Cylinders.

10.6.1 Support.

Where manifolded, cylinders shall be mounted and supported in a rack provided for this purpose, including facilities for convenient, individual servicing, or weighing of contents.

10.6.2 Securement.

Containers shall be secured with manufacturer-listed supports to prevent container movement and physical damage.

10.6.3 General.
Tanks, pumps, filters, hangers, waterflow detection devices, and waterflow valves shall be in accordance with manufacturers' requirements but are not required to be listed.

10.6.4 Piping Support.

10.6.4.1
Listed pipe shall be supported in accordance with any listing limitations.

10.6.4.2
Pipe that is not listed and listed pipe with listing limitations that do not include piping support requirements shall be supported from structural members using support methods in accordance with the design, installation, and operations manual.

10.6.4.3
Piping laid on open joists or rafters shall be supported in a manner that prevents vertical and lateral movement of the nozzle.

10.7 Nozzles.
Nozzles shall be supported in manner that prevents lateral and vertical movement.

10.8 Galvanic Corrosion.

10.8.1
In areas where the exterior of the pipe is regularly subject to extreme humidity, moisture, or spray, pipe hangers shall be resistant to galvanic corrosion.

10.8.2
Dielectric pipe hanger insulators, such as nonmetallic bands between the hangers and the pipe wall, or stainless steel hangers shall be used.

Chapter 11 Installation Requirements for Seismic Protection of Water Mist Systems
[Reserved]
Chapter 12 Installation Requirements for Hanging, Support, and Anchorage of Hybrid Systems [Reserved]

Chapter 13 Installation Requirements for Seismic Protection of Hybrid Systems [Reserved]

Chapter 14 Installation Requirements for Hanging, Support, and Anchorage of Fire Pump System

14.1 General.

14.1.1 Pipe and Fittings.

14.1.1.1

The support of pipe and fittings shall comply with the requirements of Chapter 5.

14.1.1.2

The seismic protection, where applicable, of pipe and fittings shall comply with the requirements of Chapter 5.

14.1.2 Fire Pumps, Controllers, Drivers, and Fuel Tanks.

14.1.2.1

Fire pumps, controllers, drivers, and fuel tanks shall be supported in accordance with Section 14.2 and the manufacturer’s installation instructions.

14.1.2.2

Where required to be protected against damage from earthquakes, fire pumps, controllers, drivers, and fuel tanks, shall be protected against seismic activity in accordance with Section 14.3 and the manufacturer’s installation instructions.

14.2 Anchorage.

14.2.1* General.

Where required, housekeeping pads shall be provided beneath the fire pump, controller, driver, and fuel tank.

14.2.2 Centrifugal Fire Pumps.

14.2.2.1*
Overhung impeller and impeller between bearings design pumps and driver shall be mounted on a common grouted base plate. [20:6.4.1]

14.2.2.2*
Pumps of the overhung impeller close coupled in-line type (see Figure A.14.2.2.2) shall be permitted to be mounted on a base attached to the pump mounting base plate. [20:6.4.2]

14.2.2.3
The base plate shall be securely attached to a solid foundation in such a way that pump and driver shaft alignment is ensured. [20:6.4.3]

14.2.2.4*
The foundation shall be sufficiently substantial to form a permanent and rigid support for the base plate. [20:6.4.4]

14.2.2.5
The base plate, with pump and driver mounted on it, shall be set level on the foundation. [20:6.4.5]

14.2.3  Vertical Shaft Turbine-Type Pumps.

14.2.3.1
Certified dimension prints shall be obtained from the manufacturer. [20:7.4.3.1]

14.2.3.2
The foundation for vertical pumps shall be built to carry the entire weight of the pump and driver plus the weight of the water contained in it. [20:7.4.3.2]

14.2.3.3
Foundation bolts shall be provided to firmly anchor the pump to the foundation. [20:7.4.3.3]

14.2.3.4
The foundation shall be of sufficient area and strength that the load per square inch (square millimeter) on concrete does not exceed design standards. [20:7.4.3.4]

14.2.3.5
The top of the foundation shall be carefully leveled to permit the pump to hang freely over a well pit on a short-coupled pump. [20:7.4.3.5]

14.2.3.6
On a well pump, the pump head shall be positioned plumb over the well, which is not necessarily level. [20:7.4.3.6]

### 14.2.4 Positive Displacement Pumps.

#### 14.2.4.1

The pump and driver shall be mounted on a common grouted base plate. [20:8.8.1]

#### 14.2.4.2

The base plate shall be securely attached to a solid foundation in such a way that proper pump and driver shaft alignment will be maintained. [20:8.8.2]

#### 14.2.4.3

The foundation shall provide a solid support for the base plate. [20:8.8.3]

### 14.2.5 Packaged Fire Pump Units.

#### 14.2.5.1

Packaged fire pump units shall be properly anchored and grouted in accordance with 14.2.2.1. [20:4.31.8]

#### 14.2.5.2*

The interior floor of a package pump house shall be of solid construction with grading to provide proper drainage for the fire pump components. [20:4.31.9]

#### 14.2.5.2.1

The interior floor shall be permitted to be provided with grouting in accordance with 14.2.2.1 or installed after the packaged pump house is set in place in accordance with 14.2.2.3. [20:4.31.9.1]

#### 14.2.5.2.2

The structural frame for a packaged pump house shall be mounted on an engineered footing designed to withstand the live loads of the packaged unit and the applicable wind loading requirements. [20:4.31.9.2]

#### 14.2.5.2.3

The foundation footings of a package pump house shall include the necessary anchor points required to secure the package to the foundation. [20:4.31.9.3]

#### 14.2.5.3
A highly skid-resistant, solid structural plate floor with grout holes shall be permitted to be used where protection from corrosion and drainage is provided for all incidental pump room spillage or leakage. [20:4.31.10]

**14.3 Earthquake Protection.**

**14.3.1 General.**

Where water-based fire protection systems to be protected against damage from earthquakes, 14.3.2 and 14.3.3 shall apply. [20:4.30.1]

**14.3.1.1**

Alternative methods of providing earthquake protection for the installation of fire pumps based on a seismic analysis certified by a registered professional engineer such that system performance will be at least equal to that of the building structure under expected seismic forces shall be permitted.

**14.3.2* Seismic Loads.**

Horizontal seismic loads shall be determined in accordance with 14.3.2; ASCE/SEI 7, *Minimum Design Loads for Buildings and Other Structures*; local, state, or international codes; or other sources acceptable to the authority having jurisdiction. [20:4.30.2]

**14.3.2.1**

The weight of the fire pump being anchored ($W_p$) shall be taken as 1.3 times the operating weight of the fire pump.

**14.3.2.2**

The horizontal seismic load shall be determined by multiplying the seismic coefficient ($c_p$) by the weight of the fire pump ($W_p$) determined in 14.3.2.1.

**14.3.2.3**

Anchorage to the foundation shall be able to withstand the horizontal seismic load determined in 14.3.2.2.

**14.3.3 Components.**

**14.3.3.1 Pump Driver and Controller.**

The fire pump, driver, and fire pump controller shall be attached to their foundations with materials capable of resisting applicable seismic loads. [20:4.30.3.1]

**14.3.3.1.1**
Where the fire pump, driver, or fire pump controller is mounted on a housekeeping pad, the housekeeping pad shall be reinforced to withstand the seismic forces of the mounted equipment per 14.3.3.1.2 and 14.3.3.1.3.

14.3.3.1.2

The housekeeping pad shall extend 24 in. (600 mm) from all edges of the fire pump base plate.

14.3.3.2* High Center of Gravity.

Pumps with high centers of gravity, such as vertical in-line pumps, shall be mounted at their base and braced above their center of gravity. [20:4.30.3.2]

14.3.3.3* Pipe and Fittings.

Pipe and fittings shall be protected in accordance with Chapter 5. [20: 4.30.3.3]

14.3.3.4 Appurtenances.

Seismic protection of appurtenances, including trim pieces, shall be required where they are essential for post-earthquake operation of the fire pump. [20:4.30.3.4]

14.3.3.4.1*

Where seismically protecting smaller diameter trim lines, restraint shall be sufficient. [20:4.30.3.4.1]

Chapter 15 Installation Requirements for Seismic Protection of Fire Pump Systems
[Reserved]

Chapter 16 Installation Requirements for Hanging, Support, and Anchorage of Private Fire Water Tanks

16.1 General.

16.1.1

This chapter shall apply to the design, materials, and installation of supports, anchorage, restraint, and foundations to resist gravity, buoyancy, and wind or earthquake forces on fire protection system tanks.

16.1.2

Design and installation of components other than those provided for support, anchorage, and restraint shall be in accordance with NFPA 22.


16.2.1
The basic load conditions for the tank and tank support, anchorage, and foundation design shall be based on the facility location and the location and configuration of the tank within the facility.

16.2.2*

The tank and its supports, anchorage, and foundations shall withstand controlling combinations of basic load conditions per locally adopted building codes and this standard.

16.2.2.1

Loads, load factors, and allowable stresses specified in this chapter shall be considered to be based on allowable stress design (ASD).

16.2.2.2*

Load and resistance factor design (LRFD) shall be an acceptable alternative method where approved and the loads, load factors, and allowable stresses or capacities specified in this chapter are converted to their LRFD equivalents.

16.2.3 Dead Load. [22:4.12.1; 13.3.1]

16.2.3.1

The dead load shall be the estimated weight of all permanent construction and fittings. [22:4.12.1.1; 8.3.1; 13.3.1.1]

16.2.3.2*

Unit weights of construction materials and fittings shall be determined from consensus standards or documents provided by the manufacturer.

16.2.3.3

The weight of soil permanently resting on buried tanks or structural elements shall be included as a dead load.

16.2.3.3.1

The weight of soil shall be permitted to be excluded where this creates a more severe condition for the item being designed.

16.2.3.4

Dead load shall be multiplied by a load factor of 1.0 and included in all load combinations.

16.2.3.4.1

Dead load shall be multiplied by a load factor of 0.6 and combined with the following loads where this creates a more severe condition for the item being designed:

(1) Buoyancy forces
(2) Horizontal wind forces multiplied by a load factor of 0.6
(3) Earthquake forces
16.2.4 Live Load. [22:4.12.2; 8.3.2; 13.3.2]

16.2.4.1
The weight of liquid contained in the tank shall be considered to be live load.

16.2.4.1.1
The unit weight of water shall be considered to be 62.4 lb/ft$^3$ (1000 kg/m$^3$). [22:4.12.2.2; 8.3.2.2; 13.3.2.2]

16.2.4.1.2
Under normal conditions, the maximum liquid live load shall be the weight of all the liquid to the inlet of the overflow, if an overflow is provided, or if not, when the water overflows the top of the tank.

16.2.4.2
A uniform roof live load of 25 lb/ft$^2$ (122 kg/m$^2$) on the horizontal projection shall be applied.

16.2.4.2.1*
Reduction of roof live loads in accordance with local building code requirements shall be permitted.

16.2.4.2.2
The roof live load shall not be less than 12 lb/ft$^2$ (59 kg/m$^2$) on the horizontal projection.

16.2.4.3 Live Load — Large Tank Risers. [22:13.3.3]

16.2.4.3.1
The water located directly above any tank riser shall not be considered to be carried by the tower columns. [22:13.3.3.1]

16.2.4.3.1.1
Such water shall be considered to be carried by the tower columns where the tank riser is suspended from the tank bottom or from the tower columns. [22:13.3.3.1.1]

16.2.4.3.2
If a hemispherical or ellipsoidal tank bottom is rigidly attached to the top of a large tank riser by a flat horizontal diaphragm plate and the tank riser is supported by a separate solid foundation or is suspended from the tower, the tank riser plate shall be considered as supporting the water load in a hollow cylinder having an outside radius equal to the radius of the tank riser at the tank bottom plus one-half the distance from the edge of the tank riser to the connection of the flat horizontal diaphragm plate to the hemispherical or ellipsoidal bottom plates. [22:13.3.3.2]

16.2.4.3.2.1
The inside radius of the hollow cylinder shall be considered to be equal to the radius of the tank riser at the tank bottom. [22:13.3.3.2.1]

16.2.4.3.2.2
The load shall be deducted from the weight of the tank water when designing the tower. [22:13.3.3.2.2]

16.2.4.3.2.3

The load shall not be required to be deducted from the weight of the tank water where the tank riser is suspended from the tower. [22:13.3.3.2.3]

16.2.4.3.3

If a hemispherical or ellipsoidal shape is continuous to the shell of a large tank riser without a flat horizontal diaphragm plate and the tank riser is supported by a separate solid foundation or is suspended from the tower, the tank riser plate shall be designed to carry the water load of a hollow cylinder that extends from the bottom of the tank to the top of the tank. [22:13.3.3.3]

16.2.4.3.3.1

The outside radius of the hollow cylinder shall be assumed to be 2 ft (0.61 m) greater than, and the inside radius shall be assumed to be equal to, the radius of the tank riser shell at the tank bottom. [22:13.3.3.3.1]

16.2.4.3.3.2

The load shall not be deducted from the tank water load when designing the tank and tower. [22:13.3.3.3.2]

16.2.4.3.3.3

The load shall be permitted to be deducted for the tower design of tanks with ellipsoidal bottoms of a flat shape at the connection to tank risers supported by a separate solid foundation. [22:13.3.3.3.3]

16.2.4.3.4

If the tank bottom is a torus shape, the tank riser plate shall be designed to carry the weight of all water in the tank between a cylinder that intersects the bottom at its lowest elevation and a cylinder that is equal to the diameter of the tank riser. [22:13.3.3.4]

16.2.4.3.4.1

The load shall be deducted from the weight of the tank water when designing the tower. [22:13.3.3.4.1]

16.2.4.4

Proper provision shall be made for temporary stresses during erection. [22:13.3.2.3]

16.2.4.5 Including Live Load in Load Combinations.

Live load shall be included in load combinations such that the controlling condition for the item being designed results, considering the following cases:

(1) The tank is either completely full, partially full, or empty.
(2) The roof live load is applied over the entire roof, part of the roof, or none of the roof.

16.2.5 Roof Snow Load.

16.2.5.1
Where the tank will be erected outdoors in an area subject to snowfall, the location-specific uniform roof snow load required by the local building code shall be included in the design.

16.2.5.1.1
Where a location-specific roof snow load has not been established by the local building code, a minimum uniform roof snow load of 25 lb/ft² (122 kg/m²) on the horizontal projection shall be used.

16.2.5.2
Where roofs have slopes of less than 30 degrees, the uniform roof snow load shall not be reduced based on roof slope or tributary area.

16.2.5.2.1
Roof snow load reductions shall be permitted as allowed by the local building code where the slope is 30 degrees or more.

16.2.5.3
Where roof snow loads exceed the roof live loads given in 16.2.4.2, the roof live load shall be replaced by the roof snow load in 16.2.4.5 load combinations.

16.2.5.3.1
Roof snow loads shall not be required to be combined with roof live loads.

16.2.6 Loads on Buried Tanks and Foundations.

16.2.6.1*
Where tanks or foundations are buried, design shall include forces resulting from the weight of soil and water in soil per the recommendations of a registered professional engineer.

16.2.6.1.1
Vertical downward loads from soil above the item, lateral load from soil or water pressure against tank walls, and vertical upward loads from buoyancy of an empty tank in water-saturated soil shall be considered.

16.2.6.2
Earthquake effects of soils shall be considered per 16.2.8.6.

16.2.6.3 Including Loads on Buried Items in Load Combinations.

16.2.6.3.1
Soil resting on buried tanks and foundations shall be considered dead load and be included in load combinations per 16.2.3.4.
Where soil or water in soil results in lateral or uplift pressure, these effects shall be multiplied by a factor of either 0.9 or 1.6, whichever creates a more severe condition for the item being designed, and included in all load combinations.

16.2.7 Wind Load. [22:4.12.3; 8.3.3; 13.3.4]

16.2.7.1*

Under normal conditions, the wind load or pressure shall be assumed to be 30 lb/ft² (147 kg/m²) on vertical plane surfaces, 18 lb/ft² (88 kg/m²) on vertical projected areas of cylindrical surfaces, and 15 lb/ft² (73 kg/m²) on vertical projected areas of conical and double-curved plate surfaces.

16.2.7.2

The load on trussed towers shall be assumed to be concentrated at the panel points.

16.2.7.2*

Where 3-second gust wind velocities based on the basic wind speeds given in, or derived in a manner equivalent to, the 2005 (or earlier) edition of ASCE/SEI 7, Minimum Design Loads for Buildings and Other Structures, are over 100 mph (161 km/hr), all of these specified unit pressures shall be adjusted in proportion to the square of the velocity, assuming that the pressures are for 100 mph (161 km/hr).

16.2.7.3*

Where 3-second gust wind velocities based on the basic wind speeds given in, or derived in a manner equivalent to, the 2010 (or later) edition of ASCE/SEI 7, Minimum Design Loads for Buildings and Other Structures, for Risk Category IV structures are over 130 mph (209 km/hr), all of these specified unit pressures shall be adjusted in proportion to the square of the velocity, assuming that the pressures are for 130 mph (209 km/hr).

16.2.7.4

The wind shall be considered to be blowing from any direction. [22:12.4.1.1]

16.2.7.5

Wind load shall be multiplied by a load factor of 1.0 and included in load combinations with dead load, liquid live load, and the roof live or snow load that create the most conservative condition for the item being designed.

16.2.7.5.1

Wind load shall not be required to be included where the tank is buried or is located within a building that protects it from wind loads.

16.2.7.5.2

Wind and earthquake loads shall not be required to be considered simultaneously. [22:4.12.7.2; 8.4.2.2; 13.4.7.3]
16.2.8 Earthquake Load. [22:4.12.4]

16.2.8.1
Tanks, their supporting structures and foundations, and their anchorage shall comply with the seismic requirements per the local building code, and per the specific design standards and design criteria specified in this standard for the particular tank type, whichever is more stringent.

16.2.8.2
The weight of the contained liquid shall be included for determining earthquake forces.

16.2.8.3*
Flat-bottom tanks shall be designed by a method that accounts for the sloshing of the contents (effective mass method). [22:4.12.4.3]

16.2.8.4*
Horizontal earthquake design forces for gravity (i.e., elevated) tanks and pressure tanks shall be determined assuming the entire liquid mass acts as a rigid mass unless otherwise allowed by another standard.

16.2.8.5
For determining earthquake forces on the tank, roof live or snow load, whichever is larger, shall be added to the tank weight using either of the following two methods:

(1) By assuming 25 percent of the roof live or snow load is present when determining the earthquake shear and overturning moment but using none of this roof live or snow load to determine the resisting shear or moment

(2) By performing an analysis using 100 percent of the roof live or snow load and a second analysis using no roof live or snow load

16.2.8.6
Where the tank is buried, tank earthquake design forces shall be determined assuming the tank is located at grade.

16.2.8.6.1
Earthquake effects of soils shall be included as required per the recommendations of a registered professional engineer. (See A.16.2.6.1.)

16.2.8.7
Earthquake forces shall be considered to be applied in any direction for horizontal accelerations, and either upward or downward for vertical accelerations, whichever condition results in controlling forces for the item being designed.

16.2.8.8
Earthquake load shall be multiplied by a load factor of 1.0 and included in load combinations with dead load, liquid live load, and the roof live or snow load, that create the most conservative condition for the item being designed.

16.2.8.8.1

Wind and earthquake loads shall not be required to be considered simultaneously. [22:4.12.7.2; 8.4.2.2; 13.4.7.3]

16.3 Unit Stresses. [22: 8.4; 13.4]

16.3.1

Unit stresses determined using the loads and pressures in this standard shall not exceed the maximum permissible stresses based on the allowable stress design (ASD) method.

16.3.2

Wind and Earthquake Stress Increases.

16.3.2.1

Where wind or earthquake loads are included in the design load combination, the maximum permissible increase in ASD unit stresses shall be one-third.

16.3.2.2

An item sized using the wind or earthquake stress increase shall be confirmed to be adequate for load combinations that do not include wind or earthquake.

16.4 General Tank Location, Support, and Anchorage Requirements.

16.4.1

Interior timber shall not be used to support or brace tank structures. [22:4.3.1.5]

16.4.2*

Gravity tanks shall not be supported by wood tower or building members.

16.4.3 Foundations.

16.4.3.1

Foundations or footings shall furnish support and anchorage for tanks or their supporting towers for all applicable load conditions, including gravity loads, buoyancy loads, lateral loads from soil, wind loads, and earthquake loads.

16.4.3.2

Foundations or footings shall meet the requirements in 16.13.2, 16.13.3, and 16.13.5.

16.4.4
If the tank or supporting trestle is to be placed on a building, the building shall be designed and built to carry the maximum loads. [22:4.3.4]

16.4.5
Anchorage shall meet the requirements in 16.13.4.

16.4.6 Protection of Buried Tanks. [22:11.5]

16.4.6.1
Tanks shall be located completely below the frost line to protect against freezing. [22:11.5.6]

16.4.6.2
Tanks shall be designed to resist the pressure of earth against them. [22:11.5.1]

16.4.6.3
The tank shall be located above the maximum ground water level so that the buoyancy of the tank, when empty, does not force it upward.

16.4.6.3.1
Where tanks cannot be located above the maximum groundwater level or are exposed to floodwater, they shall be safeguarded against movement by anchoring with nonmetallic straps to a bottom hold-down pad or deadman anchors with fittings built up or protected to prevent corrosion failure over the life of the tank or by securing by other equivalent means using recognized engineering standards.

16.4.6.4
Bedding and backfill shall be noncorrosive inert material, of a type recommended by the tank manufacturer, such as crushed stone or pea gravel that is properly compacted. [22:11.5.4]

16.4.6.5
Tanks shall be set on the minimum depth of bedding, as recommended by the tank manufacturer, that extends 1 ft (0.3 m) beyond the end and sides of the tank. [22:11.5.5]

16.4.6.5
Tanks shall be installed in accordance with the manufacturer's instructions.

16.5 Welded-Carbon Steel Suction Tanks (Cylindrical) and Gravity Tanks and Composite Concrete and Carbon Steel Gravity Tanks.

16.5.1 Design and Materials.
All tank design, foundations, materials, accessories, fabrication, construction, and welding shall be in accordance with AWWA D100, Welded Carbon Steel Tanks For Water Storage, or AWWA D107, Composite Elevated Tanks For Water Storage, and this standard.

16.5.2 Corrosion Protection for Steel Bottom Plates on Soil or Concrete.
16.5.2.1

The underside of all bottom plates shall be protected against corrosion by one of the methods required by 16.5.2.1.1 or 16.5.2.1.2. [22:5.4.1]

16.5.2.1.1

The sand pad, including pH range of the lime sand mix, sulfate content, and chloride content, shall meet the requirements of AWWA D100, *Welded Carbon Steel Tanks For Water Storage*, or AWWA D107, *Composite Elevated Tanks For Water Storage*. [22:5.4.1.1]

16.5.2.1.2*

Where permitted by environmental authorities, an oiled sand cushion shall be permitted to be used in accordance with AWWA D100, *Welded Carbon Steel Tanks For Water Storage*. [22:5.4.1.2]

16.5.3 Flat-Bottom Cylindrical Steel Suction Tanks for Which Wind Design is Required.

16.5.3.1

Adequacy of the tank to resist shear and overturning from wind shall be assessed assuming the tank is empty, using only the dead weight of the tank itself (i.e., the shell, roof, bottom, and permanent accessories) to resist loads.

16.5.3.2

Shear anchorage shall be provided at the base of the tank where the net lateral force from wind, calculated as the lateral force from wind minus the resisting frictional force, is greater than zero.

16.5.3.2.1

If the tank has a steel bottom plate, a resisting frictional force of tan30° multiplied by the dead weight of the empty tank shall be permitted.

16.5.3.2.2

If the tank has no bottom plate, both of the following shall apply (see A.16.5.4.1.1):

1. The resisting frictional force shall be taken as zero.
2. The following conditions shall be met:
   a. Only half the provided anchors shall be considered effective to resist shear.
   b. Liners shall be protected from damage due to sliding.

16.5.3.2.3

Shear anchorage shall consist of embedded steel bolts cast into concrete and meet the requirements in 16.13.4.1. (See A.16.13.4.1.5.)

16.5.3.3*
Overturning anchorage shall be provided at the base of the tank where the net overturning moment from wind, calculated as the overturning moment from wind minus two-thirds of the moment resisting wind overturning, is greater than zero.

16.5.3.3.1

The moment resisting wind overturning at the tank base shall be determined using only the dead weight of the tank shell plus that portion of the roof dead weight supported by the tank shell, and assuming this dead weight is applied at the center of the tank.

16.5.3.3.2

If the tank has no bottom plate, the following conditions shall be met (see A.16.5.4.1.1):

1. Only half the provided anchors shall be considered effective to resist overturning.
2. Liners shall be protected from damage due to sliding.

16.5.3.3.3

Where the overturning moment from wind exceeds two-thirds of the resisting moment, the required ASD tension force per anchor due to wind overturning forces shall be determined using Equation 16.5.3.3.3:

\[ T = \frac{4M_{NET}}{kN} \]  \[\text{[16.5.3.3.3]}\]

where:

\( T \) = the ASD tension force per anchor (lb or N)

\( M_{NET} \) = the net overturning moment, equal to the overturning moment from wind minus 2/3 of the moment resisting overturning (lb-ft or N-m)

\( k \) = factor accounting for the number of effective anchors (1.0 when a bottom plate exists or 0.5 when a bottom plate does not exist)

\( N \) = the number of anchors provided

\( D \) = the diameter of the tank (ft or m)

16.5.3.4

Wind uplift anchorage consisting of embedded steel bolts or straps (minimum 0.25 in. [6.4 mm] thick) cast into concrete shall be permitted.

16.5.4* Flat-Bottom Cylindrical Steel Suction Tanks for Which Earthquake Design is Required.

16.5.4.1

Tanks shall have a steel bottom plate.

16.5.4.1.1*
If the tank has no bottom plate, the following conditions shall be met:

1. Anchorage shall be provided to resist the total base shear without considering any resistance from friction between the tank and its support.
2. Anchorage shall be provided to resist the total uplift on the tank shell without considering any resistance provided by the contained liquid.
3. Only half the provided anchors shall be considered effective to resist shear or overturning.
4. Liners shall be protected from damage due to sliding or uplift.

16.5.4.2

Shear anchorage shall be provided at the base of the tank where the net lateral force from earthquake, calculated as the lateral force from earthquake minus the resisting frictional force, is greater than zero.

16.5.4.2.1

If the tank has no bottom plate, the conditions in 16.5.4.1.1 shall be met.

16.5.4.2.2*

If the tank has a steel bottom plate, a resisting frictional force of \( \tan 30^\circ \) multiplied by the dead weight of the tank, plus contained water multiplied by the factor \((1 - 0.06 S_{DS})\), shall be permitted.

16.5.4.2.3

The design short period spectral response acceleration parameter, \( S_{DS} \), shall be permitted to be determined from Table 16.5.4.2.3 based on the mapped short period spectral response acceleration parameter, \( S_S \), from ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*.

**Table 16.5.4.2.3 Design Short Period Acceleration Parameter (\( S_{DS} \))**

<table>
<thead>
<tr>
<th>( S_S ) (g)</th>
<th>Default ( S_{DS} ) (g)</th>
<th>( S_S ) (g)</th>
<th>Default ( S_{DS} ) (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.33 or less</td>
<td>0.34</td>
<td>2.2</td>
<td>1.76</td>
</tr>
<tr>
<td>0.4</td>
<td>0.39</td>
<td>2.3</td>
<td>1.84</td>
</tr>
<tr>
<td>0.5</td>
<td>0.47</td>
<td>2.4</td>
<td>1.92</td>
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<tr>
<td>0.6</td>
<td>0.53</td>
<td>2.5</td>
<td>2</td>
</tr>
<tr>
<td>0.7</td>
<td>0.58</td>
<td>2.6</td>
<td>2.08</td>
</tr>
<tr>
<td>0.8</td>
<td>0.64</td>
<td>2.7</td>
<td>2.16</td>
</tr>
<tr>
<td>0.9</td>
<td>0.72</td>
<td>2.8</td>
<td>2.24</td>
</tr>
</tbody>
</table>
16.5.4.2.4

Shear anchorage shall consist of embedded steel bolts cast into concrete and meet the requirements in 16.13.4.1. *(See A.16.13.4.1.5.)*

16.5.4.3

Overturning anchorage shall be provided at the base of the tank to resist the net overturning moment from earthquake, in accordance with 16.5.4.

16.5.4.3.1

If the tank has no bottom plate, both of the following shall apply:

1. The conditions in 16.5.4.1.1 shall be met.
2. The required ASD tension force per anchor due to earthquake overturning forces shall be determined using Equation 16.5.4.3.1 *(see A.16.5.4.1.1.)*:

\[
T = \frac{4M_{EQ}}{kND} - \frac{w_D}{kN}
\]  

*[16.5.4.3.1]*

where:

- \(T\) = the ASD tension force per anchor (lb or N)
- \(M_{EQ}\) = the earthquake overturning moment (lb-ft or N-m)
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\[ T = \frac{4M_{EQ}}{ND} \left( \frac{w_t + w_L}{N} \right) \pi D \quad \text{[16.5.4.3.2]} \]

where:
- \( T \) = the ASD tension force per anchor (lb or N)
- \( M_{EQ} \) = the earthquake overturning moment (lb-ft or N-m)
- \( N \) = the number of anchors provided
- \( D \) = the diameter of the tank (ft or m)
- \( w_t \) = the dead weight (no roof live or snow load) at the bottom of the tank from the tank shell and that portion of the roof supported by the tank shell per length of circumference (lb/ft or N/m)
- \( w_L \) = the weight of water adjacent to the tank shell per length of circumference that is effective for overturning resistance (lb/ft or N/m) as determined from AWWA D100, *Welded Carbon Steel Tanks For Water Storage*

**16.5.4.3.3***

Anchors resisting earthquake uplift shall consist of a steel rod or bolt attached to the tank shell via an anchor chair and embedded into a reinforced concrete foundation meeting the following conditions and the requirements in 16.13.4:

1. Anchors shall be at least \( \frac{3}{4} \) in. (20 mm) in diameter.
2. Postinstalled concrete anchors, such as expansion anchors, shall not be used.
3. The anchor chair and the embedment into the reinforced concrete foundation shall be able to develop the tensile strength of the anchor (i.e., tensile stress area multiplied by the published minimum tensile stress of the anchor) or four times the calculated allowable stress design tension force, whichever is less, without failure.
4. Uplift anchors shall not have "J" or "L" or "U" hooked terminations but instead have heads or nuts, with or without plate washers, at their embedded end in the reinforced concrete foundation.
(5) The foundation shall be able to resist the uplift via dead weight, the use of a reinforced concrete mat, the addition of piles, or a similar method.

16.5.4.4*

Freeboard between the roof and the water surface corresponding to the tank overflow height shall be provided to prevent sloshing water from impacting the tank roof.

16.5.4.4.1

If freeboard is not provided, the following conditions shall be met:

1. The tank roof shall be designed to resist the forces from impact of the sloshing water.
2. The impulsive liquid mass shall be increased by the amount \( m_a \) in Equation 16.5.4.4.1.
3. The convective liquid mass shall be decreased by the amount \( m_c \) in Equation 16.5.4.4.1.
4. The tank shall be reanalyzed per the effective mass method using the adjusted masses.

\[ m_\Delta = m_c \left(1 - \frac{d_a}{d_{sl}}\right) \]  \[16.5.4.4.1\]

where:

- \( m_c \) = the convective mass calculated assuming the freeboard is adequate (lb or kg)
- \( d_a \) = the actual freeboard provided (ft or m)
- \( d_{sl} \) = the calculated expected sloshing wave height (ft or m), which exceeds \( d_a \)

16.6 Factory-Coated, Bolted Carbon Steel Tanks.

16.6.1 Design, Materials, Fabrication, and Installation.

All design, materials, fabrication, and installation shall be in accordance with AWWA D103, Factory-Coated Bolted Carbon Steel Tanks For Water Storage, and this standard.

16.6.2 Wind Design.

Flat-bottom, bolted, cylindrical carbon steel suction tanks for which wind design is required shall comply with 16.2.7 and 16.5.3.

16.6.3 Earthquake Design.

Flat-bottom, bolted, cylindrical carbon steel suction tanks for which earthquake design is required shall comply with 16.2.8 and 16.5.4.

16.7 Wood Gravity Tanks and Suction Tanks.
16.7.1 Main Supports.

Steel I-beams or reinforced concrete beams shall be used for the main supports where the dunnage beams rest. [22:8.5.7]

16.7.2 Spacing of Supports. [22:8.5.8]

16.7.2.1

The maximum distance in the clear between the beams where the tank bottom rests shall not exceed 21 in. (533 mm). [22:8.5.8.1]

16.7.2.2

The maximum distance between the outer edge of the outer dunnage beam and the inside surface of the tank staves, measured on a line perpendicular to the beam at its midpoint, shall not exceed 14 in. (356 mm). [22:8.5.8.2]

16.7.3 Air Circulation Under Tank Bottom.

Tank supports shall be designed to allow the free circulation of air under the tank bottom and around the ends of the staves. [22:8.5.9]

16.7.4 Clearance at Supports. [22:8.6.9]

16.7.4.1

The distance between the ends of dunnage beams and the inside surface of the staves shall be not less than 1 in. (25.4 mm) or more than 3 in. (76 mm). [22:8.6.9.1]

16.7.4.2

The supports shall be of such depth that the clearance beneath the ends of staves is not less than 1 in. (25.4 mm) at any point. [22:8.6.9.2]

16.7.5

Flat-bottom wood suction tanks for which wind design is required shall follow the requirements given in 16.2.7 and 16.5.3, accounting for the properties of and stresses allowed for wood.

16.7.6

Flat-bottom wood suction tanks for which earthquake design is required shall follow the requirements given in 16.2.8 and 16.5.4, accounting for the properties of and stresses allowed for wood.

16.8 Concrete Gravity Tanks and Suction Tanks.

16.8.1 General.

The design, materials, and construction of concrete tanks shall conform to ACI 318, Building Code Requirements for Structural Concrete and Commentary; ACI 350, Code Requirements for Environmental
16.8.2 Earthquake Design.

Concrete tanks shall meet the requirements for resisting earthquake damage by complying with the earthquake provisions of ACI 350.3, Code Requirements for Seismic Analysis and Design of Liquid-Containing Concrete Structures and Commentary, and 16.2.8 of this standard.

16.8.3 Prestressed Tanks.

Earthquake requirements for prestressed concrete tanks shall comply with the earthquake provisions of AWWA D110, Wire-And Strand-Wound, Circular, Prestressed Concrete Water Tanks; or AWWA D115, Tendon-Prestressed Concrete Water Tanks, as applicable. [22:10.4.1]


Fiberglass-reinforced plastic tanks shall meet the requirements of AWWA D120, Thermosetting Fiberglass-Reinforced Plastic Tanks; or AWWA D121, Bolted Aboveground Thermosetting Fiberglass-Reinforced Plastic Panel-Type Tanks for Water Storage. [22:11.3]

16.9.2 Wind Design.

Flat-bottom fiberglass-reinforced plastic suction tanks for which wind design is required shall follow the requirements given in 16.2.7 and 16.5.3, accounting for the allowable stresses and the anisotropic properties of fiberglass-reinforced plastic.

16.9.3* Earthquake Design.

Flat-bottom fiberglass-reinforced plastic suction tanks for which earthquake design is required shall follow the requirements given in 16.2.8 and 16.5.4, accounting for the allowable stresses and the anisotropic properties of fiberglass-reinforced plastic.

16.10 Pressure Tanks.

16.10.1 Supports. [22:7.1.7.2]

16.10.1.1

The supports shall be steel or reinforced concrete and shall be located in a manner that prevents sagging or vibration and that properly distributes the loads caused by the weight of the vessel when full of water. [22:7.1.7.2.1]

16.10.1.2

Stresses shall not exceed those permitted by AISC 360, Specification for Structural Steel Buildings, for steel supports and ACI 318, Building Code Requirements for Structural Concrete and Commentary, for concrete supports.
16.10.1.3

Horizontal tanks shall have at least one support near each end of the tank that is located so that combined stresses in any part of the tank resulting from internal pressure, gravity loads, lateral soil pressure, and earthquake or wind do not exceed those allowed.

16.11 Embankment-Supported Coated Fabric Suction Tanks.

16.11.1*

The embankment and earth base that support the tank shall be installed in accordance with 16.11.1 through 16.11.1.11.

16.11.1.1

The embankment shall be designed for stability and drainage. [22:9.4.1.1]

16.11.1.1.1

Where two tanks are installed with a single embankment between tanks, such an embankment shall be designed to resist the load of a full single tank when one tank is drained. [22:9.4.1.1.1]

16.11.1.2

A shallow excavation shall be permitted to be made below nominal grade level where allowed by local soil and groundwater conditions permit. [22:9.4.1.2]

16.11.1.2.1

The removed soil, if suitable, shall be permitted to be used to extend the embankment above grade for the required height (cut and fill method). [22:9.4.1.2.1]

16.11.1.3

The internal and external slopes of the embankment shall be 1 1/2 horizontal to 1 vertical.

16.11.1.3.1

The slope shall be maintained in the original design condition to ensure the integrity of the embankment. [22:9.4.1.3.1]

16.11.1.3.2

The soil shall provide a stable embankment. [22:9.4.1.3.2]

16.11.1.3.3

Compliance with these requirements shall be subject to verification by a qualified professional soils engineer. [22:9.4.1.3.3]

16.11.1.4

The inside corners of the embankment at the intersections of dike walls shall be rounded using a radius of ±1 ft (±0.31 m), approximately, at the bottom and a radius of ±2 1/2 ft (±0.76 m), approximately, at the
top of the dike, with uniform gradation from the bottom to the top, as approved by an authorized design or soils engineer. [22:9.4.1.4]

16.11.1.5

The floor of the embankment shall be graded to locate the inlet/outlet fitting at a minimum distance of 3 in. (76 mm) below the toe of the embankment inside juncture with the floor. [22:9.4.1.5]

16.11.1.5.1

The grading between the fitting location and all points along the juncture of the sloping side walls and the floor shall be uniform to provide positive drainage. [22:9.4.1.5.1]

16.11.1.6

Earth dike construction tolerances shall be as follows: [22:9.4.1.6]

(1) ±6 in: (152 mm) for surface variance on the interior slope of the dike walls
(2) +2 percent on a specified vertical dimension for the dike height
(3) ±1 percent on horizontal dimensions specified for the dike length and width where approved by the soils engineer

16.11.1.7

A 6 in. (152 mm) thick layer of fine sand or top soil shall be used for the surface layer of the floor and shall be underlaid by a 3 in. (76 mm) thickness of selected pea gravel to provide a firm, smooth bed and good drainage. [22:9.4.1.7]

16.11.1.8

The finished surfaces of the inside dike walls and the floor shall be free from sharp rocks and debris. [22:9.4.1.8]

16.11.1.9

A 4 in. (102 mm) diameter porous drain pipe shall be provided around the perimeter of the floor to ensure positive drainage of melted snow and rainwater from inside the dike. [22:9.4.1.9]

16.11.1.9.1

The outlet of the pipe also shall serve as a telltale leak detector for the tank. [22:9.4.1.9.1]

16.11.1.10

A concrete-lined gutter shall be provided through the top and down the outside of the end wall nearest the inlet/outlet fitting to provide positive drainage of melted snow and rainwater from the tank top. (See Figure A.16.11.1.)

16.11.1.11

The exterior sides and top of the dike walls shall be protected against surface erosion. [22:9.4.1.11]

16.12 Steel Tank Towers.

16.12.1.1 Bolts and anchor bolts shall conform to ASTM A307, Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60,000 PSI Tensile Strength, Grade A or Grade B. ASTM A36/A36M, Standard Specification for Carbon Structural Steel, shall be considered an acceptable alternative material for anchor bolts. [22:13.2.2.1]


16.12.2 Wind Load.

Tank towers shall meet the requirements for resisting wind damage by complying with the wind design load provisions of AWWA D100, Welded Carbon Steel Tanks For Water Storage, as well as 16.2.7 and Section 16.3 of this standard.

16.12.3 Earthquake Load.

Tank towers shall meet the requirements for resisting earthquake damage by complying with the earthquake design load provisions of AWWA D100, Welded Carbon Steel Tanks For Water Storage, as well as 16.2.8 and Section 16.3 of this standard.

16.12.3.1 Anchor Bolts.

There shall be at least two anchor bolts per column in locations that are subject to earthquakes. [22:13.5.22]

16.12.4 Base Braces. [22:13.5.19]

16.12.4.1 Where the tower is supported by a building, insecure earth, or foundations that extend more than approximately 1 ft (0.3 m) above grade, rigid members shall be placed between the adjacent column bases or foundations. [22:13.5.19.1]

16.12.4.2 Rigid members shall be provided between adjacent column bases where the columns are welded to the base plates and the batter exceeds 1.8 horizontal to 12 vertical. [22:13.5.19.2]

16.12.5 Grouting of Base Plates. [22:13.6.5]

16.12.5.1 During field erection, tower columns shall be built on thin metal wedges that, after completion of the structure, shall be driven to equal resistance so that all columns are loaded equally. [22:13.6.5.1]
16.12.5.2

The spaces beneath the base plates and the anchor bolt holes shall be completely filled with portland cement mortar that consists of a minimum of one part portland cement to three parts clean sand. [22:13.6.5.2]


16.13.1 Concrete Specifications.

Concrete foundations and footings shall be built of concrete with a specified compressive strength of not less than 3000 psi (20.69 MPa). Design, materials, and construction shall conform to ACI 318, Building Code Requirements for Structural Concrete and Commentary, with water considered as a live load. [22:12.1]

16.13.2 Suction Tank Foundations. [22:12.2]

16.13.2.1

Except as allowed by 16.13.2.2.4, suction tanks shall be set on a concrete slab foundation or a concrete ringwall foundation with a cushion of sand, compacted crushed stone, or granular base. [22:12.2.1]

16.13.2.1.1

When a suction tank is set on a concrete ringwall foundation with a cushion of sand, at least 3 in. (76.2 mm) of clean, dry sand, laid on the compacted grade, shall be provided at the finished tank grade and shall slope up toward the center of the tank at the rate of 1 in. in 10 ft (25.4 mm in 3 m). [22:12.2.1.1]

16.13.2.1.2

For suction tanks set on concrete foundations, the junction of the tank bottom and the top of the concrete foundation shall be tightly sealed to prevent water from entering the base. [22:12.2.1.2]

16.13.2.1.3

For tanks supported on concrete slab foundations, a sand cushion at least 1 in. (25.4 mm) thick or a 1/2 in. (12.7 mm) cane fiber joint filler that complies with ASTM D1751, Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types), shall be provided between the flat bottom and the foundation. Where a starter ring that is installed in accordance with AWWA D103, Factory-Coated Bolted Carbon Steel Tanks For Water Storage, is embedded in a concrete slab floor, the sand cushion and cane fiber joint filler shall not be required. [22:12.2.1.3]

16.13.2.1.4

Embankment-supported coated fabric suction tank foundations shall comply with 16.11.1. [22:12.2.1.4]

16.13.2.2
For ringwall foundations, a minimum 10 in. (254 mm) wide reinforced concrete ring wall that extends below the frost line and at least 1.0 ft (0.30 m) below finished grade shall be placed directly beneath the tank shell where tanks are supported on a cushion of sand, on crushed stone, or granular bases. \[22:12.2.2\]

16.13.2.2.1

The ring shall project at least 6 in. (152 mm) to a maximum of 12 in. (300 mm) above the surrounding grade and shall be reinforced against temperature and shrinkage and shall be reinforced to resist the lateral pressure of the confined fill with its surcharge. \[22:12.2.2.1\]

16.13.2.2

The minimum reinforcement shall conform to requirements in ACI 318, *Building Code Requirements for Structural Concrete and Commentary.*

16.13.2.3

The tops of ring wall foundations shall be level within ±1/8 in. (±3.2 mm) in one plate length [approximately 34 ft (10.4 m)], and no two points on the wall shall differ by more than ±1/4 in. (±6.4 mm). \[22:12.2.2.3\]

16.13.2.4

In lieu of a concrete foundation, steel suction tanks of 4000 gal (15.1 m³) or less shall be permitted to be supported on granular berms, with or without steel retainer rings, in accordance with AWWA D100, *Welded Carbon Steel Tanks For Water Storage,* or AWWA D103, *Factory-Coated Bolted Carbon Steel Tanks For Water Storage,* as applicable. \[22:12.2.2.4\]

16.13.3

Where soil does not provide direct support for the tank without excessive settlement, shallow foundation construction shall not be adequate, and a proper foundation shall be designed by a foundation engineer. \[22:12.2.3\]

16.13.3 Foundation Piers for Elevated Tanks. \[22:12.3\]

16.13.3.1

The tops of foundation piers shall be level, shall be at least 6 in. (152 mm) above grade, and shall be located at the correct elevations. \[22:12.3.1\]

16.13.3.2

The bottom of foundations shall be located below the frost line or at least 4 ft (1.2 m) below grade, whichever is greater. \[22:12.3.2\]
Pier foundations shall be both of the following:

1. Of any suitable shape
2. Of reinforced concrete

16.13.3.3.1
Pier foundations of plain concrete shall be permitted where there is a compelling reason to omit reinforcing, and their use and design are determined to be suitable by a foundation engineer.

16.13.3.3.2
Where the pier foundation supports a tower, the center of gravity of the pier shall lie in the continued center of the gravity line of the tower column, or it shall be designed for the eccentricity. [22:12.3.3.1]

16.13.3.3.3
The top surface shall extend at least 3 in. (76 mm) beyond the bearing plates on all sides and shall be chamfered at the edge. [22:12.3.3.2]

16.13.3.4 Grouting.
Bearing plates or base plates of tower legs shall comply with one of the following:

1. Have complete bearing on the foundation
2. Be laid on 1 in. (25.4 mm) minimum thickness cement grout to secure a complete bearing.

16.13.4 Anchorages. [22:12.4]

16.13.4.1
Anchor bolts shall be accurately located with sufficient free length of thread to fully engage their nuts. [22:12.4.3]

16.13.4.1.1
Anchor bolts and nuts that are exposed to weather, water, or corrosive environments shall be protected by one of the following methods:

1. Galvanizing
2. Corrosion-resistant alloys
3. Field-applied coating after installation

[22:12.4.3.2]

16.13.4.1.2
Except as provided in 16.13.4.1.2.1, the minimum size of anchor bolts shall be 1 1/4 in. (32 mm). [22:12.4.3.3]
16.13.4.1.2.1
Anchor bolts and nuts less than 1 1/4 in. (32 mm) in diameter, but not less than 3/4 in. (19.1 mm) in diameter, shall be permitted to be used, provided they are protected in accordance with 16.13.4.1.1(1) or 16.13.4.1.1(2). [22:12.4.3.3.1]

16.13.4.1.3
Design of the anchor embedment strength shall be in accordance with ACI 318, Building Code Requirements for Structural Concrete and Commentary. [22:12.4.2.2]

16.13.4.1.4
The lower ends of the anchor bolts shall terminate in a head, nut, washer plate, or u-bolt. [22:12.4.2.1]

16.13.4.1.5
Anchor bolts resisting uplift from earthquake forces in suction tanks shall also meet the requirements in 16.5.4.3.3.

16.13.4.1.5*
Post-installed concrete anchors shall not be acceptable except as allowed in 16.13.4.1.5.1.

16.13.4.1.5.1
For tanks having a capacity of 4000 gal (15.1 m³) or less, and for hanging, support and bracing of pipe from concrete structures, postinstalled concrete anchors shall be permitted. (See 16.13.4.1.5.2.)

16.13.4.1.5.2
For the requirement in 16.13.4.1.5.1, 16.13.4.1.2, 16.13.4.1.2.1, and 16.13.4.1.4 shall not apply.

16.13.4.2
Anchor bolts shall be arranged to securely engage a weight at least equal to the net uplift due to wind or earthquake loads.

16.13.4.2.1
The weight of the foundation shall be able to resist the maximum net uplift that results from wind or earthquake loads unless requirements of 16.13.4.2.2 are met.

16.13.4.2.1.1
The weight of earth located vertically above the base of the foundation shall be permitted to be included.

16.13.4.2.2
Where the weight of the foundation and earth cannot resist net uplift loads, additional measures, such as providing a reinforced concrete mat foundation or piles, shall be taken to resist these loads.
16.13.5 Soil-Bearing Pressures. [22:12.6]

16.13.5.1

The design soil-bearing pressure and the corresponding depth of foundation shall be determined by subsurface investigation and by a review of foundation experience in the vicinity. [22:12.6.1]

16.13.5.1.1

Such an investigation shall include test borings made by or under the supervision of an experienced soils engineer or soils testing laboratory and to the depth necessary to determine the adequacy of support. [22:12.6.1.1]

16.13.5.2

Where the presence of limestone or other soluble rock types are suspected, subsurface investigation shall include cavity investigation and competency of bedrock. [22:12.6.2]

16.13.5.2.1

The potential for subsidence, collapse, soil liquefaction, and settlement shall be evaluated. [22:12.6.2.1]

16.13.5.3

The design soil-bearing pressure shall not exceed a pressure that can cause settlements that impair the structural integrity of the tank. [22:12.6.3]

16.13.5.4

Foundations shall not be constructed over buried pipes or immediately adjacent to existing or former deep excavations. [22:12.6.4]

16.13.5.4.1

This requirement shall not apply where foundation bases extend below the excavation. [22:12.6.4.1]

16.13.5.5

The design soil-bearing pressure shall provide for a factor of safety of 3 based on the calculated ultimate bearing capacity of the soil for all direct vertical loads, including wind or earthquake moment load on the columns.

16.13.5.5.1

The factor of safety shall not be less than 2 when considering the toe pressure for the direct vertical loads, plus the overturning moment caused by wind or earthquake shear at the tops of individual piers.

16.14 Pipe Connections and Fittings.


16.14.1.1
Connections shall be rigidly made to the tank bottom, and a standard expansion joint, where needed, shall be provided in each such pipe that is located below, and entirely independent of, the tank. [22:14.1.7.2]

16.14.1.2

Pipe inside the tank shall be braced near the top and at points not over 25 ft (7.6 m) apart. [22:14.1.7.3]

16.14.1.3

Where an expansion joint exists, it shall be of the standard type, shall be located below the tank, and shall be without connection to the tank plates. (See 16.14.1.) [22:14.1.7.4]

16.14.2 Discharge Pipe. [22:14.2]


16.14.2.1.1

Either the pipe or the large steel-plate tank riser pipe, or both, shall be braced laterally by rods of not less than 5/8 in. (15.9 mm) in diameter and shall be connected to the tower columns near each panel point. [22:14.2.4.1]

16.14.2.1.2

The end connection of braces shall be by means of eyes or shackles; open hooks shall not be permitted. [22:14.2.4.2]

16.14.2.2 Support. [22:14.2.5]

16.14.2.2.1

The discharge pipe shall be supported at its base by a double-flanged base elbow that rests on a concrete or masonry foundation. [22:14.2.5.1]

16.14.2.2.1.1

The base elbow of tanks with steel-plate tank risers, of suction tanks, or of gravity tanks shall have bell ends. [22:14.2.5.1.1]

16.14.2.2.2

The joint at the connection of yard piping to the base elbow shall be strapped, or the base elbow shall be backed up by concrete. [22:14.2.5.2]

16.14.2.2.2.1

If the discharge pipe is offset inside a building, it shall be supported at the offset by suitable hangers that extend from the roof or floors, in which case the base elbow might not be required. [22:14.2.5.2.1]

16.14.2.2.2.2

Large steel tank riser pipes shall be supported on a reinforced concrete pier that is designed to support the load specified in Section 16.2. [22:14.2.5.2.2]
16.14.2.2.2.3
Concrete grout shall be provided beneath the large tank riser to furnish uniform bearing when the tank is empty. [22:14.2.5.2.3]

16.14.2.3 Offsets. [22:14.2.6]

16.14.2.3.1
The discharge pipe outside of buildings shall extend vertically to the base elbow or building roof without offsets where possible. [22:14.2.6.1]

16.14.2.3.2
If an offset is unavoidable, it shall be supported at the offsetting elbows and at intermediate points not over 12 ft (3.7 m) apart, and it also shall be rigidly braced laterally. [22:14.2.6.2]

16.14.2.3.3
The supports shall consist of steel beams that run across the tower struts or of steel rods from the tower columns arranged so that there is no slipping or loosening. [22:14.2.6.3]

16.14.2.4 Rigid Connection. [22:14.2.8]

16.14.2.4.1
When the base of a steel-plate tank riser is in its final position on a concrete support, it shall be grouted to obtain complete bearing. [22:14.2.8.2.4]

Chapter 17 Installation Requirements for Seismic Protection of Private Fire Water Tanks
[Reserved]

Chapter 18 Installation Requirements for Hanging, Support, and Anchorage of Private Fire Service Mains

18.1* Restraint.

Private fire service mains shall be restrained against movement at changes in direction in accordance with 18.1.1, 18.1.2, or 18.1.3. [24:10.6]
18.1.1* Thrust Blocks. [24:10.6.1]

18.1.1.1

Thrust blocks shall be permitted where soil is stable and capable of resisting the anticipated thrust forces. [24:10.6.1.1]

18.1.1.2

Thrust blocks shall be concrete of a mix not leaner than one part cement, two and one-half parts sand, and five parts stone. [24:10.6.1.2]

18.1.1.3

Thrust blocks shall be placed between undisturbed earth and the fitting to be restrained and shall be capable of resisting the calculated thrust forces. [24:10.6.1.3]

18.1.1.4

Wherever possible, thrust blocks shall be located so that the joints are accessible for repair. [24:10.6.1.4]


Private fire service mains using restrained joint systems shall include one or more of the following:

(1) Listed locking mechanical or push-on joints
(2) Listed mechanical joints utilizing setscrew retainer glands
(3) Listed bell joint restraints
(4) Bolted flange joints
(5) Pipe clamps and tie rods in accordance with 18.1.2.1
(6) Other approved methods or devices

[24:10.6.2]

18.1.2.1* Sizing Clamps, Rods, Bolts, and Washers.

18.1.2.1.1 Clamps.

18.1.2.1.1.1
Clamps shall have the following dimensions:

1. 1/2 in. × 2 in. (13 mm × 50 mm) for 4 in. (100 mm) to 6 in. (150 mm) pipe
2. 5/8 in. × 21/2 in. (16 mm × 65 mm) for 8 in. (200 mm) to 10 in. (250 mm) pipe
3. 5/8 in. × 3 in. (16 mm × 75 mm) for 12 in. (300 mm) pipe

[24:10.6.2.1.1.1]

### 18.1.2.1.1.2

The diameter of a bolt hole shall be 1/8 in. (3 mm) larger than that of the corresponding bolt. [24:10.6.2.1.1.2]

### 18.1.2.1.2 Rods.

#### 18.1.2.1.2.1

Rods shall be not less than 5/8 in. (16 mm) in diameter. [24:10.6.2.1.2]

#### 18.1.2.1.2.2

Table 18.1.2.1.2.2 provides the numbers of various diameter rods that shall be used for a given pipe size. [24:10.6.2.1.2.2]

<table>
<thead>
<tr>
<th>Nominal Pipe Size</th>
<th>5/8 in. (16 mm)</th>
<th>3/4 in. (19 mm)</th>
<th>7/8 in. (22 mm)</th>
<th>1 in. (25 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>in. mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 100</td>
<td>2</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>6 150</td>
<td>2</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>8 200</td>
<td>3</td>
<td>2</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>10 250</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>—</td>
</tr>
<tr>
<td>12 300</td>
<td>6</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Nominal Pipe Size</th>
<th>5/8 in. (16 mm)</th>
<th>3/4 in. (19 mm)</th>
<th>7/8 in. (22 mm)</th>
<th>1 in. (25 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>in.</td>
<td>mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>350</td>
<td>8</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>16</td>
<td>400</td>
<td>10</td>
<td>7</td>
<td>5</td>
</tr>
</tbody>
</table>

Note: This table has been derived using pressure of 225 psi (15.5 bar) and design stress of 25,000 psi (172.4 MPa).

[24:Table 10.6.2.1.2.2]
18.1.2.1.2.3  
Where using bolting rods, the diameter of mechanical joint bolts shall limit the diameter of rods to 3/4 in. (20 mm). [24:10.6.2.1.2.3]

18.1.2.1.2.4  
Threaded sections of rods shall not be formed or bent. [24:10.6.2.1.2.4]

18.1.2.1.2.5  
Where using clamps, rods shall be used in pairs for each clamp. [24:10.6.2.1.2.5]

18.1.2.1.2.6  
Assemblies in which a restraint is made by means of two clamps canted on the barrel of the pipe shall be permitted to use one rod per clamp if approved for the specific installation by the AHJ. [24:10.6.2.1.2.6]

18.1.2.1.2.7  
Where using combinations of rods, the rods shall be symmetrically spaced. [24:10.6.2.1.2.7]

18.1.2.1.3 Clamp Bolts.  
Clamp bolts shall have the following diameters:

(1) 5/8 in. (16 mm) for pipe 4 in. (100 mm), 6 in. (150 mm), and 8 in. (200 mm)
(2) 3/4 in. (20 mm) for 10 in. (250 mm) pipe
(3) 7/8 in. (22 mm) for 12 in. (300 mm) pipe

[24:10.6.2.1.3]

18.1.2.1.4 Washers.  
18.1.2.1.4.1  
Washers shall be permitted to be cast iron or steel and round or square. [24:10.6.2.1.4.1]

18.1.2.1.4.2  
Cast iron washers shall have the following dimensions:
Steel washers shall have the following dimensions:

1. (1) 1/2 in. × 3 in. (13 mm × 75 mm) for 4 in. (100 mm), 6 in. (150 mm), 8 in. (200 mm), and 10 in. (250 mm) pipe
   (2) 1/2 in. × 3.5 in. (13 mm × 90 mm) for 12 in. (300 mm) pipe

   [24:10.6.2.1.4.3]

18.1.2.1.4.4

The diameter of holes shall be 1/8 in. (3 mm) larger than that of bolts or rods. [24:10.6.2.1.4.4]

18.1.2.2 Sizes of Restraint Straps for Tees.

18.1.2.2.1

Restraint straps for tees shall have the following dimensions:

1. (1) 5/8 in. (16 mm) thick and 21/2 in. (65 mm) wide for 4 in. (100 mm), 6 in. (150 mm), 8 in. (200 mm), and 10 in. (250 mm) pipe
   (2) 5/8 in. (16 mm) thick and 3 in. (75 mm) wide for 12 in. (300 mm) pipe

   [24:10.6.2.2.1]

18.1.2.2.2

The diameter of rod holes shall be 1/16 in. (1.6 mm) larger than that of rods. [24:10.6.2.2.2]

18.1.2.2.3

Figure 18.1.2.2.3 and Table 18.1.2.2.3 shall be used in sizing the restraint straps for both mechanical and push-on joint tee fittings. [24:10.6.2.2.3]

Figure 18.1.2.2.3 Restraint Straps for Tees. [24:Figure 10.6.2.2.3]
Table 18.1.2.2.3 Restraint Straps for Tees

<table>
<thead>
<tr>
<th>Nominal Pipe Size</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in.</td>
<td>in.</td>
<td>in.</td>
<td>in.</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>12 1/2</td>
<td>10 1/8</td>
<td>2 1/2</td>
</tr>
<tr>
<td>6</td>
<td>150</td>
<td>14 1/2</td>
<td>12 1/8</td>
<td>3 9/16</td>
</tr>
<tr>
<td>8</td>
<td>200</td>
<td>16 3/4</td>
<td>14 3/8</td>
<td>4 21/32</td>
</tr>
<tr>
<td>10</td>
<td>250</td>
<td>19 1/16</td>
<td>16 11/16</td>
<td>5 3/4</td>
</tr>
<tr>
<td>12</td>
<td>300</td>
<td>22 5/16</td>
<td>19 3/16</td>
<td>6 3/4</td>
</tr>
</tbody>
</table>
18.1.2.3 Sizes of Plug Strap for Bell End of Pipe. [24:10.6.2.3]

18.1.2.3.1

The strap shall be 3/4 in. (20 mm) thick and 2 1/2 in. (65 mm) wide. [24:10.6.2.3.1]

18.1.2.3.2

The strap length shall be the same as dimension A for tee straps as shown in Figure 18.1.2.2.3. [24:10.6.2.3.2]

18.1.2.3.3

The distance between the centers of rod holes shall be the same as dimension B for tee straps as shown in Figure 18.1.2.2.3. [24:10.6.2.3.3]

18.1.2.4 Material.

Clamps, rods, rod couplings or turnbuckles, bolts, washers, restraint straps, and plug straps shall be of a material that has physical and chemical characteristics that indicate its deterioration under stress can be predicted with reliability. [24:10.6.2.4]

18.1.2.5 Corrosion Resistance.

After installation, rods, nuts, bolts, washers, clamps, and other restraining devices shall be cleaned and thoroughly coated with a corrosion-retarding material. [24:10.6.2.5]

18.1.2.5.1

The requirements of 18.1.2.5 shall not apply to epoxy-coated fittings, valves, glands, or other accessories. [24:10.6.2.5.1]

18.1.3*

Private fire service mains utilizing one or more of the following connection methods shall not require additional restraint, provided that such joints can pass the hydrostatic test of 10.10.2.2 without shifting of piping:

(1) Threaded connections
(2) Grooved connections
(3) Welded connections
(4) Heat-fused connections
(5) Chemical or solvent cemented connections

[24:10.6.3]

Chapter 19 Installation Requirements for Seismic Protection of Private Fire Service Mains
[Reserved]

Chapter 20 Installation Requirements for Hanging, Support, and Anchorage of Foam System Components

20.1 General.

20.1.1

Unless the requirements of 20.1.2 are met, types of hangers shall be in accordance with the requirements of Chapter 20. [13:17.1.1]

20.1.2

Hangers certified by a registered professional engineer in accordance with 5.1.2 shall be an acceptable alternative to the requirements of Chapter 20.

20.1.3

Foam system piping or hangers shall not be used to support non-system components.

20.1.4

Foam system piping shall be permitted to utilize shared support structures in accordance with 20.1.6.

20.1.5

Shared support structures shall be certified by a registered professional engineer in accordance with 20.1.2. [13:17.1.4]

20.1.6

The building structure shall not be considered a shared support structure. [13:17.1.4.1.3]
20.1.7

Systems that are incompatible with the foam systems based on vibration, thermal expansion and contraction, or other factors shall not share support structures.

20.1.8

Holes through solid structural members shall be permitted to serve as hangers for the support of system piping, provided such holes are permitted by applicable building codes and the spacing and support provisions for hangers of this standard are satisfied. [13:17.1.7.3]

20.1.9

Tapping or drilling of load-bearing structural members shall not be permitted where unacceptable weakening of the structure would occur. [11:9.6.4]

20.1.10

Attachments shall be made to existing steel or concrete structures and equipment supports. [11:9.6.5]

20.1.11

Where systems are of such a design that the standard method of supporting pipe for protection purposes cannot be used, the piping shall be supported in such a manner as to produce the strength equivalent to that afforded by the standard means of support. [11:9.6.6]

20.1.12

Low-expansion system piping inside dikes or within 15 m (50 ft) of tanks not diked shall be buried under at least 0.3 m (1 ft) of earth or, if aboveground, shall be supported and protected against mechanical injury.

20.1.13

Where foam systems are required to be protected against damage from earthquakes, hangers shall also meet the requirements of Chapter 21.

20.1.14

All hangers shall be of approved types. [11:9.6.3]
20.1.15

Other fasteners shall be permitted as part of a hanger assembly that has been tested, listed, and installed in accordance with the listing requirements. [13:17.1.6.4]

20.2 Components.

20.2.1

Hanger components for foam systems shall be in accordance with the water-based fire protection system chapter and requirements of Chapter 5 Section 20.2.

20.2.2

Unless permitted by 20.2.3, hangers and their components shall be ferrous metal. [13:17.1.7.1]

20.2.3

Nonferrous components that have been proven by fire tests to be adequate for the hazard application, that are listed for this purpose, and that are in compliance with the other requirements of Section 20.2 shall be acceptable. [13:18.5.3.2]

20.2.4

All trapeze hanger materials shall be in accordance with Chapter 5.

20.2.5

All pipe stand materials shall be in accordance with Chapter 5.

20.3 Installation.

20.3.1 System Piping.

All hangers and methods of attachment for foam system piping shall be in accordance with Chapter 5 and Section 20.3.

20.3.2 Foam Concentrate Storage Tanks and Proportioning Equipment.

20.3.2.1 Foam Concentrate Storage Tanks.
All anchors and methods of attachment for foam concentrate storage tanks shall be in accordance with the requirements of Chapter 16 and Section 20.3.

20.3.2.1.2

Storage tanks for foam concentrate shall be solidly mounted and shall be permanently located. [11:4.3.2.3.1.1]

20.3.2.1.3

Other anchorage and methods of attachment shall be permitted where tested, listed, and installed in accordance with the listing requirements or with the manufacturer’s published installation instructions.

20.3.2.2 Proportioning Equipment.

20.3.2.2.1

Proportioning equipment for foam concentrate shall be both of the following:

(1) Solidly mounted
(2) Permanently located

20.3.2.2.2

Other anchorage and methods of attachment shall be permitted where tested, listed, and installed in accordance with the listing requirements or with the manufacturer’s published installation instructions.

20.3.3 Trapeze Hangers.

All trapeze hangers shall be installed in accordance with Chapter 5.

20.3.4 Pipe Stands.

All pipe stands shall be installed in accordance with Chapter 5.

20.3.5 Marine Systems.

20.3.5.1

Pipework shall be routed to afford protection against damage. [11:10.9.1]
20.3.5.2

All hangers and piping supports shall be designed for marine applications. [11:10.9.2]

20.3.5.3

Deck foam solution piping shall be independent of fire main piping. [11:10.9.3]

20.3.5.4

Where the fire main and foam main are connected to a common monitor, check valves shall be installed. [11:10.9.4]

20.3.5.5

The system shall be arranged to prevent the possibility of freezing. [11:10.9.5]

20.3.5.6

Portions of the system exposed to weather shall be self-draining. [11:10.9.5.1]

20.3.5.7

Wet or pressurized portions of the system shall be protected against freezing. [11:10.9.5.2]

20.3.5.8

Piping, valves, pipe fittings and hangers, including corrosion-protection coatings, shall be in accordance with NFPA 13. [16:6.7.1]

20.3.5.9

Each tank shall have a support structure for mounting the tank to the ship’s structure. [11:10.11.2.4]

20.3.6 Discharge Devices.

20.3.6.1 Foam-Water Sprinkler and Spray Systems.

Foam-water sprinkler and spray systems shall be installed to prevent lateral movement during system discharge.
20.3.6.2 High-Expansion Foam Generators.

High-expansion foam generators shall be installed in accordance with the manufacturer’s published installation instructions in a manner that prevents lateral movement during system discharge.

20.3.6.3 Floor-Level Fixed Foam Discharge Outlets.

Floor-level fixed foam discharge outlets shall be installed in accordance with the manufacturer’s published installation instructions in a manner that prevents lateral movement during system discharge.

20.3.6.4 Foam Chambers and Foam Makers.

Foam chambers and foam makers shall be installed in accordance with the manufacturer’s published installation instructions in a manner that prevents lateral movement during system discharge.

20.3.6.5 Foam Monitors.

Foam monitors shall be installed in accordance with the manufacturer’s published installation instructions in a manner that prevents lateral movement during system discharge.

Chapter 21 Installation Requirements for Seismic Protection of Foam System Components

21.1 General.

21.1.1

Where foam systems are required to be protected against damage from earthquakes, the requirements of Chapter 21 shall apply unless the requirements of 21.1.1.2 are met.

21.1.2

Alternative methods of providing earthquake protection of foam systems based on a seismic analysis certified by a registered professional engineer such that system performance will be at least equal to that of the building structure under expected seismic forces shall be permitted.

21.1.3
Braces and restraints shall not obstruct discharge devices.

21.1.4

Methods for seismic protection of foam systems shall be in accordance with Chapter 6 and Section 21.1.

21.2 Components.

Components for seismic protection of foam systems, including the use of flexible couplings, seismic separation assemblies, clearance, sway bracing, restraints, and hangers and fasteners subject to earthquakes shall be in accordance with Chapter 6 and this section.

21.3 Installation.

21.3.1 System Piping.

All methods of seismic protection for foam system piping shall be in accordance with Chapter 6 and Section 21.3.

21.3.2 Foam Concentrate Storage Tanks and Proportioning Equipment.

21.3.2.1 Foam Concentrate Storage Tanks.

21.3.2.1.1

All methods of seismic protection for foam concentrate storage tanks shall be in accordance with Chapter 6 and Section 21.3.

21.3.2.1.2

Other methods of seismic protection shall be permitted where tested, listed, and installed in accordance with the listing requirements or with the manufacturer's published installation instructions.

21.3.2.2 Proportioning Equipment.

Methods of seismic protection of attachments shall be tested, listed, and installed in accordance with the listing requirements or with the manufacturer's published installation instructions.

21.3.3 Discharge Devices.
Discharge devices shall be installed to prevent mechanical damage in a seismic event.
Annex A Explanatory Material

Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.1.7.4

Where both units of measure are presented (i.e., SI and Imperial), users of this standard should apply one set of units consistently and should not alternate between units.

A.3.2.1 Approved.

The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the “authority having jurisdiction” may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The “authority having jurisdiction” may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction (AHJ).

The phrase “authority having jurisdiction,” or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.3.2.4 Listed.

The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also
labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A.3.3.6.2 Foam Generators — Blower Type.

The blower can be powered by electric motors, internal combustion engines, air, gas, or hydraulic motors or water motors. The water motors are usually powered by foam solution. [11, 2021]

A.3.3.7 Four-Way Bracing.

A sway brace assembly could include a lateral and longitudinal brace in combination. [13, 2022]

A.3.3.13 Post-Installed Anchors.

Examples of these are wedge or undercut anchors, or powder-driven studs. [13, 2022]

A.3.3.14 Prying Factor.

Prying factors in NFPA 13 are utilized to determine the design loads for attachments to concrete. Prying is a particular concern for anchorage to concrete because the anchor could fail in a brittle fashion. [13, 2022]

A.3.3.18 Seismic Separation Assembly.

Seismic separation assemblies include traditional assemblies as shown in Figure A.6.3(a) and seismic loops as shown in Figure A.6.3(b). [13, 2022]

A.5.1

Throughout Chapter 5, metric units have been included where practicable. There are subjects, (e.g., section modulus) where a metric conversion might not be useful. In such situations, it is recommended to consult local requirements and products to determine whether support components are adequate for the loads, including appropriate safety factors. [13:A.17.1]

See Figure A.5.1. As an alternative to the conventional method of hanging pipe from the structure using attachments and rod, the piping can be simply laid on the structural member, provided the structure can adequately support the added load in accordance with 5.4.1.3.1 and the maximum distance between supports as required by Chapter 5 is not exceeded. Listed pipe should still be installed and supported in accordance with its listing limitations. [13:A.17.1]

To prevent movement, the pipe should be secured with an approved device to the structure and located such that the system piping remains in its original location and position. [13:A.17.1]
Figure A.5.1 Common Types of Acceptable Hangers. [13:Figure A.17.1]
A.5.1.3.1

The rules covering the hanging of sprinkler piping take into consideration the weight of water-filled pipe plus a safety factor. No allowance has been made for the hanging of non-system components from sprinkler piping. NFPA 13 provides the option to support sprinkler piping from other sprinkler piping where the requirements of 5.1.2 are met. [13:A.17.1.3.1]

A.5.1.4.1

A shared support assembly can be in the form of a pipe rack structure, a trapeze assembly, pipe stand, or other similar assembly. It is not the intent of this section for a building structure to be considered a shared support assembly. Storage racks are not intended to be considered a shared support assembly. [13:A.17.1.4.1]

A.5.1.4.1.4

It is not the intent of 5.1.4.1 to apply to flexible sprinkler hose fittings or ceiling systems. [13:A.17.1.4.1.4]

A.5.1.6.1

The listing requirements for water-based fire protection system hanger components include five times the weight of water-filled piping plus 250 lb (115 kg). However, once the listing is achieved, manufacturers often present their data in simple terms of what size pipe can be supported. The published loads in technical data sheets often represent one times the load of the piping that can be supported at maximum hanger spacing. If the product has been listed for use with fire protection systems, it has been shown to accommodate five times the weight of the water-filled pipe plus 250 lb (115 kg). [13:A.17.1.6.1]

A.5.1.6.2

Generic items utilized with hanger rods and fasteners are not required to be listed. These include items such as bolts, screws, washers, nuts, and lock nuts. [13:A.17.1.6.2]

A.5.1.6.3

Generic items utilized with hanger rods and fasteners are not required to be listed. These include items such as bolts, screws, washers, nuts, and lock nuts. [13:A.17.1.6.3]

A.5.2.1.3(1)
Hanger rods are intended only to be loaded axially (along the rod). Lateral loads can result in bending, weakening, and even breaking of the rod. Additional hangers or restraints could be necessary to minimize nonaxial loads that could induce bending or deflection of the rods. See Figure A.5.2.1.3(1) for an example of additional hangers utilized to minimize nonaxial loads. [13:A.17.2.1.3(1)]

Figure A.5.2.1.3(1) Example of Additional Hangers Utilized to Minimize Nonaxial Loads. [13:Figure A.17.2.1.3(1)]
A.5.2.2

In areas that are subject to provisions for earthquake protection, the fasteners in concrete will need to be prequalified. See 6.7.8 for information. [13:A.17.2.2]

A.5.2.2.9.3

The ability of concrete to hold the studs varies widely according to type of aggregate, quality of concrete, and proper installation. [13:A.17.2.2.9.3]

For existing structures with concrete tested to the appropriate testing standards at the time of construction, the compressive strength of the concrete should be deemed adequate. The structural capacity of existing concrete may not be known. In such cases, such capacity should be confirmed prior to relying on the structure to properly accommodate the intended load of sprinkler system attachments. [13:A.17.2.2.9.3]

A.5.2.3.1

Powder-driven studs should not be used in steel of less than 3/16 in. (5 mm) total thickness. [13:A.17.2.3.1]

A.5.3

Table 5.3.1(a) assumes that the load from 15 ft (5 m) of water-filled pipe, plus 250 lb (115 kg), is located at the midpoint of the span of the trapeze member, with a maximum allowable bending stress of 15 ksi (103 MPa). If the load is applied at other than the midpoint, for the purpose of sizing the trapeze member, an equivalent length of trapeze can be used, derived from the following formula:

\[
L = \frac{4ab}{a+b}
\]

where:

\( L = \) equivalent length
\( a = \) distance from one support to the load
\( b = \) distance from the other support to the load

[A.5.3]
Where multiple mains are to be supported or multiple trapeze hangers are provided in parallel, the required or available section modulus can be added. The table values are based on the trapeze being a single continuous member. [13:A.17.3]

A.5.3.5

Hanger components are sized based upon an ultimate strength limit of 5 times the weight of water-filled pipe plus 250 lb (115 kg). The section moduli used to size the trapeze member are based on a maximum bending stress, which provides an acceptable level of safety that is comparable to that of the other hanger components. [13:A.17.3.5]

A.5.4

To enhance permanence, proper hanger installation is important. Installation procedures should meet industry standards of practice and craftsmanship. For example, hanger assemblies are straight, perpendicular to the pipe, uniformly located, and snug to the structure with fasteners fully engaged. [13:A.17.4]

A.5.4.1.1.1

Fasteners used to support sprinkler system piping should not be attached to ceilings of gypsum or other similar soft material. [13:A.17.4.1.1.1]

A.5.4.1.3

The method used to attach the hanger to the structure and the load placed on the hanger should take into account any limits imposed by the structure. Design manual information for preengineered structures or other specialty construction materials should be consulted, if appropriate. [13:A.17.4.1.3]

System mains hung to a single beam, truss, or purlin can affect the structural integrity of the building by introducing excessive loads not anticipated in the building design. Also, special conditions such as collateral and concentrated load limits, type or method of attachment to the structural components, or location of attachment to the structural components might need to be observed when hanging system piping in preengineered metal buildings or buildings using other specialty structural components such as composite wood joists or combination wood and tubular metal joists. [13:A.17.4.1.3]

The building structure is only required to handle the weight of the water-filled pipe and components, while the hangers are required to handle 5 times the weight of the water-filled pipe. In addition, a safety factor load of 250 lb (115 kg) is added in both cases. The difference in
requirements has to do with the different ways that loads are calculated and safety factors are applied. [13:A.17.4.1.3]

When sprinkler system loads are given to structural engineers for calculation of the structural elements in the building, they apply their own safety factors in order to determine what structural members and hanging locations will be acceptable. [13:A.17.4.1.3]

In contrast, when sprinkler system loads are calculated for the hangers themselves, there is no explicit safety factor, so NFPA 13 mandates a safety factor of 5 times the weight of the pipe. [13:A.17.4.1.3]

A.5.4.1.3.3

Examples of areas of use include cleanrooms, suspended ceilings, and exhaust ducts. [13:A.17.4.1.3.3]

A.5.4.1.3.3.3

The committee evaluation of flexible sprinkler hose fittings supported by suspended ceilings was based on information provided to the committee showed that the maximum load shed to the suspended ceiling by the flexible hose fitting was approximately 6 lb (2.7 kg) and that a suspended ceiling meeting ASTM C635/C635M, Standard Specification for Manufacture, Performance, and Testing of Metal Suspension Systems for Acoustical Tile and Lay-In Panel Ceilings, and installed in accordance with ASTM C636/C636M, Standard Practice for Installation of Metal Ceiling Suspension Systems for Acoustical Tile and Lay-In Panels, can substantially support that load. In addition, the supporting material showed that the flexible hose connection can be attached to the suspended ceilings because it allows the necessary deflections under seismic conditions. [13:A.17.4.1.3.3.3]

A.5.4.1.3.3.4

An example of language for the label is as follows:

CAUTION: DO NOT REMOVE THIS LABEL.

Relocation of this device should only be performed by qualified and/or licensed individuals that are aware of the original system design criteria, hydraulic criteria, sprinkler listing parameters, and knowledge of the state and local codes including NFPA 13 installation standards. Relocation of the device without this knowledge could adversely affect the performance of this fire protection and life safety system. [13:A.17.4.1.3.3.4]

A.5.4.1.4.1
Piping in excess of 1 in. (25 mm) shall be permitted to be supported from a metal deck if the method of attachment and ability of the deck to support loads as specified in 5.4.1.3.1 are approved by a registered professional engineer. [13:A.17.4.1.4.1]

A.5.4.2

Where copper tube is to be installed in moist areas or other environments conducive to galvanic corrosion, copper hangers or ferrous hangers with an insulating material should be used. [13:A.17.4.2]

A.5.4.3.2

The hangers required by Chapter 5 are intended to accommodate general loading such as check valves, control valves, or dry or deluge valves. Where additional equipment such as backflow prevention assemblies and other devices with substantial loads are added, additional hangers should be considered. [13:A.17.4.3.2]

A.5.4.3.2.2

See Figure A.5.4.3.2.2. [13:A.17.4.3.2.2]

Figure A.5.4.3.2.2 Distance Between Hangers. [13:Figure A.17.4.3.2.2]
The “starter length” is the first piece of pipe on a branch line between the main, riser nipple, or drop and the first sprinkler. Starter pieces that are less than 6 ft (1.8 m) in length do not need a hanger of their own because they are supported by the main. However, if the intermediate hanger on the main is omitted, the starter piece needs to have a hanger because the main is going to be supported from the branch lines. The starter lengths can also apply to other piping, such as drains and test connections. [13:A.17.4.3.2.4]

A.5.4.3.2.5

When a branchline contains offsets, sections of pipe are considered adequately supported by the hangers on the adjacent pipe sections when the overall distance between hangers does not exceed the requirements in Table 5.4.2.1(a) and Table 5.4.2.1(b). The cumulative distance includes changes in horizontal direction. Multiple consecutive sections of pipe should be permitted to omit hangers. [13:A.17.4.3.2.5]

A.5.4.3.4

Sprinkler piping should be adequately secured to restrict the movement of piping upon sprinkler operation. The reaction forces caused by the flow of water through the sprinkler could result in displacement of the sprinkler, thereby adversely affecting sprinkler discharge. Listed CPVC pipe has specific requirements for piping support to include additional pipe bracing of sprinklers. (See Figure A.5.4.3.4.) [13:A.17.4.3.4]

Figure A.5.4.3.4 Distance from Sprinkler to Hanger. [13:Figure A.17.4.3.4]
A.5.4.3.4.4

See Figure A.5.4.3.4.4(a) and Figure A.5.4.3.4.4(b). [13:A.17.4.3.4.4]

**Figure A.5.4.3.4.4(a) Distance from Sprinkler to Hanger Where Maximum Pressure Exceeds 100 psi (6.9 bar) and Branch Line Above Ceiling Supplies Pendent Sprinklers Below Ceiling.** [13:Figure A.17.4.3.4.4(a)]

![Diagram](attachment-22-8-39-page-226-of-378)

**Figure A.5.4.3.4.4(b) Examples of Acceptable Hangers for End-of-Line (or Armover) Pendent Sprinklers.** [13:Figure A.17.4.3.4.4(b)]
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A.5.4.3.5

See Figure A.5.4.3.5. [13:A.17.4.3.4.5]

**Figure A.5.4.3.5 Maximum Length for Unsupported Armover. [13:Figure A.17.4.3.4.5]**

![Diagram showing maximum length for unsupported armover](image)

A.5.4.3.5.2

See Figure A.5.4.3.5.2. [13:A.17.4.3.5.2]

**Figure A.5.4.3.5.2 Maximum Length of Unsupported Armover Where Maximum Pressure Exceeds 100 psi (6.9 bar) and Branch Line Above Ceiling Supplies Pendent Sprinklers Below Ceiling. [13:Figure A.17.4.3.5.2]**
A.5.4.3.6

The movement that is being restrained is to keep the sidewall sprinkler in its intended location during and post-operation. This should not be confused with the loads applicable to seismic restraints. [13:A.17.4.3.6]

A.5.4.4.8

When a main contains offsets, sections of pipe are considered adequately supported by the hangers on the adjacent pipe sections when the overall distance between hangers does not exceed the requirements in Table 5.4.2.1(a) and Table 5.4.2.1(b). The cumulative distance includes changes in horizontal direction. Multiple consecutive sections of pipe should be permitted to omit hangers. [13:A.17.4.4.8]

A.5.4.5.3

This arrangement is acceptable to establish and secure the riser’s lateral position but not to support the riser’s vertical load. [13:A.17.4.5.3]

A.5.4.5.4.2

Note: The pendent sprinkler can be installed either directly in the fitting at the end of the armover or in a fitting at the bottom of a drop nipple.
The restraint required by 5.4.5.4.2 is needed to prevent accumulated vertical movement when the riser is pressurized. Restraint is generally provided by use of a riser clamp at the underside of a floor slab. [13:A.17.4.5.4.2]

A.5.5

Where applicable, the design of pipe stands should consider additional loading from other sources. Environmental impacts, including water accumulation at the base, corrosion, and wind, should also be taken into account as appropriate. [13:A.17.5]

The performance of piping support systems should allow for expansion and contraction due to temperature change, expansion due to internal water pressure (thrust), restrained and/or unrestrained joints or pipe runs, heavy point loads (e.g., valves), and pipe deflection (span/support spacing). Manufacturer’s installation instructions and engineering design guides should be consulted when available. [13:A.17.5]

Examples of common applications include headers and horizontal runs of pipe that need support from the floor. [13:A.17.5]

A.5.5.3.1

When a pipe stand does not resist lateral (e.g., earthquake or wind) forces, its maximum height and the weight of pipe it can support are based primarily on a limiting slenderness ratio (Kl/r), and on the axial and bending stresses caused by the vertical load applied at a specified eccentricity. [13:A.17.5.3.1]

The pipe stand heights presented in Table 5.5.3.1(a) and Table 5.5.3.1(b) have been calculated using a “K” of 2.1 (i.e., assuming the pipe stand is an individual cantilever column) and a slenderness ratio limit of 300, except where combined axial and bending stresses caused by the vertical load at an eccentricity of 12 in. (300 mm) controls the design. In these cases, the pipe stand height is reduced such that the allowable axial stress (Fa) is sufficient to limit the combined axial stress ratio (fa/Fa, i.e., actual axial stress divided by allowable axial stress) plus the bending stress ratio (fb/Fb, i.e., actual bending stress divided by allowable bending stress) to 1.0. Two cases are considered: a vertical load at a 12 in. (300 mm) eccentricity equals a) 5 times the weight of the water-filled pipe plus 250 lb (115 kg) using a bending stress allowable of 28,000 psi (193 MPa), and b) the weight of the water-filled pipe plus 250 lb (115 kg) using a bending stress allowable of 15,000 psi (103 MPa). No drift limit was imposed. [13:A.17.5.3.1]

When an engineering analysis is conducted, different pipe stand heights could be calculated if other assumptions are warranted based on actual conditions. For example, K=1.0 can be used if
the pipe at the top of the pipe stand is braced in both horizontal directions, or a shorter cantilever column could be used to limit drift. [13:A.17.5.3.1]

Pipe stands are intended to be a single piece of pipe. For lengths that require joining pipes, the pipes should be welded to ensure that strength is maintained. A single threaded fitting at the top of the pipe stand should be allowed for height adjustment in the field. (See Figure A.5.5.3.1.) [13:A.17.5.3.1]

**Figure A.5.5.3.1 Pipe Stand.** [13:Figure A.17.5.3.1]
A.5.5.3.2

These short pipe stands commonly support items such as backflow preventers, header piping, and other appurtenances. [13:A.17.5.3.2]

A.5.5.3.2(2)

The allowances for these short pipe stands do not account for eccentric loadings. See Figure A.5.5.3.2(2). [13:A.17.5.3.2(2)]

Figure A.5.5.3.2(2) Acceptable Axial Loading and Unacceptable Loading. [13:Figure A.17.5.3.2(2)]

A.5.5.4.2

Where welded steel flanges are used for the base plate, the entire circumference of the flange should be welded. [13:A.17.5.4.2]

A.5.5.4.3

Examples of acceptable anchors can be listed inserts set in concrete, listed post-installed anchors, bolts for concrete, or cast-in-place J hooks. [13:A.17.5.4.3]

A.5.5.5.3

See Figure A.5.5.5.3. [13:A.17.5.5.3]
Figure A.5.5.5.3 Example of a Horizontal Bracket Attached to a Pipe Stand. [13:Figure A.17.5.5.3]

A.5.5.6.1

The support and restraint are needed in order to maintain system performance and integrity. Water surges could be from filling the system, from system operation, or water supply related. [13:A.17.5.6.1]

A.5.5.6.2

Traditionally, pipe saddles have been used, which creates a “U” for the pipe to rest in. However, thrust forces in some applications can be large enough to move the pipe off the saddle. Therefore, a pipe ring or clamps should be around the system piping to keep it in place. [13:A.17.5.6.2]
A.6.1

Sprinkler systems are protected against earthquake damage by means of the following:

1) Stresses that would develop in the piping due to differential building movement are minimized using flexible joints or clearances.

2) Bracing is used to keep the piping fairly rigid when supported from a building component expected to move as a unit, such as a ceiling.

[13:A.18.1]

Areas known to have earthquake potential for earthquakes have been identified in building codes and insurance maps. Based on the project location, local codes and requirements will be applied. For projects using metric units, it is likely that the enforced codes, standards, and guidelines will vary compared to those used to create the simplified approaches to seismic protection in Chapter 6. These variations could include strength design of components instead of the allowable stress design (ASD) of components, such as concrete anchors, tested by way of methods other than those listed in ACI 355.2, Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary. Therefore, metric units have been included where practicable. In such situations, it is recommended to consult local requirements, authorities, and products to determine whether components are adequate for the seismic loads, including appropriate safety factors. [13:A.18.1]

Displacement due to story drift is addressed in Sections 6.2 through 6.4. [13:A.18.1]

Piping in racks needs to be treated like other sprinkler piping and protected in accordance with the proper rules. Piping to which in-rack sprinklers are directly attached should be treated as branch line piping. Piping that connects branch lines in the racks should be treated as mains. The bracing, restraint, flexibility, and requirements for flexible couplings are the same in the rack structures as at the ceiling. [13:A.18.1]

Cloud ceilings can cause challenges for a sprinkler system in an earthquake where sprinklers are installed below the clouds to protect the floor below. Depending on the support structure of the cloud and the construction material of the cloud, differential movement could damage a sprinkler that is not installed in a fashion to accommodate the movement. Currently, there are no structural requirements in ASCE/SEI 7, Minimum Design Loads and Associated Criteria for Buildings and Other Structures, for the clouds to be seismically braced. Unbraced cloud ceilings in higher seismic areas could easily displace during design earthquakes half the suspension length or more. One solution might be to use flexible sprinkler hose with the bracket connected to the
cloud so that the sprinkler will move with the cloud during seismic motion provided the ceiling
system is constructed per ASTM C635/C635M, Standard Specification for Manufacture,
Performance, and Testing of Metal Suspension Systems for Acoustical Tile and Lay-In Panel Ceilings,
and ASTM C636/C636M, Standard Practice for Installation of Metal Ceiling Suspension Systems for
Acoustical Tile and Lay-In Panels. When a sprinkler is rigidly piped to the cloud, appropriate
flexibility and clearances should be maintained to handle the anticipated movement. [13:A.18.1]

A.6.2

Strains on sprinkler piping can be greatly lessened and, in many cases, damage prevented by
increasing the flexibility between major parts of the sprinkler system. One part of the piping
should never be held rigidly and another part allowed to move freely without provision for
relieving the strain. Flexibility can be provided by using listed flexible couplings, by joining
grooved end pipe at critical points, and by allowing clearances at walls and floors.

Tank or pump risers should be treated the same as sprinkler risers.

Piping 2 in. (50 mm) or smaller in size is pliable enough so that flexible couplings are not usually
necessary. “Rigid-type” couplings that permit less than 1 degree of angular movement at the
grooved connections are not considered to be flexible couplings. [See Figure A.6.2(a) and Figure
A.6.2(b).]

Figure A.6.2(a) Riser Details. [13:Figure A.18.2(a)]
Figure A.6.2(b) Detail at Short Riser. [13:Figure A.18.2(b)]

Note to Detail A: The four-way brace should be attached above the upper flexible coupling required for the riser and preferably to the roof structure if suitable. The brace should not be attached directly to a plywood or metal deck.
A.6.2.3.1(1)

Risers do not include riser nipples as defined in 3.3.16. [13:A.18.2.3.1(1)]

A.6.2.3.1(2)(a)

See Figure A.6.2.3.1(2)(a). [13:A.18.2.3.1(2)(a)]

Figure A.6.2.3.1(2)(a) Flexible Coupling on Upper Landing or Roof Assembly. [13:Figure A.18.2.3.1(2)(a)]
A.6.2.3.1(4)

A building expansion joint is usually a bituminous fiber strip used to separate blocks or units of concrete to prevent cracking due to expansion as a result of temperature changes. Where building expansion joints are used, the flexible coupling is required on one side of the joint by 6.2.3.1(4). [13:A.18.2.3.1(4)]

For seismic separation joints, considerably more flexibility is needed, particularly for piping above the first floor. Figure A.6.3(a) shows a method of providing additional flexibility through the use of swing joints. [13:A.18.2.3.1(4)]

A.6.2.3.2(1)

See Figure A.6.2.3.2(1). [13:A.18.2.3.2(1)]

Figure A.6.2.3.2(1) Flexible Coupling on Horizontal Portion of Tie-In. [13:Figure A.18.2.3.2(1)]
A.6.2.3.2(2)

The flexible coupling should be at the same elevation as the flexible coupling on the main riser. [See Figure A.6.2.3.2(2).] [13:A.18.2.3.2(2)]

Figure A.6.2.3.2(2) Flexible Coupling on Vertical Portion of Tie-In. [13:Figure A.18.2.3.2(2)]

A.6.2.4

See Figure A.6.2.4. Drops that extend into freestanding storage racks or other similar structures should be designed to accommodate a horizontal relative displacement between the storage rack and the overhead supply piping. Free standing structures include but are not limited to freezers, coolers, spray booths, and offices. [13:A.18.2.4]

The horizontal relative displacement should be determined using the least value from one of the following formulas and be taken as the height of the top point of attachment to the storage rack above its base or the highest point of potential contact between the rack structure and the piping.
above its base, whichever is higher. The design should account for the differential movement value as determined from one of the two formulas, not both, and the lesser of the two values is acceptable. It should be determined how to account for the differential movement using flexible couplings or other approved means. [13:A.18.2.4]

\[ D = H \times 0.06 \times S_1 \times F_v \]

or

\[ D = H \times 0.05 \]

[A.6.2.4]

where:

- \( D \) = differential movement between the rack and the roof [ft (m)]
- \( H \) = height of the top point of attachment to the rack [ft (m)]
- \( S_1 \) = one second period spectral acceleration per USGS 2010 Seismic Design Maps (see ASCE/SEI 7)
- \( F_v \) = one second period site coefficient (Site Class D)

\( F_v \) is a function of \( S_1 \) and is determined as follows:

\[
\begin{align*}
S_1 & \quad F_v \\
\leq 0.1 & \quad 2.4 \\
= 0.2 & \quad 2.0 \\
= 0.3 & \quad 1.8 \\
= 0.4 & \quad 1.6 \\
\geq 0.5 & \quad 1.5
\end{align*}
\]

Note: Use straight-line interpolation for intermediate values of \( S_1 \).

[13:A.18.2.4]

Figure A.6.2.4 Flexible Couplings for Drops.
A.6.3

Plan and elevation views of a seismic separation assembly configured with flexible elbows are shown in Figure A.6.3(a), Figure A.6.3(b), and Figure A.6.3(c).

The extent of permitted movement should be sufficient to accommodate calculated differential motions during earthquakes. In lieu of calculations, permitted movement can be made at least twice the actual separations, at right angles to the separation as well as parallel to it. [13:A.18.3]

Figure A.6.3(a) Seismic Separation Assembly in which 8 in. (200 mm) Separation Crossed by Pipes Up to 4 in. (100 mm) in Nominal Diameter. (For other separation distances and pipe sizes, lengths and distances should be modified proportionally.) [13:Figure A.18.3(a)]
Figure A.6.3(b) Seismic Separation Assembly Incorporating Flexible Piping. [13:Figure A.18.3(b)]
Figure A.6.3(c) Seismic Separation Assembly Incorporating Flexible Piping.
A.6.3.3
Each four-way brace should be attached to the building structure on opposite sides of the seismic separation joint. [13:A.18.3.3]

A.6.3.5
The hangers on the piping should be as close as practically possible to the connections to the seismic separation assembly.

A.6.4
While clearances are necessary around the sprinkler piping to prevent breakage due to building movement, suitable provision should also be made to prevent passage of water, smoke, or fire. [13:A.18.4]

Drains, fire department connections, and other auxiliary piping connected to risers should not be cemented into walls or floors; similarly, pipes that pass horizontally through walls or foundations should not be cemented solidly, or strains will accumulate at such points. [13:A.18.4]
Where risers or lengths of pipe extend through suspended ceilings, they should not be fastened to the ceiling framing members. [13:A.18.4]

In areas that use suspended ceilings and are a seismic design category of D, E, or F, a larger clearance could be necessary around the sprinkler unless the suspended ceiling is rigidly braced or flexible sprinkler hose fitting are used as noted in ASTM E580/E580M, Standard Practice for Installation of Ceiling Suspension Systems for Acoustical Tile and Lay-in Panels in Areas Subject to Earthquake Ground Motions. [13:A.18.4]

A.6.4.1

Penetrations with or without clearance for seismic protection also need to meet building code requirements for fire resistance ratings as applicable. [13:A.18.4.1]

A.6.4.10

Figure A.6.4.10 is an example of piping supported by structure where there is no clearance required at the point of contact between the piping and structure. [13:A.18.4.10]

Figure A.6.4.10 Pipe with Zero Clearance. [13:Figure A.18.4.10]

A.6.4.11
Structural elements include, but are not limited to, beams, girders, and trusses. Frangible ceilings should not be considered structural elements for this purpose. [13:A.18.4.11]

A.6.5

Figure A.6.5(a) and Figure A.6.5(b) are examples of forms used to aid in the preparation of bracing calculations. [13:A.18.5]

Figure A.6.5(a) Seismic Bracing Calculation Form. [13:Figure A.18.5(a)]
## Seismic Bracing Calculations

**Seismic Brace Attachments**

<table>
<thead>
<tr>
<th>Structure attachment fitting or tension-only bracing system: Make:</th>
<th>Model:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transition attachment fitting (where applicable): Make:</td>
<td>Model:</td>
</tr>
<tr>
<td>Listed load rating:</td>
<td>Adjusted load rating per 6.5.2.3:</td>
</tr>
<tr>
<td>Sway brace (pipe attachment) fitting: Make:</td>
<td>Model:</td>
</tr>
<tr>
<td>Listed load rating:</td>
<td>Adjusted load rating per 6.5.2.3:</td>
</tr>
</tbody>
</table>

**Seismic Brace Assembly Detail**

(Provide detail on plans)

**Sprinkler System Load Calculation**

\[ F_{pw} = C_P W_p \]

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Type</th>
<th>Length (ft)</th>
<th>Total (ft)</th>
<th>Weight per ft</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>lb/ft</td>
<td>lb</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>lb/ft</td>
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<td>lb/ft</td>
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<td>lb/ft</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>lb/ft</td>
<td>lb</td>
</tr>
</tbody>
</table>

**Main Size**

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Type\Sch.</th>
<th>Spacing (ft)</th>
</tr>
</thead>
</table>

**Maximum**

\[ F_{pw} \text{ per 6.5.5.2 (if applicable)} \]

---

*Excludes tension-only bracing systems*  
© 2022 National Fire Protection Association
Figure A.6.5(b) Sample Seismic Bracing Calculation Form. [13:Figure A.18.5(b)]
Seismic Bracing Calculations

Project: Acme Warehouse
Address: 321 First Street
Any City, Any State

Contractor: Smith Sprinkler Company
Address: 123 Main Street
Any City, Any State

Telephone: (555) 555-1234
Fax: (555) 555-4321

Brace Information

Length of brace: 3 ft. 6 in.
Diameter of brace: 1 in.
Type of brace: Schedule 40
Angle of brace: 45° to 59°
Least radius of gyration:* 0.421
θr value:* 100
Maximum horizontal load: 4455 lb

Seismic Brace Attachments

Structure attachment fitting or tension-only bracing system:
Make: Bolt
Model: Bolt
Listed load rating: 1000
Adjusted load rating per 6.5.2.3: 707

Transition attachment fitting (where applicable):
Make: Acme
Model: 123
Listed load rating: 1000
Adjusted load rating per 6.5.2.3: 849

Sway brace (pipe attachment) fitting:
Make: Acme
Model: 321
Listed load rating: 1200
Adjusted load rating per 6.5.2.3: 849

Fastener Information

Orientation of connecting surface: “E”

Fastener:
Type: Through bolt

Diameter: 3/4 in.
Length (in wood): 5 1/2 in.
Maximum load: 620 lb

Seismic Brace Assembly Detail

(Provide detail on plans)

Brace identification no. (to be used on plans) SB-1
X Lateral brace □ Longitudinal brace □ 4-way brace

Sprinkler System Load Calculation ($F_{pw} = C_P W_P$)

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Type</th>
<th>Length (ft)</th>
<th>Total (ft)</th>
<th>Weight per ft</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 in.</td>
<td>Sch. 40</td>
<td>15 ft + 25 ft + 8 ft + 22 ft</td>
<td>70 ft</td>
<td>2.05 lb/ft</td>
<td>143.5 lb</td>
</tr>
<tr>
<td>1 1/4 in.</td>
<td>Sch. 40</td>
<td>25 ft + 33 ft + 18 ft</td>
<td>76 ft</td>
<td>2.93 lb/ft</td>
<td>222.7 lb</td>
</tr>
<tr>
<td>1 1/2 in.</td>
<td>Sch. 40</td>
<td>8 ft + 8 ft + 10 ft + 10 ft</td>
<td>36 ft</td>
<td>3.61 lb/ft</td>
<td>130.0 lb</td>
</tr>
<tr>
<td>2 in.</td>
<td>Sch. 40</td>
<td>20 ft</td>
<td>20 ft</td>
<td>5.13 lb/ft</td>
<td>102.6 lb</td>
</tr>
<tr>
<td>4 in.</td>
<td>Sch. 10</td>
<td>20 ft</td>
<td>20 ft</td>
<td>11.78 lb/ft</td>
<td>235.6 lb</td>
</tr>
<tr>
<td><strong>Subtotal weight</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>834.4 lb</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>W_p (incl. 15%)</strong> 959.6 lb</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Maximum $F_{pw}$ per 6.5.5.2 (if applicable)</strong> 1634 lb</td>
</tr>
</tbody>
</table>

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A.6.5.1.3
All horizontal loads given in this document are at allowable stress design levels. When performing a more advanced analysis procedure, as described in 6.1.2, care should be taken to ensure that the correct load factors (strength design or allowable stress design) are used. [13:A.18.5.1.3]

A.6.5.1.4
A shared support assembly can be used to provide both support as defined in 5.1.4.1 and provide resistance to seismic forces. When a shared support assembly is used for both support and seismic forces, the shared support assembly should be designed to resist the seismic force for all of the distribution system. The shared support assembly should be designed for a load in which the zone of influence includes the water-filled sprinkler pipe and all other distribution systems attached to the shared support assembly. [13:A.18.5.1.4]

A.6.5.1.5
It is the intent of this section to avoid any incompatibility of displacements between the shared support assembly and the sprinkler seismic bracing, as might occur if the supports are located on separate adjacent structures. [13:A.18.5.1.5]

A.6.5.2.3
The listed load rating should include a minimum safety factor of 2.2 against the ultimate break strength of the brace components and then be further reduced according to the brace angles. [13:A.18.5.2.3]

A.6.5.2.3.1
Depending on the configuration of bracing fittings and connections, it is not always the case that the weakest component of a brace assembly tested at a brace angle of 90 degrees will be the same or will fail in the same way as the weakest component when tested at other brace angles. Therefore, determining an allowable horizontal load using the factors in Table 6.5.2.3 and a listed load rating established solely by testing along the brace assembly at 90 degrees might not be conservative. In most cases, a single listed load rating can be determined by testing the brace assembly at angles of 30, 45, 60, and 90 degrees, reducing the horizontal force at failure found for each of these angles by an appropriate safety factor and then resolving the resulting maximum allowable horizontal loads to a direction along the brace, and finally taking the
minimum of these values along the brace assembly as the listed load rating. By taking the
minimum value so determined as the listed load rating, allowable horizontal loads determined
using Table 6.5.2.3 will be conservative. In some cases, and where justified by engineering
judgment, fewer or additional tests might be needed to establish a listed load rating.

[A.18.5.2.3.1]

A.6.5.4.2

The investigation of tension-only bracing using materials, connection methods, or both, other
than those described in Table 6.5.11.8(a) through Table 6.5.11.8(f), should involve consideration
of the following:

1) Corrosion resistance.
2) Prestretching to eliminate permanent construction stretch and to obtain a verifiable
   modulus of elasticity.
3) Color coding or other verifiable marking of each different size cable for field verification.
4) The capacity of all components of the brace assemblies, including the field connections, to
   maintain the manufacturer's minimum certified break strength.
5) Manufacturer's published design data sheets/manual showing product design guidelines,
   including connection details, load calculation procedures for sizing of braces, and the
   maximum recommended horizontal load-carrying capacity of the brace assemblies
   including the associated fasteners as described in Figure 6.5.12.1. The maximum
   allowable horizontal loads must not exceed the manufacturer's minimum certified break
   strength of the brace assemblies, excluding fasteners, after taking a safety factor of 2.2
   and then adjusting for the brace angle.
6) Bracing product shipments accompanied by the manufacturer’s certification of the
   minimum break strength and prestretching and installation instructions.
7) The manufacturer’s literature, including any special tools or precautions required to
   ensure proper installation.
8) A means to prevent vertical motion due to seismic forces when required.

[A.18.5.4.2]

Table A.6.5.4.2 identifies standards for specially listed tension-only bracing systems.

[A.18.5.4.2]

Table A.6.5.4.2 Specially Listed Tension-Only Seismic Bracing
A brace assembly includes the brace member, the attachment components to pipe and building, and their fasteners. There are primarily two considerations in determining the spacing of lateral earthquake braces in straight runs of pipe: (1) deflection and (2) stress. Both deflection and stress tend to increase with the spacing of the braces. The larger the midspan deflection, the greater the chance of impact with adjacent structural/nonstructural components. The higher the stress in the pipe, the greater the chance of rupture in the pipe or coupling. Braces are spaced to limit the stresses in the pipe and fittings to the levels permitted in modern building codes, with an upper limit of 40 ft (12.2 m). The braces also serve to control deflection of the pipe under earthquake loads. In the longitudinal direction, there is no deflection consideration, but the pipe must transfer the load to the longitudinal braces without inducing large axial stresses in the pipe and the couplings. [13:A.18.5.5.1]

A.6.5.5.2

The sway brace spacings in Table 6.5.5.2(a) through Table 6.5.5.2(n) were developed to allow designers to continue to use familiar concepts, such as zone of influence, to lay out and proportion braces while ensuring compatibility with modern seismic requirements. The spacing of braces was determined using the provisions of ASCE/SEI 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, assuming steel pipe with threaded or grooved connections for Table 6.5.5.2(a) through Table 6.5.5.2(f). The tabulated values are based on conservative simplifying assumptions. A detailed engineering analysis, taking into account the properties of the specific system, might provide greater spacing. However, in order to control
deflections, in no case should the lateral sway brace spacing exceed 40 ft (12.2 m).

[13:A.18.5.5.2]

A.6.5.5.10

The use of multiple short hangers spaced so as not to exceed the maximum allowable limits will limit movement of pipe in a direction perpendicular to the pipe. These short hangers are deemed to meet the requirements to have the pipe braced laterally. With the use of short hangers, additional lateral sway bracing is not required.

A.6.5.5.10.1(1)

Figure A.6.5.5.10.1(1)(a) and Figure A.6.5.5.10.1(1)(b) are examples of how to measure the distance between the top of pipe and the point of attachment. [13:A.18.5.5.10.1(1)]

**Figure A.6.5.5.10.1(1)(a) Measurement for Distance Between Top of Pipe and Point of Attachment (Example 1).** [13:Figure A.18.5.5.10.1(1)(a)]
Figure A.6.5.5.10.1(1)(b) Measurement for Distance Between Top of Pipe and Point of Attachment (Example 2). [13:Figure A.18.5.5.10.1(1)(b)]
A.6.5.5.10.2(1)

See Figure A.6.5.5.10.1(1)(a) and Figure A.6.5.5.10.1(1)(b). [13:A.18.5.5.10.2(1)]

A.6.5.5.11

The use of multiple short hangers spaced so as not to exceed the maximum allowable limits will limit movement of pipe in a direction perpendicular to the pipe. These short hangers are deemed to meet the requirements to have the pipe braced laterally. With the use of short hangers, additional lateral sway bracing is not required.

A.6.5.6

Where sway bracing is required, all pipe will be kept from moving longitudinally by one of the following methods:

1) The pipe is provided with longitudinal sway bracing directly connected to the pipe as per 6.5.6.1.
2) The pipe is deemed to be provided with longitudinal bracing by an adjacent lateral brace within 24 in. (600 mm) of a change of direction.
3) Sprinkler system branch lines are deemed to be provided with longitudinal sway bracing when the seismic load of a sprinkler system branch line is transferred to and added to the lateral load of a cross-main lateral sway brace. This connection can be directly between a sprinkler system branch line and a cross main or indirectly through a riser nipple meeting the requirements of 6.5.9.6.

A.6.5.7.2

See Figure A.6.5.7.2. [13:A.18.5.7.2]

Figure A.6.5.7.2 Examples of Brace Locations for Change in Direction of Pipe. [13:Figure A.18.5.7.2]
A.6.5.8.1

The four-way brace provided at the riser can also provide longitudinal and lateral bracing for adjacent mains. This section is not intended to require four-way bracing on a sprig or on a drop to a single sprinkler. [13:A.18.5.8.1]

A.6.5.8.1.1

See Figure A.6.2.3.1(2)(a). [13:A.18.5.8.1.1]

A.6.5.9

Location of Sway Bracing. Two-way braces are either longitudinal or lateral, depending on their orientation with the axis of the piping. [See Figure A.6.5.9(a), Figure A.6.5.9(b), Figure A.6.5.9(c), and Figure A.6.5.9(d).] The simplest form of two-way brace is a piece of steel pipe or angle. Because the brace must act in both compression and tension, it is necessary to size the brace to prevent buckling. [13:A.18.5.9]
An important aspect of sway bracing is its location. In Building 1 of Figure A.6.5.9(a), the relatively heavy main will pull on the branch lines when shaking occurs. If the branch lines are held rigidly to the roof or floor above, the fittings can fracture due to the induced stresses. In selecting brace locations, one must consider both the design load on the brace, as well as the ability of the pipe to span between brace locations. [13:A.18.5.9]

Bracing should be on the main as indicated at Location B of Figure A.6.5.9(a). With shaking in the direction of the arrows, the light branch lines will be held at the fittings. Where necessary, a lateral brace or other restraint should be installed to prevent a branch line from striking against building components or equipment. [13:A.18.5.9]

A four-way brace is indicated at Location A of Figure A.6.5.9(a). This keeps the riser and main lined up and also prevents the main from shifting. [13:A.18.5.9]

In Building 1 of Figure A.6.5.9(a), the branch lines are flexible in a direction parallel to the main, regardless of building movement. The heavy main cannot shift under the roof or floor, and it also steadies the branch lines. While the main is braced, the flexible couplings on the riser allow the sprinkler system to move with the floor or roof above, relative to the floor below. [13:A.18.5.9]

Figure A.6.5.9(a) Typical Earthquake Protection for Sprinkler Main Piping. [13:Figure A.18.5.9(a)]
Figure A.6.5.9(b), Figure A.6.5.9(c), and Figure A.6.5.9(d) show typical locations of sway bracing. [13:A.18.5.9]

**Figure A.6.5.9(b) Typical Location of Bracing on Mains on Tree System. [13:Figure A.18.5.9(b)]**
Figure A.6.5.9(c) Typical Location of Bracing on Mains on Gridded System. [13:Figure A.18.5.9(c)]
Figure A.6.5.9(d) Typical Location of Bracing on Mains on Loop System. [13:Figure A.18.5.9(d)]
For all threaded connections, sight holes or other means should be provided to permit indication that sufficient thread is engaged. [13:A.18.5.9]

To properly size and space braces, it is necessary to employ the following steps:

1. Determine the seismic coefficient, $C_p$, using the procedures in 6.5.9.3 or 6.5.9.4. This is needed by the designer to verify that the piping can span between brace points. For the purposes of this example, assume that $C_p = 0.5$.

2. Based on the distance of system piping from the structural members that will support the braces, choose brace shapes and sizes from Table 6.5.11.8(a) through Table 6.5.11.8(f) such that the maximum slenderness ratios, $l/r$, do not exceed 300. The angle of the braces from the vertical should be at least 30 degrees and preferably 45 degrees or more.

3. Tentatively space lateral braces at 40 ft (12 m) maximum distances along system piping, and tentatively space longitudinal braces at 80 ft (24 m) maximum distances along system piping. Lateral braces should meet the piping at right angles, and longitudinal braces should be aligned with the piping.

4. Determine the total load tentatively applied to each brace in accordance with the examples shown in Figure A.6.5.9(e) and the following:
   a. For the loads on lateral braces on cross mains, add $C_p$ times the weight of the branch line to $C_p$ times the weight of the portion of the cross main within the zone of influence of the brace. [See examples 1, 3, 6, and 7 in Figure A.6.5.9(e).]
   b. For the loads on longitudinal braces on cross mains, consider only $C_p$ times the weight of the cross mains and feed mains within the zone of influence. Branch lines need not be included. [See examples 2, 4, 5, 7, and 8 in Figure A.6.5.9(e).]
   c. For the four-way brace at the riser, add the longitudinal and lateral loads within the zone of influence of the brace [see examples 2, 3, and 5 in Figure A.6.5.9(e)]. For the four-way bracing at the top of the riser, $C_p$ times the weight of the riser should be assigned to both the lateral and longitudinal loads as they are separately considered.
   d. When a single brace has a combined load from both lateral and longitudinal forces (such as a lateral brace at the end of a main that turns 90 degrees), only the lateral should be considered for comparison with the load tables in 6.5.5.2.

5. If the total expected loads are less than the maximums permitted in Table 6.5.11.8(a) through Table 6.5.11.8(f) for the particular brace and orientation, and the maximum loads in the zone of influence of each lateral sway brace are less than the maximum values in Table 6.5.5.2(a) or Table 6.5.5.2(c), go on to A.6.5.9(6). If not, add additional braces to reduce the zones of influence of overloaded braces.
(6) Check that fasteners connecting the braces to structural supporting members are adequate to support the expected loads on the braces in accordance with Figure 6.5.12.1. If not, again add additional braces or additional means of support. Plates using multiple fasteners in seismic assemblies should follow the plate manufacturer guidelines regarding the applied loads.

[13:A.18.5.9]

Use the information on weights of water-filled piping contained within Table A.6.5.9(a) and Table A.6.5.9(b). The factor of 1.15 is intended to approximate the additional weight of all the valves, fittings, and other devices attached to the system.

**Figure A.6.5.9(e) Examples of Load Distribution to Bracing. [13:Figure A.18.5.9(e)]**

![Figure A.6.5.9(e) Examples of Load Distribution to Bracing.](image)

**Table A.6.5.9(a) Piping Weights for Determining Horizontal Load**

**Water-Filled Weight of Pipe lb/ft**
<table>
<thead>
<tr>
<th>Nominal Size (in.)</th>
<th>Sch 40</th>
<th>Sch 30</th>
<th>Sch 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>0.98</td>
<td>0.83</td>
<td></td>
</tr>
<tr>
<td>3/4</td>
<td>1.36</td>
<td>1.12</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2.06</td>
<td>1.82</td>
<td></td>
</tr>
<tr>
<td>1 1/4</td>
<td>2.92</td>
<td>3.54</td>
<td></td>
</tr>
<tr>
<td>1 1/2</td>
<td>3.60</td>
<td>4.26</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5.11</td>
<td>5.79</td>
<td></td>
</tr>
<tr>
<td>2 1/2</td>
<td>7.87</td>
<td>5.90</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>10.79</td>
<td>7.95</td>
<td></td>
</tr>
<tr>
<td>3 1/2</td>
<td>13.40</td>
<td>9.79</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>16.32</td>
<td>11.80</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>23.30</td>
<td>17.32</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>31.52</td>
<td>23.06</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>50.27</td>
<td>46.90</td>
<td>37.03</td>
</tr>
<tr>
<td>10</td>
<td>74.71</td>
<td>69.25</td>
<td>55.64</td>
</tr>
<tr>
<td>12</td>
<td>102.10</td>
<td>93.58</td>
<td>76.46</td>
</tr>
<tr>
<td>14</td>
<td>122.15</td>
<td>114.40</td>
<td>98.80</td>
</tr>
<tr>
<td>16</td>
<td>159.46</td>
<td>141.82</td>
<td>123.90</td>
</tr>
<tr>
<td>18</td>
<td>201.74</td>
<td>182.08</td>
<td>151.72</td>
</tr>
<tr>
<td>20</td>
<td>243.73</td>
<td>227.15</td>
<td>182.26</td>
</tr>
<tr>
<td>24</td>
<td>345.74</td>
<td>319.00</td>
<td>251.51</td>
</tr>
</tbody>
</table>

Table A.6.5.9(b) Pipe Weights for Determining Horizontal Load

Water-Filled Weight of Pipe kg/m
The factors used in the computation of the horizontal seismic load should be available from several sources, including the project architect or structural engineer or the authority having
jurisdiction. In addition, the ground motion parameter $S_s$ is available using maps or software developed by the US Geological Survey. The approach presented in NFPA 13 is compatible with the requirements of ASCE/SEI 7, *Minimum Design Loads for Buildings and Other Structures*, which provides the seismic requirements for model building codes. Sprinkler systems are emergency systems and as such should be designed for an importance factor ($I_p$) of 1.5. Seismic load equations allow the reduction of the seismic force by a component response modification factor ($R_p$) that reflects the ductility of the system; systems where braced piping is primarily joined by threaded fittings should be considered less ductile than systems where braced piping is joined by welded or mechanical-type fittings. In addition, a factor, $a_p$, is used to account for dynamic amplification of nonstructural systems supported by structures. Currently, steel piping systems typically used for fire sprinklers are assigned an $R_p$ factor of 4.5 and an $a_p$ factor of 2.5. [13:A.18.5.9.1]

**A.6.5.9.3.2.1**

The authority having jurisdiction for the site class determination of the building can be someone other than the authority having jurisdiction for the sprinkler system. [13:A.18.5.9.3.2.1]

**A.6.5.9.3.2.1**

When a structure is built on a site class E or F, the building design might incorporate features apart from the assumptions used in this standard for how a building will move when subjected to seismic forces. In these situations, the approaches used to protect mechanical systems should be confirmed. [13:A.18.5.9.3.2.2]

**A.6.5.9.3.3**

As linear interpolation of Table 6.5.9.3 is permitted, the following equation can be used to achieve the interpolated values: [13:A.18.5.9.3.3]

$$C_p = C_{p\text{-low}} + \frac{C_{p\text{-high}} - C_{p\text{-low}}}{S_{S\text{-high}} - S_{S\text{-low}}} (S_s - S_{S\text{-low}})$$

[A.6.5.9.3.3]

where:

- $C_p =$ seismic coefficient value being sought
- $C_{p\text{-low}} =$ next lower seismic coefficient value from Table 6.5.9.3
$C_{p\text{-}high} = \text{next higher seismic coefficient value from Table 6.5.9.3}$

$S_s = \text{spectral response as defined in 3.3.207}$

$S_{s\text{-}low} = \text{next lower } S_s \text{ value from Table 6.5.9.3}$

$S_{s\text{-}high} = \text{next higher } S_s \text{ value from Table 6.5.9.3}$

[13:A.18.5.9.3.3]

A.6.5.9.3.4

See Figure A.6.5.9.3.4.

Figure A.6.5.9.3.4 Typical Example of the Component Attachment to the Structure Relative to the Average Roof Height and Ceiling Height. [13:Figure A.18.5.9.3.4]
A.6.5.9.4

NFPA 13 has traditionally used the allowable stress design (ASD) method for calculations. The building codes typically use an ultimate strength design. The 0.7 referred to in this section is a
conversion value to accommodate the different calculation methods. *(See also Annex B.)* [13:A.18.5.9.4]

**A.6.5.9.5**

$S_s$ is a measure of earthquake shaking intensity. $S_s$ shall be taken as the maximum considered earthquake ground motion for 0.2-second spectral response acceleration (5 percent of critical damping), Site Class B. The data are available from the authority having jurisdiction or, in the United States, from maps developed by the US Geological Survey. All that is required to get $S_s$ is the latitude and longitude of the project site. [13:A.18.5.9.5]

The horizontal force factor was given as $F_p$ in earlier editions of NFPA 13. It has been changed to $F_{pw}$, to clearly indicate that it is a working, not an ultimate, load. In model building codes, $F_p$ is used to denote the strength design level load. [13:A.18.5.9.5]

It is not the intent of this section to default to the $C_p$ value of 0.5 before attempts to determine the value of $S_s$ and related coefficient value for $C_p$ are made, such as on-line information provided by the US Geological Survey website. [13:A.18.5.9.5]

**A.6.5.9.6**

The zones of influence do not have to be symmetrically based on brace spacing. It is the intent of NFPA 13 that the chosen zone of influence be the worst-case load scenario. [13:A.18.5.9.6]

**A.6.5.9.6.1**

Where the $C_p$ is 1.0 or greater, the calculation should be done for any riser nipple length. The loads in this condition can rapidly exceed the yield strength. Where Schedule 10 and Schedule 40 steel pipe are used, the section modulus can be found in Table 5.3.1(c) or Table 5.3.1(d). Table A.6.5.9.6.1 illustrates when the required yield strength calculation based on riser nipple length is necessary. [13:A.18.5.9.6.1]

**Table A.6.5.9.6.1 Required Yield Strength Calculation Based on Riser Nipple Length on $C_p$**

<table>
<thead>
<tr>
<th>Riser Nipple Length</th>
<th>$C_p \leq 0.50$</th>
<th>$C_p \leq 0.67$</th>
<th>$C_p &lt; 1.0$</th>
<th>$C_p &gt; 1.0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;4 ft (1.2 m)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>\leq 4 ft (1.2 m)</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
### Table A.18.5.9.6.1

<table>
<thead>
<tr>
<th>Riser Nipple Length</th>
<th>Seismic Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$C_p \leq 0.50$</td>
</tr>
<tr>
<td>≤3 ft (915 mm)</td>
<td>X</td>
</tr>
<tr>
<td>≤2 ft (610 mm)</td>
<td>X</td>
</tr>
</tbody>
</table>

Note: Conditions marked X are required to satisfy the equation provided in 6.5.9.6.2.

[A.6.5.11]

Sway brace members should be continuous. Where necessary, splices in sway bracing members should be designed and constructed to ensure that brace integrity is maintained. [A.18.5.11]

[A.6.5.11.1]

Sway brace design and installation is critical to performance and requires attention to detail. Sway brace design parameters are dynamic and interdependent. Accordingly, seismic force is influenced by geography, brace location is impacted by system design, and brace geometry is relative to the building structure. [A.18.5.11.1]

To enhance system durability and performance, sway brace installation should show evidence of good craftsmanship in conformance to approved drawings, correctly assembled and mounted at proper angles on a plane that corresponds to the parallel and perpendicular axis of the system pipe. [A.18.5.11.1]

[A.6.5.11.9]

Maximum allowable horizontal loads for steel sway braces shown in Table 6.5.11.8(a) through Table 6.5.11.8(f) are applicable when the system is designed using allowable stress design methods. The maximum allowable loads have been derived for the controlling condition (braces in compression) using allowable stress design provisions of American Institute of Steel Construction (AISC) 360, Specification for Structural Steel Buildings. [A.18.5.11.9]

In determining allowable horizontal loads in the tables, a modulus of elasticity ($E$) of 29,000 ksi, a yield stress ($F_y$) of 36 ksi, and an effective length factor ($K$) of 1.0 were assumed, since these are common. If these values are different in a specific situation, table values might need to be adjusted. Gross section properties are used for all shapes except for all-thread rods. For all-
thread rods, area and radius of gyration are based on the minimum area of the threaded rod based on the radius at the root of the threads. [13:A.18.5.11.9]

A.6.5.12

Concrete anchors can be cast-in-place [installed before the concrete is placed — see Figure A.6.5.12(a) and Figure A.6.5.12(b)] or post-installed [installed in hardened concrete — see Figure A.6.5.12(c)]. Examples of cast-in-place concrete anchors are embedded steel bolts or concrete inserts. There are several types of post-installed anchors, including expansion anchors, chemical or adhesive anchors, and undercut anchors. The criteria in Table 6.5.12.2(a) through Table 6.5.12.2(j) are based on the use of listed cast-in-place concrete inserts and listed post-installed wedge expansion anchors. The values for “effective embedment” for cast-in-place anchors and “nominal embedment” for post-installed anchors as shown in the tables represent the majority of commonly available anchors on the market at the time of publishing. Use of other anchors in concrete should be in accordance with the listing provisions of the anchor. Anchorage designs are usable under allowable stress design (ASD) methods. [13:A.18.5.12]

Values in Table 6.5.12.2(a) through Table 6.5.12.2(j) are based on ultimate strength design values obtained using the procedures in Chapter 17 of ACI 318, *Building Code Requirements for Structural Concrete and Commentary*, which are then adjusted for ASD. Concrete inserts are installed into wood forms for concrete members using fasteners prior to the casting of concrete, inserted into wood forms for concrete members using fasteners prior to the casting of concrete, or inserted into a hole cut in steel deck that will be filled with concrete topping slab. A bolt or rod can be installed into the internally threaded concrete insert after the wood form is removed from the concrete or from the underside of the steel deck after it is filled with concrete topping slab. Wedge anchors are torque-controlled expansion anchors that are set by applying a torque to the anchor’s nut, which causes the anchor to rise while the wedge stays in place. This causes the wedge to be pulled onto a coned section of the anchor and presses the wedge against the wall of the hole. Undercut anchors might or might not be torque-controlled. Typically, the main hole is drilled, a special second drill bit is inserted into the hole, and flare is drilled at the base of the main hole. Some anchors are self-drilling and do not require a second drill bit. The anchor is then inserted into the hole and, when torque is applied, the bottom of the anchor flares out into the flared hole, and a mechanical lock is obtained. Consideration should be given with respect to the position near the edge of a slab and the spacing of anchors. For full capacity in Table 6.5.12.2(a) through Table 6.5.12.2(j), the edge distance spacing between anchors and the thickness of concrete should conform to the anchor manufacturer’s recommendations. [13:A.18.5.12]
Calculation of ASD shear and tension values to be used in A.6.5.12.2 calculations should be performed in accordance with formulas in Chapter 17 of ACI 318 using the variables and recommendations obtained from the approved evaluation service reports (such as ICC-ES reports) for a particular anchor, which should then be adjusted to ASD values. All post-installed concrete anchors must be prequalified in accordance with ACI 355.2, *Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary*, or other approved qualification procedures (Section 13.4.2.3 of ASCE/SEI 7, *Minimum Design Loads for Buildings and Other Structures*). This information is usually available from the anchor manufacturer. [13:A.18.5.12]

The following variables are among those contained in the approved evaluation reports for use calculations according to Chapter 17 of ACI 318. These variables do not include the allowable tension and shear capacities but do provide the information needed to calculate them. The strength design capacities must be calculated using the appropriate procedures in Chapter 17 of ACI 318 and then converted to allowable stress design capacities.

\[ D_a = \text{anchor diameter} \]
\[ L_{anch} = \text{total anchor length} \]
\[ h_{nom} = \text{nominal embedment} \]
\[ h_{ef} = \text{effective embedment} \]
\[ h_{min} = \text{minimum concrete thickness} \]
\[ C_{ac} = \text{critical edge distance} \]
\[ N_{sa} = \text{steel strength in tension} \]
\[ l_e = \text{length of anchor in shear} \]
\[ N_{p,cr} = \text{pull-out strength cracked concrete} \]
\[ K_{cp} = \text{coefficient for pryout strength} \]
\[ V_{sa,eq} = \text{shear strength single anchor seismic loads} \]
\[ V_{st,deck,eq} = \text{shear strength single anchor seismic loads installed through the soffit of the metal deck} \]

[13:A.18.5.12]

**Figure A.6.5.12(a) Metal Deck Insert.** [13:Figure A.18.5.12(a)]
Figure A.6.5.12(b) Wood Form Insert. [13:Figure A.18.5.12(b)]

Figure A.6.5.12(c) Wedge Anchor. [13:Figure A.18.5.12(c)]
A.6.5.12.2

The values for the concrete insert and wedge anchor tables have been developed using the following formula:

\[
\frac{T}{T_{allow}} + \frac{T}{V_{allow}} \leq 1.2
\]  

[A.6.5.12.2a]

where:

Note: \( h_{aux} \) is the nominal embedment depth given in Tables 6.5.12.2(a) through (e).
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\[ T = \text{applied service tension load, including the effect of prying} \left( F_{pw} \times Pr \right) \]

\[ F_{pw} = \text{horizontal earthquake load} \]

\[ Pr = \text{prying factor based on fitting geometry and brace angle from vertical} \]

\[ T_{allow} = \text{allowable service tension load} \]

\[ V = \text{applied service shear load} \]

\[ V_{allow} = \text{allowable service shear load} \]

\[ T/T_{allow} = \text{shall not be greater than 1.0.} \]

\[ V/V_{allow} = \text{shall not be greater than 1.0.} \]

[13:A.18.5.12.2]

The allowable tension and shear loads come from the anchor manufacturer’s published data. The design loads have been amplified by an overstrength factor of 2.0, and the allowable strength of the anchors has been increased by a factor of 1.2. The effect of prying on the tension applied to the anchor is considered when developing appropriate capacity values. The applied tension equation includes the prying effect, which varies with the orientation of the fastener in relationship to the brace necessary at various brace angles. The letters A through D in the following equations are dimensions of the attachment geometry as indicated in Figure A.6.5.12.2(a) through Figure A.6.5.12.2(c). [13:A.18.5.12.2]

where:

\[ C_r = \text{critical angle at which prying flips to the toe or the heel of the structure attachment fitting} \]

\[ Pr = \text{prying factor for service tension load effect of prying} \]

\[ Tan \theta = \text{tangent of brace angle from vertical} \]

\[ Sin \theta = \text{sine of brace angle from vertical} \]

[13:A.18.5.12.2]

The greater \( Pr \) value calculated in tension or compression applies. [13:A.18.5.12.2]
The \( Pr \) value cannot be less than \( 1.000/Tan\theta \) for designated angle category A, B, and C; 1.000 for designated angle category D, E, and F; or 0.000 for designated angle category G, H, and I.

\[13:\text{A.18.5.12.2}\]

For designated angle category A, B, and C, the applied tension, including the effect of prying \( (Pr) \), is as follows:

\[
Cr = Tan^{-1}\left(\frac{C}{D}\right)
\]

\[\text{[A.6.5.12.2b]}\]

\[13:\text{A.18.5.12.2}\]

For braces acting in **TENSION**

If \( Cr > \) brace angle from vertical:

\[
Pr = \left(\frac{C + A}{Tan\theta}\right) - D
\]

\[\text{[A.6.5.12.2c]}\]

\[13:\text{A.18.5.12.2}\]

If \( Cr < \) brace angle from vertical:

\[
Pr = \left(\frac{D - \left(\frac{C - B}{Tan\theta}\right)}{B}\right)
\]

\[\text{[A.6.5.12.2d]}\]

\[13:\text{A.18.5.12.2}\]

For braces acting in **COMPRESSION**

If \( Cr > \) brace angle from vertical:
\[ Pr = \frac{\left( C - B \right) - D}{\frac{Tan\theta}{B}} \]  
\[ [A.6.5.12.2e] \]

[13:A.18.5.12.2] If \( Cr < \) brace angle from vertical:

\[ Pr = \frac{D - \left( \frac{C + A}{Tan\theta} \right)}{A} \]  
\[ [A.6.5.12.2f] \]

[13:A.18.5.12.2]

For designated angle category D, E, and F, the applied tension, including the effect of prying (\( Pr \)), is as follows:

\[ Cr = Tan^{-1}\left( \frac{D}{C} \right) \]  
\[ [A.6.5.12.2g] \]

[13:A.18.5.12.2]

For braces acting in TENSION

If \( Cr > \) brace angle from vertical:

\[ Pr = \frac{\left( \frac{D}{Tan\theta} \right) - (C - B)}{B} \]  
\[ [A.6.5.12.2h] \]

[13:A.18.5.12.2]

If \( Cr < \) brace angle from vertical:
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For braces acting in **COMPRESSION**

\[ Pr = \frac{D}{A \sin \theta} \]  

[A.6.5.12.2m]

[13:A.18.5.12.2]

The lightweight concrete anchor tables, Table 6.5.12.2(a) through Table 6.5.12.2(c) were based on sand lightweight concrete, which represents a conservative assumption for the strength of the material. For seismic applications, cracked concrete was assumed. [13:A.18.5.12.2]

The allowable tension and shear loads come from the anchor manufacturer’s published data. The design loads have been amplified by an overstrength factor of 2.0, and the allowable strength of the anchors has been increased by a factor of 1.2. The effect of prying on the tension applied to the anchor is considered when developing appropriate capacity values. The applied tension equation includes the prying effect, which varies with the orientation of the fastener in relationship to the brace necessary at various brace angles. The letters A through D in the following equations are dimensions of the geometry for structure attachment fittings with the tension load applied in line with the centerline of the concrete anchor, as indicated in Figure A.6.5.12.2(a) through Figure A.6.5.12.2(e).

**Figure A.6.5.12.2(a)** Example of Concentric Attachment Fitting Per Tables 6.5.12.2(a) Through 6.5.12.2(j).
For attachment fittings with the tension load applied offset from the centerline of the concrete anchor, as shown in the example in Figure A.6.5.12.2(b), different $Pr$ formulas and geometry that take into account the offset application of the tension load should be used.

**Figure A.6.5.12.2(b)** Example of Eccentric Attachment Fitting Not Addressed by Tables 6.5.12.2(a) Through 6.5.12.2(j).

![Plan View of Eccentric Attachment Fitting](image)

**Figure A.6.5.12.2(c)** Dimensions of Concrete Anchor for Orientations A, B, and C.

![Dimensions of Concrete Anchor](image)

**Figure A.6.5.12.2(d)** Dimensions of Concrete Anchor for Orientations D, E, and F. [13:Figure A.18.5.12.2(b)]
A.6.5.12.3

Listed devices might have accompanying software that performs the calculations to determine the allowable load. [13:A.18.5.12.3]

A.6.5.12.4
Through-bolt as described in 6.5.12.4 is intended to describe a method of bolting and attachment. It is the intent of the committee that a “through-bolt” could consist of threaded rod with a flat washer and nut on each end. [13:A.18.5.12.4]

A.6.5.12.7

The requirements for concrete anchor and concrete insert capacities in 6.5.12.7.1 through 6.5.12.7.5 are based on calculations performed in accordance with ACI 318, Building Code Requirements for Structural Concrete and Commentary, adjusted for allowable stress design (ASD), and using imperial units for anchors and inserts that have been seismically prequalified in accordance with ACI 355.2, Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary. In jurisdictions that are working in metric units, it is likely that ASD is not the standardized method of calculation for these components. For example, in some areas of the world, it is commonly required that concrete anchor and insert calculations are determined in accordance with the procedures for load and resistance factor design (LRFD), and metric-sized anchors and inserts complying with standards other than those cited within this standard are used. In those instances, the calculation procedures, along with the required concrete anchors and inserts acceptable to the authority having jurisdiction, should be used. [13:A.18.5.12.7]

A.6.5.12.7.1

Concrete anchors included in current evaluation service reports conforming to the requirements of acceptance criteria AC193 as issued by ICC Evaluation Service, Inc. should be considered to meet ACI 355.2, Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary. [13:A.18.5.12.7.1]

A.6.5.12.7.3.4

The values from Chapter 17 of ACI 318, Building Code Requirements for Structural Concrete and Commentary, are load and resistance factor design (LRFD) values that must be divided by 1.4 in order to convert them to allowable stress design (ASD) values. The factor of 0.43 was created to simplify the steps needed to account for the strength capacities and the ASD method of calculation. The 0.43 is a rounded value determined by 1.2 (allowable stress increase) divided by the quantity of 2.0 multiplied by 1.4 [i.e., 0.4286 = 1.2/(2.0 × 1.4)]. [13:A.18.5.12.7.3.4]

A.6.5.12.7.5

For any multithread anchor, special care must be taken when reviewing the ICC-ES Report for validation on which anchor diameter(s) can be used for seismic bracing. See Figure A.6.5.12.7.5 for example of a multithread anchor.
A.6.6.1

Wires used for piping restraints should be attached to the branch line with two tight turns around the pipe and fastened with four tight turns within 1 1/2 in. (38 mm) and should be attached to the structure in accordance with the details shown in Figure A.6.6.1(a) through Figure A.6.6.1(d) or other approved method. [13:A.18.6.1]

Figure A.6.6.1(a) Wire Attachment to Cast-in-Place Concrete. [13:Figure A.18.6.1(a)]
Figure A.6.6.1(b) Acceptable Details — Wire Connections to Steel Framing. [13:Figure A.18.6.1(b)]
Figure A.6.6.1(c) Acceptable Details — Wire Connections to Steel Decking with Fill. [13:Figure A.18.6.1(c)]
Figure A.6.6.1(d) Acceptable Details — Wire Connections to Wood Framing. [13:Figure A.18.6.1(d)]
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A.6.6.1(5)

See Figure A.6.6.1(5)(a) and Figure A.6.6.1(5)(b). When hangers are installed on both sides of the pipe, the $l/r$ is not restricted. [13:A.18.6.1(5)]

Figure A.6.6.1(5)(a) Hangers, with Surge Clips, Used in Combination for Restraint of Branch Lines. [13:Figure A.18.6.1(5)(a)]

Figure A.6.6.1(5)(b) Hangers, with Threaded Rod Extended to Pipe, Used in Combination for Restraint of Branch Lines. [13:Figure A.18.6.1(5)(b)]
A.6.6.4

Modern seismic codes require branch lines to be restrained, both to limit interaction of the pipe with other portions of the structure and to limit stresses in the pipes to permissible limits. The maximum spacing between restraints is dependent on the seismic coefficient, $C_p$, as shown in Table 6.6.4(a). Table 6.6.4(a) has been limited to 2 in. (50 mm) lines and smaller, because branch lines 2 1/2 in. (65 mm) or larger are required to be seismically braced. [13:A.18.6.4]

It is not the intent of this section to require restraint of piping associated with valve trim, water motor gong piping, air or nitrogen supply piping, or other piping that is not essential to the operation of the sprinkler system. Essential piping such as fire pump sensing lines and diesel fuel lines are some examples of small piping that should be restrained. [13:A.18.6.4]

A.6.6.6

Such restraint can be provided by using the restraining wire discussed in 6.6.1. For the purposes of determining the need for restraint, the length of the sprig is determined by measuring the length of the exposed pipe and does not include the fittings and sprinkler. [13:A.18.6.6]

A.6.7.8
Concrete anchors included in current Evaluation Service Reports conforming to the requirements of acceptance criteria AC193, *Mechanical Anchors in Concrete Elements*, or AC308, *Post-Installed Adhesive Anchors in Concrete Elements*, as issued by ICC Evaluation Service, Inc. should be considered to meet ACI 355.2, *Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary*. [13:A.18.7.8]

A.6.8

When using a pipestand to support the gravity load of a water-based fire protection system in an earthquake area, care should be taken in planning the seismic protection. This includes close attention to the differential movement between the system and the building or other components. [13:A.18.8]

A.6.9.1

Figure A.6.9.1(a) through Figure A.6.9.1(c) are examples of forms used to aid in the preparation of bracing calculations.

**Figure A.6.9.1(a) Seismic Bracing Calculation Form. [13:Figure A.18.5(a)]**
Seismic Bracing Calculations

Project: ____________________________ Contractor: ____________________________
Address: ____________________________________________________________________
Telephone: ____________________________________________________________________
Fax: ________________________________________________________________________

Brace Information

<table>
<thead>
<tr>
<th>Length of brace:</th>
<th>Diameter of brace:</th>
<th>Type of brace:</th>
<th>Angle of brace:</th>
<th>Least radius of gyration:*</th>
<th>$I_r$ value:*</th>
<th>Maximum horizontal load:</th>
</tr>
</thead>
</table>

Seismic Brace Attachments

<table>
<thead>
<tr>
<th>Structure attachment fitting or tension-only bracing system:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make: ____________________________ Model: ______________________</td>
</tr>
<tr>
<td>Transition attachment fitting (where applicable):</td>
</tr>
<tr>
<td>Make: ____________________________ Model: ______________________</td>
</tr>
<tr>
<td>Listed load rating: _______ Adjusted load rating per 6.5.2.3: _______</td>
</tr>
<tr>
<td>Sway brace (pipe attachment) fitting:</td>
</tr>
<tr>
<td>Make: ____________________________ Model: ______________________</td>
</tr>
<tr>
<td>Listed load rating: _______ Adjusted load rating per 6.5.2.3: _______</td>
</tr>
</tbody>
</table>

Fastener Information

<table>
<thead>
<tr>
<th>Orientation of connecting surface:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fastener:</td>
</tr>
<tr>
<td>Type:</td>
</tr>
</tbody>
</table>

Seismic Brace Assembly Detail

(Provide detail on plans)

<table>
<thead>
<tr>
<th>Brace identification no. (to be used on plans):</th>
</tr>
</thead>
</table>

Sprinkler System Load Calculation ($F_{pw} = C_p W_p$)

$C_p = \_\_\_\_\_\_\_\_\_\_\_$

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Type</th>
<th>Length (ft)</th>
<th>Total (ft)</th>
<th>Weight per ft</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>lb/ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>lb</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>lb</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>lb</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>lb</td>
</tr>
</tbody>
</table>

Subtotal weight: lb

$W_p$ (incl. 15%) lb

Total ($F_{pw}$) lb

Maximum $F_{pw}$ per 6.5.2.2 (if applicable)

* Excludes tension-only bracing systems

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NFPA 2000, Standard for Hanging and Bracing of Fire Suppression Systems
November 21–22, 2019, Savannah, GA
©2022 National Fire Protection Association (NFPA)
Figure A.6.9.1(b) Sample Seismic Bracing Calculation Form. [13:Figure A.18.5(b)]
Seismic Bracing Calculations

Sheet ______ of ______

Project: Acme Warehouse
Address: 321 First Street
Any City, Any State

Contractor: Smith Sprinkler Company
Address: 123 Main Street
Any City, Any State
Telephone: (555) 555-1234
Fax: (555) 555-4321

Brace Information

| Length of brace: | 3 ft. 6 in. |
| Diameter of brace: | 1 in. |
| Type of brace: | Schedule 40 |
| Angle of brace: | 45° to 59° |
| Least radius of gyration:* | 0.421 |
| f*r value:* | 100 |
| Maximum horizontal load: | 4456 lb |

Seismic Brace Attachments

| Structure attachment fitting or tension-only bracing system: |
| Make: | Bolt |
| Model: | Bolt |
| Listed load rating: | 1000 |
| Adjusted load rating per 6.5.2.3: | 707 |
| Transition attachment fitting (where applicable): |
| Make: | Acme |
| Model: | 123 |
| Listed load rating: | 1200 |
| Adjusted load rating per 6.5.2.3: | 849 |

Sway brace (pipe attachment) fitting:

| Make: | Acme |
| Model: | 321 |
| Listed load rating: | 1200 |
| Adjusted load rating per 6.5.2.3: | 849 |

Fastener Information

| Orientation of connecting surface: | “E” |
| Fastener: | Through bolt |
| Type: | Through bolt |
| Diameter: | 3/4 in. |
| Length (in wood): | 5 1/2 in. |
| Maximum load: | 620 lb |

Seismic Brace Assembly Detail

(Provide detail on plans)

Brace identification no. (to be used on plans) | SB-1

Lateral brace ✔️
Longitudinal brace ☐
4-way brace ☐

Sprinkler System Load Calculation \( F_{pw} = C_p W_p \)

\[ C_p = \frac{0.40}{\text{Depth of beam}} \]

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Type</th>
<th>Length (ft)</th>
<th>Total (ft)</th>
<th>Weight per ft</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 in.</td>
<td>Sch. 40</td>
<td>15 ft + 25 ft + 8 ft + 22 ft</td>
<td>70 ft</td>
<td>2.05 lb/ft</td>
<td>143.5 lb</td>
</tr>
<tr>
<td>1¼ in.</td>
<td>Sch. 40</td>
<td>25 ft + 33 ft + 18 ft</td>
<td>76 ft</td>
<td>2.93 lb/ft</td>
<td>222.7 lb</td>
</tr>
<tr>
<td>1½ in.</td>
<td>Sch. 40</td>
<td>8 ft + 8 ft + 10 ft + 10 ft</td>
<td>36 ft</td>
<td>3.61 lb/ft</td>
<td>130.0 lb</td>
</tr>
<tr>
<td>2 in.</td>
<td>Sch. 40</td>
<td>20 ft</td>
<td>20 ft</td>
<td>5.13 lb/ft</td>
<td>102.6 lb</td>
</tr>
<tr>
<td>4 in.</td>
<td>Sch. 10</td>
<td>20 ft</td>
<td>20 ft</td>
<td>11.78 lb/ft</td>
<td>235.6 lb</td>
</tr>
</tbody>
</table>

Subtotal weight | 834.4 lb

\( W_p \) (incl. 15%) | 959.6 lb

Maximum \( F_{pw} \) per 6.5.5.2 (if applicable) | 1634
Figure A.6.9.1(c) Sample Seismic Bracing Calculation Form
# SIESEMIC BRACING CALCULATIONS

## Cable Type Seismic Bracing

### PROJECT INFORMATION

- **Name:** ABC Manufacturing  
- **Address:** 5678 Broadway  
- **City, State, Zip:** Anywhere, CA 99999  
- **Project No.:** XYZ-3456

### CALCULATIONS PREPARED BY:

- **Name:** John Doe  
- **Company Name:** John's Fire Protection  
- **Address:** 12345 Main Street  
- **City, State, Zip:** Anywhere, CA 44139  
- **Phone:**  
- **Fax:**  
- **Email:**

### Calculation of APPLICABLE Seismic Design Category

The Building **RISK CATEGORY** = III  
The SITE CLASS = D

<table>
<thead>
<tr>
<th>Short Period (0.2 sec) MAX. CONSIDERED</th>
<th>Long Period (1 sec) MAX. CONSIDERED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral Response Acceleration (Smx)</td>
<td>Spectral Response Acceleration (S11)</td>
</tr>
<tr>
<td>Fa = 1.10</td>
<td>Fv = 2.00</td>
</tr>
<tr>
<td>S1 = 1.0</td>
<td>S1 = 0.2</td>
</tr>
<tr>
<td>Smx = FaS1 = 1.10 x 1.0 = 1.100</td>
<td>S11 = FvS1 = 2.00 x 0.2 = 0.400</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Short Period (0.2 sec) DESIGN Spectral Response Acceleration (Sds)</th>
<th>Long Period (1 sec) DESIGN Spectral Response Acceleration (S1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sds - 2/3 Sd = (2 x 1.100)/3 = 0.733</td>
<td>S1 = 2/3 S11 = (2 x 0.400)/3 = 0.267</td>
</tr>
</tbody>
</table>

### Short Period Seismic Design Category = D  
Long Period Seismic Design Category = D

### The APPLICABLE Seismic Design Category is “D”

### Calculation of APPLICABLE Horizontal Load Factor (HLF)

The BRACED COMPONENT description is: Non-ASME Steel or Copper Piping, including in-line components, w/Joints Made by Threading, Bonding or Compression/Grooved Couplings

- The Component Importance Factor (Ip) = 1.5  
- The Component Amplification Factor (Ic) = 2.5  
- The Component Response Factor (Rc) = 4.5  
- Anchorage of the Braced Component is in the in the TOP 1/3 OF THE BUILDING. (z) = 3 and (h) = 3

Max. Seismic Design Forced (Fp) Formula:

\[
F_p = 1.6 \text{ Sds} / p W_p = 1.6 \times 0.733 \times 1.5 \times W_p = 1.76 W_p
\]

**BASE Seismic Design Forced (Fp) Formula:**

\[
F_p = \frac{0.4 \text{ Sds} / p W_p}{(1 + 2 \frac{z}{h})} = \frac{0.4 \times 2.5 \times 0.733 \times W_p}{(1 + 2 \frac{3}{3})} = 0.73 W_p
\]

Min. Seismic Design Forced (Fp) Formula:

\[
F_p = 0.3 \text{ Sds} / p W_p = 0.3 \times 0.733 \times 1.5 \times W_p = 0.33 W_p
\]

The APPLICABLE (Fp) is 0.73Wp  
The ASD (Allowable Stress Design) HLF (Cp in NFPA-13) = 0.7 Fp  
**THEREFORE**, the Horizontal Load Factor (HLF) = 0.51
Seismic Calculation For
Lateral Brace on 4 in. Sch 10 Fire Sprinkler Piping w/ZOI ≤ 471 lb and ≤ 40 ft Spacing.

<table>
<thead>
<tr>
<th>Horizontal Earthquake Load (Fpw)</th>
<th>ZONE OF INFLUENCE CALCULATION for Fire Sprinkler Piping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone of Influence (ZOI) wt (lb) = 471.20 + 15% Ftg Allowance (See Remarks - Max. Fpw)</td>
<td></td>
</tr>
<tr>
<td>Brace Zone of Influence (ZOI) WL = TOTAL ZOI WT = 471.2 lb x 1.15 = 541.88 lb</td>
<td></td>
</tr>
<tr>
<td>Horizontal Load Factor (HLF or Cp) = 0.51</td>
<td></td>
</tr>
<tr>
<td>Horizontal Earthquake Load (Fpw) = Zone of Influence Wt x HLF = 541.88 lb x 0.51 = 276 lb FPW = 276 lb</td>
<td></td>
</tr>
<tr>
<td>TOTAL Zone of Influence Weight (lb) = 471.20</td>
<td></td>
</tr>
</tbody>
</table>

Seismic Brace Size

The LOAD RATING for Size XX Seismic Brace is 600 lb
The allowable Horizontal Earthquake Load on the Seismic Brace = LOAD RATING x sin Brace Angle from Vertical.

The Allowable Horizontal Earthquake Load on Size XX Brace = 600 x sin 30 = 600 x 0.500 = 300 lb
300 lb > 276 lb Fpw
THEREFORE; Size XX Brace at a Brace Angle of 30 degrees or more From Vertical OK.

Anchorage in 4000 psi NORMAL-WEIGHT CONCRETE using the XXX End Fitting

The Allowable Horizontal Load Carrying Capacity of the 1/2 in. x 41/2 in. XXXXXX Wedge Anchor is based or 3.75 in. Embedment.
Fastener Orientation A and a Brace Angle of 30 Degrees From Vertical.

Concrete Anchor Allowable Horizontal Load Carrying Capacity Formula:

\( (TPr / Tallow) + (V / Vallow) \leq 1.2 \)

Where:
- \( I \) = Applied Service Tension Load
- \( P_r \) = Prying Effect
- \( Tallow = \) Allowable Service Tension Load
- \( V \) = Applied Service Shear Load
- \( Vallow = \) Allowable Service Shear Load

Fastener Orientation 2 Prying Factor Formula:

\( P_r = (((C + A) / \tan \theta) - D) / A \)

Where:
- \( P_r \) = Prying Effect
- \( \tan \theta = \) Tangent of Brace Angle from Vertical
- \( A = 0.7000 \)
- \( B = 0.8000 \)
- \( C = 0.9620 \)
- \( D = 0.5890 \)

HORIZONTAL EARTHQUAKE LOAD CARRYING CAPACITY OF THE 1/2 in. x 4 1/2 in. Powers SD2

Where:
- Allowable Horizontal Earthquake Load (Fpw) = 621 lb per Anchor
- Allowable Seismic Tension Load (Per ICC-ES Report XXXX - 2162 lb)
- Allowable Seismic Shear Load (Per ICC-ES Report XXXX - 2417 lb)

621 lb Allowable Fpw on (1) 1/2 in. x 4 1/2 in. XXXXXX Wedge Anchor > 359 lb Fpw*;
THEREFORE, 1/2 in. x 4 1/2 in. XXXXXX Wedge Anchor at a Brace Angle of 30 degrees or more from Vertical OK.

* ASD Calculations based ACSE 7-XX 13.4.2, the ICC-ES Report and ACI 318-14, Chapter 17 (See Page 3)

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NFPA 200 (2 of 3)
ROD STIFFENER REQUIREMENTS - SINGLE HANGER

Piping and Conduit

Upward Vertical Earthquake Load Formula: $F_{vs} = \left( \frac{HLF}{\tan \theta} + F_{vsx} \right) W_p$

Where:
- $HLF$ = The Horizontal Load Factor
- $\tan \theta$ = Tangent of Sway brace Angle from Vertical
- $F_{vsx}$ = Operating Weight of braced Component (Dead Load)
- $W_p$ = NET UPWARD VERTICAL Force or NFPA 280 CP Exemption
  - $F_{vs} = \left( \frac{HLF}{\tan \theta} + F_{vsx} \right) W_p - 0.6 W_p$
  - $F_{vs} = \left( (0.51 / 0.5774) + (0.7 \times 2.0 \times 0.733) \right) \times 541.88 - 0.6 W_p$
  - $F_{vs} = \left( (0.885 + 0.103 \times 541.88 \right) - 325.128 = 210 \text{ lb}$
- The Net Upward Vertical Load is $210 \text{ lb}$

Maximum Length of Un-Braced 3/8 in. Dia. Hanger Rod Formula is: $KV_r \leq 200$

AISC 360 Design Comp. Strength (ASD/ksi) = $P_n / \sigma_c$

Where:
- $P_n = FcvAg$
- $Fcv$ = Critical Stress per EQ. E3-2 or E3-3
- $Ag$ = Gross Cross-sectional Area = 0.07
- $\sigma_c = 1.67$ Safety Factor

If $KV_r \leq 4.71 \times \sqrt{E/F_y}$, then $Fcr = (0.658 \times (Fy / Fe)) Fy$

If $KV_r \leq 4.71 \times \sqrt{E/F_y}$, then $Fcr = 0.877Fe$

$E$ = Modulus of Elasticity = 29,000 Ksi

$Fy$ = Specified Minimum Yield Strength = 36 ksi

$4.71 \times \sqrt{E/F_y} (29,000 \text{ ksi} / 36 \text{ ksi}) = 133.68 \text{ ksi}$

$K = AISC 360$ Factor for the Buckled Shape = 1.00

$I = Maximum \text{ Length of unbraced rod or maximum Rod Stiffener Clip Spacing} = 16 \text{ in.}$

$r = The \ Hanger \ rod \ Least \ Radius \ Of \ Gyration \ = 0.0785$

(Based on the Roof Properties of 3/8 in. dia. Rod)

$KV_r > 200.00$

$Fe = \pi^2 E^2 / (KV_r)^2$

$Fe = 9.8696 \times 29,000 / (1 \times 15.70 / 0.0785)^2 = 7.155$

$KV_r > 133.68$

THEREFORE; $Fe = 0.877Fe$

$Fe = 0.877 \times 7.155 = 6.275$

The Allowable Stress Design (ASD) Shear and Tension values reflected in this report were calculated based on the requirements of ASCE 7-XX, ACI 318-XX Chapter 17 and the anchor manufacturer's ICC-ES Report with the following assumptions regarding installation:

1. The anchors will be installed in accordance with ICC-ES Evaluation Report ESR-XXXX
2. The Minimum Concrete Thickness is $\geq$ the value of $h_{min}$ in ESR-XXXX
3. The Minimum Edge Distance is $\geq$ the value of $C_{ac}$ in ESR-XXXX
4. The remaining Three Edge Distances are $\geq 1.5 \times$ the value of $C_{ac}$ in ESR-XXXX

Remarks:

Max. $F_{pw}$ of 769 lb is per the NFPA 13 formula for pipe with 4.25 in. ID, 4.5 in. OD and = 30ksi $F_y$

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A.7.1.1.2.2

See Figure A.7.1.1.2.2. [15:A.6.3.2.2.2]

Figure A.7.1.1.2.2 Typical Arrangement of Support Legs for Pipe Stands. [15:Figure A.6.3.2.2.2]

A.7.1.1.2.5

See Figure A.7.1.1.2.5. [15:A.6.3.2.2.5]

Figure A.7.1.1.2.5 Sway/Support Brace. [15:Figure A.6.3.2.2.5]
Diagonal Brace

Note: Where diagonal braces are used as supports, the maximum dimension between support legs can be exceeded by one-half the total horizontal distance of the diagonal braces.
A.7.1.1.2.7

See Figure A.7.1.1.2.7. [15:A.6.3.2.2.7]

Figure A.7.1.1.2.7 Support Leg Footings. [15:Figure A.6.3.2.2.7]
Support Leg Footings

- 3 7/8 in. (91 mm) diameter bolt circle with 1 1/2 in. (40 mm) x 5 in. (127 mm) flange
- 4 3/4 in. (100 mm) diameter bolt circle with 2 in. (50 mm) x 6 in. (150 mm) flange
- 5 1/2 in. (140 mm) diameter bolt circle with 2 1/2 in. (65 mm) x 7 in. (127 mm) flange
- 6 in. (152 mm) diameter bolt circle with 3 in. (80 mm) x 7 1/2 in. (190 mm) flange

Grade to Concrete footing or pier with this dimension at a depth to be below the frost line.
A.7.1.1.2.8

See Figure A.7.1.1.2.8(a) through Figure A.7.1.1.2.8(d). [15:A.6.3.2.2.8]

Figure A.7.1.1.2.8(a) Typical Pipe Stand Bracket. [15:Figure A.6.3.2.2.8(a)]

![Diagram of a typical pipe stand bracket.]

Note: Pipe stand brackets are now replacing the old style pipe stand without the bracket. The bracket makes installation easier and allows for adjustment horizontally and vertically. The standard bracket is made to fit 2 in. (50 mm), 2½ in. (65 mm), or 3 in. (80 mm) pipe stands.

Figure A.7.1.1.2.8(b) Acceptable Attachment for Pipe to Support Legs — Example 1. [15:Figure A.6.3.2.2.8(b)]
**PLAN**

- **Cap**
- **Standard U-bolt** (size based on loop piping dia.)
- **Pipe clamp** (size based on pipe stand dia.)
- **Hex nuts both sides**
- **Standard M.I. flange**

**SECTION A–A**

1. Ring — support leg — 1 size smaller than ring size but not less than 2 in. (50 mm)
2. Ring — support leg — Same size as top ring but not more than 3 in. (80 mm) or less than 2½ in. (65 mm)
Figure A.7.1.1.2.8(c) Acceptable Attachment for Pipe to Support Legs — Example 2.  
[15:Figure A.6.3.2.2.8(c)]

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A.7.1.1.6

In cases where the piping cannot be supported by structural members, piping arrangements that are essentially self-supporting are often employed together with such hangers as are necessary. [15:A.6.3.2.6]

A.7.1.1.7

The performance of piping support systems should allow for expansion and contraction due to temperature change, expansion due to internal water pressure (thrust), restrained and/or unrestrained joints or pipe runs, heavy point loads (e.g., valves), and pipe deflection (span/support spacing). Manufacturer’s installation instructions and engineering design guides should be consulted. [15:A.6.3.2.7]

A.8.1.3

The weight of the system during hydrostatic or pneumatic testing should be considered.
The weight of fluid-filled pipe or tube can be calculated per the applicable pipe or tube standard. Table A.0(a) through Table A.0(f) lists the weight of fluid-filled pipes with a specific gravity of 0.5, 1.0, and 1.7. It is the responsibility of the design engineer to determine the specific gravity required.

### Table A.8.1.3(a) Fluid-Filled Sch 40 Steel Pipe Weight (lb/ft)

<table>
<thead>
<tr>
<th>Nominal Pipe or Tube Size (in.)</th>
<th>¼</th>
<th>½</th>
<th>¾</th>
<th>1</th>
<th>1¼</th>
<th>1½</th>
<th>2</th>
<th>2½</th>
<th>3</th>
<th>3½</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>SG = 0.5</td>
<td>0.5</td>
<td>0.9</td>
<td>1.3</td>
<td>1.9</td>
<td>2.6</td>
<td>3.2</td>
<td>4.4</td>
<td>6.8</td>
<td>9.2</td>
<td>11.3</td>
<td>13.6</td>
<td>19.0</td>
<td>25.3</td>
<td>39.4</td>
</tr>
<tr>
<td>SG = 1.0</td>
<td>0.5</td>
<td>1.0</td>
<td>1.4</td>
<td>2.1</td>
<td>1.9</td>
<td>3.6</td>
<td>5.1</td>
<td>7.9</td>
<td>10.8</td>
<td>13.4</td>
<td>16.3</td>
<td>23.3</td>
<td>31.5</td>
<td>50.3</td>
</tr>
<tr>
<td>SG = 1.7</td>
<td>0.5</td>
<td>1.1</td>
<td>1.5</td>
<td>2.3</td>
<td>3.4</td>
<td>4.2</td>
<td>6.9</td>
<td>9.3</td>
<td>13.0</td>
<td>16.4</td>
<td>20.2</td>
<td>29.4</td>
<td>40.3</td>
<td>65.4</td>
</tr>
</tbody>
</table>

### Table A.8.1.3(b) Fluid-Filled Sch 40 Steel Pipe Weight (kg/m)

<table>
<thead>
<tr>
<th>Nominal Pipe Size (mm)</th>
<th>8</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>32</th>
<th>40</th>
<th>50</th>
<th>65</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>125</th>
<th>150</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>SG = 0.5</td>
<td>0.7</td>
<td>1.3</td>
<td>1.9</td>
<td>2.8</td>
<td>3.9</td>
<td>4.8</td>
<td>6.5</td>
<td>10.1</td>
<td>13.7</td>
<td>16.8</td>
<td>20.2</td>
<td>28.3</td>
<td>37.6</td>
<td>58.6</td>
</tr>
<tr>
<td>SG = 1.0</td>
<td>0.7</td>
<td>1.5</td>
<td>2.1</td>
<td>3.1</td>
<td>2.8</td>
<td>5.4</td>
<td>7.6</td>
<td>11.8</td>
<td>16.1</td>
<td>19.9</td>
<td>24.3</td>
<td>34.7</td>
<td>46.9</td>
<td>74.8</td>
</tr>
<tr>
<td>SG = 1.7</td>
<td>0.7</td>
<td>1.6</td>
<td>2.2</td>
<td>3.4</td>
<td>5.1</td>
<td>6.2</td>
<td>9.1</td>
<td>13.8</td>
<td>19.3</td>
<td>24.4</td>
<td>30.1</td>
<td>43.7</td>
<td>60.0</td>
<td>97.3</td>
</tr>
</tbody>
</table>

### Table A.8.1.3(c) Fluid-Filled Sch 80 Steel Pipe Weight (lb/ft)

<table>
<thead>
<tr>
<th>Nominal Pipe Size (in.)</th>
<th>¼</th>
<th>½</th>
<th>¾</th>
<th>1</th>
<th>1¼</th>
<th>1½</th>
<th>2</th>
<th>2½</th>
<th>3</th>
<th>3½</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>SG = 0.5</td>
<td>0.6</td>
<td>1.1</td>
<td>1.6</td>
<td>2.3</td>
<td>3.3</td>
<td>4.0</td>
<td>5.7</td>
<td>8.6</td>
<td>11.7</td>
<td>14.4</td>
<td>17.5</td>
<td>24.7</td>
<td>34.2</td>
<td>53.3</td>
</tr>
<tr>
<td>SG = 1.0</td>
<td>0.6</td>
<td>1.2</td>
<td>1.7</td>
<td>2.5</td>
<td>3.6</td>
<td>4.4</td>
<td>6.3</td>
<td>9.5</td>
<td>13.1</td>
<td>16.4</td>
<td>20.0</td>
<td>28.7</td>
<td>39.9</td>
<td>63.2</td>
</tr>
<tr>
<td>SG = 1.7</td>
<td>0.6</td>
<td>1.3</td>
<td>1.8</td>
<td>2.7</td>
<td>3.9</td>
<td>4.9</td>
<td>7.2</td>
<td>10.8</td>
<td>15.1</td>
<td>19.1</td>
<td>23.5</td>
<td>34.2</td>
<td>47.8</td>
<td>77.1</td>
</tr>
</tbody>
</table>

### Table A.0(d) Fluid-Filled Sch 80 Steel Pipe Weight (kg/m)

<table>
<thead>
<tr>
<th>Nominal Pipe Size (mm)</th>
<th>8</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>32</th>
<th>40</th>
<th>50</th>
<th>65</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>125</th>
<th>150</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>SG = 0.5</td>
<td>0.7</td>
<td>1.3</td>
<td>1.9</td>
<td>2.8</td>
<td>3.9</td>
<td>4.8</td>
<td>6.5</td>
<td>10.1</td>
<td>13.7</td>
<td>16.8</td>
<td>20.2</td>
<td>28.3</td>
<td>37.6</td>
<td>58.6</td>
</tr>
<tr>
<td>SG = 1.0</td>
<td>0.7</td>
<td>1.5</td>
<td>2.1</td>
<td>3.1</td>
<td>2.8</td>
<td>5.4</td>
<td>7.6</td>
<td>11.8</td>
<td>16.1</td>
<td>19.9</td>
<td>24.3</td>
<td>34.7</td>
<td>46.9</td>
<td>74.8</td>
</tr>
<tr>
<td>SG = 1.7</td>
<td>0.7</td>
<td>1.6</td>
<td>2.2</td>
<td>3.4</td>
<td>5.1</td>
<td>6.2</td>
<td>9.1</td>
<td>13.8</td>
<td>19.3</td>
<td>24.4</td>
<td>30.1</td>
<td>43.7</td>
<td>60.0</td>
<td>97.3</td>
</tr>
</tbody>
</table>
A.8.1.5.1

Detection system components can be considered part of the system.

A.8.2.2

Hangers and supports can be designed and manufactured per the requirements of MSS SP-58, *Pipe Hangers and Supports — Materials, Design, Manufacture, Selection, Application, and Installation.*

A.8.2.5

See Figure A.8.2.5(a) through Figure A.8.2.5(c).

**Figure A.8.2.5(a) Example of a Hanger and Restraint Assembly.**

---

**Table A.8.1.3(e) Fluid-Filled Type-L Copper Tube Weight (lb/ft)**

<table>
<thead>
<tr>
<th>Nominal Tube Size (in.)</th>
<th>¼</th>
<th>½</th>
<th>¾</th>
<th>1</th>
<th>1¼</th>
<th>1½</th>
<th>2</th>
<th>2½</th>
<th>3</th>
<th>3½</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>SG = 0.5</td>
<td>0.1</td>
<td>0.3</td>
<td>0.6</td>
<td>0.8</td>
<td>1.2</td>
<td>1.5</td>
<td>2.4</td>
<td>3.5</td>
<td>4.8</td>
<td>6.3</td>
<td>8.0</td>
<td>11.7</td>
<td>16.0</td>
<td>29.5</td>
</tr>
<tr>
<td>SG = 1.0</td>
<td>0.2</td>
<td>0.4</td>
<td>0.7</td>
<td>1.0</td>
<td>1.4</td>
<td>1.9</td>
<td>3.1</td>
<td>4.5</td>
<td>6.3</td>
<td>8.3</td>
<td>10.6</td>
<td>15.7</td>
<td>21.8</td>
<td>39.6</td>
</tr>
<tr>
<td>SG = 1.7</td>
<td>0.2</td>
<td>0.5</td>
<td>0.8</td>
<td>1.3</td>
<td>1.8</td>
<td>2.5</td>
<td>4.0</td>
<td>6.0</td>
<td>8.3</td>
<td>11.1</td>
<td>14.2</td>
<td>21.4</td>
<td>30.0</td>
<td>53.8</td>
</tr>
</tbody>
</table>

**Table A.8.1.3(f) Fluid-Filled Type-L Copper Tube Weight (kg/m)**

<table>
<thead>
<tr>
<th>Nominal Tube Size (in.)</th>
<th>8</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>32</th>
<th>40</th>
<th>50</th>
<th>65</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>125</th>
<th>150</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>SG = 0.5</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.4</td>
<td>0.5</td>
<td>0.7</td>
<td>1.1</td>
<td>1.6</td>
<td>2.2</td>
<td>2.9</td>
<td>3.6</td>
<td>5.3</td>
<td>7.3</td>
<td>13.4</td>
</tr>
<tr>
<td>SG = 1.0</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.5</td>
<td>0.6</td>
<td>0.9</td>
<td>1.4</td>
<td>2.1</td>
<td>2.8</td>
<td>3.8</td>
<td>4.8</td>
<td>7.1</td>
<td>9.9</td>
<td>18.0</td>
</tr>
<tr>
<td>SG = 1.7</td>
<td>0.1</td>
<td>0.2</td>
<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
<td>1.1</td>
<td>1.8</td>
<td>2.7</td>
<td>3.8</td>
<td>5.0</td>
<td>6.4</td>
<td>9.7</td>
<td>13.6</td>
<td>24.4</td>
</tr>
</tbody>
</table>
Figure A.8.2.5(b) Example of a Hanger and Restraint Assembly.
Figure A.8.2.5(c) Example of a Hanger and Restraint Assembly.
A.8.2.6

Beam clamps should be positively engaged to a beam to eliminate risk of the beam clamp detaching during system discharge or during a seismic event. Beam clamps held to a beam with a set screw (e.g., C-style beam clamps) cannot be used unless they can be positively engaged to the beam. (See Figure A.8.2.6(a) and Figure A.8.2.6(b).)

Figure A.8.2.6(a) Example of an Acceptable Positively Engaged Beam Clamp.

![Diagram of a positively engaged beam clamp](image)

Figure A.8.2.6(b) Example of an Unacceptable Beam Clamp Engaged with a Set Screw.
A.8.4.3


A.8.4.5.1

Restraint minimum design loads in Table 8.4.5(a) and Table 8.4.5(b) were calculated using a specific gravity of 1.0, assume a 90-degree elbow, a fluid velocity of 50 ft/s (15.2 m/s), and only consider mass flow.

A.8.5.4

Maximum allowable span lengths in Table 8.4.5(a) and Table 8.5.4(b) were calculated using an allowable bending stress of 12,900 psi (88.9 MPa) for channel and 16,600 psi (114.5 MPa) for angle iron, a maximum deflection of 0.25 in. (6.4 mm), and the trapeze was considered to be supported with a center concentrated load. The piping system was assumed to be Sch 80 steel pipe filled with fluid with a specific gravity of 1.0. Additionally, the span lengths were limited by a kl/r ratio of 200 to allow the trapeze members to be used for restraint and bracing applications. (See Figure A.8.5.4(a) and Figure A.8.5.4(b).)

Figure A.8.5.4(a) Typical Hanger and Restraint Trapeze Channel and Angle Iron Profiles.
Figure A.8.5.4(b) Typical Trapeze Hanger and Restraint Components.
A.8.7.3

See Figure A.8.7.3.

**Figure A.8.7.3 Restrainment Exclusion at a Double Change of Direction.**

A.8.7.4

See Figure A.8.7.4.

**Figure A.8.7.4 Typical Trapeze Hanger and Restrainment Components.**
A.8.7.5

See Figure A.8.7.5.

Figure A.8.7.5 Nozzle Restraint Location.
A.8.7.6

See Figure A.8.7.6.

**Figure A.8.7.6 Nozzle Restraint Locations.**
A.9.4.4

A bracing system of metal straps or storage racks provides a dependable method of securing agent storage containers. Metal straps at the bottom and top one third of each agent container provide protection against tipping and falling.

A.10.5

The FSSA Pipe Design Handbook for Use with Special Hazards Fire Suppression Systems provides guidance on pipe support and hangers.

A.14.2.1

Housekeeping pads are used to mount equipment above the structural slab, thereby keeping them out of water caused by leaks or flushing of systems and can be the structural interface between the equipment and the structural slab. Housekeeping pads are not required for every installation.
A.14.2.2.1

Flexible couplings are used to compensate for temperature changes and to permit end movement of the connected shafts without interfering with each other. [20:A.6.4.1]

A.14.2.2.2

See Figure A.14.2.2.2.

Figure A.14.2.2.2 Overhung Impeller — Closed Coupled Single Stage — In-Line (Showing Seal and Packaging). [20:Figure A.6.1.1(c)]
A.14.2.2.4

A substantial foundation is important in maintaining alignment. The foundation preferably should be made of reinforced concrete. [20:A.6.4.4]

A.14.2.5.2

Figure A.14.2.5.2 illustrates a typical foundation detail for a packaged fire pump assembly. [20:A.4.31.9]
Figure A.14.2.5.2  Typical Foundation Detail for Packaged Fire Pump Assembly. [20:Figure A.4.31.9]

A.14.3.2

This chapter contains specific requirements for seismic design of fire pumps. It is a simplified approach that was developed to coincide with ASCE/SEI 7, Minimum Design Loads for Buildings and Other Structures, and current building codes. [20:A.4.30.2]

A.14.3.3.1.1

See Figure A.14.3.3.1.1.
Figure A.14.3.3.1.1 Typical Detail of a Reinforced Concrete Pad.

A.14.3.3.2

The top bracing for these pumps will connect to the pump above its center of gravity. The opposite end of the bracing can connect to the floor or the mounting structure for the pump. [20:A.4.30.3.2]

A.14.3.3.3

The exhaust piping from diesel fire pumps can be secured by following the criteria in Chapter 5. [20:A.4.30.3.3]

A.14.3.3.4.1

Hangers that offer lateral restraint on these smaller diameter trim lines should be sufficient. [20:4.30.3.4.1]

A.16.2.2

Tanks, and their supports, anchorage, and foundations; must be designed for appropriate combinations of several basic load conditions. At a minimum, they must resist dead, liquid live, and roof live loads. Where snow loads are greater, they are used in lieu of the rooflive load. Tanks, supports, anchorage, and foundations that are not buried or protected within a building must be designed for wind load. If buried they must be designed for...
earth or groundwater pressures, or both, and where subject to earthquake they must be designed to resist earthquake forces.

The specific design loads depend on the facility location (e.g., to determine the controlling wind speed and earthquake acceleration parameters) and the tank’s location within that facility (e.g., a tank located inside a building would not need to be designed for wind forces or snow loads), as well as the tank’s configuration (e.g., if it is an elevated tank, a ground-supported suction tank or a buried tank).

The load combinations that control the design of various elements can vary. For example, since a tank could be full, partially full, or empty, the condition that is most conservative for the element being designed should be used. The controlling case for anchorage that resists wind forces on an exterior abovegrade tank or buoyancy forces on a buried tank would likely be associated with an empty tank, while for earthquake the largest forces on anchors would likely occur when the tank was full. Likewise, since roof live or snow loads can be applied to only a portion of the roof, partial loading should be considered if this produces a more unfavorable load effect than if the load is applied over the full structure or member. Some combinations of basic load conditions are not required to be considered, for example, it is assumed that wind and earthquake forces will not occur simultaneously.

A.16.2.2.2

Design of concrete structures and foundations is almost exclusively based on load and resistance factor design (LRFD) and LRFD methodologies have been used in ACI 318, Building Code Requirements for Structural Concrete and Commentary, since the 1970s. Allowable stress design (ASD) is still widely used for most other materials, such as steel and wood. Where LRFD is used, both loads and capacities must be consistent with the LRFD method. It is critical that LRFD capacities, for example, for postinstalled concrete anchors, not be used where loads and load factors are based on ASD.

A.16.2.3.2

The unit weight of steel is typically taken as 490 lb/ft³ (7849 kg/m³); the unit weight of normal weight concrete is commonly considered to be 144 to 150 lb/ft³ (2307 to 2403 kg/m³). The unit weight of wood is approximately 30 lb/ft³ (481 kg/m³).

A.16.2.4.2.1

Reduction of roof live loads is often allowed in local building codes as the tributary area supported by the member becomes larger or the roof slope becomes steeper.

A.16.2.6.1

Because soil conditions can be highly variable and complex, guidance is typically established by a geotechnical or civil engineer. Some building codes provide general guidance where soils are relatively uniform.

A.16.2.7.1
These pressures assume a wind speed from the 2005 (or earlier) edition of ASCE/SEI 7, *Minimum Design Loads for Buildings and Other Structures*, of 100 mph (161 km/hr), or a wind speed from the 2010 (or later) edition of ASCE/SEI 7 of 130 mph (209 km/hr). For faster wind speeds, these pressures must be increased (see 16.2.7.2 and 16.2.7.3). These ASCE/SEI 7 wind speeds differ because in 2005 wind speed maps were based on ASD and an importance factor of 1.0, but since 2010 maps are based on LRFD and importance factor of 1.15. See A.16.2.7.2 and A.16.2.7.3 for more information.

A.16.2.7.2

Calculated ASCE/SEI 7-05, *Minimum Design Loads for Buildings and Other Structures*, wind loads, like those in 16.2.7.1, are allowable stress design (ASD) and are derived from the same wind speed data. In both, the 3-second gust basic wind speeds are based on the 50-year mean return interval (MRI) and the importance factor for Risk Category IV structures, such as fire protection system tanks, of 1.15 is not included in the mapped wind speeds but is applied separately. Therefore, the 16.2.7.1 pressures can be directly adjusted using the basic wind speeds from ASCE/SEI 7-05 or wind speeds derived in an equivalent manner.

If a non-ASCE/SEI 7-05 standard provides wind speeds using a different unit (e.g., fastest-mile or 10-minute), these must be converted to equivalent 3-second gust speeds at a 50-year MRI such that they are equivalent to the ASCE/SEI 7-05 values.

Where the ASCE/SEI 7-05 wind speeds (or equivalent) exceed 100 mph (161 km/hr), 16.2.7.1 pressures should be divided by the square of 100 mph (161 km/hr), which was the assumed wind speed used to generate the pressures, and then be multiplied by the square of the actual wind speed.

A.16.2.7.3

The 3-second gust basic wind speeds in ASCE/SEI 7-10, *Minimum Design Loads for Buildings and Other Structures*, and ASCE/SEI 7-16, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, are shown in separate maps vs. risk category. Unlike ASCE/SEI 7-05, these maps directly incorporate the importance factor and are associated with longer MRI such that wind forces calculated from them are load and resistance factor design (LRFD), instead of ASD. Therefore, the basic wind speed for Risk Category IV from ASCE/SEI 7-10 or ASCE/SEI 7-16 will be higher than earlier editions of ASCE/SEI 7 and the adjustment factor to be applied to 16.2.7.1 pressures must be calculated differently. Even though wind loads calculated using ASCE/SEI 7-10 and ASCE/SEI 7-16 would be LRFD, the factor determined in this section will still yield ASD loads since the loads in 16.2.7.1 to which it is applied are ASD loads.

Where the ASCE/SEI 7-10 or ASCE/SEI 7-16 wind speeds (or equivalent) exceed 130 mph (209 km/hr), 16.2.7.1 pressures should be divided by the square of 130 mph (209 km/hr), which was the assumed LRFD wind speed used to generate the pressures, and then be multiplied by the square of the actual LRFD wind speed.
A.16.2.8.3

The effective mass method for flat-bottom tanks supported at or below grade is outlined for cylindrical welded steel tanks in AWWA D100, *Welded Carbon Steel Tanks For Water Storage*, for cylindrical bolted steel tanks in AWWA D103, *Factory-Coated Bolted Carbon Steel Tanks For Water Storage*, and for rectangular concrete tanks in ACI 350.3, *Code Requirements for Seismic Analysis and Design of Liquid-Containing Concrete Structures and Commentary*. Tanks made of other materials such as wood or fiberglass-reinforced plastic, or that are of different configuration such as rectangular pressed-steel panel tanks, should be designed, supported, and anchored using similar methods based on the specific properties of those tanks and materials.

For most equipment (e.g., boilers, chillers, transformers), the horizontal earthquake acceleration acts on the entire mass of the equipment, resulting, at the base of the equipment, in a horizontal shear force (i.e., base shear) and an overturning moment. The overturning moment caused by the horizontal earthquake force is partially or fully resisted by the entire mass of the equipment being acted on by gravity (reduced by the expected vertical earthquake acceleration). Typically, friction is ignored, and the equipment is anchored to resist the earthquake-induced base shear and any residual overturning that is not resisted by the entire self-weight of the equipment.

The water in a flat-bottom tank near grade does not act as a single rigid mass in the same way that a chiller or transformer does. This is accounted for by using the effective mass method.

The contained water in a tank represents most (perhaps 70 percent or more for concrete tanks and 90 percent or more for steel tanks) of the mass subject to earthquake acceleration. As shown in Figure A.16.2.8.3, horizontal seismic accelerations on flat-bottom storage tanks located near grade cause the part of the water near the tank base to move essentially as a rigid mass in unison with the tank walls (this is known as the impulsive liquid mass) while the liquid near the free surface at the top of the tank moves in an oscillating or sloshing motion (this is known as the convective liquid mass).

The relative proportions of the impulsive and convective liquid depend on the ability of the tank to confine the liquid. The greater the confinement, the greater is the impulsive liquid (and, consequently, the earthquake lateral forces) and the smaller is the convective liquid. For example, in a ground-supported cylindrical suction tank with sufficient freeboard and constant water height (H), as the tank diameter (D) decreases, the confinement of the liquid (and, thus, the impulsive liquid weight) increases. The impulsive liquid might be only 20 percent of the total liquid weight when the tank diameter is six times its height, but might be close to 80 percent of the total liquid weight when the tank diameter and height are equal.

The natural period of vibration of the impulsive liquid is low (for ground-supported tanks, it is typically less than the period defined as $T_s = S_{01}/S_{DS}$) and so it experiences high accelerations (based on $S_{DS}$), as does the mass of the tank itself. Conversely, the natural period of vibration of the convective liquid is high (often in the range of 2 seconds to 4 seconds and potentially much higher) and so it experiences much lower accelerations and usually contributes only slightly to the seismic loads in the tank. Therefore, even
when the convective liquid weighs much more than the impulsive liquid, the impulsive liquid still controls the seismic loads (i.e., base shear and overturning moment) in the tank. For ground-supported cylindrical steel tanks, horizontal acceleration of the impulsive water mass typically causes 95 percent or more of the sliding (i.e., base shear) force and 90 percent or more of the overturning moment.

See additional discussion regarding freeboard requirements (the distance between the water surface at the top of the tank and the roof) and anchorage of suction tanks for earthquake forces in A.16.5.4.

**Figure A.16.2.8.3 Effective Mass Method.**

A.16.2.8.4

Unlike flat-bottom tanks located near grade, the entire liquid mass for elevated tanks and pressure tanks is assumed to be acting in an impulsive mode. The convective mode is neglected.

A.16.4.2

The tank itself can be of wood, but members of supporting towers or of supporting buildings should not be wood.

A.16.5.2.1.2

In accordance with AWWA D100, *Welded Carbon Steel Tanks For Water Storage*, the oiled sand mixture should consist of approximately 18 gal (68 L) of No. 2 fuel oil per cubic yard (cubic meter) of sand.
practice, quantities of 6 gal to 9 gal (22.7 L to 34 L) of oil per cubic yard (cubic meter) of sand have been shown to be acceptable. \[22: \text{A.5.4.1}\]

**A.16.5.3.3**

The intent is to provide a factor of safety against wind-caused overturning of 1.5 when the tank is empty.

**A.16.5.4**

See A.16.2.8.3 for additional discussion of the effective mass method used for design of flat-bottom suction tanks. Where insufficient freeboard (i.e., the distance between the water surface at the top of the tank and the roof) is provided, the tank analysis and anchorage forces required should account for this (see 16.5.4.4).

**A.16.5.4.1.1**

Seismic anchorage of flat-bottom water tanks located near grade differs from that of other equipment. First, unlike rigid equipment, very little of the contained water resists overturning. Thin bottom plates of steel or other materials like fiberglass-reinforced plastic can lift only a small amount of water near the tank shell, and this is often insufficient to prevent uplift of the shell. Therefore, uplift anchors are commonly needed. With respect to base shear on the tank, when a bottom plate exists, friction between the tank and the soil or foundation can be used to resist this force (using friction is not allowed for most equipment). Often, this friction is adequate, but if not, additional shear anchorage would be needed.

If a bottom plate is not provided (as sometimes occurs in wood suction tanks and cylindrical steel tanks, both of which have liners to contain the water) then all the uplift at the tank shell and all of the base shear must be resisted by anchors. When a bottom plate exists, anchors around the entire tank perimeter can be taken as effective because the bottom plate stiffens the shell, but when there is no bottom plate only half of the anchors are effective to resist the base shear or overturning (see Figure A.16.5.4.1.1). The use of a tank without a bottom plate is also problematic where earthquake must be resisted because the liner would be subject to damage as the tank slides or uplifts, even if only slightly.

**Figure A.16.5.4.1.1 Plan View at Base of Tank Having No Bottom Plate.**
A.16.5.4.2.2

The design short period spectral response acceleration parameter, $S_{DS}$, can be determined using ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. It is based on the mapped short period spectral response acceleration parameter, $S_s$, adjusted to account for the applicable site class (i.e., local soils). Where the site class is unknown, ASCE 7 allows the use of Site Class D as a default. Table 16.5.4.2.2.1 is based on Site Class D. The factor $(1-0.06S_{DS})$ is intended to estimate the reduction in weight due to vertical acceleration (ASD) as determined in AWWA D100, *Welded Carbon Steel Tanks For Water Storage*.

A.16.5.4.3.2

Most of the water in the tank is not effective in resisting overturning moment from earthquake. Only a small amount directly adjacent to the shell is effective. From AWWA D100, *Welded Carbon Steel Tanks For Water Storage*, $w_L$ is the weight of water adjacent to the tank shell per length of circumference that is effective for overturning resistance. It is determined from the following:

For US Customary units:

$$w_L = 7.9t_b\sqrt{F_y}H \text{ but not more than } 1.28HD$$  \[A.16.5.4.3.2a\]

For SI units:

$$w_L = 99t_b\sqrt{F_y}H \text{ but not more than } 201.1HD$$  \[A.16.5.4.3.2b\]
where:

\[ w_L = \text{the weight of water adjacent to the tank shell per length of circumference that is effective for overturning resistance (lb/ft or N/m)} \]

\[ t_b = \text{the thickness of the tank steel bottom plate adjacent to the shell (in. or mm)} \]

\[ F_y = \text{the published minimum yield stress of the bottom plate steel (psi or MPa)} \]

\[ H = \text{maximum the height of the water in the tank (ft or m)} \]

**A.16.5.4.3.3**

Tension and compression forces resulting from tank overturning are transferred via the tank shell and therefore uplift anchors should be attached directly to the tank shell, bypassing the bottom plate. Anchors resisting earthquake uplift of the tank shell can be subject to forces much larger than the design forces. Therefore, the attachment to the tank and the embedment in the concrete need to be able to develop the tensile strength of the anchor or four times the calculated allowable stress design (ASD) force, whichever is less. AISI T-192, *Steel Plate Engineering Data: Volume 2 – Useful Information on the Design of Plate Structures, Part VII Anchor Bolt Chairs*, provides information on the design of welded steel anchor chairs. See Figure A.16.5.4.3.3 for general information regarding anchorage resisting uplift from earthquake forces.

**Figure A.16.5.4.3.3 Uplift Anchor and Steel Anchor Chair at Bottom of Tank Shell.**
A.16.5.4.4

Sufficient freeboard is needed so that the sloshing waves do not impact the roof during earthquakes. Insufficient freeboard causes: 1) upward load on the roof due to impacts from the sloshing wave, and 2) increase in impulsive mass due to constraining action of the roof. Where provided freeboard is insufficient, some of the liquid that would have responded in a convective mode instead responds in an impulsive mode. Since the convective accelerations of common suction tanks range from about 10 percent to 30 percent of impulsive accelerations, the increase in impulsive liquid weight resulting from confinement of the water by the roof can significantly increase earthquake forces on the tank. Where up-and-down movement of the free surface is restricted by other means (e.g., by adding baffles in the tank), these also confine the liquid, increasing the impulsive mass and, hence, the seismic forces. If no freeboard is provided, all the water in the tank will act as an impulsive mass.

A.16.9.1

The standard capacities shall be from 2000 gal to 50,000 gal (7.7 m³ to 190 m³). Tanks of other capacities are permitted [22:A.11.3]

A.16.9.3

Presently, there is no standard for designing or assessing fiberglass tanks for seismic loadings, but the principles found in 16.2.8 and 16.5.4 are generally applicable. Strengths of fiberglass-resin laminates are
based on testing, unlike steel for which there are standard material specifications. Fiberglass does not have the ductility typically associated with steel and its properties are anisotropic (i.e., having different strengths parallel and perpendicular to the fibers).

A.16.11.1

Typical installation of an embankment-supported coated fabric suction tank is shown in Figure A.16.11.1.

Figure A.16.11.1 Typical Installation Details of an Embankment-Supported Coated Fabric Suction Tank, Including Fittings. [22:Figure B.1(e)]
A.16.13.4.1.5

Postinstalled concrete anchors are undesirable because their capacities are highly variable and depend on the manufacturer, the quality of installation, whether the concrete cracks, how the concrete is reinforced, the embedment length, the distance from the anchor to concrete edges and adjacent anchors, and so on.

In particular, postinstalled concrete anchors should not be used to resist uplift forces because the failure mode can be nonductile (brittle) or sudden (e.g., splitting or cone failure of the concrete, or slippage of the...
anchor in the drilled hole) and embedment is often insufficient to develop the tensile strength of the anchor steel.

In limited cases where anchors are installed far from concrete edges, postinstalled concrete anchors might be tolerable to resist shear forces. If used to resist seismic shear, anchors should be prequalified for shear and tension in cracked concrete for seismic applications in regions of moderate and high seismic risk (e.g., Seismic Design Category C through F in ASCE/SEI 7, Minimum Design Loads and Associated Criteria for Buildings and Other Structures) in accordance with ACI 355.2, Qualification of Post-Installed Mechanical Anchors in Concrete, or ACI 355.4, Qualification of Post-Installed Adhesive Anchors in Concrete; and designed in accordance with ACI 318, Building Code Requirements for Structural Concrete and Commentary; or equivalent local building code or standards.

A.16.14.1

The use of a tank, in part, for purposes other than fire protection, is not advised. Frequent circulation of the water results in an accumulation of sediment that can obstruct the piping of sprinklers, and a fluctuating water level hastens decaying of wood and corrosion of steel. [22:A.14.1.7]

A.18.1
It is a fundamental design principle of fluid mechanics that dynamic and static pressures, acting at changes in size or direction of a pipe, produce unbalanced thrust forces at locations such as bends, tees, wyes, dead ends, and reducer offsets. This design principle includes consideration of lateral soil pressure and pipe/soil friction, variables that can be reliably determined using current soil engineering knowledge. Refer to A.18.1.2 for a list of references for use in calculating and determining joint restraint systems. [24:A.10.6]

Section 18.1 does not mandate which method of restraint should be used. This decision is left to the design professional or the owner. [24:A.10.6]

Except for the case of welded joints and approved special restrained joints, such as is provided by approved mechanical joint retainer glands or locked mechanical and push-on joints, the usual joints for underground pipe are expected to be held in place by the soil in which the pipe is buried. Gasketed push-on and mechanical joints without special locking devices have limited ability to resist separation due to movement of the pipe. [24:A.10.6]

A.18.1.1

The use of concrete thrust blocks is one method of restraint, provided that stable soil conditions prevail and space requirements permit placement. Successful blocking is dependent on factors such as location, availability and placement of concrete, and possibility of disturbance by future excavations. [24:A.10.6.1]

Resistance is provided by transferring the thrust force to the soil through the larger bearing area of the block so that the resultant pressure against the soil does not exceed the horizontal bearing strength of the soil. The design of thrust blocks consists of determining the appropriate bearing area of the block for a particular set of conditions. The parameters involved in the design include pipe size, design pressure, angle of the bend (or configuration of the fitting involved), and the horizontal bearing strength of the soil. [24:A.10.6.1]

Table A.18.1.1(a) gives the nominal thrust at fittings for various sizes of ductile iron and PVC piping. Figure A.18.1.1(a) shows an example of how thrust forces act on a piping bend. [24:A.10.6.1]

Table A.18.1.1(a) Thrust at Fittings at 100 psi (6.9 bar) Water Pressure for Ductile Iron and PVC Pipe
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<thead>
<tr>
<th>Nominai Pipe Diameter in. (mm)</th>
<th>Total Pounds (Newtons)</th>
<th></th>
<th></th>
<th></th>
<th></th>
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<td></td>
<td>Dead End</td>
<td>90 Degree</td>
<td>45 Degree</td>
<td>22 1/2 Degree</td>
<td>11 1/4 Degree</td>
<td>5 1/8 Degree</td>
<td></td>
</tr>
<tr>
<td>lbf N</td>
<td>lbf N</td>
<td>lbf N</td>
<td>lbf N</td>
<td>lbf N</td>
<td>lbf N</td>
<td>lbf N</td>
<td></td>
</tr>
<tr>
<td>4 (100)</td>
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<td>2,559 11,383</td>
<td>1,385 6,161</td>
<td>706 3,140</td>
<td>355 1,579</td>
<td>162 721</td>
<td></td>
</tr>
<tr>
<td>6 (150)</td>
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<td>5,288 23,522</td>
<td>2,862 12,731</td>
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<td>8 (200)</td>
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<td>9,097 40,465</td>
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<td>2,510 11,165</td>
<td>1,261 5,609</td>
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<td>10 (250)</td>
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<td>12 (300)</td>
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<td>9,278 41,271</td>
<td>4,664 20,733</td>
<td>2,126 9,457</td>
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<td>Nominial Pipe Diameter in. (mm)</td>
<td>Total Pounds (Newtons)</td>
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<td>lbf</td>
<td>N</td>
<td>lbf</td>
</tr>
<tr>
<td>18 (450)</td>
<td>29,86</td>
<td>5</td>
<td>132,8</td>
<td>46</td>
<td>42,23</td>
<td>5</td>
<td>187,87</td>
</tr>
<tr>
<td>20 (500)</td>
<td>36,64</td>
<td>4</td>
<td>163,0</td>
<td>01</td>
<td>51,82</td>
<td>2</td>
<td>230,51</td>
</tr>
<tr>
<td>24 (600)</td>
<td>52,27</td>
<td>9</td>
<td>232,5</td>
<td>48</td>
<td>73,93</td>
<td>4</td>
<td>328,87</td>
</tr>
<tr>
<td>30 (750)</td>
<td>80,42</td>
<td>5</td>
<td>357,7</td>
<td>48</td>
<td>113,7</td>
<td>38</td>
<td>505,93</td>
</tr>
<tr>
<td>36 (900)</td>
<td>115,2</td>
<td>09</td>
<td>512,4</td>
<td>75</td>
<td>162,9</td>
<td>31</td>
<td>724,75</td>
</tr>
<tr>
<td>42 (1,050)</td>
<td>155,5</td>
<td>28</td>
<td>691,8</td>
<td>23</td>
<td>219,9</td>
<td>50</td>
<td>978,38</td>
</tr>
<tr>
<td>48 (1,200)</td>
<td>202,6</td>
<td>83</td>
<td>901,5</td>
<td>79</td>
<td>286,6</td>
<td>37</td>
<td>1,275,0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>29,86</td>
<td>5</td>
<td>132,8</td>
<td>46</td>
<td>42,23</td>
<td>5</td>
<td>187,87</td>
</tr>
<tr>
<td></td>
<td>36,64</td>
<td>4</td>
<td>163,0</td>
<td>01</td>
<td>51,82</td>
<td>2</td>
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<td></td>
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<td>9</td>
<td>232,5</td>
<td>48</td>
<td>73,93</td>
<td>4</td>
<td>328,87</td>
</tr>
<tr>
<td></td>
<td>80,42</td>
<td>5</td>
<td>357,7</td>
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<td>113,7</td>
<td>38</td>
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<td>512,4</td>
<td>75</td>
<td>162,9</td>
<td>31</td>
<td>724,75</td>
</tr>
<tr>
<td></td>
<td>155,5</td>
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<td>691,8</td>
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<td>286,6</td>
<td>37</td>
<td>1,275,0</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Notes:

(1) For SI units, 1 lb = 0.454 kg; 1 in. = 25 mm.

(2) To determine thrust at pressure other than 100 psi (6.9 bar), multiply the thrust obtained in the table by the ratio of the pressure to 100 psi (6.9 bar). For example, the thrust on a 12 in. (305 mm), 90-degree bend at 125 psi (8.6 bar) is $19,353 \times \frac{125}{100} = 24,191$ lb (10,973 kg).

Figure A.18.1.1(a) Thrust Forces Acting on Bend. [24:Figure A.10.6.1(a)]
Thrust blocks are generally categorized into two groups — bearing and gravity blocks. Figure A.18.1.1(b) depicts a typical bearing thrust block on a horizontal bend. [24:A.10.6.1]

**Figure A.18.1.1(b) Bearing Thrust Block.** [24:Figure A.10.6.1(b)]
$T$ = thrust force resulting from change in direction of flow

$S_b$ = horizontal bearing strength of soil

$h$ = block height

$H_f$ = total depth to bottom of block
The following are general criteria for bearing block design:

(1) The bearing surface should, where possible, be placed against undisturbed soil.
(2) Where it is not possible to place the bearing surface against undisturbed soil, the fill between the bearing surface and undisturbed soil should be compacted to at least 90 percent Standard Proctor density.
(3) Block height \((h)\) should be equal to or less than one-half the total depth to the bottom of the block \((H_t)\) but not less than the pipe diameter \((D)\).
(4) Block height \((h)\) should be chosen so that the calculated block width \((b)\) varies between one and two times the height.
(5) Gravity thrust blocks can be used to resist thrust at vertical down bends. In a gravity thrust block, the weight of the block is the force providing equilibrium with the thrust force. The design problem is then to calculate the required volume of the thrust block of a known density. The vertical component of the thrust force in Figure A.18.1.1(c) is balanced by the weight of the block. For required horizontal bearing block areas, see Table A.18.1.1(b).

\[24:\text{A.10.6.1}\]

The required block area \((A_b)\) is as follows:

\[A_b = (h)(b) = \frac{T(S_f)}{S_b}\]  

\[\text{[A.18.1.1a]}\]

where:
\[ A_b = \text{required block area (ft}^2) \]

\[ h = \text{block height (ft)} \]

\[ b = \text{calculated block width (ft)} \]

\[ T = \text{thrust force (lbf)} \]

\[ S_f = \text{safety factor (usually 1.5)} \]

\[ S_b = \text{bearing strength (lb/ft}^2) \]

[24:A.10.6.1]

Then, for a horizontal bend, the following formula is used:

\[ b = \frac{2(S_f)(P)(A)\sin\left(\frac{\theta}{2}\right)}{(h)(S_b)} \]  

[A.18.1.1b]

where:
\[ b = \text{calculated block width (ft)} \]

\[ S_f = \text{safety factor (usually 1.5 for thrust block design)} \]

\[ P = \text{water pressure (lb/in.}^2\text{)} \]

\[ A = \text{cross-sectional area of pipe based on outside diameter} \]

\[ h = \text{block height (ft)} \]

\[ S_b = \text{horizontal bearing strength of soil (lb/ft}^2\text{)(in.}^2\text{)} \]

[24:A.10.6.1]

A similar approach can be used to design bearing blocks to resist the thrust forces at locations such as tees and dead ends. Typical values for conservative horizontal bearing strengths of various soil types are listed in Table A.18.1.1(c). [24:A.10.6.1]

**Figure A.18.1.1(c) Gravity Thrust Block. [24:Figure A.10.6.1(c)]**
$T = \text{thrust force resulting from change of direction of flow}$

$T_x = \text{horizontal component of thrust force}$

$T_y = \text{vertical component of thrust force}$

$S_b = \text{horizontal bearing strength of soil}$
## Table A.18.1.1(b) Required Horizontal Bearing Block Area

<table>
<thead>
<tr>
<th>Nominal Pipe Diameter</th>
<th>Bearing Block Area</th>
<th>Nominal Pipe Diameter</th>
<th>Bearing Block Area</th>
<th>Nominal Pipe Diameter</th>
<th>Bearing Block Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>in.</td>
<td>mm</td>
<td>ft²</td>
<td>m²</td>
<td>in.</td>
<td>mm</td>
</tr>
<tr>
<td>3</td>
<td>80</td>
<td>2.6</td>
<td>0.24</td>
<td>12</td>
<td>300</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>3.8</td>
<td>0.35</td>
<td>14</td>
<td>350</td>
</tr>
<tr>
<td>6</td>
<td>150</td>
<td>7.9</td>
<td>0.73</td>
<td>16</td>
<td>400</td>
</tr>
<tr>
<td>8</td>
<td>200</td>
<td>13.6</td>
<td>1.3</td>
<td>18</td>
<td>450</td>
</tr>
<tr>
<td>10</td>
<td>250</td>
<td>20.5</td>
<td>2</td>
<td>20</td>
<td>500</td>
</tr>
</tbody>
</table>

### Notes:

1. Although the bearing strength values in this table have been used successfully in the design of thrust blocks and are considered to be conservative, their accuracy is totally dependent on accurate soil identification and evaluation. The ultimate responsibility for selecting the proper bearing strength of a particular soil type must rest with the design engineer.

2. Values listed are based on a 90-degree horizontal bend, an internal pressure of 100 psi (6.9 bar), a soil horizontal bearing strength of 1000 lb/ft² (4880 kg/m²), a safety factor of 1.5, and ductile iron pipe outside diameters.

   (a) For other horizontal bends, multiply by the following coefficients: for 45 degrees, 0.541; for 221/2 degrees, 0.276; for 111/4 degrees, 0.139.

   (b) For other internal pressures, multiply by ratio to 100 psi (6.9 bar).
(c) For other soil horizontal bearing strengths, divide by ratio to 1000 lb/ft$^2$ (4880 kg/m$^2$).

(d) For other safety factors, multiply by ratio to 1.5.

[24:Table A.10.6.1(b)]

Example: Using Table A.10.6.1(b), find the horizontal bearing block area for a 6 in. (150 mm) diameter, 45-degree bend with an internal pressure of 150 psi (10.3 bar). The soil bearing strength is 3000 lb/ft$^2$ (14850 kg/m$^2$), and the safety factor is 1.5. [24:A.10.6.1]

From Table A.10.6.1(b), the required bearing block area for a 6 in. (150 mm) diameter, 90-degree bend with an internal pressure of 100 psi (6.9 bar) and a soil horizontal bearing strength of 1000 psi (70 bar) is 7.9 ft$^2$ (0.73 m$^2$). [24:A.10.6.1]

For example:

\[
\text{Area} = \frac{7.9 \text{ ft}^2 (0.541) \left(\frac{150}{100}\right)}{\left(\frac{3000}{1000}\right)} = 2.1 \text{ ft}^2
\]

[A.18.1.1c]

In lieu of the values for soil bearing strength shown in Table A.10.6.1(c), a designer might choose to use calculated Rankine passive pressure ($P_p$) or other determination of soil bearing strength based on actual soil properties. [24:A.10.6.1]

Table A.18.1.1(c) Horizontal Bearing Strengths
### Soil Bearing Strength ($S_b$)

<table>
<thead>
<tr>
<th>Soil</th>
<th>lb/ft²</th>
<th>kN/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muck</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Soft clay</td>
<td>1000</td>
<td>48</td>
</tr>
<tr>
<td>Silt</td>
<td>1500</td>
<td>72</td>
</tr>
<tr>
<td>Sandy silt</td>
<td>3000</td>
<td>145</td>
</tr>
<tr>
<td>Sand</td>
<td>4000</td>
<td>190</td>
</tr>
<tr>
<td>Sand clay</td>
<td>6000</td>
<td>285</td>
</tr>
<tr>
<td>Hard clay</td>
<td>9000</td>
<td>430</td>
</tr>
</tbody>
</table>

Note: Although the bearing strength values in this table have been used successfully in the design of thrust blocks and are considered to be conservative, their accuracy is totally dependent on accurate soil identification and evaluation. The ultimate responsibility for selecting the proper bearing strength of a particular soil type must rest with the design engineer.

\[ y = PA \sin \theta \]

It can be easily shown that $T_y = PA \sin \theta$. The required volume of the block is as follows:

$$ V_g = \frac{S_f PA \sin \theta}{W_m} $$

\[ [A.18.1.1d] \]
where:

\[ V_g = \text{block volume (ft}^3\text{)} \]

\[ S_f = \text{safety factor} \]

\[ P = \text{water pressure (psi)} \]

\[ A = \text{cross-sectional area of pipe interior} \]

\[ W_m = \text{density of block material (lb/ft}^3\text{)} \]

[24:A.10.6.1]

In a case such as the one shown, the horizontal component of thrust force is calculated as follows:

\[ T_x = PA(1 - \cos \theta) \quad [A.18.1.1e] \]

where:

\[ T_x = \text{horizontal component of thrust force} \]

\[ P = \text{water pressure (psi)} \]

\[ A = \text{cross-sectional area of pipe interior} \]

[24:A.10.6.1]
The horizontal component of thrust force must be resisted by the bearing of the right side of the block against the soil. Analysis of this aspect follows the same principles as the previous section on bearing blocks. \[24:\text{A.10.6.1}\]

**A.18.1.2**

A method for providing thrust restraint is the use of restrained joints. A restrained joint is a special type of joint that is designed to provide longitudinal restraint. Restrained joint systems function in a manner similar to that of thrust blocks, insofar as the reaction of the entire restrained unit of piping with the soil balances the thrust forces. \[24:\text{10.6.2}\]

The objective in designing a restrained joint thrust restraint system is to determine the length of pipe that must be restrained on each side of the focus of the thrust force, which occurs at a change in direction. This will be a function of the pipe size, the internal pressure, the depth of cover, and the characteristics of the solid surrounding the pipe. The manufacturer’s installation instructions should be referenced to determine the distance from each change in direction that joints should be restrained. \[24:\text{10.6.2}\]

The following documents apply to the design, calculation, and determination of restrained joint systems:

(2) *AWWA M41, Ductile-Iron Pipe and Fittings*
(3) *AWWA M9, Concrete Pressure Pipe*
(4) *AWWA M11, Steel Pipe — A Guide for Design and Installation*

\[24:\text{10.6.2}\]

Figure A.18.1.2 shows an example of a typical connection to a fire protection system riser utilizing restrained joint pipe. \[24:\text{10.6.2}\]

**Figure A.18.1.2 Typical Connection to Fire Protection System Riser Illustrating Restrained Joints.** \[24:\text{Figure A.10.6.2}\]
A.18.1.2.1

Examples of materials and the standards covering these materials are as follows:

(1) Clamps, steel
(2) Rods, steel
(3) Bolts, steel (ASTM A307, Standard Specification for Carbon Steel Bolts, Studs, Threaded Rod 60,000 PSI Tensile Strength)
(4) Washers, steel, cast iron (Class A cast iron as defined by ASTM A126, Standard Specification for Gray Iron Castings for Valves, Flanges and Pipe Fittings)
(5) Anchor straps, plug straps, steel
(6) Rod couplings, turnbuckles, malleable iron (ASTM A197/A197M, Standard Specification for Cupola Malleable Iron)

[24: A.10.6.2.1]

A.18.1.3

Solvent-cemented and heat-fused joints such as those used with CPVC piping and fittings are considered restrained. They do not require thrust blocks. [24:A.10.6.3]


This annex is not a part of the requirements of this NFPA document but is included for informational purposes only. Annex B is extracted in its entirety from the 2022 edition of NFPA 13.

B.1 General.

Seismic design of nonstructural components is governed by the provisions of Chapter 13 of ASCE/SEI 7, Minimum Design Loads and Associated Criteria for Buildings and Other Structures. In ASCE/SEI 7, fire sprinkler piping is classified as a “Designated Seismic System,” due to its critical safety function. Design earthquake forces are multiplied by an importance factor, \( I_p = 1.5 \), and both the bracing and the piping itself must be designed for seismic forces. The seismic design requirements for the hanging and bracing of sprinkler piping systems provided in Chapter 6 of this standard presume that sprinkler piping is being constructed in the United States or in a country or jurisdictions where the seismic requirements are those specified in ASCE/SEI 7. There are locations outside the United States that wish to use the seismic design
requirements of Chapter 6 of this standard. In Section B.3, suggested conversion factor adjustments are provided to adjust country building code design ground motion criteria to those in ASCE/SEI 7 so the procedures of Chapter 6 of this standard can be used.

The lateral sway bracing provisions of 6.5.5 were developed to allow the use of the concept of zone of influence (ZOI), while providing designs that comply with ASCE/SEI 7. One of the main changes between the current seismic sway bracing design approach adopted in this standard and the approach used in early editions of NFPA 13 is that the spacing of the sway braces can be constrained by the flexural capacity of the pipe, as well as the capacity of the brace assembly or the capacity of the connection between the brace assembly and the supporting structure. This standard provides a design that complies with the seismic design requirements of ASCE/SEI 7 for the pipe itself.

The ZOI approach yields the force demand on the bracing element and connections to the structure. Another way to look at a ZOI force is as a reaction in a system of continuous beams (i.e., the multiple spans of a piping system). By using conservative simplifying assumptions, a maximum ZOI force limited by the flexural capacity of the pipe can be developed for a given pipe size and span (i.e., spacing between horizontal sway braces). The method used to develop these maximum ZOI forces is described in Section B.2, along with a discussion of the assumptions on the geometry of the piping system, the determination of the seismic design force coefficients, and the flexural capacity of the pipe.

In this annex, the term *main* can be taken to mean a sprinkler main, either a feed main or a cross-main, that requires sway bracing.

**B.2 Assumptions on System Geometry.**

While every fire sprinkler system is uniquely designed for a particular structure, there are general similarities in the layout and geometry that can be used to simplify the design approach for earthquake protection. These similarities were used to develop assumptions on the effects of piping system continuity on the distribution of bending and shear forces in the pipe, and assumptions on spacing of branch lines between sway brace locations.

**B.2.1 Continuity in Piping Systems.**

For lateral brace design purposes, piping systems can be idealized as a system of continuous beams. The bending moments in the sprinkler mains (i.e., the beams) were computed assuming three continuous spans, which generates the largest bending moment in any system of continuous beams. The loads generated by the branch lines are idealized as point loads. The tributary mass of the main is lumped along with the mass of the branch lines as point loads at the assumed branch line locations.

**B.2.2 Branch Line Locations.**

In many sprinkler system installations, the branch lines constitute a substantial portion of the seismic mass. While there are significant variations in the spacing of the branch lines, their geometry is
constrained by the need to provide adequate water coverage, which imposes limits on the spacing of the branches. Defining a “span” of the main as the distance between lateral sway braces, the seismic provisions make the following assumptions:

1. There is a branch located at the center of the sprinkler main for spans of 25 ft (7.6 m) or less.
2. There are branches at third-points of the sprinkler main for spans greater than 25 ft (7.6 m) and less than 40 ft (12 m).
3. There are branches at quarter-points of the sprinkler main for spans of 40 ft (12 m).

It was further assumed that there is a branch line located in close proximity to each sway brace.

The layout of branch lines, maximum bending moment $M_{\text{max}}$ in the pipe, and reaction $R_{\text{max}}$ (horizontal loads at sway brace locations) for sprinkler mains with spans less than 25 ft (7.6 m) is illustrated in Figure B.2.2(a). Maximum demands for spans greater than 25 ft (7.6 m) and less than 40 ft (12 m) are given in Figure B.2.2(b), and for spans of 40 ft (12 m) in Figure B.2.2(c).

**Figure B.2.2(a) Maximum Demands for Spans Less Than 25 ft (7.6 m).**

Zone of influence load to $R_2$

$L = \text{distance between sway braces (span)}$

$P = \text{branch line lateral load + tributary lateral load from main}$

$w = \text{lateral load of the main (included in } P)$

$R_1, R_2, R_3, R_4 = \text{zone of influence load (reactions)}$

$$M_{\text{max}} = 0.175PL$$

$$R_{\text{max}} = 2P$$

**Figure B.2.2(b) Maximum Demands for Spans Greater Than 25 ft (7.6 m) and Less Than 40 ft (12.2 m).**
Zone of influence load to $R_2$

$L = \text{distance between sway braces (span)}$

$P = \text{branch line lateral load + tributary lateral load from main}$

$w = \text{lateral load of the main (included in } P)$

$R_1, R_2, R_3, R_4 = \text{zone of influence load (reactions)}$

$M_{\text{max}} = 0.267PL$

$R_{\text{max}} \approx 3P$

Figure B.2.2(c) Maximum Demands for Spans of 40 ft (12 m). [13:Figure E.2.2(c)]

Zone of influence load to $R_2$

$L = \text{distance between sway braces (span)}$

$P = \text{branch line lateral load + tributary lateral load from main}$

$w = \text{lateral load of the main (included in } P)$

$R_1, R_2, R_3, R_4 = \text{zone of influence load (reactions)}$

$M_{\text{max}} = 0.372PL$

$R_{\text{max}} \approx 4P$
B.3 Computing the Seismic Demand on Piping Systems.

In ASCE/SEI 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, seismic demands on nonstructural components and systems are a function of the ground shaking intensity, the ductility and dynamic properties of the component(s) or system, and the height of attachment of the component(s) in the structure. Seismic forces are determined at strength design (SD) levels. The horizontal seismic design force is given by Equation B.3a:

\[
F_p = 0.4 a_p S_{DS} W_p \left( 1 + 2 \frac{z}{h} \right) \left( \frac{R_p}{I_p} \right)
\]

[B.3a]

where:

-  \( F_p \) = seismic design force
-  \( a_p \) = component amplification factor, taken as 2.5 for piping systems
-  \( S_{DS} \) = short-period spectral acceleration, which takes into account soil conditions at the site
-  \( W_p \) = component operating weight
-  \( R_p \) = component response modification factor as follows: (1) 9 for high-deformability piping with joints made by welding or brazing; (2) 4.5 for high- or limited-deformability piping with joints made by threading, bonding, compression couplings, or grooved couplings; or (3) 1.5 for low-deformability piping such as cast iron and nonductile plastics
-  \( I_p \) = component importance factor, taken as 1.5 for fire sprinkler systems
-  \( z \) = height of the component attachment to the structure with respect to the grade plane
-  \( h \) = average roof height of the structure with respect to the grade plane
-  \( R_p = 9 \) for high-deformability piping with joints made by welding or brazing
-  \( R_p = 4.5 \) for high- or limited-deformability piping with joints made by threading, bonding, compression couplings, or grooved couplings
\[ Rp = 1.5 \] for low-deformability piping such as cast iron and nonductile plastics

\[ F_p \] need not be greater than \( 1.6 \, SDS_l p \, W_p \) and cannot be less than \( 0.30 \, SDS_l p \, W_p \).

As illustrated in Figure E.3(a), NFPA 13 uses a simplified default seismic factor, \( C_p \), which combines ground shaking, \( SDS \); dynamic amplification, \( a_p \); component response, \( R_p / I_p \); and location in the building, \((z/h)\), into a single variable. Conservative assumptions are made for each variable so that the only information needed to find \( C_p \) is the short-period mapped spectral acceleration for the maximum considered earthquake (MCE), \( S_S \).

**Figure B.3(a) Simplified Default Seismic Factor, \( C_p \). [13:Figure E.3(a)]**

\[
F_p = \frac{0.4 \, a_p \, S_D S}{(R_p / I_p)} \left( 1 + \frac{z}{h} \right) W_p
\]

\[ F_{pw} = C_p \cdot W_p \]

The importance factor, \( I_p \), for fire sprinkler systems is specified in ASCE/SEI 7 as 1.5. The amplification factor, \( a_p \), for piping systems is specified as 2.5. Piping systems (even when seismically braced) are considered flexible, since the fundamental period of vibration for the system is greater than 0.06 seconds. A component response factor, \( R_p \), of \( R_p = 4.5 \) was assumed for all piping. Finally, it was assumed that the system is installed at the roof level, \( h \).

Assume the system is laterally braced at the roof, \( z = h \), and substitute these values into the lateral force Equation B.3b as follows:
ASCE/SEI 7 forces are determined at the strength design (SD) level. This standard is based on allowable stress design (ASD). To convert $F_p$ to an ASD load, $F_{pw}$, the load from ASCE/SEI 7 is multiplied by a 0.7 load factor as follows in Equation B.3c:

$$F_{pw} = 0.7 F_p = 0.7 S_{DS} W_p = C_p W_p \quad \text{[B.3c]}$$

Solve for $C_p$ as follows in Equation B.3d:

$$C_p = 0.7 S_{DS} \quad \text{[B.3d]}$$

The short-period spectral acceleration, SDS, is obtained by modifying the mapped short-period spectral acceleration, SS, for the effects of the local soil conditions. In the United States, values for SS are obtained from seismic hazard maps published by the US Geological Survey (USGS). Web-based tools available from USGS will generate values for SS based on the latitude and longitude of the project site. Most countries do not base their seismic hazard maps on the ground motion criteria that USGS uses to determine the SS values specified in ASCE/SEI 7. Instead, these countries might use seismic zones [similar to those in the outdated Uniform Building Code (UBC)] to convey the seismic hazard. Although different countries might use different zone identifiers, zones are often numbered, with the highest number seismic zone having the strongest potential ground motions (e.g., in the UBC, Zones 0 to 4 were used, and Zone 4 had the highest seismic hazard). Although not universally true, there is often a zone factor, $Z$, associated with each zone that represents the peak ground acceleration based on design earthquake ground motions having a 10 percent chance of being exceeded in a 50-year period (i.e., about a 500-year return period). For these countries, a suggested correlating adjustment is $SS = 4.5 Z$. The 4.5 factor is determined by multiplying the peak ground acceleration by a factor of 2.5 to convert it to peak spectral acceleration and then by a factor of 1.8 to convert design earthquake ground motions to maximum considered earthquake ground motions, which are the basis for determining SS. For example, for a $Z$ factor of 0.4 (i.e., the highest value in the UBC), the value of SS would be 1.8, (resulting in $C_p = 0.84$ from Table 6.5.9.3). Also, for these countries, if a value of $S_1$ is needed, the value might be taken as $1.8 Z$, which is the same relative relationship between the short-period and one-second spectral acceleration that was used in the 1997 UBC. The spectral acceleration used for seismic design is determined by Equation B.3e:

$$S_{DS} = \frac{2}{3} S F_a \quad \text{[B.3e]}$$
Fa is an amplification factor based on soil conditions and the intensity of ground shaking expected, (measured by SS). Soil conditions are defined by site classification, ranging from Site Class A (hard rock) to Site Class F (extremely soft soils and fill) in Table 20.3-1 of ASCE/SEI 7 and summarized in Table B.3(a). The values of Fa are given in Table 11.4-1 of ASCE/SEI 7, and vary from 0.8 to 2.51.6. For the zone of influence (ZOI) method, the default values of Fa are taken as the maximum tabulated values for Site Class A through D and are summarized in Table B.3(b).

Table B.3(a) Site Class

<table>
<thead>
<tr>
<th>Site Class</th>
<th>Soil Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Hard rock</td>
</tr>
<tr>
<td>B</td>
<td>Rock</td>
</tr>
<tr>
<td>C</td>
<td>Very dense soil and soft rock</td>
</tr>
<tr>
<td>D</td>
<td>Stiff soil</td>
</tr>
</tbody>
</table>

Table B.3(b) Values of Fa

<table>
<thead>
<tr>
<th>Site Class</th>
<th>Mapped Maximum Considered Earthquake Spectral Response Acceleration Parameter at Short Period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SS ≤ 0.33</td>
</tr>
<tr>
<td>Default Fa</td>
<td>1.6</td>
</tr>
<tr>
<td>A</td>
<td>0.8</td>
</tr>
<tr>
<td>B</td>
<td>0.9</td>
</tr>
<tr>
<td>C</td>
<td>1.3</td>
</tr>
<tr>
<td>D</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Note: Use straight-line interpolation for intermediate values of SS.

By combining Equations B.3d and B.3e, Cp can be written as shown in Equation B.3f:
The site class can be determined by a geotechnical engineer. Additionally, the site class and seismic design category of a structure are separate pieces of information. Although both terms are classified by a letter ranging from A to F, the seismic design category determines when seismic protection is required for buildings and nonstructural elements, while the site class represents the type of soil underneath a structure and its ability to resist or absorb seismic forces. Each of these designations should be determined independently in accordance with local regulations.

Table 6.5.9.3 was populated by solving for $C_p$ for different values of SS. For example, when SS = 1.0, the following in Equation B.3g is true:

$$C_p = 0.467S_sF_a = 0.467(1.0)(1.1) = 0.51$$  \[B.3g\]

As illustrated in Figure B.3(b), the seismic design load, $F_p$, includes a function of the height of the component attachment to the structure relative to the average roof height of the structure.

**Figure B.3(b) Seismic Design Load Relative to Height. [13:Figure E.3(b)]**

$$F_p = \frac{0.4a_pS_{DS}}{\left(\frac{R_p}{I_p}\right)}\left(1 + 2\frac{z}{h}\right)W_p$$

The most conservative seismic design load assumes the seismic attachment is at 100 percent of the average roof height, where $z = 1.0$ and $h = 1.0$. In this case, the function becomes a constant equal to 3.0 in accordance with Equation B.3h:

$$1 + 2\frac{1.00}{1.00} = 1 + 2 = 3.0$$  \[B.3h\]
If the seismic attachment is installed at 75 percent of the average roof height, where \( z = 0.75 \) and \( h = 1.0 \), the function becomes a constant equal to 2.5 in accordance with Equation B.3i:

\[
1 + 2 \left( \frac{0.75}{1.00} \right) = 1 + 1.5 = 2.5
\]

[B.3i]

Since 2.5 is 83.3 percent of 3.0, the seismic design load for seismic attachments installed at 75 percent of the average roof height can be multiplied by a factor of 0.833. Because it might be difficult to accurately measure the average roof height of the structure relative to the grade plane, 6.5.9.3.4 assumes a multiplier of 0.875 is used.

If the seismic attachment is installed at 50 percent of the average roof height, where \( z = 0.50 \) and \( h = 1.0 \), the function becomes a constant equal to 2.5 in accordance with Equation B.3j:

\[
1 + 2 \left( \frac{0.50}{1.00} \right) = 1 + 1 = 2.0
\]

[B.3j]

Since 2.0 is 66.6 percent of 3.0, the seismic design load for seismic attachments installed at 50 percent of the average roof height can be multiplied by a factor of 0.666. Because it might be difficult to accurately measure the average roof height of the structure relative to the grade plane, 6.5.9.3.5 assumes a multiplier of 0.750 is used.

**B.4 Flexural Capacity of Piping.**

The flexural capacity for different diameters and thicknesses of pipe were computed using allowable stress design (ASD). NFPA 13 has traditionally used ASD for design. While ASCE/SEI 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, generally uses the strength design (SD) approach, ASD is preferred for the design of piping systems. For example, the ASTM B31, *Standards of Pressure Piping*, series of piping codes are based on ASD. ASD was chosen for sprinkler piping design to limit the complexity of the analysis. Use of SD would require the use of the plastic modulus, \( Z \), of the pipe rather than the elastic section modulus, \( S \). Use of \( Z \) would trigger analysis of local and global buckling behavior of the pipe. SD is most appropriate when used with compact pipe sections that can develop the full limit capacity of the material, including strain hardening. Thin-wall pipes and materials without well-defined post-elastic behavior are not easily considered using SD.

Permissible stresses in the pipe for seismic loading are from 13.6.7 of ASCE/SEI 7. Assuming high- or limited-deformability pipe with threaded or grooved couplings, the permissible flexural stress under SD level demands is \( 0.7F_y \), where \( F_y \) is the yield stress of the material. Since seismic design in NFPA 13 is based on ASD, the SD capacity must be reduced to an ASD level.

The permissible flexural stress for ASD is determined by adjusting the SD level flexural capacity. The SD capacity is first reduced by a load factor to ASD levels, and then can be increased by the allowable stress...
increase for seismic loading. The use of an allowable stress increase for piping systems is typical when
determining the strength of the pipe itself.

For fire sprinkler piping, the SD flexural capacity, $M_{cap}$, is reduced by a load factor of 0.7 to yield the ASD
flexural capacity. The duration of load factor for the piping system, taken as 1.33, is then applied. Taking $S$
as the section modulus of pipe, this yields an allowable moment capacity in the pipe, as shown in Equation
B.4a:

$$M_{cap} = 0.7 \left(1.33\right) \left(0.7F_y\right) = 0.65F_y$$

[B.4a]

To populate Table 6.5.5.2(a) through Table 6.5.5.2(n), which give the maximum zone of influence loads,
the largest reaction (due to branch lines and the tributary mass of the main) limited by flexure for a given
pipe size and span between sway braces was computed.

For example, to determine the maximum permissible ZOI for a 4 in. (100 mm) diameter steel Schedule
10 main spanning 30 ft (9.1 m), first compute the flexural capacity of the pipe:

$S = 1.76$ in.$^3$ (28800 mm$^3$)

$F_y = 30,000$ psi (2050 bar)

The flexural capacity of the pipe is as follows

$$M_{cap} = (0.65F_y)S = (0.65)(30,000)(1.76)$$

[B.4b]

$= 34,320$ in.-lb (3900 kgn) $= 2860$ ft-lb (395 kgn)

For spans greater than 25 ft (7.6 m) and less than 40 ft (12 m), the branch lines are assumed to be located
at $1/3$-points in the span. The point load $P$ is associated with the branch line and tributary mass of the
main and $L$ is distance between sway braces. From Figure B.2.2(b), the maximum moment in the main,$M_{max}$ is:

$$M_{max} = 0.267PL$$

Setting $M_{cap} = M_{max}$ and solving for $P$, the result is as follows in Equation B.4c:

$$M_{cap} = (0.65F_y)S = 0.267PL$$

$$P = \frac{M_{cap}}{0.267L} = \frac{2860}{0.267(30)} = 357 \text{ lb}$$

[B.4c]
The maximum permissible ZOI load = 3P = 1071 lb (485 kg).

**B.5 Sample Seismic Calculation Using the ZOI Method.**

To illustrate the application of the ZOI method, the approach can be applied to a sample problem based on the sample seismic bracing calculation in Figure A.6.5(b). The sample calculation yielded a total weight of 480 lb (220 kg), which was obtained using a seismic factor of 0.5. To determine our own seismic factor, to get the total weight of the water-filled pipe, divide by the seismic factor of 0.5, as shown in Equation B.5a:

\[ W_p = \frac{480}{0.5} = 960 \text{ lb (435 kg)} \]  

[B.5a]

Assume the 4 in. (100 mm) Schedule 10 pipe is the main that will be braced and that distance between sway braces (i.e., span) is 20 ft (6.1 m). The installation is in a region of high seismicity and based on the latitude and longitude of the building site, SS = 1.75.

To calculate the seismic load, use Table 6.5.9.3 to determine the seismic coefficient, \( C_p \). The value of \( Ss = 1.75 \) coordinates to 0.82.

The horizontal force on the brace, from 6.5.6.3, is as shown in Equation B.5b:

\[ F_{pw} = C_p W_p = 0.82(960) = 787 \text{ lb} \]  

[B.5b]

From Table 6.5.5.2(a), the maximum ZOI load, \( F_{pw} \), for a 4 in. Schedule 10 pipe spanning 20 ft (6.1 m) is 1634 lb (740 kg), which is larger than the calculated demand of 787 lb (355 kg). The 4 in. (100 mm) Schedule 10 pipe is adequate for the seismic load and a brace would be selected with a minimum capacity of 787 lb (355 kg).

If the sway brace was attached to the 2 in. (50 mm) Schedule 40 pipe, the ZOI demand \( F_{pw} \) of 787 lb (355 kg) would be compared to the maximum capacity for a 2 in. (50 mm) Schedule 40 pipe found in Table 6.5.5.2(c) and Table 6.5.5.2(d). For a 20 ft (6.1 m) span, this is 520 lb (236 kg), less than the demand of 787 lb (355 kg). A 2 in. (50 mm) pipe would be inadequate, and a sway brace would have to be added to reduce the ZOI demand, or the system pipe size increased.

**B.6 Limitations of the ZOI Method.**

The ZOI approach can be used for a variety of piping materials. There are, however, important limitations of which the designer should be aware. The first is that the appropriate component response factor, \( R_p \), must be used. To select the proper value, the piping systems must be classified as high-, limited-, or low-deformability. Definitions of these terms are given in Section 11.2 of ASCE/SEI 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. The second major assumption is that the flexural behavior of the pipe is not governed by local buckling of the pipe wall. For steel pipe, this can be achieved by observing the thickness to diameter limits given in the *AISC Specifications for the Design, Fabrication,
and Erection of Structural Steel Buildings. Establishing the local buckling characteristics of pipe fabricated from other materials can require testing.

The tables for the maximum load, \( F_{pw} \), in zone of influence are based on common configurations of mains and branch lines. There can be cases where the actual configuration of the piping system could generate higher stresses in the piping than assumed in the tables. For example, a main braced at 40 ft (12.2 m) intervals, with a single branch line in the center of the span, can have a smaller maximum load capacity, \( F_{pw} \), than the tabulated value. Where the configuration of the mains and branch lines vary significantly from the assumed layout, the pipe stresses should be checked by engineering analysis.

**B.7 Allowable Loads for Concrete Anchors.**

This section provides step-by-step examples of the procedures for determining the allowable loads for concrete anchors as they are found in Table 6.5.12.2(a) through Table 6.5.12.2(j). Table 6.5.12.2(a) through Table 6.5.12.2(j) were developed using the prying factors found in Table B.7(a) and the representative strength design seismic shear and tension values for concrete anchors found in Table B.7(b).

**Table B.7(a) Prying Factors for Table 6.5.12.2(a) through Table 6.5.12.2(j) Concrete Anchors**

<table>
<thead>
<tr>
<th>( Pr ) Range</th>
<th>Figure 6.5.12.1 Designated Angle Category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Lowest</td>
<td>2</td>
</tr>
<tr>
<td>Low</td>
<td>3.5</td>
</tr>
<tr>
<td>High</td>
<td>5.0</td>
</tr>
<tr>
<td>Highest</td>
<td>6.5</td>
</tr>
</tbody>
</table>

**Table B.7(b) Representative Strength Design Seismic Shear and Tension Values Used for Concrete Anchors**
<table>
<thead>
<tr>
<th>Anchor Dia. (in.)</th>
<th>Min. Nominal Embedment (in.)</th>
<th>LRFD Tension (lb)</th>
<th>LRFD Shear (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8</td>
<td>2.375</td>
<td>670</td>
<td>871</td>
</tr>
<tr>
<td>1/2</td>
<td>3.750</td>
<td>714</td>
<td>1489</td>
</tr>
<tr>
<td>5/8</td>
<td>3.875</td>
<td>936</td>
<td>1739</td>
</tr>
<tr>
<td>3/4</td>
<td>4.500</td>
<td>1372</td>
<td>1833</td>
</tr>
</tbody>
</table>

Wedge Anchors in 3000 psi (207 bar) Lightweight Sand Concrete on 4 1/2 in. Flute Width Metal Deck

<table>
<thead>
<tr>
<th>Anchor Dia. (in.)</th>
<th>Min. Effective Embedment (in.)</th>
<th>LRFD Tension (lb)</th>
<th>LRFD Shear (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8</td>
<td></td>
<td>1.750</td>
<td>804</td>
</tr>
<tr>
<td>1/2</td>
<td></td>
<td>1.750</td>
<td>804</td>
</tr>
<tr>
<td>5/8</td>
<td></td>
<td>1.750</td>
<td>804</td>
</tr>
<tr>
<td>3/4</td>
<td></td>
<td>1.750</td>
<td>804</td>
</tr>
</tbody>
</table>

Metal Deck Inserts in 3000 psi (207 bar) Lightweight Sand Concrete on 4 1/2 in. Flute Width Metal Deck

<table>
<thead>
<tr>
<th>Anchor Dia. (in.)</th>
<th>Min. Nominal Embedment (in.)</th>
<th>LRFD Tension (lb)</th>
<th>LRFD Shear (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8</td>
<td>2.375</td>
<td>739</td>
<td>1141</td>
</tr>
<tr>
<td>1/2</td>
<td>3.750</td>
<td>983</td>
<td>1955</td>
</tr>
<tr>
<td>5/8</td>
<td>3.875</td>
<td>1340</td>
<td>2091</td>
</tr>
<tr>
<td>3/4</td>
<td>4.500</td>
<td>1762</td>
<td>3280</td>
</tr>
</tbody>
</table>

Wood Form Inserts in 3000 psi (207 bar) Lightweight Sand Concrete

<table>
<thead>
<tr>
<th>Anchor Dia. (in.)</th>
<th>Min. Effective Embedment (in.)</th>
<th>LRFD Tension (lb)</th>
<th>LRFD Shear (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8</td>
<td></td>
<td>1.100</td>
<td>1358</td>
</tr>
<tr>
<td>1/2</td>
<td></td>
<td>1.690</td>
<td>1358</td>
</tr>
<tr>
<td>5/8</td>
<td></td>
<td>1.750</td>
<td>1358</td>
</tr>
<tr>
<td>3/4</td>
<td></td>
<td>1.750</td>
<td>1358</td>
</tr>
</tbody>
</table>

Wood Form Inserts in 3000 psi (207 bar) Normal Weight Concrete

<table>
<thead>
<tr>
<th>Anchor Dia. (in.)</th>
<th>Min. Nominal Embedment (in.)</th>
<th>LRFD Tension (lb)</th>
<th>LRFD Shear (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8</td>
<td>2.375</td>
<td>1087</td>
<td>1170</td>
</tr>
<tr>
<td>1/2</td>
<td>3.750</td>
<td>1338</td>
<td>2574</td>
</tr>
</tbody>
</table>

Wedge Anchors in 3000 psi (207 bar) Normal Weight Concrete

<table>
<thead>
<tr>
<th>Anchor Dia. (in.)</th>
<th>Min. Effective Embedment (in.)</th>
<th>LRFD Tension (lb)</th>
<th>LRFD Shear (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8</td>
<td></td>
<td>1.100</td>
<td>1598</td>
</tr>
<tr>
<td>1/2</td>
<td></td>
<td>1.690</td>
<td>1598</td>
</tr>
</tbody>
</table>

Wood Form Inserts in 3000 psi (207 bar) Normal Weight Concrete

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### Anchor Dia. (in.) | Min. Nominal Embedment (in.) | LRFD Tension (lb) | LRFD Shear (lb) | Anchor Dia. (in.) | Min. Effective Embedment (in.) | LRFD Tension (lb) | LRFD Shear (lb)
--- | --- | --- | --- | --- | --- | --- | ---
5/8 | 3.875 | 2070 | 3424 | 5/8 | 1.750 | 1598 | 2130
3/4 | 4.500 | 3097 | 5239 | 3/4 | 1.750 | 1598 | 2130

**Wedge Anchors in 4000 psi (276 bar) Normal Weight Concrete**

| Anchor Dia. (in.) | Min. Nominal Embedment (in.) | LRFD Tension (lb) | LRFD Shear (lb) | Anchor Dia. (in.) | Min. Effective Embedment (in.) | LRFD Tension (lb) | LRFD Shear (lb)
--- | --- | --- | --- | --- | --- | --- | ---
3/8 | 2.375 | 1233 | 1170 | 3/8 | 1.100 | 1845 | 1235
1/2 | 3.750 | 1545 | 2574 | 1/2 | 1.690 | 1845 | 2249
5/8 | 3.875 | 2390 | 3900 | 5/8 | 1.750 | 1845 | 2460
3/4 | 4.500 | 3391 | 5239 | 3/4 | 1.750 | 1845 | 2460

**Wedge Anchors in 6000 psi (414 bar) Normal Weight Concrete**

| Anchor Dia. (in.) | Min. Nominal Embedment (in.) | LRFD Tension (lb) | LRFD Shear (lb) | Anchor Dia. (in.) | Min. Effective Embedment (in.) | LRFD Tension (lb) | LRFD Shear (lb)
--- | --- | --- | --- | --- | --- | --- | ---
3/8 | 2.375 | 1409 | 1170 | 3/8 | 1.100 | 2259 | 1235
1/2 | 3.750 | 1892 | 2574 | 1/2 | 1.690 | 2259 | 2249
5/8 | 3.875 | 2928 | 3900 | 5/8 | 1.750 | 2259 | 3013
3/4 | 4.500 | 4153 | 5239 | 3/4 | 1.750 | 2259 | 3013

**B.7.1 Selecting a Wedge Anchor Using Table 6.5.12.2(a) through Table 6.5.12.2(e).**

**B.7.1.1 Procedure.**

To select a wedge anchor using Table 6.5.12.2(a) through Table 6.5.12.2(e), proceed as follows:
(1) Determine the ASD horizontal earthquake load $F_{pw}$.
(2) Calculate the weight of the water-filled pipe within the zone of influence of the brace.
(3) Find the applicable seismic coefficient $C_p$ in Table 6.5.9.3.
(4) Multiply the zone of influence weight by $C_p$ to determine the ASD horizontal earthquake load $F_{pw}$.
(5) Select a concrete anchor from Table 6.5.12.2(a) through Table 6.5.12.2(e) with a maximum load capacity that is greater than the calculated horizontal earthquake load from B.7.1.1(1).
(6) Locate the table for the applicable concrete strength.
(7) Find the column in the selected table for the applicable designated angle category (A through I) and the appropriate prying factor $Pr$ range.
(8) Scan down the category column to find a concrete anchor diameter, embedment depth, and maximum load capacity that is greater than the calculated horizontal earthquake load $F_{pw}$ from B.7.1.1(1).

B.7.1.1.2 An Alternative to B.7.1.1(5).

As an alternative to using the maximum load values in Table 6.5.12.2(a) through Table 6.5.12.2(e), select a concrete anchor that has been tested in accordance with ACI 355.2, *Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary*, for seismic loading and that has an allowable strength, including the effects of prying, taken as 0.43 times the normal strength determined in accordance with Chapter 17 of ACI 318, *Building Code Requirements for Structural Concrete and Commentary*, as per 6.5.12.7.3.4.

B.7.1.2 Example.

The following is an example of the procedure found in B.7.1.1.1:

(1) Zone of influence $F_{pw}$.
(2) 40 ft of 2 1/2 in. Sch. 10 pipe, plus 15 percent fitting allowance: $40 \times 5.89 \text{ lb/ft} \times 1.15 = 270.94 \text{ lb}$
(3) Seismic coefficient $C_p$ from Table 18.5.9.3: $C_p = 0.35$
(4) $F_{pw} = 0.35 \times 270.94 = 94.8 \text{ lb}$
(5) Select a concrete anchor from Table 6.5.12.2(a) through Table 6.5.12.2(e).
(6) Use the table for 4000 psi normal weight concrete.
(7) Fastener orientation “A” — assume the manufacturer’s prying factor is 3.0 for the fitting. Use the $Pr$ range of 2.1–3.5.
(8) Allowable $F_{pw}$ on 3/8 in. dia. with 2.375 in. embedment = 138 lb and is greater than the calculated $F_{pw}$ of 94.8 lb.

B.7.2 Calculation for Maximum Load Capacity of Concrete Anchors.

B.7.2.1 Procedure.

The following shows how the effects of prying and brace angle are calculated when using Table B.7(a):
(1) Determine the allowable seismic tension value ($T_{allow}$) and the allowable seismic shear value ($V_{allow}$) for the anchor, based on data found in the anchor manufacturer's approved evaluation report. Note that, in this example, it is assumed the evaluation report provides the allowable tension and shear capacities. If this is not the case, the strength design anchor capacities must be determined using the procedures in Chapter 17 of ACI 318, *Building Code Requirements for Structural Concrete and Commentary*, which are then converted to ASD values by dividing by a factor of 1.4. As an alternative to calculating the allowable seismic tension value ($T_{allow}$) and the allowable seismic shear value ($V_{allow}$) for the anchor, the seismic tension and shear values that were used to calculate Figure 6.5.12.1 for anchor allowable load tables can be used.

(2) Find the ASD seismic tension capacity ($T_{allow}$) for the anchor according to the strength of concrete, diameter of the anchor, and embedment depth of the anchor. Divide the ASD tension value by 2.0 and then multiply by 1.2.

(3) Find the ASD seismic shear capacity ($V_{allow}$) for the anchor according to the strength of concrete, diameter of the anchor, and embedment depth of the anchor. Divide the ASD shear value by 2.0 and then multiply by 1.2.

(4) Calculate the applied seismic tension ($T$) and the applied seismic shear ($V$) based on the calculated horizontal earthquake load $F_{pw}$.

(5) Calculate the designated angle category applied tension factor, including the effects of prying ($Pr$), using the following formulas:

Category A, B, and C:

$$Pr = \left(\frac{C + A}{\tan \theta}\right) - D$$

[B.7.2.1a]

Category D, E, and F:

$$Pr = \left(\frac{C + A}{\tan \theta}\right) - \left(\frac{D}{\tan \theta}\right)$$

[B.7.2.1b]

Category G, H, and I:

$$Pr = \left(\frac{D}{\sin \theta}\right)$$

[B.7.2.1c]
(6) Calculate the ASD applied seismic tension (T) on the anchor, including the effects of prying, and when applied at the applicable brace angle from vertical and the designated angle category (A through I) using the following formula:

\[ T = F_{pwe} \times Pr \]  \hspace{1cm} \text{[B.7.2.1d]} 

(7) Calculate the ASD applied seismic shear (V) on the anchor, when applied at the applicable brace angle from vertical and the designated angle category (A through I) using the following formulas:

- Category A, B, and C:
  \[ V = \frac{F_{pwe}}{Tan\theta} \]  \hspace{1cm} \text{[B.7.2.1e]}

- Category D, E, and F:
  \[ V = \frac{F_{pwe}}{Sin\theta} \]  \hspace{1cm} \text{[B.7.2.1f]}

- Category G, H, and I:
  \[ V = \frac{F_{pwe}}{Sin\theta} \]  \hspace{1cm} \text{[B.7.2.1g]}

(8) Check the anchor for combined tension and shear loads using the following formula:

\[ \left( \frac{T}{T_{allow}} \right) + \left( \frac{V}{V_{allow}} \right) \leq 1.2 \]  \hspace{1cm} \text{[B.7.2.1h]}

Confirm that \( T/T_{allow} \) and \( V/V_{allow} \) ≤1.0.

**B.7.2.2 Example.**

In this example, a sample calculation of the maximum load capacity of concrete anchors is provided showing how the values in Table 6.5.12.2(a) through Table 6.5.12.2(e) were calculated.

1. Determine the allowable seismic tension value (\( T_{allow} \)) and the allowable seismic shear value (\( V_{allow} \)) for a concrete anchor in Figure 6.5.12.1.
2. The Table B.7(b) strength design seismic tension value (\( T_{allow} \)) for a 1/2 in. carbon steel anchor with 3 3/4 in. embedment depth in 4000 psi normal weight concrete is 1545 lb. Therefore, the allowable stress design seismic tension value (\( T_{allow} \)) is 1545/1.4/2.0 × 1.2 = 662 lb.
(3) The Table B.7(b) strength design seismic shear value (\(V_{allow}\)) for a 1/2 in. carbon steel anchor with 3 3/4 in. embedment is 2574 lb. Therefore, the allowable stress design seismic shear value (\(V_{allow}\)) is 2574/1.4/2.0 × 1.2 = 1103 lb.

(4) Use the applied seismic tension value (\(T\)) and the applied seismic shear value (\(V\)) based on an ASD horizontal earthquake load (\(F_{pw}\)) of 100 lb, a 30-degree brace angle from vertical, and designated angle category A.

(5) Calculate the ASD applied seismic tension value (\(T\)) on the anchor, including the effects of prying, using the following formula and Figure B.7.2.2:

\[ T = \frac{F_{pw} \left[ \frac{C + A}{\tan \theta} - D \right]}{A} \]

where:

\(T\) = applied service tension load, including the effect of prying

\(F_{pw}\) = horizontal earthquake load (\(F_{pw} = 170\))

\(\tan \) = tangent of brace angle from vertical (\(\tan 0^\circ = 0.5774\))

\(A = 0.7500\)
\(B = 1.5000\)
\(C = 2.6250\)
\(T = F_{pw} \times Pr\)

\(T =\)

\[ F_{pw} \left( \frac{2.625 + 0.75}{0.5774} - 1.0 \right) \]

\[ 0.75 \]

\(T =\)

\[ F_{pw} (5.8452 - 1.0) \]

\[ 0.75 \]

\(T =\)
\[
T = \frac{4.8451}{0.75} = 6.46\text{ lb}
\]

\[
T = 100\text{ lb} \times 6.46 = 646\text{ lb}
\]

**Figure B.7.2.2 Concrete Anchor for Sample Calculation in B.7.2.2. [13:Figure E.7.2.2]**

(6) The ASD applied seismic shear value \( V \) on the anchor for anchor orientations A, B, and C is equal to the ASD horizontal earthquake load \( F_{pw} = 100\text{ lb} \).

(7) Calculate the maximum allowable horizontal earthquake load \( F_{pw} \) using the formula:

\[
\left(\frac{T}{T_{allow}}\right) + \left(\frac{V}{V_{allow}}\right) \leq 1.2
\]

\[
\left(\frac{646}{662}\right) + \left(\frac{100}{1105}\right) = 1.0655(\leq1.2)
\]

[B.7.2.2b]

**Annex C Informational References**

**C.1 Referenced Publications.** The documents or portions thereof listed in this annex are referenced within the informational sections of this standard and are not part of the requirements of this document unless also listed in Chapter 2 for other reasons.
**C.1.1 NFPA Publications.**
National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.


**C.1.2 Other Publications.**

**C.1.2.1 ACI Publications.**
American Concrete Institute, 38800 Country Club Drive, Farmington Hills, MI 48331-3439.


**C.1.2.2 AISI Publications.**
American Iron and Steel Institute, 25 Massachusetts Avenue, NW, Suite 800, Washington, DC 200301.


**C.1.2.3 AISC Publications.**
American Institute of Steel Construction, 130 East Randolph, Suite 2000, Chicago, IL 60601.


*AISC Specifications for the Design, Fabrication, and Erection of Structural Steel Buildings.*

**C.1.2.4 ASCE Publications.**
American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, VA 20191-4400.

C.1.2.5 ASTM Publications.
ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.
ASTM A197/A197M, Standard Specification for Cupola Malleable Iron,
ASTM B31, Standards of Pressure Piping, 2010

C.1.2.6 AWWA Publications.
American Water Works Association, 6666 West Quincy Avenue, Denver, CO 80235.
AWWA D107, Composite Elevated Tanks For Water Storage, 2016.
AWWA D110, Wire-And Strand-Wound, Circular, Prestressed Concrete Water Tanks, 2013, revised 2018,
AWWA D115, Tendon-Prestressed Concrete Water Tanks, 2020.


AWWA M9, *Concrete Pressure Pipe*, Third Edition.


**C.1.2.7 FSSA Publications.**

Fire Suppression Systems Association, 3601 E. Joppa Road, Baltimore, MD 21234.


**C.1.2.8 ICC Publications.**

International Code Council, 500 New Jersey Avenue, NW, 6th Floor, Washington, DC 20001.


**C.1.2.9 MSS Publications.**

Manufacturers Standardization Society (MSS) of the Valve and Fittings Industry. 127 Park St. NE, Vienna, VA 22180-4602. [http://msshq.org/Store/index.cfm](http://msshq.org/Store/index.cfm)


**C.1.2.10 Other Publications.**


**C.2 Informational References. (Reserved)**
C.3 References for Extracts in Informational Sections.


According to the final ballot results, the ballot did receive the necessary affirmative votes to pass ballot. The Technical Committee recommends NFPA 461 to enter the A2025 cycle. Please see the attached report for results and any comments received.

24 Eligible to Vote
3 Not Returned (Geary, Megasko, Nelson)

The criteria necessary to pass ballot is a simple majority of the Technical Committee and Correlating Committee, if any. See Section 4.3.2.1(b) of the Regulations Governing the Development of NFPA Standards.
Per section 4.3.2.1(b) of the Regs, prior to entering a future Revision Cycle and approval for public review, a Ballot of the Committee is required to pass by at least, a simple majority. Note: This ballot is for formally voting on whether or not you are in agreement with the release of the NFPA 461 draft.

Eligible to Vote: 24
Not Returned: 3
Ronald J. Megasko,
Chris Geary,
Andrew Nelson

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<th>Votes</th>
<th>Comments</th>
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Daniel Strub Add NFPA 69 "Standard on Explosion Prevention Systems" to: - Page 7 (Paragraph 2.2) - Page 22 (Paragraph 5.4) Reason: NFPA 69 is cited in numerous paragraphs in the standard. The citation needs to be explained as a general requirement.

Negative 1
Jeffry T. Dudley I feel there needs to be more coordination and scrubbing of the document to ensure the correct terminology matching the definitions is used in all locations.

Abstain 0

Total Voted: 21

For Simple majority, the affirmative votes needed are 13
Chapter 1 Administration

1.1* Scope.

This standard shall establish the minimum fire protection and life safety requirements for the construction, operation, and maintenance of fixed or mobile buildings, structures, and operations associated with a spaceport as well as structures associated with testing and development of the launch vehicle.

1.2 Purpose.

The purpose of this standard shall be to provide minimum requirements for the protection of life and property from fire and similar risks at spaceports.

1.3 Application.

1.3.1* This standard shall apply only to buildings or structures where energetic material is stored or used operationally, and to buildings or structures that support the storage or operational use of energetic material.

1.3.2 All other buildings or structures associated with a spaceport shall comply with the applicable NFPA codes and standards or with the applicable local codes and standards.

1.3.3 This standard shall be applicable to solid and liquid propellants only.

1.3.4 The use or storage of gaseous propellants shall be outside the scope of this standard.

1.3.5 This standard shall be only applicable to launch sites that meet the requirements of 14 CFR 410.15 (c), (d), and (e) and 14 CFR 420.17 (a)(3)–(a)(6).

1.3.6 If a launch site is not subject to licensure by the US FAA, the launch site shall meet equivalent requirements to that noted.

1.4 Retroactivity.

It shall not be the intent that the provisions of this document be applied to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the document, except in those cases where it is determined by the authority having jurisdiction (AHJ) that the existing situation involves a distinct hazard to life or adjacent property.

1.5 Equivalency.

1.5.1 Nothing in this standard shall be intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard.

1.5.2 Technical documentation shall be submitted to the AHJ to demonstrate equivalency.
1.5.3
The system, method, or device shall be approved for the intended purpose by the AHJ.

1.6 Units of Measurement.
The units of measurement used in this standard shall be in accordance with Table 1.6.

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<tr>
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<th>Primary Unit</th>
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<td>m³</td>
</tr>
<tr>
<td>Volume, water</td>
<td>liters</td>
<td>L</td>
</tr>
</tbody>
</table>

1.6.1 Primary Units.
Primary units of measurement shall be in accordance with the modernized metric system known as the International System of Units (SI), except where specific units are customary for industry practice.

1.6.2 Secondary Units and Conversions.

1.6.2.1
Secondary units of measurement, where provided, shall be in accordance with US customary units (inch-pound units), except where specific units are customary for industry practice.

1.6.2.2
Where secondary units are not provided, converted values and converted trade sizes shall be used.

1.6.2.3
Where extracted text contains values expressed in only one system of units, the values in the extracted text shall be retained without conversion to preserve the values established by the responsible technical committee in the source document.

1.6.3 Measurement of Pressure.
All measurements of pressure shall be gauge values, unless otherwise noted.

1.6.4 Unit Application and Enforcement.
1.6.4.1*

The values presented in this standard shall be expressed with a degree of precision that is appropriate for practical application and enforcement.

1.6.4.2*

Either the primary units or secondary units shall be acceptable for satisfying the requirements in this standard.

Chapter 2 Referenced Publications

2.1 General.

The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.
2.2 NFPA Publications.
National Fire Protection Association, Batterymarch Park, Quincy, MA 02169-7471.

NFPA 505, Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations, 2018 edition.
2.3 Other Publications.

2.3.1 API Publications.

2.3.2 ASME Publications.
American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990. www.asme.org

2.3.3 NACE Publications.
NACE International, 15835 Park Ten Place, Houston, TX 77084-4906. www.nace.org

2.3.4 US Government Publications.
Title 14, Code of Federal Regulations, Part 410.15.

2.3.5 Other Publications.

2.4 References for Extracts in Mandatory Sections.

Chapter 3 Definitions

3.1 General.

3.1.1
The definitions contained in this chapter shall apply to the terms used in this standard.

3.1.2
Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used.
3.1.3
Merriam-Webster’s Collegiate Dictionary, 11th edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved.
Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ).
An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.3* Code.
A standard that is an extensive compilation of provision covering broad subject matter or that is suitable for adoption into law independently of other codes and standards.

3.2.4* Listed.
Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.5 Shall.
Indicates a mandatory requirement

3.2.6 Should.
Indicates a recommendation or that which is advised but not required.

3.2.7 Standard.
An NFPA standard, the main text of which contains only mandatory provisions using the word “shall” to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA manuals of style. When used in a generic sense, such as in the phrase “standards development process” or “standards development activities,” the term “standards” includes all NFPA standards, including codes, standards, recommended practices, and guides.

3.3 General Definitions.

3.3.1 Contingency Abort.
Cessation of vehicle flight during ascent or descent in a manner that does not jeopardize public health and safety and the safety of property, in accordance with mission rules and procedures. Contingency abort includes landing at an alternative location that has been designated as a contingency abort location in advance of vehicle flight. [14 CFR 401.5, 2021]

3.3.2 Crew.
Any employee or independent contractor of a licensee, transferee, or permittee, or of a contractor or subcontractor of a licensee, transferee, or permittee, who performs activities in the course of that employment or contract directly relating to the launch, reentry, or other operation of or in a launch vehicle or reentry vehicle that carries human beings. A crew consists of flight crew and any remote operator. [14 CFR 401.5, 2021]

3.3.3 Energetic Liquid.
A liquid, slurry or gel, consisting of, or containing, an explosive, oxidizer, fuel or combination thereof, that may undergo, contribute to, or cause rapid exothermic decomposition, deflagration or detonation. [NASA Technical Standard 8179.12A: 3.2, 2018]
3.3.4* Energetic Material.
A material consisting of, or containing, an explosive, oxidizer, fuel or combination thereof, that may undergo, contribute to, or cause rapid exothermic decomposition, deflagration or detonation. [NASA Technical Standard 8179.12A: 3.2, 2018]

3.3.5 Equivalent Level of Safety.
An approximately equal level of safety as determined by qualitative or quantitative means. [14 CFR 401.5, 2021]

3.3.6 Expendable Launch Vehicle.
A launch vehicle whose propulsive stages are flown only once. [14 CFR 401.5, 2021]

3.3.7 Flight Crew.
Crew that is on board a vehicle during a launch or reentry. [14 CFR 401.5, 2021]

3.3.8 Flight safety system.
A system designed to limit or restrict the hazards to public health and safety and the safety of property presented by a launch vehicle or reentry vehicle while in flight by initiating and accomplishing a controlled ending to vehicle flight. A flight safety system may be destructive resulting in intentional break up of a vehicle or nondestructive, such as engine thrust termination enabling vehicle landing or safe abort capability. [14 CFR 401.4, 2021]

3.3.9 Launch.
To place or try to place a launch vehicle or reentry vehicle and any payload from Earth in a suborbital trajectory, in Earth orbit in outer space, or otherwise in outer space, and includes preparing a launch vehicle for flight at a launch site in the United States. Launch includes the flight of a launch vehicle and includes pre- and post-flight ground operations. [14 CFR 401.5, 2021]

3.3.9.1 Beginning of Launch.
(1) Under a license, launch begins with the arrival of a launch vehicle or payload at a U.S. launch site. (2) Under a permit, launch begins when any pre-flight ground operation at a U.S launch site meets all of the following criteria: is closely proximate in time to flight, entails critical steps preparatory to initiating flight, is unique to space launch, and is inherently so hazardous as to warrant the FAA's regulatory oversight. [14 CFR 401.4, 2021]

3.3.9.2 End of Launch.
(1) For launch of an orbital expendable launch vehicle (ELV), launch ends after the licensee's last exercise of control over its launch vehicle. (2) For launch of an orbital reusable launch vehicle (RLV) with a payload, launch ends after deployment of the payload. For any other orbital RLV, launch ends upon completion of the first sustained, steady-state orbit of an RLV at its intended location. (3) For a suborbital ELV or RLV launch, launch ends after reaching apogee if the flight includes a reentry, or otherwise after vehicle landing or impact on Earth, and after activities necessary to return the vehicle to a safe condition on the ground. [14 CFR 401.5, 2021]

3.3.10* Launch Complex.
A defined area that supports launch vehicle or payload operations or storage and includes launch pads or associated facilities.

3.3.11* Launch Facility.
A facility that involves direct operation or support of the vertical or horizontal launch/landing of rockets, spacecraft, or other means of transportation to space.

3.3.12 Launch Operator.
A person who conducts or who will conduct the launch of a launch vehicle and any payload. [14 CFR 401.5, 2021]

3.3.13 Launch Pad.
The load-bearing base or platform (fixed or mobile, commonly referred to as a pad) from which a rocket vehicle is launched or landed.
3.3.14 Launch Site.
The location on Earth from which a launch takes place and includes all necessary facilities and structures at that location.

3.3.15 Launch Vehicle.
A vehicle built to operate in, or place a payload in, outer space or a suborbital rocket. [14 CFR 401.5, 2021]

3.3.16 Operator.
A holder of a license or permit under 51 U.S.C. Subtitle V, chapter 509. [14 CFR 401.5, 2021]

3.3.17 Owner.
The organization with fiscal responsibility for the profitability of the facility.

3.3.18 Payload.
An object that a person undertakes to place into outer space by means of a launch vehicle, including components of the vehicle specifically designed or adapted for that object [14 CFR 401.5, 2021]

3.3.19* Professional Engineer.
A person registered or licensed to practice engineering in a jurisdiction, subject to all laws and limitations imposed by the jurisdiction. [101, 2021]

3.3.20 Qualified Person.
An individual by possession of a recognized degree, certificate, or professional standing, or who by extensive knowledge, training, and experience, has successfully demonstrated his ability to solve or resolve problems relating to the subject matter, the work, or the project.

3.3.21 Quantity-Distance.
The quantity of explosive material and distance separation relationships that provide defined levels of protection. [DESR 6055.09, Explosives Safety Standards, 2019]

3.3.22 Reentry Site.
The location on Earth at which a launch vehicle, or component thereof, returns to the earth in a controlled manner that permits the launch vehicle or component to be reused for subsequent launches, as well as the necessary facilities at that location (also referred to as landing site).

3.3.23 Reentry Vehicle.
A vehicle designed to return from Earth orbit or outer space to Earth substantially intact. A reusable launch vehicle that is designed to return from Earth orbit or outer space to Earth substantially intact is a reentry vehicle. [14 CFR 401.5, 2021]

3.3.24 Remote Operator.
A crew member who has the ability to control, in real time, a launch or reentry vehicle's flight path, and is not on board the controlled vehicle. [14 CFR 401.5, 2021]

3.3.25 Reusable Launch Vehicle (RLV).
A launch vehicle that is designed to return to Earth substantially intact and therefore may be launched more than one time or that contains vehicle stages that may be recovered by a launch operator for future use in the operation of a substantially similar launch vehicle. [14 CFR 401.5, 2021]

3.3.26 Spacecraft.
Devices, manned and unmanned, that are designed to be suborbital or placed into an orbit about the earth or into a trajectory to another celestial body.

3.3.27 Spaceflight Participants.
A noncrew individual carried aboard a launch vehicle or reentry vehicle.
3.3.28* Spaceport.

A physical location that provides the capability to safely process and launch items on a defined trajectory to achieve a desired, and specifically defined, mission objective.

Chapter 4 General Requirements

4.1 General.

4.1.1
The requirements of this chapter shall apply to all new spaceport facilities.

4.1.2
For existing spaceport facilities, this chapter shall apply when a building or structure undergoes any of the following changes:

(1) Change of occupancy
(2) Increase in hazard conditions
(3) Modification associated with an operational licensee modification

4.1.3 System Effectiveness.

4.1.3.1
Active and passive systems utilized to achieve the goals of this chapter shall mitigate the hazard or condition for which they are being used.

4.1.3.2
Any proposed changes or variations from the approved design shall be approved by the AHJ prior to the actual change.

4.1.4 Design Feature Maintenance.

4.1.4.1
The design features required to meet the performance goals and objectives for the spaceport facility shall be both maintained by the owner and accessible to the AHJ for the life of the facility.

4.1.4.2
The spaceport facility shall be maintained in accordance with all documented assumptions, design specifications, and applicable codes and standards.

4.2 Goals.

4.2.1* General.

The main goal of this standard shall be to provide a spaceport environment that is safe from fire, hazardous materials events, explosions, and similar risks by the following means:

(1) Occupant protection
(2) Structural integrity
(3) Exposure protection

4.2.2 Occupant Protection.

A structure shall be designed, constructed, and maintained to allow occupants who are not familiar with fire, hazardous materials events, explosions, and similar risks the time needed to evacuate, relocate, or defend in place.

4.2.2.1 Unobstructed Egress.

4.2.2.1.1
In every spaceport building or structure, means of egress from all parts of the building shall be maintained free and unobstructed.

4.2.2.1.2
Means of egress shall be accessible to the extent necessary to ensure safety for occupants
4.2.2.2 Awareness of Egress System.

4.2.2.2.1 Every exit shall be visible (see 4.2.2.2.2).

4.2.2.2.2 If not visible, the route to reach every exit shall be indicated.

4.2.2.2.3 Each means of egress, in its entirety, shall be arranged or marked so that the way to a place of safety is indicated.

4.2.3 Structural Integrity.

Structural integrity shall be maintained for the time needed to evacuate, relocate, or defend in place occupants who are not familiar with fire, hazardous materials events, explosions, and similar risks.

4.2.4 Exposure protection.

Engineering and operational controls shall be developed and implemented to ensure that protection from exposure to hazardous operations and energetic or hazardous materials is provided.

4.3 Siting Analysis.

4.3.1 An initial siting analysis shall be performed for all spaceports in accordance with Chapter 5.

4.3.2 Existing spaceports shall have an initial siting analysis completed within 3 years of adoption of this standard.

4.3.3 The siting analysis shall be updated when a spaceport building, structure, or facility undergoes any of the following:

(1) Change of occupancy
(2) Increase in hazard conditions
(3) Modification associated with an operational licensee modification

4.3.4 The updated siting analysis shall only include the area of change and the associated effects on adjacent areas.

4.4 Spaceport Facility Hazard Analysis.

4.4.1* Spaceport facilities storing, using, or dispensing energetic material shall be required to perform a spaceport facility hazard analysis in accordance with Chapter 6.

4.4.2 Spaceport facilities that do not store, use, or dispense energetic materials shall comply with the applicable NFPA standard or Chapter 6.

4.4.3 Neighboring spaceport buildings and structures that are located outside of any hazards identified in the siting analysis shall comply with the requirements of the applicable building and fire codes.

4.4.4* Safeguards.

4.4.4.1 Multiple Safeguards.
4.4.4.1.1
The design of every spaceport building or structure that complies with Chapter 6 shall be such that reliance for safety to life does not depend solely on any single safeguard.

4.4.4.1.2
At least one additional safeguard(s) shall be provided for life safety in case any single safeguard is rendered ineffective.

4.4.4.2 Appropriateness of Safeguards.
Every building or structure shall be provided with means of egress and other fire and life safety safeguards of the kinds, numbers, locations, and capacities appropriate to the individual building or structure, with due regard to the following:

(1) Character of the occupancy, including fire load
(2) Capabilities of the occupants
(3) Number of persons exposed
(4) Fire protection available
(5) Capabilities of response personnel
(6) Height and construction type of the building or structure
(7) Other factors necessary to provide occupants with a reasonable degree of safety

4.4.4.3 Final Determination.
The AHJ shall make the final determination as to whether the performance objectives of all safeguards have been met.

4.5 Storage and Handling of Energetic or Hazardous Materials.
Storage and handling of energetic or hazardous materials shall comply with Chapter 7.

4.6 Operation of Spaceports.
4.6.1
Operation of spaceport facilities shall comply with Chapter 8.

4.6.2
Preincident planning for emergency response associated with spaceports shall comply with Chapter 9.

4.7 Technical Assistance.
4.7.1*
The authority having jurisdiction shall be permitted to require a review by an approved independent third party with expertise in the matter to be reviewed at the submitter's expense. [1:1.16.1]

4.7.2
The independent reviewer shall provide an evaluation and recommended changes associated with the proposed design, operation, or process of the spaceport to the AHJ.

4.7.3
The AHJ shall be authorized to require design submittals to bear the stamp of a registered design professional or qualified person.

4.8 Assumptions/Constraints.
4.8.1 Single Fire Source.
This standard shall assume a single fire source or event.
4.8.2 Propellant.
The fire protection and life safety methods of this standard shall assume propellants are either solid or liquid as gaseous propellants are outside the scope of this standard.

4.8.3 Malicious or Intentional Acts.
This standard shall not apply to malicious or intentional acts.

Chapter 5 Siting and Layout
5.1 General.

5.1.1
A spaceport and support facilities siting analysis shall comply with this chapter.

5.1.2
The provisions of this chapter shall apply to all areas within the designated spaceport.

5.1.3*
Remotely located facilities that are not directly connected to the spaceport, but have the ability to dictate or otherwise control spaceport operations associated with the space vehicle shall also be included in the evaluation.

5.1.4*
It shall be the intent of this chapter to ensure that hazards associated with spaceport operations are contained within the designated spaceport extents.

5.1.5*
The siting and layout shall include an analysis of planned and existing facilities and operations involving explosives, energetic liquids, and pyrotechnics (EELP) or occurring within the hazard zones created by EELP. [NASA Technical Standard 8179.12A: A.2]

5.1.6
Spaceports shall be provided with all-weather accessibility for personnel safety and emergency response personnel.

5.1.7
All spaceports shall be designed with egress from all facilities and hazard areas.

5.1.8
Lightning protection shall be in accordance with NFPA 780.

5.2 Spaceport Site Provisions.

5.2.1*
A written spaceport and site analysis shall identify safety measures and establish the fire protection design criteria for the entire spaceport.
5.2.2*
The written spaceport and site analysis shall include the following:
(1) Facilities adjacent to the spaceport
(2) Identification and location of each hazard
(3) Fire prevention and protection features
(4) Operational and administrative controls
(5) Process hazard analysis
(6)* Site plan for the entire facility, including the following:
   (a) Buildings and structures, including descriptions of use
   (b)* Emergency response access, including roads and sidewalks
   (c) Fire hydrants and hose connections
   (d) Fire pumps
   (e) Hazardous material control areas, including NFPA hazard diamonds
   (f) Separation and setback distances
   (g) Toxic cloud dispersions distances
   (h) Heat flux distances
   (i) Water supplies
   (j) Explosives and energetics quantity and distance arcs
   (k) Utilities both above and below ground, including the following:
      i. Propellant lines
      ii. Electrical
      iii. Gas
      iv. Water
      v. Hazardous and nonhazardous materials tanks
(7) Storage and transportation plans for hazardous materials
(8) Evaluation of emergency response plans and capabilities, including the following:
   (a) Any onsite personnel trained for emergency situations
   (b) Any offsite agencies expected to respond to emergency situations
   (c) Any personal protective equipment (PPE) available to responding parties
   (d) Proximity of healthcare facilities and capability of onsite medical treatment

5.2.3
The written evaluation shall be initiated under the direction of a qualified person or qualified personnel in the following areas:
(1) Fire protection engineering
(2) Explosives or energetics
(3) Hazardous chemicals (fluid or gases)
(4) High energy systems (electrical or pressurized)
(5) Spacecraft or spaceport operations
(6) Emergency response

5.2.4
The written evaluation shall be a living document, updated as the spaceport design is refine and maintained for the life of the spaceport.

5.2.4.1*
The written evaluation shall be reviewed and updated as necessary in conjunction with operational license applications, modifications, and renewals.

5.2.4.2
The written evaluation shall be updated where modifications to the facility impact the quantity or type of hazards present which do not otherwise affect operational licenses.

5.3 Site Hazards.

5.3.1
The following hazards and calculations shall be evaluated to identify not only the location of the spaceport, but to evaluate separation of individual hazards located within the spaceport:

1. Distance to limit concentration levels arising from flammable gas or vapor dispersion
2. Distance to limit concentration levels arising from toxic gas or vapor dispersion
3. Distance to limit heat flux or heat dosage levels arising from fires
4. Location and identify of all explosive and energetic hazards for the entire facility

5.3.2
The duration of hazardous material spills shall be determined based upon the shortest of the following:

1. The demonstrated and approved shutdown time based on automated surveillance and detection that does not require human intervention, which can be verified in detailed design and operation.
2. Ten minutes for approved surveillance and detection that required human intervention for shutdown.
3. The time needed to empty the available system inventory if no approved surveillance and detection is present.

5.3.3
The spaceport site shall comply with all of the following:

1. In the event of a flammable gas or vapor release, the predicted concentration of the lower flammability limit (LFL) shall not extend beyond the defined exclusions zone(s) to areas of the spaceport that are open to the general public.
2. In the event of a toxic gas or vapor release, the predicted maximum concentration shall not exceed the table below
3. In the event of a combustible or flammable fluid release and subsequent ignition, the maximum radiant heat flux from the fire shall not exceed the limits of the table below

5.3.4*
A hazard analysis shall be performed by a qualified person or qualified personnel to categorize and identify hazards to occupied or important structures on the spaceport site.

5.3.4.1
The hazard analysis shall identify mitigation methods via separation distances other approved means.

5.3.4.2
Non-explosive-related facilities within quantity distance (QD) arcs shall be included in the hazard analysis.
5.4 Space Launch Facilities Explosive Siting Requirements.
Facilities that manufacture, test, process, or store explosive or hazardous materials that have explosive properties shall implement QD and separation requirements of the following standards as applicable:
(1) NFPA 2
(2) NFPA 30
(3) NFPA 55
(4)* NFPA 70
(5) NFPA 69
(6) NFPA 495

5.5* Records.
5.5.1
The launch provider that submits the site plan shall maintain a copy of the following:
(1) Complete site plan and final safety submission
(2) AHJ approval

5.5.2
Spaceports shall develop and maintain current (i.e., with the latest site plan approval) installation maps and drawings that show QD arcs or risk-based evaluation distances, as applicable.

5.5.3
Spaceports shall reconcile site plans with the local AHJ master planning documents.

5.5.4
Records shall be maintained for the lifetime of the building(s) or change/termination of the launch or launch support operations.

Chapter 6 Facilities
6.1 General.
6.1.1*
This chapter shall provide the requirements for a spaceport facility hazard analysis for facilities that use or store energetic materials as required in Chapter 4.

6.1.2
The spaceport facility hazard analysis shall be developed in accordance with this chapter and other applicable NFPA standards.

6.2* Spaceport Facility Hazard Analysis.
6.2.1 General.
6.2.1.1*
The spaceport facility hazard analysis shall be based on an evaluation of the fire risks, hazards associated with the facility, operational procedures, safeguards, and active and passive fire protection features.

6.2.1.2
The spaceport facility hazard analysis shall be prepared by a licensed professional engineer or qualified personnel with experience in fire protection and life safety system design.
6.2.2 Plan Submittal Documentation.
Where a fire hazard analysis is submitted to the AHJ for review and approval, the owner shall document, in an approved format, each performance objective and applicable scenario including any calculation methods or models used in establishing the proposed design’s fire and life safety performance.

6.2.3 Sources of Data.
Data sources shall be identified and documented using a source other than a required design scenario, an assumption, or a facility design specification.

6.2.3.1
The criteria for data sources reflected in the requirement of 6.2.3 shall be specified.

6.2.3.2
A justification for the source of data per the requirement of 6.2.3 shall be provided.

6.2.3.3
Copies of all references relied upon by the fire hazard analysis to support a required design scenario, an assumption, or a facility design specification shall be made available to the AHJ if requested.

6.2.4 Operations and Maintenance (O&M) Manual.

6.2.4.1
An approved operations and maintenance manual shall be both of the following:
(1) Provided by the owner to the AHJ and the fire department for review
(2) Maintained at the facility in an approved location

6.2.4.2
It shall be the responsibility of the facility owner/operator to ensure that the operations and hazards within the facility align with the spaceport facility hazard assessment.

6.2.5 Information Transfer to the Fire Service.
Where a fire hazard analysis is approved and used, the owner shall ensure that information regarding the operating procedures in the fire hazard analysis is transferred to the local fire service for inclusion in the prefire plan.

6.2.6 Annual Certification.
Where a fire hazard analysis is approved and used, the owner shall annually certify that the design features and systems have been maintained in accordance with the approved fire hazard analysis.

6.3* Stakeholders.
Stakeholders shall be identified and documented in the spaceport facility hazard analysis.

6.4 Hazard Analysis.
6.4.1*
The following shall be documented and considered to determine the level of acceptable risk
(1) Type and quantity of energetic material
(2) Type of operations and activities performed within the building
(3) Life safety aspects of an emergency event
(4) Fire threat to the occupants and exposed property or operations
(5) Construction and compartmentation
(6) Fire suppression and detection features
(7) Response time by emergency services
(8) Local firefighting capabilities and resources
(9) Redundant infrastructure, including off-site operations
(10) Life safety of emergency responders, the general public, and occupants of the spaceport

6.4.2
The spaceport facility hazard assessment shall address the entire building, including all the adjacent support areas and exposures.

6.4.3*
Hazard from energetic materials shall be identified and described.

6.4.4 Impact of Hazards.
6.4.4.1
It shall be determined if identified hazards can result in severe injury, loss of life, damage to or loss of property damage, or inability to perform launch or support operations.

6.4.4.2
It shall be determined how a hazardous incident could affect life safety, property, launch capabilities, and surrounding communities.

6.4.4.3
The frequency of hazards presents or the operations that create the hazard shall be determined.

6.4.5
Requirements based on federal, state, or local regulations shall be determined.

6.4.6*
Methods for mitigating the severity or frequency of hazards shall be determined.

6.4.7*
Alternative methods to reduce or eliminate a hazard if mitigation methods are not achievable shall be determined.

6.4.8*
Methods for identifying and evaluating the effectiveness of mitigations to reduce or eliminate risk shall be implemented.

6.4.9
Characteristics of the building or its contents, equipment, or operations that are not inherent in the design specifications, but which affect occupant behavior or the rate of hazard development, shall be identified.
6.4.10
The performance of fire protection systems, building features, and emergency procedures shall reflect the documented performance and reliability of the components of those systems, features, or procedures unless design specifications are incorporated to modify their expected performance.

6.4.11 Occupant Characteristics.

6.4.11.1
The selection of occupant characteristics to be used in the fire hazard analysis shall be approved by the AHJ.

6.4.11.2
The fire hazard analysis shall provide an accurate reflection of the expected population of building users representing the normal occupant profile, unless design specifications are used to modify the expected occupant features.

6.4.11.3
Occupant characteristics shall not vary across free scenarios, except as authorized by the AHJ.

6.4.12 Response Characteristics.

6.4.12.1
The basic response characteristics of sensibility, reactivity, mobility, and susceptibility shall be evaluated to include the expected distribution of characteristics of a population based on the use of the building.

6.4.12.2
The source of data for the characteristics referenced in 6.4.12.1 shall be documented.

6.4.12.3
It shall be assumed that there is at least one person located at the most remote point from the exit in every normally occupied room or area.

6.4.12.4 Number of Occupants.

6.4.12.4.1
The design shall be based on the maximum number of people that every occupied room or area is expected to contain.

6.4.12.4.2
Where the success or failure of the design is contingent on the number of occupants not exceeding a specified maximum, operational controls shall be used to ensure that the maximum number of occupants is not exceeded.

6.4.13
The inclusion of trained employees as part of the fire safety system shall be identified and documented.

6.4.14
Design characteristics or other conditions related to the availability, response, effectiveness, roles, and other characteristics of emergency response personnel shall be specified, estimated, or characterized for evaluation of the design.

6.4.15
The design shall not include mutually inconsistent assumptions, specifications, or statement of conditions.

6.5 Energetic Materials.

6.5.1
The fire hazard analysis shall identify the properties of the energetic materials to be stored, used, or handled.
6.5.2
The fire hazard analysis shall provide safeguards to accomplish the following objectives, considering both normal operations and possible abnormal conditions:

1. Minimize the potential occurrence of unwanted release, fire, or other emergency incidents resulting from the storage, use, or handling of energetic materials.

2. Minimize the potential failure of buildings, equipment, or processes by ensuring that such buildings, equipment, or processes are designed and suitable for the hazards present.

3. Minimize the potential exposure of people or property to unsafe conditions or events involving an unintended reaction or release.

4. Minimize the potential for an unintentional reaction that results in a fire, explosion, or other dangerous condition.

5. Provide a means to contain, treat, neutralize, or otherwise handle plausible releases to minimize the potential for adverse impacts to persons or property outside of the immediate area of a release.

6. Provide safeguards to minimize the risk of and limit damage and injury that might result from an energetic reaction.

7. Maintain power to provide for continued operation of safeguards and important systems that are relied upon to prevent or control an emergency condition.

8. Maintain ventilation where ventilation is relied upon to minimize the risk of emergency conditions.

9. Minimize the potential for exposing combustible hazardous materials to unintended sources of ignition and for exposing any energetic material to fire or physical damage that can lead to endangerment of people or property.

6.6 Performance Criteria.

6.6.1 General.
A design shall meet the objectives specified in Section 4.4 for each required design scenario, assumption, and specification.

6.6.2 Fire Conditions.
Occupants shall not be exposed to instantaneous or cumulated untenable conditions unless they are intimate with ignition.

6.6.3 Explosion Conditions.
The design shall provide a level of safety for occupants and individuals immediately adjacent to the property from the effects of unintentional detonation or deflagration.

6.6.4 Hazardous Materials Exposure.
The design shall provide a level of safety for occupants and individuals immediately adjacent to the property from the effects of an unauthorized release of hazardous materials or the unintentional reaction of hazardous materials.

6.6.5 Property Protection.
The design shall limit the effects of all required design scenarios from causing property damage.

6.6.6 Occupant Protection from Untenable Conditions.
Means shall be provided to evacuate, relocate, or defend in place occupants not intimate with ignition so that they are not exposed to instantaneous or cumulative untenable conditions from smoke, heat, or flames.

6.6.7 Emergency Responder Protection.
Buildings in the spaceport shall be designed and constructed to prevent structural failure under fire conditions to enable firefighters and emergency responders to conduct search and rescue operations.
6.6.8 Occupant Protection from Structural Failure.
Buildings in the spaceport shall be designed and constructed to prevent structural failure under fire conditions to protect the occupants.

6.7 Design Scenarios.

6.7.1
The proposed design shall be considered to meet the goals and objectives if it achieves the performance criteria for each required design scenario.

6.7.2
The AHJ shall approve the parameters involved with required design scenarios.

6.7.3
Design scenarios shall be evaluated using a method acceptable to the AHJ and based on the conditions.

6.7.4
Each scenario shall be as challenging and realistic as any that could realistically occur in the building.

6.7.5
Design scenarios demonstrated by the design team determined to be inapplicable based on building use and conditions by the AHJ shall not be required to be evaluated fully.

6.8 Safety Factors.
Approved safety factors shall be included in the design methods and calculations to reflect uncertainty in the assumptions, data, and other factors associated with the fire hazard analysis.

6.9 Documentation.

6.9.1
All aspects of the fire hazard analysis shall be documented.

6.9.2
The format and content of the documentation shall be acceptable to the AHJ.

6.10 Technical References and Resources.

6.10.1
The AHJ shall be provided with documentation to support the validity, accuracy, relevance, and precision of the proposed methods.

6.10.2
The engineering standards, calculation methods, and other forms of scientific information provided shall be applicable to the particular application and methodologies used.

6.11 Facility Design Specifications.
All details of the proposed facility design that affect the ability of the facility to meet the stated goals and objectives shall be documented.

6.12 Performance Criteria.
Performance criteria, including sources, shall be documented.

6.13 Occupant Characteristics.
Assumptions about occupant characteristics shall be documented.

6.14 Design Scenarios.
Descriptions of design hazard scenarios shall be documented.
6.15 Input Data.
Input data to models and assessment methods, including sensitivity analysis, shall be documented.

6.16 Output Data.
Output data from models and assessment methods, including sensitivity analysis, shall be documented.

6.17 Safety Factors.
Safety factors utilized shall be documented.

6.18 Prescriptive Requirements.
Retained prescriptive requirements shall be documented.

6.19 Systems and Features.
All provided fire protection systems and features of the buildings in the spaceport shall comply with all applicable NFPA standards for those systems and features.

Chapter 7 Hazardous Materials

7.1 Hazardous Materials Classification.

7.1.1 Materials shall be classified into one or more of the categories of hazardous materials, based on the definitions found in NFPA 2, NFPA 30, NFPA 54, NFPA 55, NFPA 58, NFPA 59, NFPA 59A, NFPA 400, and NFPA 495.

7.1.2 Materials shall be classified by the registered design professional (RDP) and submitted to the AHJ for review and approval on the basis of the character of the contents and the processes or operations conducted in the building or structure.

7.2 Hazardous Materials Storage, Use, or Handling.

7.2.1* Occupancies with storage, operational use, or handling of hazardous materials shall comply with Chapter 5 or Chapter 6.

7.2.2* Where not addressed by Chapter 5 or Chapter 6, the storage, operational use, or handling of hazardous materials shall comply with the applicable NFPA standard.

Chapter 8 Operations, Maintenance, and Training

8.1 General.

8.1.1 Each operating company shall develop documented operating, maintenance, and training procedures based on experience and conditions under which the launch facility is operated.
8.1.2
The operating company shall meet all of the following:

(1) Document procedures and plans covering operation, maintenance, training, and personnel access control and accountability

(2) Maintain up-to-date drawings, charts, and records of launch and support facilities and equipment

(3) Revise plans and procedures where operating conditions have changed, ground support equipment has been updated, or lessons have been learned from an incident investigation

(4) Ensure that site and ground support equipment is returned to a stable condition upon end of operation in accordance with specific hazards listed in Chapters 8 and 9 of this standard

(5) Establish a documented emergency plan

(6) Establish liaisons with local authorities such as police departments, fire departments, or municipal works to coordinate emergency plans and the local authorities’ roles in emergency situations

(7) Analyze and document all safety-related incidents to determine their cause and prevent the possibility of recurrence

8.1.3 Permits.

8.1.3.1
Permits shall be obtained in accordance with the requirements of the jurisdiction in which the facility operates. [55:4.1]

8.1.3.2
Operations that shall be considered for permitting include the following:

(1) New construction of facilities, launch pads, or hazardous materials storage

(2) Building modifications and additions

(3) Hot work operations

(4) Additional storage of any hazardous or flammable/combustible exceeding the MAQ

(5) Hazardous operations involving energetic materials and explosives

8.1.4 Facility Closure.

8.1.4.1
Where required by the AHJ, no facility storing hazardous materials listed in 1.1.1 of NFPA 400 shall close or abandon an entire storage area without notifying the AHJ at least 30 days prior to the scheduled closing.

8.1.4.2
The AHJ shall be permitted to reduce the 30-day period specified in 8.1.4.1 where there are special circumstances requiring such reduction.

8.1.5 Facilities Out of Service.

8.1.5.1 Facilities Temporarily Out of Service.
Facilities that are temporarily out of service shall continue to maintain a permit and be monitored and inspected. [400:1.9.3.2]

8.1.5.2 Facilities Permanently Out of Service.
Facilities for which a permit not kept current or that are not monitored and inspected on a regular basis shall be deemed to be permanently out of service and shall be closed in accordance with 14.2.6 of NFPA 400. [400:1.9.3.2]

8.1.6* Closure Plan.
8.1.6.1

Where required by the AHJ, the permit holder or applicant shall submit a closure plan to the fire department to terminate storage, dispensing, handling, or use of hazardous materials at least 30 days prior to facility closure. [400:1.9.4]

8.1.6.2

The closure plan shall demonstrate that hazardous materials that were stored, dispensed, handled, or used in the facility have been transported, disposed of, or reused in a matter that eliminates the need for further maintenance and any threat to public safety or health.


8.1.7.1

Where required by the AHJ, a hazardous materials management plan (HMMP) shall be submitted to the AHJ. [55:4.5.1]

8.1.7.2

The HMMP shall comply with the requirements of the fire code. [55:4.5.1.1]

8.1.7.3

When required by the AHJ, a hazardous materials inventory statement (HMIS) shall be completed and submitted to the AHJ. [400:1.12.1]

8.1.7.4

Safety data sheets (SDS) shall be available on the premises for GH2 or LH2.

8.1.7.5

Where approved, SDSs shall be permitted to be retrievable by electronic access.

8.1.8 Release of Energetics and Other Hazardous Materials.

8.1.8.1

Hazardous materials shall not be released into a sewer, storm drain, ditch, drainage canal, lake, river, or tidal waterway; upon the ground, a sidewalk, a street, or a highway; or into the atmosphere, unless such release is permitted by the following:

(1) Federal, state, or local governing regulations
(2) Pressure relief devices and vents designed as part of a system

8.1.8.2

Provisions shall be made for controlling and mitigating unauthorized releases. [400:6.1.3.2]

8.1.8.3

Accurate records of the unauthorized releases of hazardous materials shall be kept by the permittee. [400:6.1.3.3]

8.1.8.4

The fire department shall be notified immediately or in accordance with approved emergency procedures when an unauthorized release becomes reportable under state, federal, or local regulations. [400:6.1.3.4]

8.1.8.5

When an unauthorized release due to primary container failure is discovered, the involved primary container shall be repaired or removed from service. [400:6.1.3.5]

8.1.8.6

The person, firm, or corporation responsible for an unauthorized release shall institute and complete all actions necessary to remedy the effects of such unauthorized release, whether sudden or gradual, at no cost to the AHJ. [400:6.1.3.7.1]
8.1.8.7
When deemed necessary by the AHJ, cleanup of an unauthorized release shall be permitted to be initiated by the fire department or by an authorized individual or firm, and costs associated with such cleanup shall be borne by the owner, operator, or other person responsible for the unauthorized release. [400:6.1.3.7.2]

8.1.9 Ignition Source Controls.

8.1.9.1
Smoking shall be prohibited in the following locations:
(1) Within 25 ft (7.6 m) of outdoor storage or areas, dispensing areas, or open use areas
(2) In rooms or areas where energetic and hazardous materials are stored, dispensed, or used in open systems in amounts requiring a permit in accordance with 8.1.3

8.1.9.2
Flames and high-temperature devices shall not be used in a manner that creates a hazardous condition. [400:6.1.5.2]

8.1.9.3
Energy-consuming equipment with the potential to serve as a source of ignition shall be listed or approved for use with applicable energetic or other hazardous materials. [400:6.1.5.3]

8.1.9.4
Powered industrial trucks shall be operated and maintained in accordance with NFPA 505. [1:10.17]

8.1.9.5
Parking of vehicles that are not immediately involved in operations shall be kept at least 50 ft (15 m) from areas that contain hazardous materials.

8.1.9.5.1
Vehicles that are used for operations shall be kept at a minimum of 50 ft (15 m) from areas that contain hazardous materials.

8.1.9.5.2
Vehicles shall have chocks applied, the emergency brake set, and the ignition shut off.

8.1.9.5.3
Any vehicles not necessary to accomplish operations shall be kept and parked at least 100 ft (30 m) away.

8.1.10 Signs.

8.1.10.1
Signs shall be durable, and the size, color, and lettering of signs shall be in accordance with nationally recognized standards. [400:6.1.8.1.1]

8.1.10.2
Signs shall be in English as the primary language or in symbols allowed by NFPA 400. [400:6.1.8.1.2]

8.1.10.3
Signs shall meet the following criteria:
(1) They shall not be obscured.
(2) They shall be maintained in a legible condition.
(3) They shall not be removed, unless for replacement.

[400:6.1.8.1.3]
8.1.10.4 Hazardous Materials Identification.

8.1.10.4.1
Visible hazard identification signs in accordance with NFPA 704 shall be placed at the following locations, except where the AHJ has received an HMMP and a hazardous materials inventory statement in accordance with 8.1.7.1 and has determined that omission of such signs is consistent with safety:

(1) On stationary aboveground tanks.
(2) On stationary aboveground containers.
(3) On other entrances and locations designated by the AHJ.

8.1.10.4.2
Individual containers, cartons, or packages shall be conspicuously marked or labeled in accordance with nationally recognized codes and standards.

8.1.10.4.3
Rooms or cabinets containing compressed gases shall be conspicuously labeled as follows: COMPRESSED GAS.

8.1.10.4.4
Where “no smoking” is not applicable to an entire site or building, signs shall be provided as follows:

(1) In rooms or areas where energetic and hazardous materials is stored or dispensed or used in open systems in amounts requiring a permit in accordance with Section 1.8 of NFPA 400.
(2) Within 25 ft (7.6 m) of outdoor storage, dispensing, or open-use areas.

8.11* Confined Space.

All identified confined spaces shall meet the requirements of OSHA Standard 29 CFR 1910.146.

8.2 Manual of Operating Procedures.

8.2.1
All spaceport and launch support facilities ground support equipment (GSE) and components shall be operated in accordance with the operating procedures manual.

8.2.2
The operating procedures manual shall be accessible to all personnel.

8.2.3
The operating procedures manual shall be kept available in the operating control center.

8.2.4
The operating procedures manual shall be updated when there are changes to equipment or operating procedures.

8.2.5
The operating procedures manual shall include procedures for the startup and shutdown of all GSE and components associated with the launch facility, including those for initial launch sequence activities, fuel transfer, and fueling operations, to ensure that all components operate as designed.

8.2.6 Purging and Cool Down.
8.2.6.1
The operating procedures manual shall include procedures for purging GSE and components, making inert, and cooldown.

8.2.6.2
Procedures shall ensure that the cooldown of each system of components that is under the operating company’s control, and that is subjected to cryogenic temperatures, is limited to a rate and distribution pattern that maintains the thermal stresses within the design limits of the system during the cooldown period regarding the performance of expansion and contraction devices.

8.2.7
The operating procedures manual shall include procedures to ensure that each control system is adjusted to operate within its design limits.

8.2.8
The operating procedures manual shall include procedures to maintain the temperatures, levels, pressures, pressure differentials, and flow rates within their design limits for installed equipment, including the following:

(1) Fired heaters and boilers
(2) Turbines and other prime movers
(3) Pumps, compressors, and expanders
(4) Purification, treatment, and regeneration equipment
(5) Vaporizers, heat exchangers, and cold boxes
(6) Process and storage vessels, tanks, and containers
(7) Transfer equipment
(8) Safety-related equipment

8.2.9
The operating procedures manual shall include procedures for the following:

(1) Determining the existence of any abnormal conditions and the response to those conditions at launch facilities
(2) The safe transfer of energetic materials and other hazardous fluids, including prevention of overfilling of containers
(3) Access control and accountability

8.2.10
The operating procedures manual shall include procedures for monitoring operations.

8.2.11
Written procedures shall be kept up to date and available to all personnel engaged in transfer operations.

8.2.12
Changes to written procedures shall be documented and reviewed after consideration of operability, safety, and security.

8.3 Emergency Procedures.

8.3.1
Each launch facility and launch support facility shall develop and maintain emergency procedures.
8.3.2
The emergency procedures shall include, at a minimum, emergencies that are anticipated from an operating malfunction, a structural collapse, personnel error, forces of nature, and activities carried on adjacent to the launch facilities.

8.3.3
The emergency procedures shall include, but not be limited to, procedures for responding to controllable emergencies, including the following:

(1) Notification of personnel
(2) Use of equipment for handling the emergency
(3) Shutdown or isolation of various portions of the equipment
(4) Other steps to ensure that the escape of gas or liquid is promptly cut off or reduced as much as possible

8.3.4
The emergency procedures shall include procedures for recognizing an uncontrollable emergency and for taking action to achieve the following:

(1) Minimizing harm to personnel at the spaceport and the public
(2) Prompt notification of the emergency to local officials, including the possible need to evacuate persons from the vicinity of the launch or support facilities

8.3.5
The emergency procedures shall include procedures for coordinating with local officials in the preparation of an emergency evacuation plan that sets forth the steps necessary to protect the public in the event of an emergency, including the following:

(1) Quantity and location of fire equipment throughout the launch and support facilities
(2) Potential hazards at launch and support facilities
(3) Communication and emergency control capabilities at launch and support facilities
(4) Status of the emergency

8.4 Site Access Control and Accountability.

8.4.1
Each launch and support facility shall establish a system that provides positive identification and access for personnel authorized to enter and operate within the site.

8.4.2
Each facility shall establish a means to provide real-time accountability of personnel on site.

8.4.3 Security.

8.4.3.1
A security plan shall use a risk-based evaluation to identify, evaluate, and control security risk to prevent unauthorized access and to the spaceport and support facilities by employee and the general public.

8.4.3.2
Spaceports and support facilities shall have a security system with controlled access designed to restrict entry by unauthorized persons.

8.4.3.3
Spaceports and support facilities shall construct protective deterrents, such as a peripheral fence, building, wall, or natural barrier, to secure against unauthorized entry.
8.4.3.4
The location and arrangement of the protective deterrents shall minimize the following:

(1) Pocketing of escaping gases
(2) Interference with application of firefighting operations
(3) Redirection of flames against hazardous materials containers
(4) Impeding egress of personnel during an emergency

8.4.3.5
The provisions of 8.4.3.4 shall be met by either one continuous enclosure or several
independent enclosures or other approved means.

8.4.3.6*
Security controls and processes shall be permitted to be used to control access to individual
storage areas located in secure spaceports and support facilities.

8.4.3.7*
At least two personnel exit gates or doors shall be provided for rapid escape of personnel in
the event of an emergency.

8.4.3.7.1
Personnel exit gates or doors shall meet the egress components requirements of Section 7.
of NFPA 101.

8.4.3.7.2
Personnel exit gates or doors shall be permitted to be locked from the ingress side provided
they meet the applicable requirements of Section 7.2 of NFPA 101.

8.4.3.7.3
Travel distance to personnel exit gates or doors shall be approved by the AHJ.

8.4.3.7.4
Personnel exit gates or doors shall be accessible and identifiable by a means of marking
acceptable by the AHJ.

8.4.3.8
Provisions shall be made to provide access to the enclosed spaceports or support facilities
by emergency personnel or services.

8.4.3.9
Illumination shall be provided as necessary in the vicinity of protective deterrents and in
other areas to promote security of the facility.

8.4.3.10
Illumination shall be provided for egress path personnel exit gates or doors in accordance
with Section 7.1 of NFPA 101 to facilitate egress.

8.5 Monitoring Operations.

8.5.1
Operations monitoring shall be conducted continuously throughout the operation.

8.5.2
At sites with onsite control centers, operating personnel shall be permitted to leave the
control room to perform scheduled field inspections or to address activities in the field relate
to the site’s operation.

8.5.3
Safety-related alarms required by Chapter 6 shall provide notice to onsite personnel
performing operations monitoring unless the control center has an alternate method to
communicate during operations monitoring.
8.5.4
Inspections shall be conducted at least at the intervals set out in the written operating procedures.

8.5.5
Pressure and vacuum monitoring shall be meet the requirements of NFPA 55.

8.6 Commissioning.

8.6.1
Prior to startup of facilities, a commissioning plan shall be developed to test and verify that all components are functional within their design ranges.

8.6.2
Piping shall be commissioned in accordance with ASME B31.1, Power Plant Piping; ASME B31.3, Process Piping; ASME B31.4, Pipeline Transportation Systems for Liquids and Slurries; ASME B31.5, Refrigeration Piping and Heat Transfer Components; or ASME B31.8 Gas Transmission and Distribution Piping Systems; as applicable.

8.6.3
Boilers and pressure vessels shall be commissioned in accordance with the ASME Boiler and Pressure Vessel Code.

8.6.4
Control systems and related instrumentation shall be commissioned in accordance with recognized standards.

8.7 Maintenance Manual.

8.7.1
Each operating company shall have a documented plan that sets out inspection and maintenance program requirements, including fire protection and hazard detection, for each component used in its facility that is identified as requiring inspection and maintenance.

8.7.2
Each maintenance program shall be conducted in accordance with its documented plan for facility components identified in the plan as requiring inspection and maintenance.

8.7.3
Each operating company shall perform periodic inspections, tests, or both, on components and support systems in service in its facility identified as requiring inspection on a schedule that is included in the maintenance plan.

8.7.4
The maintenance manual shall refer to maintenance procedures, including procedures for the safety of personnel and property while repairs are carried out, regardless of whether the equipment is in operation.

8.7.5
The maintenance manual shall include the following for facility components:

(1) The manner of carrying out and the frequency of inspections and tests.

(2) A description of any other action, in addition to those referred to in Section 8.2, necessary to maintain the facility in accordance with this standard.

(3) All procedures to be followed during repairs on a component that is operating while it is being repaired, to ensure the safety of persons and property at the site.

8.7.6
Procedures for the inspection of all pipe-in-pipe components, including vacuum levels, shall be specified and demonstrated to be applicable for the installed condition.
8.7.7
Procedures for the repair and maintenance of all pipe-in-pipe components, including vacuum levels, shall be specified and demonstrated to be applicable for the installed condition.

8.8 Maintenance.

8.8.1
Each operating company shall ensure that components in its launch or support facilities that could accumulate combustible mixtures are purged in accordance with Chapters 7 and 8 after being taken out of service and before being returned to service.

8.8.2
Where the operation of a component that is taken out of service could cause a hazardous condition, a tag bearing the words "Do Not Operate," or the equivalent, shall be attached to the controls of the component (see 8.8.2.1).

8.8.2.1
If a "Do Not Operate" tag is not or cannot be attached to the controls of the component, the component shall be locked out.

8.8.2.2
The support system or foundation of each component shall be inspected annually.

8.8.2.3
If the foundation is found to be incapable of supporting the component, it shall be repaired.

8.8.3 Emergency Power.

8.8.3.1
Where mechanical ventilation, treatment systems, temperature control, alarm, detection, or other electrically operated safety systems are required by NFPA 5000 or NFPA 1, such systems shall be provided with standby power or emergency power as required by 34.3.2.7 of NFPA 5000. [5000:34.3.2.7.1]

8.8.3.2
Standby power for mechanical ventilation, exhaust treatment, and temperature control systems shall not be required where such systems are engineered and approved as fail-safe. [5000:34.3.2.7.2]

8.8.3.3
The secondary source of power shall be an approved means of legally required standby power in accordance with NFPA 70.

8.8.3.4
Each emergency power source at the spaceport shall be tested monthly to ensure that it is operational.

8.8.3.5
Annual testing of the emergency power source shall be conducted to ensure that it is capable of performing at its documented intended capacity, taking into account the power required to start some and simultaneously operate other equipment that would be served by the power source in an emergency.

8.8.4
Repairs that are carried out on components of the launch facility shall be carried out in a manner that ensures the following:

(1) Integrity of the components is maintained, in accordance with this standard.
(2) Components operate in a safe manner.
(3) Safety of personnel and property during a repair activity is maintained.
8.8.5
Each operating company shall comply with the following:

(1) Keep the grounds free from rubbish, debris, and other materials that could present a fire hazard.

(2) Ensure that the presence of foreign material contaminants, snow, or ice is avoided or controlled to maintain the operational safety of each launch facility component.

(3) Maintain the grassed area so that it does not create a fire hazard.

(4) Ensure that fire control access routes within or around launch and launch support facilities are unobstructed and maintained in all weather conditions.

8.8.6 Control Systems, Inspection, and Testing.

8.8.6.1
Each operating company shall ensure that a control system that is out of service for 30 days or more is tested prior to returning it to service to ensure that it is in working order.

8.8.6.2
Each operating company shall ensure that the inspections and tests in 8.8.6 are carried out at the intervals specified.

8.8.6.3
Control systems used seasonally shall be inspected and tested before use each season.

8.8.6.4
Control systems used as part of the fire protection and hazard detection systems shall be inspected and tested in accordance with the applicable fire code.

8.8.6.5
Control systems used as part of the fire protection and hazard detection systems shall conform to all of the following:

(1) Monitoring equipment shall be maintained in accordance with NFPA 72 and NFPA 1221.

(2) Fire protection water systems shall be maintained in accordance with NFPA 13, NFPA 14, NFPA 15, NFPA 20, NFPA 22, NFPA 24, NFPA 25, NFPA 750, and NFPA 1962.

(3) Portable or wheeled fire extinguishers provided in facility and on tank vehicles shall be maintained in accordance with NFPA 10.

(4) Fixed fire-extinguishing systems and other fire control equipment shall be maintained in accordance with NFPA 11, NFPA 12A, NFPA 17, NFPA 102, and NFPA 2001.

(5) Detection devices not covered by NFPA 72 shall be tested and calibrated in accordance with manufacturer’s instructions once each calendar year at intervals not greater than 15 months.

8.8.6.6
All relief valves protecting hazardous fluid components shall be randomly inspected and set-point tested at the intervals prescribed in 8.8.6.6.1.

8.8.6.6.1
Inspection intervals shall be in accordance with either of the following:

(1) Annual in-service inspection of the external portions of the valve and its installation in accordance with Section 2 of ANSI/NB-23, National Board Inspection Code, Part 2, Inspection, on in-service inspection requirements for pressure relief devices, including listed conditions that can be observed on the valves externally.

(2) In accordance with API 510, Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration.
8.8.6.6.2
Set-point testing intervals shall be in accordance with either of the following:
(1) At intervals not exceeding five years, plus three months
(2) At a frequency in accordance with API RP 576, *Inspection of Pressure-Relieving Devices*

8.8.6.7
Stop valves for isolating pressure or vacuum-relief valves shall be locked or sealed open.

8.8.6.8
Stop valves shall not be operated except by an authorized person.

8.8.6.9
Where a component is served by a single safety device and the safety device is taken out of service for maintenance or repair, the component shall also be taken out of service, unless safety is accomplished by an alternative means.

8.8.7 Meteorological and Geophysical Events.

8.8.7.1
Launch and support facilities and, in particular, the hazardous materials storage container and its foundation, shall be externally inspected after each major meteorological disturbance to ensure that the structural integrity is intact.

8.8.7.2
If a potentially damaging geophysical or meteorological event occurs, the following shall be accomplished:
(1) The spaceport shall be shut down as soon as is practical.
(2) The nature and extent of damage, if any, shall be determined.
(3) The spaceport activities shall not be restarted until operational safety is reestablished.

8.8.8 Corrosion Protection.

8.8.8.1 Design and Installation.

8.8.8.1.1
All metallic components (e.g., containers, piping, valves, vaporizers, heat exchangers, and so on) containing hazardous fluids (i.e., liquid or vapor state) that could have their integrity or reliability adversely affected by external, internal, or atmospheric corrosion during their intended service life shall be protected from corrosion.

8.8.8.1.2
The design of and installation procedure for external corrosion-control cathodic protection systems shall be documented.

8.8.8.1.3
Components whose integrity or reliability could be adversely affected by corrosion shall be treated as follows:
(1) Protected from corrosion in accordance with 8.8.8.1 through 8.8.8.5, as applicable
(2) Inspected under a program of scheduled maintenance in accordance with 8.8.8.6 and 8.8.8.7

8.8.8.2 Atmospheric Corrosion Control.
8.8.8.2.1
Each exposed component that is subject to atmospheric corrosion shall be protected from atmospheric corrosion by either of the following:

1. Material that has been designed to resist the corrosive atmosphere involved
2. Coating or jacketing suitable for the prevention of atmospheric corrosion

8.8.8.2.2
Where coatings are used, both of the following shall apply:

1. The component being coated shall be prepared to accept the coating.
2. The coating shall be applied as required by the coating manufacturer to ensure performance of the coating.

8.8.8.3 External Corrosion Control: Buried or Submerged Components.

8.8.8.3.1
Each buried or submerged component that is subject to external corrosion shall be protected from external corrosion by either of the following:

1. Material that has been designed to resist the corrosive environment involved
2. Both of the following means:
   a. An external protective coating designed for operating and environmental conditions of the installation site and installed to prevent corrosion of the protected component
   b. A cathodic protection system (e.g., impressed-current type or galvanic anode system) designed to protect components in their entirety in accordance with the following:
      i. The cathodic protection system shall be controlled so as not to damage the component or its coating.
      ii. Each component under cathodic protection shall be installed with test stations to determine the adequacy of the cathodic protection.
      iii. Each test station shall have test leads installed that remain mechanically secure and electrically conductive, are attached to a component to minimize stress conditions on that component, and are coated with electrically insulating material compatible with the coating on the component.

8.8.8.3.2
Prior to installation, each container, length of pipe, and other components shall be visually inspected at the installation site to identify damage.

8.8.8.3.2.1
Damage to the container, pipe, or component that could impair its serviceability shall be repaired as permitted by pressure vessel, pipe, and component codes.

8.8.8.3.2.2
Any coating damage shall be repaired using materials compatible with the existing coating following the manufacturer’s procedures.

8.8.8.3.3
Components shall be tamped in place surrounded by earth or sand that is free of rocks and abrasives.

8.8.8.3.4 ASME Containers.

8.8.8.3.4.1
The portions of a partially underground, unmounded ASME container that are below the surface of the ground and for a vertical distance of at least 3 in. (75 mm) above that surface shall comply with 8.8.8.1.1.
8.8.8.3.4.2
The remaining aboveground portion of the ASME container shall be coated against atmospheric corrosion.

8.8.8.3.4.3
The part of an aboveground ASME container in contact with saddles or a foundation shall be provided a means to minimize corrosion.

8.8.8.3.5
Where cathodic protection is applied, components that are electrically interconnected shall be protected as a unit.

8.8.8.3.6
Within one year of complete system installation, all buried or submerged components shall comply with the requirements of 8.8.8.3.

8.8.8.3.7
The requirements of 8.8.8.3 shall not apply where technical documentation that a corrosive environment does not exist is approved by the AHJ.

8.8.8.3.7.1
The technical documentation shall be based on testing, investigation, or experience in the area of application.

8.8.8.3.7.2
The technical documentation shall include, as a minimum, soil resistivity measurements and tests for corrosion-accelerating bacteria.

8.8.8.3.8 Initial Tests.

8.8.8.3.8.1
Tests shall be required after six months of burial of the system identified in 8.8.8.3.1, including component-to-soil potential measurements with respect to either a continuous reference cell electrode or an electrode using close spacing, not to exceed 20 ft (6 m), and soil resistivity measurements at potential profile peak locations to evaluate the potential profile at the component or along the pipeline.

8.8.8.3.8.2
If tests indicate that a corrosive condition exists, the affected components shall be cathodically protected in accordance with 8.8.8.

8.8.8.3.9 Additional Tests.

8.8.8.3.9.1
After the initial tests in 8.8.8.3.8, additional tests shall be conducted every three years, not to exceed 39 months, to reevaluate the condition of the unprotected components.

8.8.8.3.9.2
If tests indicate that an active corrosion exists either by electrical survey of leak repair or exposed pipe inspection records, the affected components shall be cathodically protected in accordance with 8.8.8.3.

8.8.8.3.10
Where insulating devices (e.g., flange, fitting, union) for cathodic protection are installed, precaution shall be taken to prevent arcing in areas where combustible atmospheres are anticipated.

8.8.8.3.11 Current Protection.
8.8.8.3.11.1
Where components are in close proximity to electric transmission tower footings, ground cables, or counterpoises, or in areas where fault currents or unusual risk of lightning is anticipated, they shall be provided with protection against damage due to fault currents or lightning.

8.8.8.3.11.2
Protective measures shall be taken at insulating devices.

8.8.8.4 Internal Corrosion Control.
Each component that is subject to internal corrosive attack shall be protected from internal corrosion by one of the following:

(1) Material that has been designed to resist the corrosive fluid involved
(2) Coating, inhibitor, or other means

8.8.8.5 Interference Currents.

8.8.8.5.1
Each component that is subject to electrical current interference shall be protected by a continuing program to minimize the detrimental effects of interference currents.

8.8.8.5.2
Each cathodic protection system shall be designed and installed to minimize any adverse effects it might cause to adjacent metal components.

8.8.8.5.3
Each impressed current power source shall be installed to prevent adverse interference with communications and control systems.

8.8.8.6 Monitoring Corrosion Control.

8.8.8.6.1
Corrosion protection shall be monitored to provide recognition of ineffective corrosion protection in accordance with 8.8.8.6.2 through 8.8.8.6.4.
8.8.8.6.2
Cathodic protection of buried or submerged components shall comply with the following:

1. Cathodic protection systems installed in accordance with 8.8.8.3 shall be monitored by testing and the results documented and retained.

2. Cathodic protection system tests shall be described by producing a voltage of \(-0.80\) volts or greater negative, with reference to a silver–silver chloride half-cell.

3. Each buried or submerged component under cathodic protection shall be tested by personnel qualified to perform corrosion-control monitoring at least once each calendar year, with intervals not to exceed 15 months, to determine whether the cathodic protection is performing as designed.

4. Each cathodic protection rectifier or other impressed current power source shall be inspected by personnel qualified to perform corrosion-control monitoring at least six times each calendar year, with intervals not to exceed two and a half months, to ensure that it is performing as designed.

5. Each reverse current switch, diode, and interference bond whose failure would jeopardize component protection shall be electrically checked for performance at least six times each calendar year, with intervals not to exceed two and a half months, by personnel qualified to perform corrosion-control monitoring.

6. Other interference bonds shall be checked at least once each calendar year, with intervals not to exceed 15 months.

7. Whenever any portion of a buried pipe is exposed, the exposed portion of the pipe shall be examined for evidence of external corrosion in either of the following instances:

   a. If general external or localized external pitting corrosion is identified, additional examination in the exposed area shall be conducted to identify the extent of the corrosion.

   b. If damage to the component coating is observed, the coating shall be repaired in accordance with 8.8.8.3(2).

8.8.8.6.3
Each component that is protected from atmospheric corrosion shall be inspected at intervals not exceeding three years.

8.8.8.6.3.1
Components located at soil-to-air interfaces, under disbonded coatings, at pipe supports, in splash zones, and deck penetrations shall be inspected.

8.8.8.6.3.2
Components covered by insulation that are subject to atmospheric corrosion shall be periodically monitored in accordance with a written program based upon the principles of NACE SP 0198, Control of Corrosion Under Insulation and Fireproofing Materials — A Systems Approach.

8.8.8.6.4
Components that are protected from internal corrosion shall have monitoring devices designed to detect internal corrosion.

8.8.8.6.4.1
Monitoring devices shall be located where corrosion is most likely to occur.

8.8.8.6.4.2
Internal corrosion-control monitoring devices shall be monitored at least two times each calendar year, with intervals not to exceed seven and a half months.

8.8.8.6.4.3
Monitoring shall not be required for corrosion-resistant materials if it is demonstrated that the component is not adversely affected by internal corrosion during its service life.
8.8.8.6.4.4 Whenever a pipe is opened, the internal surface shall be examined for evidence of corrosion.

8.8.8.7 Remedial Measures.

8.8.8.7.1 Corrective action shall be taken when inspection determines that atmospheric, external, or internal corrosion is not controlled in accordance with 8.8.8. [59:12.3.2]

8.8.8.7.2 Components observed during monitoring per 8.8.8.6.2, 8.8.8.6.3, and 8.8.8.6.4 shall be replaced where uniform or localized corrosion, or localized corrosion pitting, has resulted in remaining wall thickness less than that required for the maximum allowable operating pressure (MAOP) of the pipeline, or a remaining wall thickness less than 50 percent of the nominal wall thickness.

8.8.8.7.3 Where components are observed with atmospheric corrosion not exceeding values in 8.8.8.7.2, the coating shall be repaired in accordance with 8.8.8.3.2(2).

8.8.8.8 Retroactivity.

8.8.8.8.1 All new spaceports and components shall meet all the requirements for corrosion control in 8.8.8.1.

8.8.8.8.2 All expanded or modified spaceports, or spaceports replacing components containing liquefied natural gas (LNG) and hazardous fluids (liquid or vapor state) shall meet the requirements for corrosion control in 8.8.8.1 for expanded, modified, or replaced portions of the plant.

8.8.8.8.3 Corrosion control requirements shall be applied retroactively to existing plants in accordance with 8.8.8.8.3.1.
8.8.8.4
Atmospheric corrosion control requirements shall be applied to existing facilities in accordance with the following:

(1) The following atmospheric corrosion-control procedures shall be met within one year of the issuance of this standard:
   (a) Coating of exposed components in accordance with 8.8.8.2.1(2)
   (b) Monitoring in accordance with 8.8.8.6
   (c) Remedial measures in accordance with 8.8.8.7
   (d) Recordkeeping

(2) The following procedures for components covered by thermal insulation or fireproofing materials shall be met within three years of issuance of this standard:
   (a) Coating in accordance with 8.8.8.2.1(2)
   (b) Monitoring in accordance with 8.8.8.6.3
   (c) Remedial measures in accordance with 8.8.8.7
   (d) Recordkeeping

(3) The following procedures for internal corrosion control shall be met within one year of the issuance of this standard:
   (a) Component monitoring in accordance with 8.8.8.6.4
   (b) Remedial measures in accordance with 8.8.8.7
   (c) Recordkeeping

8.9 Personnel Training.

8.9.1
Every spaceport and space launch support facility shall have a written training plan to instruct all personnel operating at the site.

8.9.2
The training plan shall include training of permanent maintenance, operating, and supervisory personnel with respect to the following:

(1) Basic operations carried out at the spaceport and space launch facilities
(2)* Characteristics and potential hazards involved in operation and maintenance of the spaceport and space launch support facility
(3) Subsections for each propellant type anticipated to be used at launch site
(4) Methods of carrying out the duties of maintaining and operating the spaceport and space launch support facilities as set out in the manual of operating and maintenance procedures in Section 8.2.
(5) Methods of carrying out emergency procedures required by Section 8.3 as they relate to their assigned functions
(6) Personnel safety and general construction industry safety-related training as it relates to the assigned functions

8.9.2.1
All operating and supervisory personnel shall be trained in the following:

(1) Instructions on the facility operations, including controls, functions, and operating procedures
(2) Hazardous materials transfer procedures
(3) Purging practices and principles
8.9.2.2
All personnel involved in operation and maintenance of spaceport and launch support facilities, including immediate supervisors, shall be trained in the following aspects of fire protection and fire drills:

(1) Potential causes and areas of fire
(2) Types, sizes, and predictable consequences of fire
(3) Assigned fire control duties in accordance with the emergency procedures in Section 8.3, which includes use of fire protection and emergency response equipment
(4) Hands-on experience in carrying out duties as listed in the emergency procedures in Section 8.3

8.9.2.3
Personnel responsible for security as it relates to their assigned functions and described in the security procedures shall be trained to do the following:

(1) Recognize security breaches
(2) Carry out security procedures as it relates to their assigned functions
(3) Be familiar with basic plant operations and emergency procedures as necessary to perform their assigned functions
(4) Identify situations where it would be necessary to obtain assistance to maintain the security of the energetic materials facilities

8.9.3
All spaceport personnel shall meet the following requirements:

(1) Spaceport and launch support facilities personnel shall receive training per 8.9.2.
(2) Spaceport and launch support facilities personnel shall have experience related to their assigned duties.

8.9.4
Any person who has not completed the training or received experience set out in 8.9.2 shall be under the supervision of trained personnel.

8.9.5
Transient or mission support personnel shall be both of the following:

(1) Escorted by personnel trained in accordance with 8.9.2
(2) Required to attend a briefing that covers the following:
   (a) Warning devices and signage
   (b) Emergency actions
   (c) Personnel protective equipment
   (d) Any other unique or pertinent information regarding hazards

8.9.6
Persons who are required to receive training per 8.9.2 shall receive refresher training in the same subjects at least one of the following:

(1) Annually
(2) As determined by the spaceport authority
(3) As required by governing laws, regulations, or other applicable standards

8.10 Records.
8.10.1
Each operating company shall maintain for a period of not less than 5 years a record of the date and type of each maintenance activity performed on each component of the energetic materials facility, including a record of the date that a component is taken out of or placed into service.

8.10.2
Records shall be made available during business hours upon request.

8.10.3
A record of all training shall be maintained for each employee of an energetic materials facility, and the records shall be maintained for at least 2 years after the date an employee ceases to be employed at the energetic materials facility.

Chapter 9 Preincident Planning

9.1 General.
The requirements of NFPA 1620 shall be incorporated into the preplanning process in addition to the content of this chapter.

9.2* Spaceport Assessment.

9.2.1
The spaceport operator shall provide information regarding any existing and new hazards that pose a risk to responders and public safety.

9.2.2
The identified hazards shall be documented on a locally developed form acceptable the AH.

The preplanning process shall include identification of hazardous materials classification of all commodities that are located on site or will be transported to the site for operations.

9.4* Explosives.
The preplanning process shall include identification of the classification of all explosives that are located on site or will be transported to the site for operations.

9.5* Operations/Processes.
The preplanning process shall include identification of any operations and processes conducted at the site that poses a hazard.

9.6* Launch and Support Facilities.
The preplanning process shall include assessing the processing, launch, and direct support facilities to identify any challenges that can assist, delay, or impact mitigations.

9.7* Launch Complex.
The preplanning process shall include assessing the launch complex and identify any challenges that can assist, delay, or impact mitigations.

9.8* Launch Vehicle/Spacecraft.
The preplanning process shall include assessing the launch vehicle to identify any challenges that can assist, delay, or impact mitigations.

9.9 Training of Emergency Response Personnel.

9.9.1*
The requirements of NFPA 1410 shall be incorporated into the preplanning process in addition to the content of this chapter.

9.9.2
The spaceport operator shall provide training on spaceport-specific operations and hazards identified in Chapter 9.

Annex A Explanatory Material
Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.1.1
The buildings and structures can include, but are not limited to, the launch site, landing site, launch tower, fueling structures, payload integration facilities, propellant processing/storage facilities, and static test stands.

A.1.3.1
The primary hazard associated with a launch vehicle or payload is the energetic material whether it be solid/liquid propellant or explosive material for abort or stage separation. If no energetic material is present, the launch vehicle or payload contains typical Class A, B, or C combustible materials. Care must be taken to ensure that buildings or structures that support the storage or use of energetic materials are properly protected. For example, an umbilical tower for a launch vehicle does not use or contain energetic material; however, it is directly associated with the storage and use of energetic material. It is the intent of this standard that the umbilical tower comply with the requirements of this standard due to the risk associated with the energetic material. Operational use includes use, handling, or processing of energetic materials.

A.1.6.4.1
It is not intended that the application or enforcement of these values be more precise than the precision expressed.

A.1.6.4.2
Users of this standard should apply one system of units consistently and not alternate between units.

A.3.2.1 Approved.
The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the "authority having jurisdiction" may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The "authority having jurisdiction" may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction (AHJ).
The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.3.2.3 Code.
The decision to designate a standard as a "code" is based on such factors as the size and scope of the document, its intended use and form of adoption, and whether it contains substantial enforcement and administrative provisions.

A.3.2.4 Listed.
The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.
A.3.3.4 Energetic Material.

Explosives and propellants that have been properly initiated evolve large volumes of hot gas in a short time. The difference between explosives and propellants is the rate at which the reaction proceeds. In explosives, a fast reaction produces a very high-pressure shock in the surrounding medium. This shock is capable of shattering objects. In propellants, a slower reaction produces a lower pressure over a longer period of time. This lower sustained pressure is used to propel objects. Pyrotechnics evolve large amounts of heat but much less gas than propellants or explosives. Various external stimuli can cause release of the energy contained in energetic materials. Knowing the response of individual energetic materials to specific stimuli is important from the point of view of safety.

Energetic materials are sensitive to four external stimuli: impact, shock, electrostatic, and thermal. Eliminating or controlling these stimuli are key to eliminating the unintentional initiation of energetic material. The hazards associated with energetic material are blast, fragments, mass fire, fire, and toxicity. (See also, DESR 6055.09, Explosives Safety Standards.)

A.3.3.10 Launch Complex.

Launch complexes are also enclosed by physical means (e.g., fences) in most cases. “Inside the fence line” is a common expression at the Western and Eastern Ranges and it serves to denote a transfer of responsibility between the range and the complex operator.

A.3.3.11 Launch Facility.

Launch facilities can include the processing of payloads or testing conceptual/operational launch capabilities. Examples of such facilities include, but are not limited to, launch complexes/platforms, airstrips/runways, processing facilities, or support facilities that present unique hazards related to space travel. Unique hazards presented by space flight include, but are not limited to, combining fuel/oxidizers, munitions, and other chemical hazards.

A.3.3.19 Professional Engineer.

With regard to this standard, a professional engineer can also be defined as an individual who is a registered professional engineer who has passed the fire protection engineering written examination administered by the National Council of Examiners for Engineering and Surveying (NCEES) (or equivalent) and has relevant fire protection engineering experience. However, 3.3.19 should be considered the primary definition for this term.

A.3.3.28 Spaceport.

A spaceport is a designated area on land or water that consists of a launch site or landing site, or both, including all associated launch facilities. For the purposes of this standard, a spaceport will also typically consist of the following:

(1) Office and administrative areas.
(2) Hazardous storage. For items such as explosives, fuels, energetic material, and other classified hazardous materials.
(3) Nonhazardous storage. For items needed to allow operations to proceed (e.g., lifting fixtures stored in facilities close to the launch area for easy availability).
(4) Processing facilities. Physical locations that permit either (1) on-site buildup of rockets, satellites, and other needed items to meet mission objectives; or (2) on-site disassembly of items as required to meet post-launch safety needs. These areas can be placed near the actual launch site or in locations that permit unimpeded access to the launch site.
(5) Launch site. The actual physical location for the launch event. The launch site allows final loading of the booster with propellants and placement of the payload on the booster.
(6) Recovery site. A physical location that allows landing of reusable items following the launch (e.g., portions of a booster designed and built to permit multiple usages).
(7) Specialized sites or facilities. Physical locations that are not launch sites but permit operations that closely parallel what occurs at a launch site (e.g., rocket engine test stands, which require propellant loading, engine firing, disposal of unused propellant, and engine disassembly).
A.4.2.1
At times, specific operations associated with spaceport facilities pose risks that might not be addressed with designated egress, active or passive protection systems, or other means an methods. Such specific operations might necessitate that a small group of essential, highly trained personnel are the only personnel potentially exposed to a hazard. It should be understood that, due to the inherent nature of the work and materials used in these types of facilities and operations, an emergency could result in unavoidable casualties.

A.4.4.1
The intent of this standard is to provide design and operational criteria for spaceport facilities that use energetic materials where compliance with the applicable NFPA standard might not be practical.

A.4.4.4
Safeguards do not only include active and passive systems or features. Safeguards can also include administrative controls, operational procedures, or similar methods. Because buildings that do not comply with Chapter 6 are required to follow applicable codes and standards, it is not necessary to provide safeguards for such buildings as the applicable codes and standards are assumed to provide a level of protection and safety that has been deemed appropriate.

A.4.7.1
It is recognized that due to the nature of this industry that information that is proprietary, sensitive, or considered trade secrets might not be made available for general record keeping. In some instances, nondisclosure agreements might be appropriate; however, it is not the intent of 4.7.1 to create a potential conflict of interest or require a competing party be involved.

A.5.1.3
The intent of 5.1.3 is to ensure remote operational facilities, such as launch or mission control centers, that can directly control or dictate launch operations (e.g., launch confirmation, launch aborts, and so on) from a location not directly located at the spaceport (i.e., not on the same property) are evaluated. It is not the intent of 5.1.3 to apply to facilities not located on the spaceport property that produce components, materials, or products of a nonhazardous nature for spaceport operations or space vehicles. Nor is it the intent of 5.1.3 to apply to remote facilities that monitor operations but have no measure of control on the operations.

A.5.1.4
In rare instances, specific operations can have impacts beyond the designated spaceport boundaries. Such operations can be permitted by the AHJ, with the protection measures agreed upon by all parties and governing agencies. Any such instance needs to be fully documented and included in the written evaluation identified in Section 5.4. However, space vehicle flight is not addressed within this standard.

A.5.1.5
The process may include evaluations of blast, fragment, thermal flux, and glass breakage hazards; protective construction; grounding, bonding, and lighting protection systems (LPS) electrical installations; natural or man-made terrain features; or other operations and location requirements. [NASA Technical Standard 8179.12A: A.2]

A.5.2.1
A written spaceport and site analysis is a risk assessment identifying and analyzing potential incidents having a bearing on the safety of spaceport personnel and the general public, as well as continuing operations by minimizing downtime.

A.5.2.2
It is acceptable to have multiple site plans as needed to convey the necessary information. As an example, toxic vapor dispersion arcs can be independent of heat flux distances. Static fires, wet dress rehearsals, fueling, and similar processes, as well as launch operations, should also be included.
A.5.2.2(6)
A topographic map with contours (where terrain features are considered to provide natural barricading) or topography that otherwise influences the facility’s layout should be included.

A.5.2.2(6)(b)
Emergency response should ensure that any security measures or procedures do not impact or impair emergency operations or personnel. A review of the site security response plan in accordance with the regulatory agencies should be considered.

A.5.2.4.1
The intent of 5.2.4.1 is that evaluation is renewed once the operational license is renewed.

A.5.3.4
Although site plans for construction of vulnerable facilities (e.g., passenger terminals, high-rise buildings, restaurants) located on spaceports that are outside but near quantity distance (QD) arcs are not required, it is recommended that they be submitted to the AHJ for review and comment.

A.5.4(4)
The intent of referencing NFPA 70 is to pull in the electrical classification requirements for electrical installations.

A.5.5
The AHJ should be provided detailed analysis regarding inherited hazards of the space vehicle and support operations that could affect exposed vulnerable construction, such as the following:

(1) Release of hazardous and toxic materials
(2) Explosion pressures and fragmentation
(3) Acoustic hazards
(4) Nonionizing and ionizing radiation
(5) Space vehicle pressure systems
(6) Debris risk
A.6.1.1

It is important that stakeholders, particularly the AHJ, ask the correct questions to gain a better understanding of the equipment, materials, and processes used as they can, and mostly likely will, be different from manufacturer to manufacturer and operator to operator. Some initial questions that should be asked include the following:

(1) What is being manufactured/stored in the building?
(2) How is it stored?
(3) How does it enter/leave the building?
(4) How is it used in any processes in the building?
(5) What energetic materials are being used?
(6) What is the quantity, location, container type, and process for all energetic materials being used?
(7) What hazardous materials are being used?
(8) What is the quantity, location, container type, and process for all hazardous materials being used?
(9) What “safeties” or safety systems are in use for the energetic material?
(10) Describe the equipment/process/system in a dormant state.
(11) Describe the equipment/process/system in an active state.
(12) What procedures does the launch operator have for the use/operation of this equipment/system?
(13) What administrative controls will be developed related to the use/storage of energetic materials?
(14) What interlocks are proposed (e.g., active, passive, or administrative) for the energetic materials?
(15) What propellants will be used?
(16) What is the quantity, location, container type, and process for all propellants being used?

A.6.2

The spaceport facility hazard analysis should follow a recognized process in its development, such as NFPA 551 or the SFPE Guide to Performance-Based Design.

A.6.2.1.1

Additional resources are available that provide insight into the hazards, risk mitigation, and active/passive systems and features that might be prudent to include in a spaceport facility hazard analysis. These resources include NASA STD 8179.12 and AFSCMAN 91-710, volume 5.

A.6.3

Determining which stakeholders should be part of the spaceport facility hazard analysis should be based on roles and responsibilities with regard to the spaceport. Some examples of stakeholders include the following:

(1) Public safety officials, including firefighters, law enforcement officers, emergency services personnel, healthcare workers, environmental officials, transportation workers, and legal service providers
(2) Launch and launch support operations, including launch providers, flight and support hardware/equipment manufacturers, and facilities and infrastructure officials
(3) Community development officials
(4) Private industry entities
A.6.4.1
Protection for spaceport facilities should be specific to the nature and anticipated operations and fire risks of each facility. NFPA 551 can be used as a reference guide for conducting an evaluating fire risk assessments.

A.6.4.3
It should be determined what hazards exist that would result in an incident involving fire, hazardous materials release, explosion, severe injury, or loss of life.

A.6.4.6
Mitigation strategies can include identification of limitations, what category of mitigation is most appropriate to the hazard, and elimination of the hazard.

A.6.4.7
Alternative methods should include justification or rational for the alternative method and define the acceptable risk level.

A.6.4.8
The determination in 6.4.8 should include the roles and responsibilities for implementation, implementation actions and process, roles and responsibilities for the evaluation, how a mitigation is measured, and if the mitigation methods are effective.

A.7.2.1
Where the performance assessment scope addresses portions of the spaceport, Chapter 5 and Chapter 6 can be used for those portions and the applicable NFPA standards can be used for the remainder of the spaceport. The performance assessment should address the adjacent portions of the building that are following the applicable NFPA standards where necessary.

A.7.2.2

A.8.1.6
The closure plan regarding hazardous material also includes energetics.

A.8.1.10.4.1(3)
Factors such as emergency responding forces travel of direction to the spaceport, the potential vapor exposure, BLEVE, and other factors that pose significant risk to responders and the public.

A.8.1.11
NFPA 350 provides additional guidance for safe entry into confined spaces.

A.8.4.3.6
Access needs to be limited to those that are familiar with the specific operations occurring. Examples of security controls and processes include, but are not limited to, the following:

1. Access badges
2. Authorized personnel listings
3. Electronic accountability systems
4. Access control systems
5. Escort processes

A.8.4.3.7
Travel distances to and between personnel gates can vary depending on the size of the enclosed area, location of persons during normal operations, and type of hazardous commodity. Other considerations such as donning PPE, topography of the area, notification of an incident, environmental influences, and other actions that can delay egress need to be factored in.
A.8.8.7.2
Corroded pipe can be repaired by a method that reliable engineering tests and analyses show can permanently restore the serviceability of the pipe.

A.8.9.2(2)
Some of the potential hazards include risk of frostbite from contact with energetic materials or cold refrigerants, as well as asphyxiants, flammability of mixtures with air, odorless vapors, boiloff characteristics, and reactions with water.

A.9.2
The intent of preincident planning is to facilitate the development and implementation of operations risk management (ORM) mitigations and associated response to possible incidents that occur at spaceport or support facilities.

A.9.3
Where determining the hazardous classification, the preplanning process should address the following:

1. Commodity physical and chemical state
2. Type of storage
3. Transportation mode of commodity
4. Quantity stored
5. How the commodity is used
6. Location
7. Exposures
8. Reactivity/incompatibles
9. DOT ERG instructions
10. Safety data sheet (SDS)
11. Radioactive material

A.9.4
Where determining the hazardous classification, the preplanning process should address the following:

1. Commodity physical and chemical state
2. Mode of transportation
3. Type of storage
4. Quantity stored
5. How the commodity is used
6. Location
7. Exposures
8. Reactivity/incompatibles
9. DOT ERG instructions
10. Safety data sheet (SDS)
A.9.5
Where determining the hazards that are inherent to the operations and processing, the preplanning process should address the following:

1. Quiescent environment (i.e., hazards present with no activity)
2. Detailed description of expected operations and processes
3. Identify planned mitigations to reduce risk
4. Define responsibilities to ensure effectiveness of controls
5. Actions planned in the event of an incident
6. Responsibilities of parties in the event of an incident

A.9.6
Where assessing the launch complex or support facilities, the preplanning process should address the following:

1. Type of construction of launch complex or other launch support facilities
2. Inherent hazards associated with the facility or support equipment
3. Location of hazards
4. Interior layout/mixed occupancies
5. Large bays/open areas
6. Occupant loading/mobility
7. Restricted ingress/egress
8. Confined spaces
9. Engineering/facility drawings
10. Infrastructure
11. Lightning protection
12. Fire protection features

A.9.7
Where assessing the launch complex, the preplanning process should address the following:

1. How support structures and platforms interface with the launch vehicle and payload
2. Whether the interface is mobile or fixed
3. Any unique construction features present
4. Confined spaces as defined by 29 CFR 1910.146
5. High angles/elevated areas that might need to be accessed during emergencies
6. Available lightning protection features
7. Fire protection features
A.9.8

The type of launch vehicle/spacecraft will vary depending on the user, technology, or the overall purpose of the launch. The launch vehicle/spacecraft presents various hazards with varying degrees of risk depending on multiple factors. The potential that humans could be passengers increases the possibility of a requirement to provide aided rescue. It is important that emergency responders be informed of these hazards to facilitate mitigation and maintain overall safety.

Where assessing the launch vehicle/spacecraft, the preplanning process should address the following:

1. Inherent hazards (e.g., pinch points, sharp edges, doors, and so on)
2. Hazardous materials/explosives
3. Launch/space vehicle construction materials
4. Any nominally available fire protection features
5. Launch countdown/operation restrictions, including the following:
   a. Vehicle systems and operation
   b. Shutdown
   c. Launch abort systems
   d. Equipment configurations or operations that could impede or prevent emergency egress by emergency responders
6. Passengers/crew, including the following:
   a. Total
   b. PPE/spacesuits
   c. Equipment configurations or operations that could impede or prevent emergency egress of the passengers/crew
7. Access and egress:
   a. Number/location
   b. Function of egress system
   c. Specialized tools

A.9.9.1

The intent of providing training to emergency responders should focus on achieving maximum unity, compatibility, and effectiveness during launch-related emergencies. Emergency response personnel should participate in regular training and exercises involving simulated launch-related accidents throughout the year. Frequent command-level training for those persons assigned to major roles in the IMS plan is also essential. Command training can be presented in the form of workshop or tabletop exercises designed to develop effective emergency management techniques. Guidance for emergency plan exercises is provided in NFPA 424.

Annex B  Informational References

B.1 Referenced Publications.

The documents or portions thereof listed in this annex are referenced within the informational sections of this standard and are not part of the requirements of this document unless also listed in Chapter 2 for other reasons.
B.1.1 NFPA Publications.
National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

B.1.2 Other Publications.

B.1.2.1 SFPE Publications.

B.1.2.2 US Government Publications.

B.1.2.3 Other Publications.

B.2 Informational References. (Reserved)

B.3 References for Extracts in Informational Sections. (Reserved)
# 2025 ANNUAL REVISION CYCLE

*Public Input Closing Dates may vary according to standards and schedules for Revision Cycles may change. Please check the NFPA Website for the most up-to-date information on Public Input Closing Dates and schedules at www.nfpa.org/document # (i.e. www.nfpa.org/101) and click on Next Edition tab.*

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## Tech Session Preparation (& Issuance)

| Notice of Intent to Make a Motion (NITMAM) Closing Date | 3/27/2025 | 6 | 3/27/2025 | 6 |
| Posting of Standards that Received No NITMAMs (Consent Standards) | 3/28/2025 | 15 days | 3/28/2025 | 15 days |
| Appeal Closing Date for Consent Standards (15 Days after posting) | 4/12/2025 | 10 days | 4/12/2025 | 10 days |
| SC Issuance Date for Consent Standards (10 Days) | 4/22/2025 | | 4/22/2025 | |
| **Posting of the Report of the Motions Committee (Certified Amending Motions (CAMs))** | 5/8/2025 | | 5/8/2025 | |

## Tech Session

Association Meeting for Standards with CAMs 6/16-19, 2025 6/16-19, 2025

## Appeals and Issuance

Appeal Closing Date for Standards with CAMs (20 Days after ATM)  |
Council Issuance Date for Standards with CAMs*
# 2025 FALL REVISION CYCLE

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# 2026 ANNUAL REVISION CYCLE

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## 2026 FALL REVISION CYCLE

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